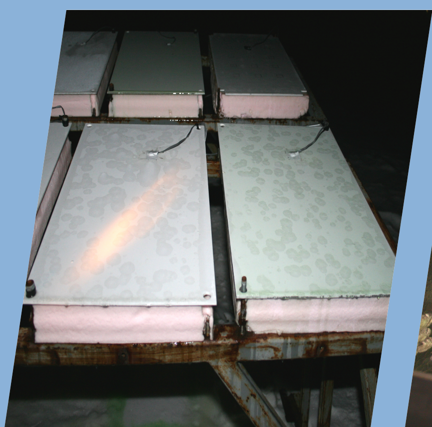
TP 14938E

Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions



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Prepared by:

APS Aviation Inc.

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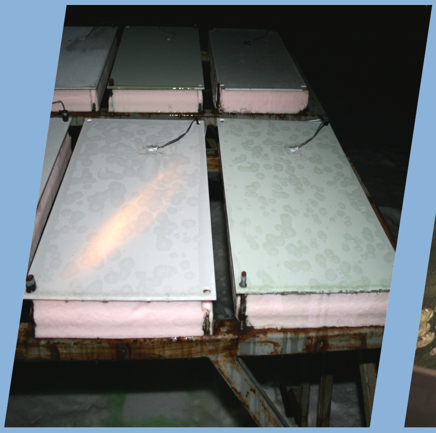

by

Marco Ruggi

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APS Aviation Inc.

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

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

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Un sommaire français se trouve avant la table des matières.

***This report was prepared and signed by Marco Ruggi, reviewed and signed by John D'Avirro, and approved and signed by John Detombe in October 2009 as part of the first submission to Transport Canada (Final Draft 1.0). A final Transport Canada technical and editorial review was completed in March 2018; John Detombe was not available to participate in the final review or to sign the current version of this report.*

PREFACE

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

- To evaluate weather data from previous winters that can have an impact on the format of the holdover time guidelines;
- 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 conduct endurance time tests in frost on various test or wing surfaces;
- To conduct endurance time tests on non-aluminum plates;
- To conduct endurance time tests to support the removal of the below -25°C row of the holdover time guidelines;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests to expand the current holdover guidelines to include conditions of rain and snow;
- To evaluate the effect of poor fluid application on fluid endurance times;
- To evaluate holdover times for anti-icing in a hangar;
- To review the use of the visibility table for use with holdover times;
- To conduct research at the NRC wind tunnel to further develop and expand ice pellet allowance times;
- To conduct various aerodynamic research activities at the NRC wind tunnel;
- To initiate research for development of ice detection capabilities for departing aircraft at the runway threshold; and
- To update the regression coefficient report with the newly-qualified de/anti-icing fluids.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2008-09 are documented in seven reports. The titles of the reports are as follows:

- TP 14933E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2008-09 Winter;
- TP 14934E Winter Weather Impact on Holdover Time Table Format (1995-2009);
- TP 14935E Research for Further Development of Ice Pellet Allowance Times: Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09;
- TP 14936E Aircraft Ground Icing Research General Activities During the 2008-09 Winter;
- TP 14937E Regression Coefficients and Equations Used to Develop the Winter 2009-10 Aircraft Ground Deicing Holdover Time Tables;

- TP 14938E Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions; and
- TP 14939E Exploratory Wind Tunnel Aerodynamic Research Examination of Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09.

In addition, an interim report entitled *Endurance Times Using Composite Surfaces* will be written.

This report has the following objective:

- Substantiate the current aircraft ground deicing holdover times in frost conditions.

This objective was met by conducting flat plate endurance time testing in natural frost conditions. Additional work was conducted in the NRC wind tunnel as well as with the TC JetStar wing to provide a full-scale validation of the flat plate test results obtained.

PROGRAM ACKNOWLEDGEMENTS

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

APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Stephanie Bendickson, Matthew Bowen, Chris Burke, Michael Chaput, John D'Avirro, Peter Dawson, Jeff Ford, Benjamin Guthrie, Michael Hawdur, Eric Perocchio, Michelle Pineau, Dany Posteraro, Marco Ruggi, Joey Tiano, David Youssef and Victoria Zoitakis.

Special thanks are extended to Angelo Boccanfuso, Yagusha Bodnar, Frank Eyre, 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.

In memory of the late Barry Myers whose wisdom and knowledge combined with his dedication and perseverance has played a fundamental role in the development of the aircraft ground de-icing program. His presence will be missed by all who had the privilege of making his acquaintance.

PROJECT ACKNOWLEDGEMENTS

The author of this report would like to acknowledge and thank ABAX, Clariant, Dow, Kilfrost, and Octagon, for their diligence and commitment in providing fluid samples required for this project.

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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 (TDC). Several reports were produced as part of this winter's research program. Their subject matter is outlined in the preface. The work described in this report was, in part, co-sponsored by the Federal Aviation Administration (FAA).

16. Abstract

Frost is an important consideration in aircraft deicing. The irregular and rough frost accretion patterns can result in a significant loss of lift on critical aircraft surfaces. This potential hazard is amplified by the frequent occurrence of frost accretion during winter airport operations. Testing was conducted by APS to substantiate the fluid holdover times currently issued in the HOT Guidelines.

Data from tests performed over the last six winters measuring fluid endurance time on flat plates during natural frost conditions were analysed. The results indicated that for Type I fluids, the measured endurance times do not violate the long used HOT of 45 minutes. The results also indicated that for Type III fluids, the issued HOT is satisfactory. The endurance time data collected for Type II and Type IV fluids indicated HOT reductions were necessary; fluid failure was experienced prematurely and was a result of the fluid and plate temperature reaching the fluid freeze point rather than a typical failure occurring as a result of fluid dilution. Results from 2008-09 testing in the wind tunnel and with the full-scale JetStar wing support the previously collected flat plate results which indicate a need for reductions to the current Type II and Type IV HOT's.

A separate frost table has been added to the HOT guidelines which will include changes to the temperature ranges to allow greater flexibility for fluid use and to minimize the operational impact of necessary HOT reductions. Use of fluid dilutions will not be restricted; however, HOT reductions will apply when nearing the fluid lowest operational use temperature (LOUT).

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Plusieurs rapports de recherches sur les essais de technologies de dégivrage et d'antigivrage au cours d'hivers précédents ont été produits pour le compte de Transports Canada. Ils sont disponibles au Centre de développement des transports CDT). Plusieurs rapports ont été produits dans le cadre du programme de recherches de l'hiver en cours. Leur objet est défini à la préface. Les travaux décrits dans le présent rapport ont été en partie coparrainés par la Federal Aviation Administration (FAA).

16. Résumé

Le givre est un facteur important pour le dégivrage d'aéronefs. Les formes irrégulières et brutes d'accrétion de givre peuvent causer une perte importante de portance sur les surfaces critiques d'aéronefs. La possibilité de ce danger est amplifiée par la présence fréquente d'accrétion de givre durant les opérations aéroportuaires en hiver. APS a mené des essais visant à valider les durées d'efficacité de liquides publiées dans les guides actuels de durées d'efficacité.

Les données d'essais effectués au cours des six derniers hivers sur la mesure sur plaques planes des durées d'efficacité des liquides dans des conditions naturelles de givre ont été analysées. Les résultats ont démontré que, dans le cas de liquides de type I, les durées d'efficacité mesurées n'enfreignent pas les durées d'efficacité de 45 minutes en vigueur depuis longtemps. Les résultats ont également démontré que, dans le cas de liquides de type III, les durées d'efficacité publiées sont satisfaisantes. Les données de durées d'efficacité recueillies sur les liquides de types II et IV ont démontré la nécessité de réduire les durées d'efficacité; une défaillance prématurée des liquides est apparue, car la température du liquide et de la plaque atteignait le point de congélation du liquide, plutôt qu'une défaillance typique causée par la dilution du liquide. Les résultats de 2008-2009 dans la soufflerie et sur l'aile pleine grandeur du JetStar sont conformes aux résultats recueillis précédemment sur plaque plane, ce qui démontre le besoin de réduire les durées d'efficacité actuelles pour les liquides de types II et IV.

Un tableau distinct sur le givre a été ajouté aux guides de durées d'efficacité. Il comprendra des changements aux fourchettes de température, permettra une plus grande flexibilité d'utilisation de liquides et minimisera l'impact opérationnel des réductions nécessaires des durées d'efficacité. L'utilisation de dilutions de liquide ne sera pas limitée; cependant, les réductions des durées d'efficacité s'appliqueront à l'approche de la température minimale d'utilisation opérationnelle (LOUT) du liquide.

17. Mots clés Givre, perte d'efficacité au point de congélation du liquide, durée d'efficacité, guides de durées d'efficacité, temps d'endurance, soufflerie, aile de JetStar	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires

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EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) undertook a test program to collect frost endurance time data on flat plates in natural conditions to substantiate the aircraft ground de/anti-icing fluid holdover times (HOT).

Background

Frost is an important consideration in aircraft deicing. The irregular and rough frost accretion patterns can result in a significant loss of lift on critical aircraft surfaces. This potential hazard is amplified by the frequent occurrence of frost accretion during winter airport operations. A survey of deicing activities at airports in North America, Europe and Asia demonstrated that in regions with colder climates, up to 25 percent of deicing operations are frost-related. In regions with milder climates, close to 90 percent of all deicing operations are for frost removal.

Data and Conclusions

Testing was conducted by APS to substantiate the fluid holdover times currently issued in the HOT Guidelines.

Data from tests performed over the last six winters measuring fluid endurance time on flat plates during natural frost conditions were analysed. The results indicated that for Type I fluids, the measured endurance times do not violate the long used HOT of 45 minutes. The results also indicated that for Type III fluids, the issued HOT is satisfactory. The endurance time data collected for Type II and Type IV fluids indicated HOT reductions were necessary; fluid failure was experienced prematurely and was a result of the fluid and plate temperature reaching the fluid freeze point rather than a typical failure occurring as a result of fluid dilution. Results from 2008-09 testing in the wind tunnel and with the full-scale JetStar wing support the previously collected flat plate results which indicate a need for reductions to the current Type II and Type IV HOT's.

Recommendations

It is recommended that changes be issued to the current frost HOT's for winter 2009-10 operations to address the issues with reduced HOT's in active frost conditions. This recommendation has already been adopted: a separate frost table added to the HOT guidelines will include changes in temperature ranges to allow greater flexibility for fluid use and to minimize the operational impact of HOT

reductions. Use of fluid dilutions will not be restricted; however, HOT reductions will apply when nearing the fluid lowest operational use temperature (LOUT).

It is also recommended that the outdoor procedures for Type I and Type II/III/IV natural frost endurance time testing should be added in future revisions of ARP5945 and ARP5485 to enable verification of any new Type I or Type II/III/IV non-glycol products. Holdover time for the current generation of fluids have been substantiated; therefore testing for any newly developed fluids of this generation is not recommended.

SOMMAIRE

En vertu d'un contrat avec le Centre de développement des Transports (CDT) de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris un programme d'essais pour la collecte de données sur les durées d'endurance du givre sur des plaques planes dans des conditions naturelles, afin de valider les durées d'efficacité des liquides de dégivrage et d'antigivrage d'aéronefs au sol.

Contexte

Le givre est un facteur important pour le dégivrage d'aéronefs. Les formes irrégulières et brutes d'accrétion de givre peuvent causer une perte importante de portance sur les surfaces critiques d'aéronefs. La possibilité de ce danger est amplifiée par la présence fréquente d'accrétion de givre durant les opérations aéroportuaires en hiver. Une études des activités de dégivrage à des aéroports d'Amérique du Nord, d'Europe et d'Asie a démontré que, dans les régions au climat plus froid, jusqu'à 25 pourcent des opérations de dégivrage sont liées au givre. Dans les régions au climat plus doux, près de 90 pourcent de toutes les opérations de dégivrage comportent l'enlèvement du givre.

Données et conclusions

Des essais ont été menés par APS pour valider les durées d'efficacité actuelles publiées dans les guides de durées d'efficacité.

Les données d'essais effectués au cours des six derniers hivers sur la mesure sur plaques planes des durées d'efficacité des liquides dans des conditions naturelles de givre ont été analysées. Les résultats ont démontré que, dans le cas de liquides de type I, les durées d'efficacité mesurées n'enfreignent pas les durées d'efficacité de 45 minutes en vigueur depuis longtemps. Les résultats ont également démontré que, dans le cas de liquides de type III, les durées d'efficacité publiées sont satisfaisantes. Les données de durées d'efficacité recueillies sur les liquides de types II et IV ont démontré la nécessité de réduire les durées d'efficacité; une défaillance prématurée des liquides est apparue, car la température du liquide et de la plaque atteignait le point de congélation du liquide, plutôt qu'une défaillance typique causée par la dilution du liquide. Les résultats de 2008-2009 dans la soufflerie et sur l'aile pleine grandeur du JetStar sont conformes aux résultats recueillis précédemment sur plaque plane, ce qui démontre le besoin de réduire les durées d'efficacité actuelles pour les liquides de types II et IV.

Recommandations

Nous recommandons la publication de changements aux durées d'efficacité actuelles des opérations de l'hiver 2009-2010, afin de corriger les problèmes de réduction des durées d'efficacité dans des conditions de formation active de givre. Cette recommandation a déjà été adoptée : un tableau distinct sur le givre, ajouté aux guides sur les durées d'efficacité, comprendra les changements aux fourchettes de températures, permettra une plus grande flexibilité d'utilisation des liquides et minimisera l'impact opérationnel des réductions de durées d'efficacité. L'utilisation de dilutions des liquides ne sera pas restreinte, mais les réductions de durées d'efficacité s'appliqueront à l'approche de la température minimale d'utilisation opérationnelle (LOUT) du liquide.

Il est également recommandé que des procédures d'essais extérieurs de temps d'endurance pour les liquides de type I ainsi que de types II, III et IV, en cas de givre naturel, soient ajoutées lors des révisions futures à l'ARP5945 et à l'ARP5485, afin de permettre de vérifier tout nouveau produit sans glycol de type I ou de types II, III et IV. Les durées d'efficacité des liquides de la génération actuelle ont été validées; en conséquence, des essais ne sont pas recommandés sur tout liquide de cette génération récemment développé.

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GLOSSARY

ABZ	Aberdeen Airport
AMS	Aerospace Material Specification
APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
EDI	Edinburg Airport
EG	Ethylene Glycol
FAA	Federal Aviation Administration
GLA	Glasgow Airport
GLARE	Glass Reinforced Fiber Metal Laminate
HHET	High Humidity Endurance Tests
HOT	Holdover Time
IREQ	Institut de Recherche d'Hydro-Québec
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
MSC	Meteorological Service of Canada
NRC	National Research Council Canada
OAT	Outside Air Temperature
PG	Propylene Glycol
RH	Relative Humidity
SAE	Society of Automotive Engineers, Inc.
SDF	Louisville International Airport
TC	Transport Canada

TDC	Transportation Development Centre
UCAR	Union Carbide Corporation
UK	United Kingdom
UPS	United Postal Service
ΔT	Air to Surface Temperature Differential

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 little understanding of the hazard and of what can be done to reduce the risks posed by the operation of aircraft in winter precipitation conditions. This "winter operations contaminated aircraft - ground" program of research is aimed at overcoming this lack of knowledge.

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

Under contract to the TDC, APS Aviation Inc. (APS) undertook a test program to collect frost endurance time data on flat plates in natural conditions to substantiate the aircraft ground de/anti-icing fluid holdover times (HOT).

This is a consolidated report of all tests conducted within this program, commencing with the 2002-03 test season and ending in the 2008-09 test season. Additionally, the specifications of the test results for the 2002-03 test season are also published in a separate TC report TP 14145E, *Laboratory Test Parameters for Frost Endurance Time Tests* (1).

1.1 Background

1.1.1 Frost as a Contributor to Deicing Activity

The factors that generate frost in natural conditions are a combination of ambient air temperature, the level of humidity in the air, and the surface temperature of any exposed body. Certain combinations of these conditions will generate greater frost accretion. Surface temperature is a key component to frost generation; in the natural environment, surface temperature is controlled by factors such as wind and sky condition. The ideal conditions for frost accretion are the following:

Outside Ambient Temperature:	Below 3ºC (Above 3ºC will likely produce dew)
Relative Humidity:	Above 60 percent
Wind Speed:	Less than 5 km/h
Sky Condition:	Clear

In ideal frosting conditions, the surface temperature of any exposed body will be several degrees lower than the outside air temperature (OAT). Due to the high relative humidity (RH), the water molecules in the air will accumulate on the exposed body and will freeze to create frost.

When the OAT is above 3ºC, the surface temperature of the exposed body is generally not low enough to allow freezing. In such cases, the water molecules accumulating on the exposed body will not freeze and will produce dew.

Frost is an important consideration in aircraft deicing. The irregular and rough frost accretion patterns can result in a significant loss of lift on critical aircraft surfaces. This potential hazard is amplified by the frequent occurrence of frost accretion during winter airport operations.

1.1.2 Frequency of Occurrence

In airline operations, removal of frost contamination represents a significant portion of deicing operations. A survey of deicing activities at airports in North America, Europe and Asia was reported in TC report, TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004)* (2). The survey reported that at airport locations having relatively mild winter climates, such as London and Paris, close to 90 percent of all deicing operations were frost-related. In colder winter climates, such as Montreal, where other forms of winter contamination such as snow are more prevalent, up to 25 percent of deicing operations were frost-related.

Figure 1.1 is a chart illustrating the percentage of total deicing operations related to different types of precipitation. The results, based on worldwide data, show that approximately 33 percent of all aircraft deicing is due to frost accretion.

1.1.3 Effect of Frost Roughness on Wing Aerodynamics

Frost can be an insidious type of threat to the safety of aircraft operations. Because it often appears to be a minor degree of contamination, it does not offer the same obvious signal of danger as other types of contamination, like snow or ice. However, certain characteristics of frost cause it to become a genuine concern, as it is a rough substance that always adheres to the aircraft surface.

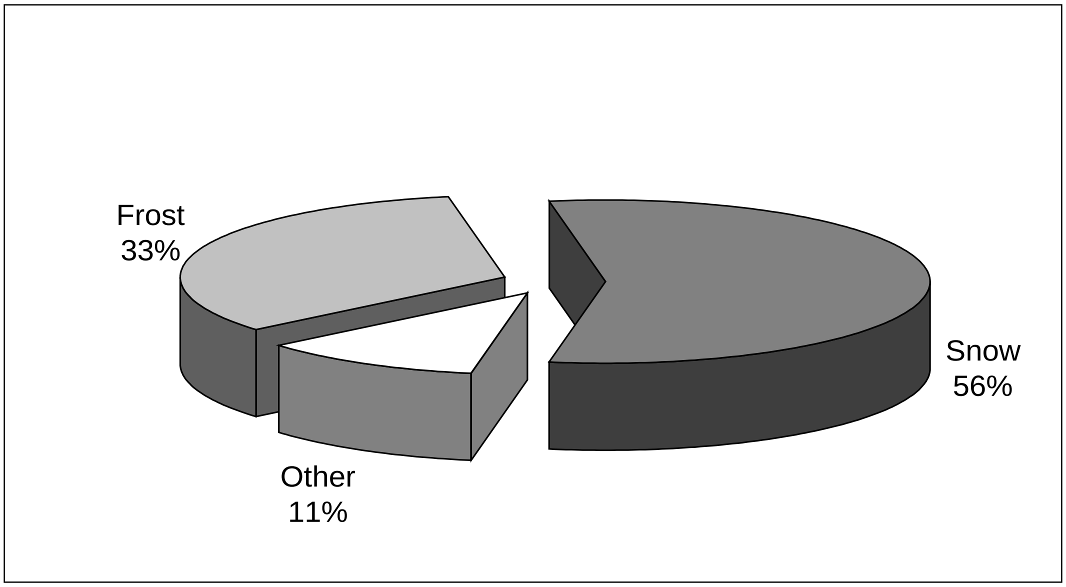

Figure 1.1: Frequency of Deicing Operations Airport Survey 2000-03

1.2 History of Previous Research

1.2.1 Current Holdover Times

The fluid holdover time guidelines are based on endurance time test data for each certified fluid, measured in prescribed temperature and precipitation conditions. These conditions, as well as the test procedure, have been defined in Aerospace Recommended Practice (ARP) 5485 for precipitation conditions including freezing fog, snow, freezing drizzle, freezing rain and rain on a cold-soaked wing. Although values for frost HOT's have always been a part of the Holdover Time (HOT) guidelines, fluid endurance times in frost have never been measured. The current values for frost HOT were based primarily on results from High Humidity Endurance Tests (HHET). These HOT values are summarized in Table 1.1.

1.2.2 Frost Parameters in Proposed Aerospace Standard

In the late 1990s, a workgroup of the Society of Automotive Engineers (SAE) G-12 Fluids Subcommittee was set up to develop the laboratory procedures for endurance time testing. The parameters in Table 1.2 were selected as representative frost conditions for ARP5485. In summary, Table 1.2 indicates that the plate temperature is 3°C colder than the air temperature in all conditions; and that the icing intensity ranges from 0.20 g/dm²/h at 0°C to 0.06 g/dm²/h at -25°C.

Table 1.1: HOT Values for Frost Conditions Prior to Winter 2009-10

Outside Air Temperature		Fluid Concentration Neat Fluid/Water	Approximate Holdover Times (hours: minutes)			
			Active Frost			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -3 to -14 *(-10 for TIII)*	below 27 to 7 *(14 for TIII)*	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
below -14 *(-10 for TIII)* to -25	below 7 *(14 for TIII)* to -13	100/0		8:00	2:00	12:00

Table 1.2: Proposed SAE ARP5485 Procedure – Frost Test Conditions

Condition	FROST A	FROST B	FROST C	FROST D	FROST E	FROST F
Type I	Yes	No	Yes	No	Yes	No
Type II, III and IV, Neat fluid	Yes	Yes	No	Yes	Yes	Yes*
Types II and IV, 75/25 (Neat fluid/water)	Yes	Yes	No	Yes	No	No
Types II and IV, 50/50 (Neat fluid/water)	Yes	Yes	No	No	No	No
Air temperature, °C	0 ± 0.5	-3 ± 0.5	-10 ± 0.5	-14 ± 0.5	-25 ± 0.5	-25 ± 0.5
Air temperature standard deviation	± 0.3	± 0.3	± 0.3	± 0.3	± 0.5	± 0.5
Plate temperature, °C	-3 ± 0.5	-6 ± 0.5	-13 ± 0.5	-17 ± 0.5	-28 ± 0.5	3 °C below air
Relative humidity	> 94 %	> 90 %	> 80 %	> 80 %	> 70 %	Report**
Icing Intensity, $g/dm^2/h$	0.20 ± 0.02	0.20 ± 0.02	0.15 ± .02	0.13 ± 0.02	0.06 ± 0.01	Report**
Icing intensity range across a test plate, $g/dm^2/h$	≤ 0.06	≤ 0.06	≤ 0.06	≤ 0.04	≤ 0.02	Report**

*This test will be performed if the lowest operational use temperature is below -25°C
**These values will depend on the actual air and plate temperatures

1.2.3 Winter 2000-01 Testing at IREQ

During the 2000-01 winter, the SAE G-12 HOT Subcommittee determined the need to test fluid endurance in active frost conditions. APS conducted tests to substantiate values for fluid endurance in active frost conditions as published in current HOT tables, and, simultaneously, to evaluate the proposed ARP5485 procedure for measuring fluid endurance times in frost conditions. This study was reported in the TC report, TP 13831E, *Endurance Time Tests in Simulated Frost Conditions* (3).

These tests were conducted at the Institut de Recherche d'Hydro-Québec (IREQ) at Varennes (near Montreal), Quebec, on SAE fluid Types I, II and IV.

An example of the resultant endurance times for Type I fluids in the laboratory are shown in Figure 1.2. The measured fluid endurance times demonstrated an unexpected pattern in active frost conditions; the values at 0°C and at -25°C were significantly longer than at -10°C. The results were counter-intuitive and cast doubt on the validity of the tests.

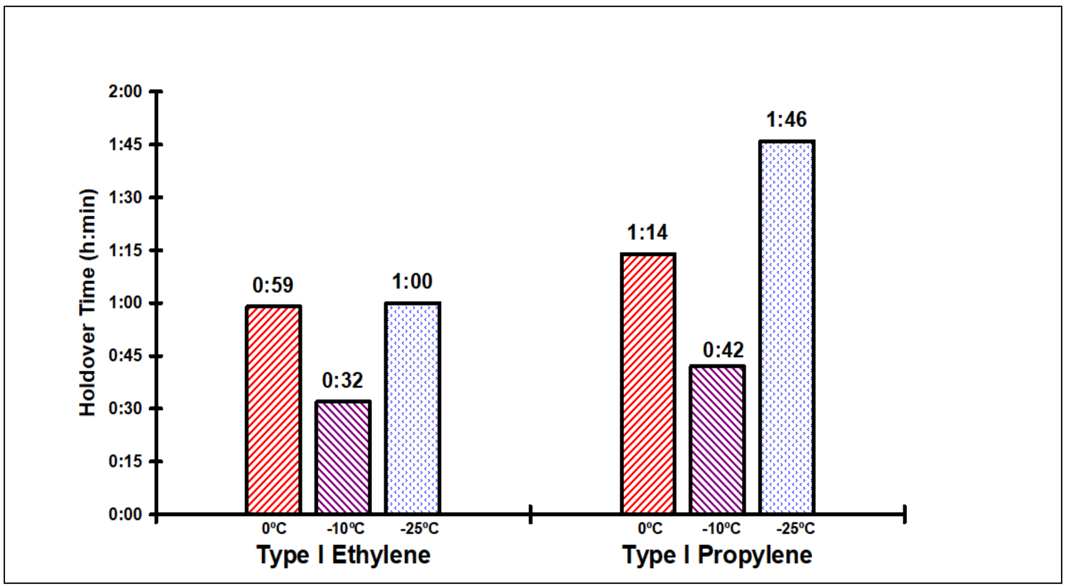

Figure 1.2: Comparison of Frost Endurance Times as a Function of Temperature

These results also indicated that the current HOTs of 45 minutes for frost were not adequate and generated safety concerns. This led the experts and regulatory authorities to question the proposed procedure stipulated in ARP5485.

During the tests, it was also observed that the environmental conditions specified in ARP5485 did not produce the desired frost rates at temperatures of -25°C.

These results led to the recommendation that further work (see next section) was necessary to:

1) Validate the proposed parameters in ARP5485. The primary focus of the validation was on the icing intensities and the plate/air temperature differential; and
2) Validate the proposed procedure in ARP5485 for testing on small plates and compare the results to endurance times on aircraft wings.

1.2.4 Winter 2001-02 and 2002-03 Testing

The objective of the research conducted in the winters of 2001-02 and 2002-03 was to establish test parameters that reflect the natural environmental conditions for active frost and to document rates of natural frost accretion to enable specification of frost intensity for fluid endurance time testing. Frost rates were measured during both winter seasons over a range of conditions and temperatures. The rates were measured using a painted white aluminum insulated plate that was found to be representative of aircraft wing surfaces.

The research program also documented wing-to-air temperature differential (ΔT) over a range of temperatures.

A field trial was also conducted on an operational aircraft in natural frost conditions. The test showed that heated Type I fluids enriched substantially after application on the wing due to the evaporation of water from the water/glycol mix. The fluid enrichment contributed greatly to the fluid endurance time, and it was concluded that a suitable laboratory test procedure needed to account for fluid enrichment.

As a supplement to this research, endurance times for Type I fluids were measured in natural frost conditions. All of the times measured exceeded the current HOT values of 45 minutes; this was in contrast to the lower times measured previously in the laboratory.

1.2.5 Recommendations from Winter 2001-02 and 2002-03 Testing

1.2.5.1 Type I fluids

From the consolidated data collected over the two winters, a new set of test parameters for Type I fluids was determined. These parameters are described in Table 1.3.

The results collected showed that endurance times for Type I fluids exhibited an inverse relationship to the OAT; the shortest endurance times in any temperature range occurred at the warm end of the range. Therefore, the recommended test parameters for Type I fluids in frost conditions were specified at the warm end of each temperature range. It should be noted that this protocol was only recommended for use with heated Type I fluids. Type II and IV fluid endurance time testing in frost conditions should follow the HOT protocol and be conducted at the cold end of each temperature range.

Table 1.3: Recommended Frost Endurance Test Parameters – Type I Fluid

Condition	-3°C and above	Below -3 to -6°C	Below -6 to -10°C	Below -10°C
Air temperature, °C	3	-3	-6	-10
Plate temperature, °C	-3	-9	-12	-16
Icing intensity, $g/dm^2/h$	0.3	0.23	0.2	0.15

Based on the findings of the natural frost endurance tests with SAE Type I fluid, different approaches were recommended for finalizing the test process for these fluids.

- **Alternative 1:** Substantiate Type I HOT of 45 minutes (outdoor). Because the measured outdoor endurance times of Type I fluids all exceeded the current values in the HOT guidelines, one alternative approach was to finalize substantiation of the current frost HOT value (45 minutes). Using this alternative, the ARP document for determining Type I laboratory endurance times would not include a test standard for SAE Type I fluids in frost. It is recommended however, to include the outdoor test procedure in the ARP for testing new non-glycol Type I fluids. The current endurance time database developed from tests in natural conditions would be supplemented by additional low-cost field tests, with attention given to testing in mild conditions when high frost icing intensity may occur.
- **Alternative 2:** Conduct further research to correlate with the indoor procedure. This alternative would necessitate a correlation of the laboratory procedure with either the outdoor frost procedure or with an aircraft wing. Subsequent to this correlation, include a test standard for SAE Type I fluids in frost in the ARP document for Type I fluids. This test standard would be specific to Type I fluids and would not apply to other fluid types. This approach implies that extensive research followed by laboratory testing would be conducted on current fluids to evaluate endurance times.

These alternative recommendations were presented at a meeting of the SAE G-12 HOT working group, September 3-4, 2003, with the recommendation to proceed with Alternative 1 (as is described below). This recommendation was accepted and therefore this report contains the results of tests based on Alternative 1.

1.2.5.2 Type II/III/ IV fluids

From the consolidated data collected over two seasons, a new set of test parameters for Type II, III and IV fluids were determined and are listed in Table 1.4.

Table 1.4: Recommended Frost Endurance Test Parameters – Type II, III and IV Fluids

Condition	Above 0°C	0 to -3°C	Below -3 to -14°C	Below -14 to -25°C
Air temperature, °C	0	-3	-14	-25
Plate temperature, °C	-6	-9	-20	-31
Icing intensity, $g/dm^2/h$	0.20	0.18	0.11	0.05

Several approaches were presented for finalizing the test process for Type II, III and IV fluids:

- **Alternative 1: Substantiate Type II, III and IV fluid holdover times (outdoor).** Substantiate the current frost HOT values through a series of one-time tests in natural frost. In this alternative, the ARP5485 document would not include a test standard for SAE Type II, Type III and Type IV fluids in frost. If there is a desire to have a standard for testing, then this alternative could include the outdoor protocol that is used to substantiate the Type II, III and IV HOT.
- **Alternative 2: Conduct further research to complete the indoor procedure.** This alternative would involve correlation of the indoor procedure with aircraft wings. Based on the findings from the correlation work, incorporate a frost endurance test standard for SAE Type II, III and IV fluids in the ARP5485 document. This approach implies that extensive research followed by laboratory testing would be conducted on current fluids to evaluate endurance times.
- **Alternative 3: Status quo**: neither substantiating the current values by testing in natural frost, nor including a Type II, III and IV fluids test standard for frost in ARP5485.

These alternatives were presented at a meeting of the SAE G-12 HOT working group on September 3-4, 2003, with the recommendation to proceed with Alternative 1. This recommendation was accepted, and therefore this report is based upon Alternative 1.

1.3 Aluminum vs. Non-Aluminum Test Surfaces – Effect on Fluid Endurance Time

In recent years, there has been an increase in the manufacturing of aircraft wings with non-aluminum materials. The trend has not slowed; in fact, a significant amount of materials being used in the construction of the Airbus 380 wing are non-aluminum.

Previous work has been done to validate the frost tests with actual aircraft wings. This work is documented in the TC report TP 14145E, *Laboratory Test Parameters for Frost Endurance Time Tests* (1). A full-scale test session using Type I fluid was conducted on February 18-19, 2002 using a US Airways B 737 aircraft. Four different surfaces were tested: wing, standard aluminum plate, white aluminum plate and white Kevlar plate. Testing was conducted to explore the temperature differential between the plate temperature and ambient temperature (ΔT), and fluid endurance times on the different test surfaces. These are the findings that came out of this work:

- The temperature differential for the dry unpainted aluminum plate was considerably less than the dry painted plates;
- The temperature differential for the white-painted aluminum plates did not change when wetted;
- When wetted, the unpainted aluminum plate would change and take on the same temperature differential as the painted aluminum plate (whether wet or dry);
- The temperature differential for the white-painted Kevlar surface showed some increase when wetted, but remained less than that observed on the white-painted aluminum surface (whether wet or dry);
- The fluid endurance times measured using unpainted and painted aluminum plate surfaces were similar; and
- Frost rate values collected on the dry white-painted aluminum surface are valid representations of rates experienced on fluid-covered wing surfaces. The results with the non-aluminum surfaces indicated that the white aluminum insulated plate was an adequate representation of the wing. The comparison of ΔT of the white aluminum insulated plate and the composite surface did not warrant further investigation. However, because composite surfaces tend to be the first surfaces on the wing to accrete frost, and because more and more aircraft are being constructed with composite materials, TC requested that limited endurance time testing of Type I fluids on composite surfaces be carried out. Testing was conducted overnight during suitable frost conditions with representative Type I fluids, both ethylene and propylene based.

1.3.1 2004-05 Research in Frost Conditions using Non-Aluminum Test Plates

Preliminary comparative tests conducted in 2004-05 with Type I fluid indicated that on average, endurance times were 20 percent shorter on non-aluminum test surfaces. As a result of this testing, it was recommended that additional data be collected to support the reduced endurance times observed using non-aluminum test surfaces. It was recommended that different composite materials used in aircraft construction be explored to measure any varying effects on fluid endurance time.

1.3.2 2005-06 Research in Frost Conditions using Non-Aluminum Test Plates

Comparative testing was conducted in 2005-06 using five different composite material test plates and one standard aluminum test plate. The comparative tests conducted during natural frost conditions, using Type I fluid heated to 60ºC, indicated that on average, the measured endurance time using the white painted composite test plate was 23 percent ± 9 percent shorter than the endurance time measured using the white painted aluminum test plate. It was recommended that additional data should be collected to support the reduced endurance times observed using composite test surfaces in natural frost conditions.

1.4 Full-Scale Validation of Flat Plate Endurance Time Testing in Frost with Type II, III, and IV Fluids

Ongoing research conducted by APS has led to the substantiation of fluid endurance times currently issued in the HOT Guidelines. The endurance time data collected for Type II, III, and IV fluids indicated that several cells of the HOT tables need to be reduced. This result is not surprising, as the current holdover times have been somewhat based upon high humidity tests, which are not representative of active frost. During several outdoor tests, fluid failure was experienced prematurely and occurred as a result of the fluid and plate temperature reaching the fluid freeze point; fluid dilution was minimal during these tests.

The option to issue a separate frost table was proposed and was presented at the SAE meetings in San Diego, Montreal and Warsaw. The separate frost table would include changes to the temperature ranges to allow greater flexibility for fluid use and to minimize the number of HOT reductions. Use of fluid dilutions would not be restricted. However, HOT reductions would apply when nearing the lowest operational use temperature (LOUT) of the fluid. It was recommended that full-scale testing be conducted in order to validate the HOT reductions observed during flat plate testing.

1.4.1 2008-09 Full-Scale Endurance Time Testing with the TC JetStar Wing

The objective of this testing was to perform a full-scale validation of the proposed HOT reduction in Type II, III and IV fluids and develop a correlation of plate failure to wing failure for thickened fluids in natural frost conditions. To achieve this objective, a series of full-scale endurance time tests were conducted simultaneously with flat plate tests in natural frost conditions. These full-scale endurance time tests were conducted on the JetStar wing surface in conjunction with flat plate testing.

Testing was conducted during four test events with representative Type II, III and IV fluids. Testing was geared towards simulating freeze point failure with 75/25 dilutions close to LOUT of -14 ºC.

The results indicated a correlation between the JetStar wing and the white painted insulated flat plates. The radiational cooling observed on the flat plates was representative of the radiational cooling experienced on an actual aircraft wing. The full-scale results supported the previously collected flat plate endurance time data during natural frost conditions, which indicates a need for reductions to the current Type II and Type II HOT's.

1.4.2 2008-09 Full-Scale Frost Anti-Icing Fluid Freeze Point Failure Simulation in the NRC Open Circuit Wind Tunnel

Previous flat plate testing conducted in natural frost conditions demonstrated that anti-icing fluids could experience premature failure when approaching the fluid LOUT. Due to radiational cooling, the temperature of the test surface would approach the fluid freeze point, causing ice to form sporadically in the fluid. The ice contamination did not seem to adhere to the surface. However, the aerodynamic impact of the failed fluid needed to be investigated.

The objective of this preliminary testing was to investigate the aerodynamic impact of anti-icing fluid failed during active frost conditions as a result of the surface temperature approaching the fluid freeze point. Two tests were conducted at the NRC open circuit wind tunnel.

The results from the wind tunnel tests demonstrated similar crystalline formations as observed with the white painted insulated aluminum plates. Although the contamination did not seem to adhere during the plate tests, the wind tunnel tests demonstrated that the contamination was not removed by the time of rotation, and that the level of contamination worsened by the end of the test. However, during a typical frost operation, the wing skin temperature could be warmed during taxi and takeoff (rather than cooled, as in the wind tunnel) and the results may have potentially been less severe. The wind tunnel results support the previously collected flat plate endurance time data collected during natural frost conditions, which indicates a need for reductions to the current Type II and Type IV HOT's.

1.5 Project Objective

The objective of this project was to collect data to substantiate the fluid holdover times in frost from the collection of flat plate endurance time data in natural conditions. Additional work was conducted in the NRC wind tunnel as well as with the TC JetStar wing to provide a full-scale validation of the flat plate test results obtained. The sections of the TDC work statement pertaining to the work described in this report are provided in Appendix A. APS would like to acknowledge the support of the fluid manufacturers for having provided fluid samples for testing.

1.6 Report Format

The following list provides short descriptions of the remaining chapters in this report:

- Section 2 provides a description of the methodology used to carry out the tests;
- Section 3 presents the data that were collected during the tests;
- Section 4 presents the analysis of the test data;
- Section 5 presents the data collected on non-aluminum surfaces;
- Section 6 presents the data collected from the full-scale validation of the flat plate results;
- Section 7 presents the proposed changes to the frost HOT guidelines;
- Section 8 presents the conclusions; and
- Section 9 presents the recommendations.

2. METHODOLOGY

This section describes the overall approach, test parameters and experimental procedures followed in this project.

2.1 Test Site

Fluid endurance time testing during frost conditions was conducted at the APS test site located at the Montreal-Trudeau Airport over six winters from 2002-03 to 2007-08; additional full-scale work using the TC JetStar wing was conducted during the winter of 2008-09. Testing was conducted by APS personnel. The location of the test site is shown on the plan view of the airport in Figure 2.1. The APS test site is located near the Meteorological Service of Canada's (MSC) automated weather observation station. A view of the test site is shown in Photo 2.1.

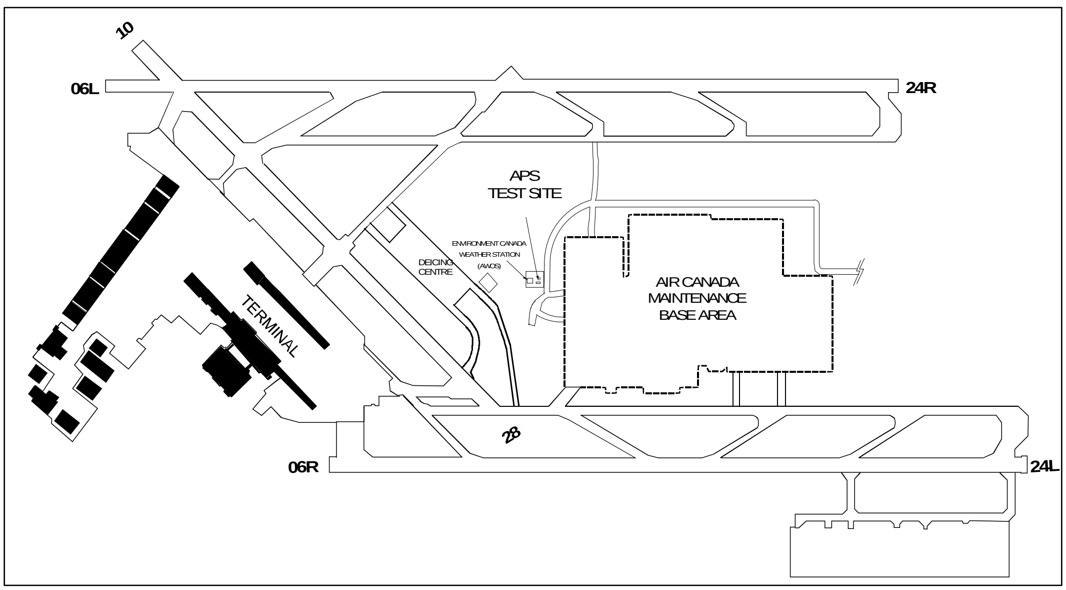

Figure 2.1: Plan View of APS Montreal - Trudeau International Airport Test Site

2.2 Description of Test Procedure

Substantiation of aircraft ground deicing HOT's in frost conditions required gathering fluid endurance time data during natural frost events. A complete description of the procedure used for testing is provided in Appendix B. Additional test data was obtained from Environment Canada, which included a record of OAT, wind, RH, and sky conditions at hourly intervals.

Fluid endurance time testing in frost conditions was conducted using standard aluminum test plates (see Figure 2.2) painted white using aircraft grade paint. An insulation backing was mounted onto each white-painted test plate to avoid heat exchange via the underside (see Photo 2.2). This test plate configuration will be referred to as "frosticator plate" for the remainder of this report. Testing frost production on this surface was found to be representative of aircraft wing surfaces, where only the skin surface is exposed. This is reported in TC report, TP 14145E, *Laboratory Test Parameters for Frost Endurance Time Tests* (1).

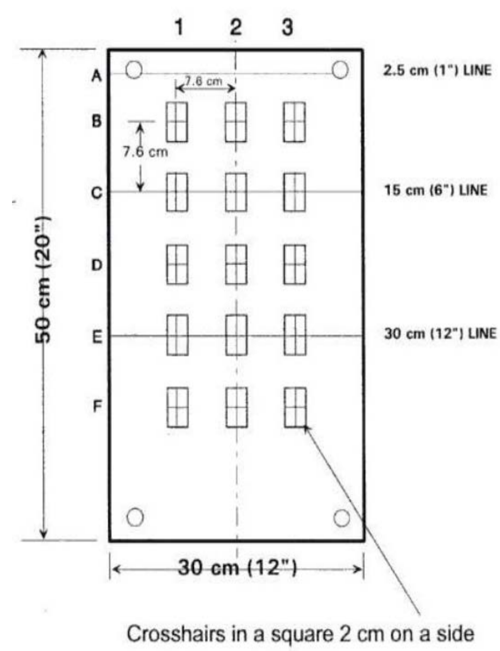

Figure 2.2: Schematic of Standard Holdover Time Test Plate

Tests were generally conducted whenever conditions were suitable for frost accretion, i.e.:

Outside Ambient Temperature:	Below 3°C
Relative Humidity:	Above 60 percent
Wind Speed:	Less than 5 km/h
Sky Condition:	Clear

The test surfaces were positioned with a 10° inclination following the standard flat plate HOT testing protocol; up to 12 plates were tested simultaneously on a test stand (see Photo 2.5).

To measure and document the rate of frost accretion, two test surfaces were weighed at half to one hour intervals depending on the frost accretion intensity. Photo 2.6 demonstrates the two frosticator plates used to measure the frost accretion rate. Weighing the very small mass of collected frost was a challenge. The weigh scales (see Photo 2.7) used to weigh frost collection surfaces had a resolution of 0.1 g, and the mass of the test surface was large relative to the amount of frost collected. The scale had to be kept in a location sheltered from the wind, which meant that the surfaces had to be carried to the scale. If the scale was kept in a warm location and the cold surface was left on the scale for any length of time, the scale reading was affected by cooling from the surface. Therefore, the measurements were done rapidly. One surface at a time was weighed to minimize the time that the surfaces were away from the test position. Both measurements were conducted sequentially within a five minute period.

Thermistor probes were attached at the 15 cm line of each frosticator test plate (see Photo 2.8), allowing the temperature of each test surface to be continuously monitored during the test event. Surface temperature data was stored in a data logger and retrieved at the end of each test session.

From 2004-05 onwards, Brix measurements were taken at the beginning and end of each test to document fluid dilution.

2.3 Data Forms

Three data forms were required for fluid endurance time testing in frost conditions:

- Data form for documenting rate of frost accretion;
- Data form for documenting fluid endurance time; and
- Data form for documenting meteorological information.

The data forms are provided in the procedure given in Appendix B.

2.4 Equipment

APS measurement instruments and test equipment are calibrated and verified on an annual basis. This calibration is carried out according to a calibration plan derived from approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

Much of the equipment used for these tests has already been described in the discussion on procedures, however some equipment requires additional explanation.

2.4.1 Frosticator Test Plate Surfaces

Fluid endurance time testing in frost conditions was conducted using standard aluminum test plates (see Figure 2.2) painted white using aircraft grade paint. An insulation backing was attached to each white-painted test plate to avoid heat exchange via the underside (see Photo 2.2).

When testing with composite materials, the same frosticator setup was employed. The composite test plate was painted white and an insulation backing was attached.

2.4.2 Thermistor Probes

Each test surface had a thermistor probe installed at the 15 cm line, inset 1/3 of the width from the edge (see Photo 2.7). Surface temperature data collected was constantly monitored during the test event and was stored in a data logger.

2.4.3 Test Stand

The stand used for standard endurance time tests was used to position the frosticator plate's fluid endurance time testing in frost conditions. The frosticator plates were placed at a 10º inclination on the test stand.

2.4.4 Weigh Scale

A weigh scale (see Photo 2.5), with a precision of 0.1 g, was used to measure the rate of frost accretion. The scale was zeroed prior to the weighing of each frosticator plate.

2.4.5 Twelve-Hole Fluid Spreader

Type I ethylene glycol (EG) and propylene glycol (PG) based fluid, mixed to a 10ºC freeze point buffer, was applied at 20ºC. A fluid quantity of 0.5 L applied at 20ºC was seen to produce the extent of fluid enrichment documented for aircraft wings during actual frost sprays, and this quantity was used as a standard for all tests. Fluid was applied with the standard twelve-hole spreader (see Photo 2.8), which distributed the fluid evenly along the top of the frosticator plate.

Note: Type II, Type III and Type IV fluids were applied at OAT by freely pouring (without the spreader) the substance over the test surface.

2.5 Fluids

This section provides information concerning the various fluids utilised for fluid endurance time testing in frost conditions over the winters of 2002-03 through to 2007-08.

Type I fluid endurance time testing was conducted using four fluid brands. Type II, III and IV fluid endurance time testing was conducted using 17 fluid brands. Table 2.1 shows the fluids used for fluid endurance time testing in frost conditions.

The Type II, III and IV fluids were requested from the manufacturers at the same viscosity as previously tested to develop the brand-specific HOT tables for each fluid. This viscosity level is typically referred to as the lowest on-wing viscosity. For testing of 75/25 and 50/50 dilutions, the Neat fluids were mixed with hard water according to the water mixing protocols for diluting fluids.

APS personnel measured all Type II, III and IV fluid viscosities using the methods specified for each fluid by the respective fluid manufacturer. Viscosity measurements were carried out using a Brookfield viscometer (Model DV-I+) fitted with a constant temperature bath (Brookfield TC-500), which is recommended for accurate results. The refrigerated TC-500 bath provides fine control of temperature in a large variable range (from -10ºC to 130°C) with a stability of ± 0.03°C. The Brix values of all fluids were also recorded (the Brix value of water is zero). Table 2.2 shows that the viscosity of the samples tested during the winters of 2003-04 to 2007-08 were within experimental error of the lowest on-wing viscosities that are provided in the HOT table guidelines. Each fluid's viscosity was measured only in the seasons it was tested.

Table 2.1: Fluids for Endurance Time Testing in Frost Conditions

FLUID TYPE	FLUID NAME
I	Clariant Safewing MP I 1938 ECO
I	Dow UCAR ADF EG
I	Dow UCAR ADF PG
I	Safetemp HOC-PG
II	Aviation Xi'an KHF-II
II	Clariant Safewing MP II 2025 ECO
II	Kilfrost P1491
II	Kilfrost ABC 2000
II	Kilfrost ABC II+
II	Newave FCY-2
II	SPCA Ecowing 26
III	Clariant Safewing MP III 2031 ECO
IV	Clariant Safewing MP IV 2012
IV	Clariant Safewing MP IV 2001
IV	Clariant Safewing MP IV 2030 ECO
IV	Dow UCAR Ultra+
IV	Dow UCAR Endurance EG106
IV	Kilfrost ABC-S
IV	Octagon Maxflight
IV	Octagon Maxflo
IV	SPCA AD-480

Table 2.2: Type II, III and IV Fluids Tested

Fluid Name	Fluid Type*	2007-08 Viscosity** (mPa.s)	2006-07 Viscosity** (mPa.s)	2005-06 Viscosity** (mPa.s)	2004-05 Viscosity** (mPa.s)	2003-04 Viscosity** (mPa.s)	Viscosity from HOT Tables (mPa.s)	Viscosity Method	Brix
Aviation Xi'an KHF-II	II	9200	-	-	-	-	8750	20°C, 0.3r/min, Spindle LV2, 150 mL of fluid, 10 min	38.75
Clariant Safewing MP II 2025 ECO	II	-	4800	–	5400	5500	5500	20°C, 0.3r/min, Spindle SC4-34, 10 mL of fluid, 15 min	35.25
Kilfrost P1491 (LV)	II	-	-	–	–	2650	–	20°C, 0.3r/min, Spindle LV2, 250 mL beaker, 10 min	35.75
Kilfrost ABC 2000	II	-	2600	1900	3300	2300	2350	20°C, 0.3r/min, Spindle LV2, 150 mL of fluid, 10 min	35.75
Kilfrost ABC II Plus	II	-	-	–	5100	4200	3600	20°C, 0.3r/min, Spindle LV2, 150 mL of fluid, 10 min	36
Newave FCY-2	II	8250	-	-	-	-	7000	20°C, 0.3r/min, Spindle LV2, 150 mL of fluid, 10 min	31.5
SPCA Ecowing 26	II	5050	-	5000	–	5400	4900	20°C, 0.3r/min, Spindle SC4-34, 10 mL of fluid, 30 min	35.5
Clariant Safewing MP III 2031 ECO	III	96	-	24 (new batch)	660	810	30	0°C, 0.3r/min, Spindle LV1, 500 mL of fluid, 33 min. 20sec	35.5
Clariant Safewing MP IV Protect 2012	IV	-	6800	7200	7100	7200	7800	20°C, 0.3r/min, Spindle SC4-34, 10 mL of fluid, 15 min	34.75
Clariant Safewing MP IV 2001	IV	-	-	–	15600	18800	18000	20°C, 0.3r/min, Spindle SC4-34, 10 mL of fluid, 15 min	35
Clariant Safewing MP IV 2030 ECO	IV	-	-	12500	12000	10500	10500	20°C, 0.3r/min, Spindle SC4-34, 10 mL of fluid, 15 min	35
Dow UCAR Ultra+	IV	-	34850	–	41000	37300	36000	0°C, 0.3r/min, Spindle SC4-31, 10 mL of fluid, 10 min	39.5
Dow UCAR Endurance EG106	IV	25500	-	-	-	-	24850	0°C, 0.3r/min, Spindle SC4-31, 10 mL of fluid, 10 min	31.5
Kilfrost ABC-S	IV	-	14550	6350	16000	17400	17000	20°C, 0.3r/min, Spindle LV2, 150 mL of fluid, 10 min	36
Octagon Maxflight	IV	-	-	–	5840	5460	5540	20°C, 0.3r/min, Spindle LV1, 500 mL of fluid, 33 min. 20 sec	35.5
Octagon Maxflo	IV	7450	7800	8140	–	–	8670	20°C, 0.3r/min, Spindle LV1, 500 mL of fluid, 10 min.	36
SPCA AD-480	IV	-	-	–	–	15800	15200	20°C, 0.3r/min, Spindle SC4-34, 10 mL of fluid, 30 min	35.5

* Neat concentration fluids
** APS measured viscosity using manufacturer's method

2.6 Test Plan

2.6.1 2002-03 Test Season

In 2002-03, fluid endurance time testing in frost conditions was conducted using only Type I fluids. Frost accretion intensity was measured to validate the test methodology.

2.6.2 2003-04 Test Season

The primary focus of the 2003-04 test season was to explore Type II/III/IV fluid endurance times in active frost conditions. Fluid endurance time testing in frost conditions was also conducted using Type I fluids in conjunction with the Type II/III/IV fluid testing being conducted. Due to limited funding in 2003-04, the number of test sessions was kept to a minimum.

2.6.3 2004-05 Test Season

Type II/III/IV fluid endurance time tests were conducted on a 12-position stand during active frost conditions in 2004-05.

While Type II/III/IV fluid endurance time tests were being conducted, the effect of white aluminum and white composite test plates on fluid endurance times was explored. Both aluminum and composite surfaces were prepared using the frosticator configuration. These tests were conducted using poured Type I fluids heated to 20ºC. Two simultaneous tests (one using the aluminum plate and the other using the composite plate) were conducted multiple times during selected test sessions.

2.6.4 2005-06 Test Season

Type II/III/IV fluid endurance time tests were conducted on a 12 position stand during active frost conditions in 2005-06.

While Type II/III/IV fluid endurance time tests were being conducted, the effect of painted white aluminum, cross weave carbon fiber, uni-directional carbon fiber (two test plates were used at different thicknesses), and GLARE (Glass Reinforced Fiber Metal Laminate) test plates on fluid endurance times was explored. Both aluminum and composite surfaces were prepared using the frosticator configuration. These tests were conducted using Type I fluids heated to 20ºC applied using a 12-hole fluid spreader. Five simultaneous tests (one using the aluminum plate and the other four using the composite plates) were conducted multiple times during selected test sessions.

2.6.5 2006-07 Test Season

Type II/III/IV fluid endurance time tests were conducted on a 12 position stand during active frost conditions in 2006-07. Priority was given to testing in the above -3ºC condition. No Type I testing was conducted.

2.6.6 2007-08 Test Season

Type II/III/IV fluid endurance time tests were conducted on a 12-position stand during active frost conditions in 2007-08. Priority was given to testing at the lower limits of the fluid temperature ranges. No Type I testing was conducted.

2.6.7 2008-09 Test Season

Testing during the winter of 2008-09 focused on the full-scale validation of the proposed reductions to the frost HOT's. Testing was conducted in the NRC open circuit wind tunnel and with the TC JetStar wing (see Section 6). Limited flat plate endurance time testing was only conducted as part of the full-scale JetStar wing project.

Photo 2.1: APS Test Site Located at P.E. Trudeau Airport

Photo 2.2: Frost Plate with Insulated Backing

Photo 2.3: Test Stand with Insulated Frosticator Plates

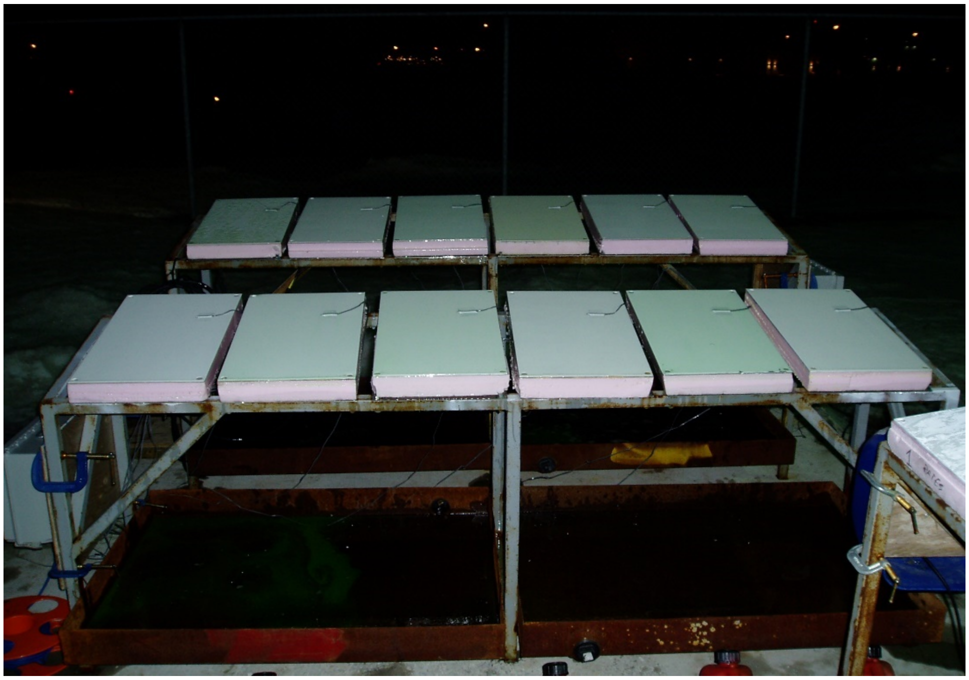

Photo 2.4: Test Stand with Icing Intensity Frosticator Plates

Photo 2.5: Weigh Scale Used to Measure Icing Intensity

Photo 2.6: Temperature Data Logger

Photo 2.7: Thermistor on Frosted Surface at 15 cm Line

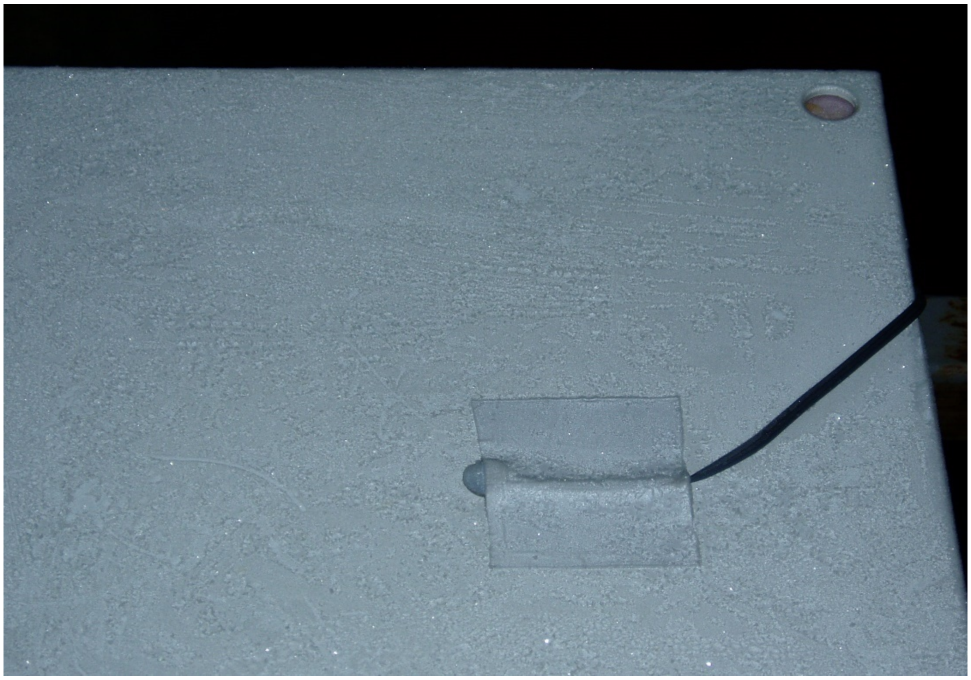

Photo 2.8: Standard Twelve-Hole Spreader

3. DESCRIPTION AND PROCESSING OF DATA

3.1 Log of Tests

Initial Type I fluid tests were conducted at the APS test site during the winter of 2002-03 in conjunction with tests measuring frost intensity. Further tests with Type I, Type II, Type III and Type IV fluids were conducted during the winters of 2003-04 through 2007-08.

To facilitate the accessibility of the data collected, three logs were created for the series of tests conducted by APS at the Montreal-Trudeau test site. The logs were separated into the following three groupings:

- Type I Tests (Table 3.1);
- Type II/III/IV Tests – Failed (Table 3.2); and
- Type II/III/IV Tests – Not Failed (Table 3.3).

Each log provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. The following is a brief description of the column headings used in the test logs:

Test No.: Exclusive number identifying each test.

Date: Date when the test was conducted.

Run No.: Run number in which the test was performed.

Plate No.: Frosticator plate position on the test stand (positions 1 to 12).

Chart Completed: X designates a Type II, III, and IV test that failed. Data collected for these tests has been graphically plotted and is included in Appendix C.

Start Time: Start time for the test recorded in local time.

End Time: End time for the test recorded in local time.

Fluid Dilution: Aircraft deicing fluid glycol concentration.

Fluid Type: Aircraft deicing fluid type.

Fluid Quantity: Quantity of aircraft deicing fluid applied to test plate.

Fluid Name:	Manufacturer brand name specific to each aircraft deicing fluid.
Fluid Brix Initial:	Fluid Brix measurement, following fluid application, measured at the 15 cm line.
Fluid Brix Final:	Fluid Brix measurement, at time of failure, measured at the 15 cm line.
Endurance Time:	Total Time elapsed during the test, measured in minutes.
Average Rate:	Average precipitation rate, measured in $g/dm^2/h$, collected by two frosticator rate plates at half to one hour intervals for the duration of the test session.
Average OAT:	The average of hourly outside ambient temperature, measured in degrees Celsius, provided by Environment Canada.
Average RH:	The average of hourly RH, measured in percentage, provided by Environment Canada.
Average Wind Speed:	The average of hourly wind speed, measured in degrees Celsius, provided by Environment Canada.
Average Plate Temp:	The average of the plate surface temperature prior to fluid application and following fluid failure, measured in degrees Celsius.
ΔT:	Temperature differential between the average OAT and the average plate temperature.
Comments:	Relevant information documented by APS personnel concerning the respective test.

Table 3.1: Type I Fluid Tests

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate ($g/dm^2/h$)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
1	27-Feb-2003	1	1	N/A	23:35:00	1:25:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.8	0.073	-13.4	72	6	-15.9	2.5	Failed
2	27-Feb-2003	1	3	N/A	23:38:00	1:25:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.8	0.075	-13.4	72	6	-15.7	2.4	Failed
3	27-Feb-2003	1	2	N/A	0:15:00	2:01:00	10° Buffer	1	0.5	Safetemp HOC-PG	N/A	N/A	1.8	0.083	-13.7	72	6	-16.0	2.4	Failed
4	28-Feb-2003	2	1	N/A	2:15:00	4:05:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.8	0.044	-15.1	76	6	-17.4	2.3	Failed
5	28-Feb-2003	2	2	N/A	2:19:00	4:29:00	10° Buffer	1	0.5	Safetemp HOC-PG	N/A	N/A	2.2	0.055	-15.1	76	6	-17.4	2.3	Failed
6	28-Feb-2003	2	3	N/A	2:23:00	4:37:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	2.2	0.054	-15.1	76	6	-17.1	1.9	Failed
7	28-Feb-2003	1	1	N/A	22:50:55	23:54:30	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.1	0.151	-12.5	77	2	-16.2	3.7	Failed
8	28-Feb-2003	1	2	N/A	22:53:31	0:28:32	10° Buffer	1	0.5	Safetemp HOC-PG	N/A	N/A	1.6	0.152	-12.5	77	2	-16.9	4.4	Failed
9	28-Feb-2003	1	3	N/A	22:56:31	0:30:16	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.6	0.154	-12.5	77	2	-16.5	4.0	Failed
10	1-Mar-2003	2	1	N/A	0:48:59	2:31:56	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.7	0.085	-12.2	79	4	-13.8	1.6	Failed
11	1-Mar-2003	2	2	N/A	0:49:46	2:31:56	10° Buffer	1	0.5	Safetemp HOC-PG	N/A	N/A	1.7	0.110	-12.2	79	4	-14.9	2.6	Failed
12	1-Mar-2003	2	3	N/A	0:50:26	2:34:15	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.7	0.108	-12.2	79	4	-15.4	3.2	Failed
13	1-Mar-2003	3	1	N/A	2:46:39	3:58:24	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.2	0.089	-12.8	83	6	-16.0	3.3	Failed
14	1-Mar-2003	3	2	N/A	2:47:19	4:18:23	10° Buffer	1	0.5	Safetemp HOC-PG	N/A	N/A	1.5	0.097	-12.8	83	6	-16.5	3.7	Failed
15	1-Mar-2003	3	3	N/A	2:47:53	4:21:42	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.6	0.094	-12.8	83	6	-16.2	3.4	Failed
16	6-Mar-2003	1	2	N/A	23:00:50	0:28:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.5	0.087	-19.4	68	5	-24.1	4.7	Failed
17	6-Mar-2003	1	3	N/A	23:01:30	1:03:45	10° Buffer	1	0.5	UCAR ADF PG	N/A	N/A	2.0	0.098	-19.4	69	5	-25.1	5.7	Failed
18	7-Mar-2003	2	2	N/A	1:13:00	2:25:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.2	0.106	-20.3	67	5	-25.1	4.8	Failed
19	7-Mar-2003	2	3	N/A	1:13:30	3:05:00	10° Buffer	1	0.5	UCAR ADF PG	N/A	N/A	1.9	0.122	-20.3	66	6	-24.8	4.4	Failed
20	7-Mar-2003	3	2	N/A	3:15:00	5:03:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.8	0.093	-21.0	67	6	-25.8	4.8	Failed
21	7-Mar-2003	3	3	N/A	3:17:00	5:43:00	10° Buffer	1	0.5	UCAR ADF PG	N/A	N/A	2.4	0.085	-21.0	66	6	-25.3	4.3	Failed
22	15-Mar-2003	1	1	N/A	22:27:00	23:41:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.2	0.146	-8.0	78	0	-11.6	3.7	Failed
23	15-Mar-2003	1	2	N/A	22:30:00	0:01:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.5	0.145	-8.0	78	2	-11.3	3.4	Failed
24	15-Mar-2003	2	1	N/A	0:25:00	1:42:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.3	0.135	-8.6	81	2	-12.4	3.8	Failed
25	16-Mar-2003	2	2	N/A	0:29:00	1:55:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.4	0.126	-8.6	81	2	-12.2	3.7	Failed
26	16-Mar-2003	3	1	N/A	2:18:30	3:41:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.4	0.141	-6.9	80	7	-9.6	2.6	Failed

N/A – Not Available

Table 3.1: Type I Fluid Tests (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate ($g/dm^2/h$)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
27	16-Mar-2003	3	2	N/A	2:22:30	4:05:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.7	0.168	-6.9	80	7	-9.1	2.2	Failed
28	24-Mar-2003	1	1	N/A	0:35:00	1:52:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.3	0.275	0.2	83	6	-2.8	2.9	Failed
29	24-Mar-2003	1	2	N/A	0:39:00	2:05:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.4	0.247	0.2	83	6	-2.8	2.9	Failed
30	24-Mar-2003	2	1	N/A	2:14:30	3:15:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.0	0.304	-0.9	83	3	-3.7	2.7	Failed
31	24-Mar-2003	2	2	N/A	2:15:30	3:28:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.2	0.337	-0.9	83	3	-4.1	3.2	Failed
32	9-Apr-2003	1	1	N/A	23:19:00	0:24:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.1	0.129	-1.7	77	6	-5.8	4.1	Failed
33	9-Apr-2003	1	2	N/A	23:23:00	0:45:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.4	0.200	-1.7	77	6	-6.1	4.4	Failed
34	10-Apr-2003	2	1	N/A	1:10:00	2:20:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.2	0.229	-2.8	80	7	-6.6	3.9	Failed
35	10-Apr-2003	2	2	N/A	1:14:00	2:30:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.3	0.263	-2.8	80	7	-6.3	3.6	Failed
36	10-Apr-2003	3	1	N/A	3:15:00	4:50:00	10° Buffer	1	0.5	UCAR ADF EG	N/A	N/A	1.6	0.189	-2.9	80	5	-6.1	3.1	Failed
37	10-Apr-2003	3	2	N/A	3:20:00	4:55:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	N/A	N/A	1.6	0.189	-2.9	80	6	-6.5	3.6	Failed
38	8-Dec-2003	1	5	N/A	21:04:00	22:15:00	10° Buffer	1	0.5	UCAR ADF EG	20.25	17.00	1.2	0.111	-7.5	82	7	-13.9	6.4	Failed
39	8-Dec-2003	1	10	N/A	21:04:00	21:55:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	25.25	15.25	0.9	0.081	-7.5	82	7	-14.6	7.1	Failed
40	8-Dec-2003	1A	5	N/A	22:31:00	23:17:00	10° Buffer	1	0.5	UCAR ADF EG	21.00	16.25	0.8	0.129	-8.7	92	7	-13.6	4.9	Failed
41	8-Dec-2003	1A	10	N/A	22:21:00	23:26:00	10° Buffer	1	0.5	Clariant Safewing MP I 1938 ECO	27.25	18.25	1.1	0.154	-8.7	92	7	-14.0	5.3	Failed
50	9-Dec-2003	1B	5	N/A	2:52:30	4:12:00	10° Buffer	1	0.5	UCAR ADF EG	22.25	16.00	1.3	0.129	-11.0	93	4	-16.0	5.0	Failed
60	9-Mar-2004	1	1	N/A	22:38:00	23:50:00	10° Buffer	1	0.5	UCAR ADF PG	22.50	16.50	1.2	0.104	-3.7	65	4	-16.1	12.4	Failed
73	10-Mar-2004	2	1	N/A	0:12:00	1:25:00	10° Buffer	1	0.5	UCAR ADF PG	22.50	17.00	1.2	0.126	-3.7	66	6	-10.3	6.6	Failed
74	10-Mar-2004	2	1	N/A	1:38:40	2:46:00	10° Buffer	1	0.5	UCAR ADF EG	19.00	13.00	1.1	0.110	-4.0	66	5	-10.9	6.9	Failed
75	10-Mar-2004	2	11	N/A	2:05:00	3:15:00	10° Buffer	1	0.5	UCAR ADF EG	19.00	12.50	1.2	0.132	-4.0	66	5	-10.8	6.8	Failed
78	9-Dec-2004	1B	10	N/A	2:52:30	4:17:00	10° Buffer	1	1	Clariant Safewing MP I 1938 ECO	28.00	22.00	1.4	0.129	-11.0	93	6	-9.8	-1.3	Failed
215	12-Jan-2008	1	2	N/A	19:58:00	5:15:00	75%	2b	1	Ecowing 26	29.50	18.00	9.3	0.089	-4.1	72	7	-3.6	NA	Failed
216	12-Jan-2008	1	3	N/A	18:31:00	4:23:00	100%	3	1	Clariant Safewing MP III 2031 ECO	35.50	18.00	9.9	0.089	-3.4	71	7	-4.4	1.0	Failed
217	12-Jan-2008	1	4	N/A	19:58:30	1:50:00	75%	3b	1	Clariant Safewing MP III 2031 ECO	28.50	18.00	5.9	0.072	-3.2	70	8	-9.3	6.1	Failed
225	16-Jan-2008	1	1	N/A	18:53:35	4:05:00	100%	2	1	Ecowing 26	37.25	24.75	9.2	0.079	-10.3	74	3	-8.2	NA	Failed

N/A – Not Available

Table 3.1: Type I Fluid Tests (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate (g/dm²/h)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
226	16-Jan-2008	1	2	N/A	21:03:30	3:38:00	75%	2b	1	Ecowing 26	31.00	25.00	6.6	0.094	-11.0	78	2	-13.2	2.2	Failed
228	16-Jan-2008	1	4	N/A	21:05:00	2:05:00	75%	3b	1	Clariant Safewing MP III 2031 ECO	28.25	23.25	5.0	0.090	-10.8	76	2	-20.4	9.6	Failed
230	16-Jan-2008	1	6	N/A	21:05:30	3:38:00	75%	2b	1	X'IAN KF-II	28.75	25.50	6.5	0.094	-11.0	78	2	-17.5	6.5	Failed
234	16-Jan-2008	1	12	N/A	21:08:30	7:00:00	75%	2b	1	Newave	29.25	22.75	9.9	0.076	-10.4	76	3	-13.2	2.8	Failed
236	28-Feb-2008	1	1	N/A	19:38:00	6:00:00	100%	2	1	Ecowing 26	37.50	32.25	10.4	0.031	-18.5	52	7	-20.0	1.5	Failed
237	28-Feb-2008	1	2	N/A	19:38:30	6:15:00	100%	2	1	Ecowing 26	37.50	33.00	10.6	0.031	-18.5	52	7	-12.5	NA	Failed

N/A – Not Available

Table 3.2: Type II/III/IV Tests – Failed

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate ($g/dm^2/h$)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
42	8-Dec-2003	1	1	X	20:19:00	4:14:00	100%	4	1	Clariant Safewing MP IV 2012	35.25	26.00	7.9	0.149	-10.1	87	6	-16.3	6.2	Failed
43	8-Dec-2003	1	2	X	22:50:00	3:39:00	75%	4b	1	Clariant Safewing MP IV 2012	27.00	23.50	4.8	0.182	-9.9	92	6	-14.2	4.3	Failed
44	8-Dec-2003	1	9	X	20:32:40	4:45:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27.60	24.75	8.2	0.148	-9.4	88	5	-14.7	5.3	Failed
61	9-Mar-2004	1	3	X	19:09:00	23:45:00	75%	4b	1	Clariant Safewing MP IV 2012	28.00	18.00	4.6	0.072	-3.0	64	6	-6.8	3.8	Failed
62	9-Mar-2004	1	4	X	19:10:00	6:00:00	100%	4	1	Clariant Safewing MP IV 2001	35.75	28.00	10.8	0.112	-4.3	65	5	-7.7	3.4	Failed
63	9-Mar-2004	1	7	X	19:15:00	1:05:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.25	18.50	5.8	0.088	-3.1	63	6	-6.8	3.7	Failed
64	9-Mar-2004	1	8	X	19:16:00	4:44:00	100%	2	1	Kilfrost P1491	36.50	21.00	9.5	0.108	-3.6	64	5	-7.9	4.3	Failed
65	9-Mar-2004	1	9	X	19:17:00	4:44:00	75%	2b	1	Kilfrost P1491	28.75	21.00	9.5	0.108	-3.6	64	5	-7.7	4.1	Failed
66	9-Mar-2004	1	10	X	19:18:00	5:46:00	100%	2	1	SPCA Ecowing 26	35.75	21.50	10.5	0.112	-4.3	65	5	-7.5	3.2	Failed
67	9-Mar-2004	1	11	X	19:19:00	2:00:00	75%	2b	1	SPCA Ecowing 26	28.25	20.00	6.7	0.095	-3.1	63	6	-6.5	3.4	Failed
76	10-Mar-2004	2	3	X	0:09:00	6:00:00	75%	4b	1	Clariant Safewing MP IV 2012	28.00	22.00	5.9	0.130	-4.8	68	5	-9.1	4.3	Failed
77	10-Mar-2004	2	7	X	1:11:00	5:44:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.50	22.25	4.6	0.132	-5.0	69	5	-10.6	5.6	Failed
84	Dec-29-2004	1	6	X	17:49:20	6:50:00	100%	4	1	Clariant Safewing MP IV 2012	35.25	24	13.0	0.104	-9.3	80	6	-14.5	5.2	Failed
94	Jan-27-2005	1	6	X	18:26:00	0:22:00	100%	4	1	Clariant Safewing MP IV 2012	N/A	31	5.9	0.033	-19.2	55	13	-23.6	4.4	Failed
95	Jan-27-2005	1	9	X	18:27:00	4:45:00	100%	4	1	Octagon Maxflight	N/A	32.5	10.3	0.040	-20.2	58	11	-24.8	4.6	Failed
106	Jan-28-2005	1	12	X	18:10:00	5:10:00	100%	4	1	Clariant Safewing MP IV 2012	N/A	28.25	11.0	0.030	-14.2	62	10	-19.3	5.1	Failed
107	Jan-31-2005	1	2	X	17:57:00	21:16:00	75%	2b	1	Kilfrost ABC II+	28	28	3.3	0.189	-10.1	73	5	-17.7	7.6	Failed
108	Jan-31-2005	1	3	X	18:01:00	0:09:00	100%	4	1	Clariant Safewing MP IV 2012	35.5	28	6.1	0.154	-10.8	75	3	-18.5	7.7	Failed
109	Jan-31-2005	1	4	X	18:01:30	21:17:00	75%	4b	1	Clariant Safewing MP IV 2012	27.8	26.75	3.3	0.189	-10.1	73	5	-18.0	7.9	Failed
112	Jan-31-2005	1	9	X	18:06:30	21:15:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27.75	29	3.1	0.189	-10.1	73	5	-17.7	7.6	Failed
114	Jan-31-2005	1	11	X	18:07:30	21:15:00	75%	4b	1	Kilfrost ABC-S	27.5	28	3.1	0.189	-10.1	73	5	-18.0	7.9	Failed
115	Jan-31-2005	1	12	X	18:07:45	21:15:00	75%	2b	1	Kilfrost ABC 2000	28.25	28	3.1	0.189	-10.1	73	5	-17.6	7.5	Failed
116	Jan-31-2005	2	4	X	22:29:30	0:04:00	75%	4b	1	Clariant Safewing MP IV 2012	27	27.75	1.6	0.131	-11.9	78	3	-20.6	8.7	Failed
117	Jan-31-2005	2	9	X	22:30:10	0:40:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27	28.5	2.2	0.117	-12.5	80	3	-21.3	8.8	Failed
118	Jan-31-2005	2	11	X	22:30:50	23:50:00	75%	4b	1	Kilfrost ABC-S	27.5	27.5	1.3	0.131	-11.9	78	3	-20.5	8.6	Failed
119	Jan-31-2005	2	12	X	22:31:20	1:00:00	75%	2b	1	Kilfrost ABC 2000	28	28	2.5	0.117	-12.5	80	3	-20.7	8.2	Failed

N/A – Not Available

Table 3.2: Type II/III/IV Tests – Failed (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate (g/dm²/h)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
121	Jan-31-2005	3	4	X	0:24:55	2:55:00	75%	2b	1	Kilfrost ABC II+	28.3	27.5	2.5	0.091	-13.6	84	6	-20.3	6.7	Failed
122	Jan-31-2005	3	11	X	0:44:00	2:17:00	75%	4b	1	Kilfrost ABC-S	27.5	27.5	1.6	0.083	-14.4	84	6	-20.4	6.0	Failed
124	Jan-31-2005	4	11	X	3:14:10	5:45:00	75%	4b	1	Clariant Safewing MP IV 2030 ECO	28.25	28	2.5	0.106	-14.7	88	4	-20.2	5.5	Failed
125	Feb-02-2005	1	1	X	18:10:30	4:00:00	75%	4b	1	Clariant Safewing MP IV 2001	27.25	22	9.8	0.094	-6.4	78	8	-10.3	3.9	Failed
126	Feb-02-2005	1	2	X	17:53:00	1:01:00	75%	4b	1	Clariant Safewing MP IV 2012	29	21	7.1	0.081	-5.3	75	8	-9.9	4.6	Failed
134	Feb-02-2005	1	12	X	18:04:30	3:05:00	100%	3	1	Clariant Safewing MP III 2031 ECO	N/A	22.25	9.0	0.093	-6.1	77	8	-8.7	2.6	Failed
142	Feb-04-2005	1	9	X	17:49:10	1:58:00	100%	3	1	Clariant Safewing MP III 2031 ECO	35.5	20	8.1	0.062	-3.8	68	6	-8.6	4.8	Failed
146	Feb-25-2005	1	1	X	18:46:50	5:11:00	100%	2	1	Kilfrost ABC 2000	36	31	10.4	0.063	-13.0	71	5	-19.1	6.1	Failed
147	Feb-25-2005	1	2	X	19:55:30	23:20:00	75%	2b	1	Kilfrost ABC 2000	28.5	28.25	3.4	0.048	-11.0	67	5	-18.2	7.2	Failed
149	Feb-25-2005	1	4	X	18:47:20	22:53:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27.5	28	4.1	0.038	-10.5	65	6	-18.3	7.8	Failed
150	Feb-25-2005	1	5	X	18:48:00	2:14:00	100%	3	1	Clariant Safewing MP III 2031 ECO	35	28	7.4	0.060	-12.0	70	6	-19.0	7.0	Failed
151	Feb-25-2005	1	6	X	19:55:40	23:05:00	75%	2b	1	Kilfrost ABC II+	27	28	3.2	0.048	-11.0	67	5	-18.2	7.2	Failed
153	Feb-25-2005	1	10	X	18:48:40	22:41:00	75%	4b	1	Clariant Safewing MP IV 2030 ECO	28.5	28	3.9	0.038	-10.5	65	6	-17.0	6.5	Failed
155	Feb-25-2005	1	12	X	18:48:20	5:25:00	100%	4	1	Clariant Safewing MP IV 2001	36.25	30.5	10.6	0.063	-13.4	72	6	-19.7	6.3	Failed
156	Feb-25-2005	2	2	X	23:43:40	0:51:00	75%	2b	1	Kilfrost ABC 2000	27.5	27.25	1.1	0.081	-14.1	78	8	-22.1	8.0	Failed
157	Feb-25-2005	2	4	X	23:28:20	1:02:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27.5	27.5	1.6	0.081	-13.3	76	7	-22.0	8.7	Failed
158	Feb-25-2005	2	6	X	23:38:30	1:11:00	75%	2b	1	Kilfrost ABC II+	28	27.75	1.5	0.088	-13.3	76	8	-21.3	8.0	Failed
159	Feb-25-2005	2	10	X	23:28:50	0:44:00	75%	4b	1	Clariant Safewing MP IV 2030 ECO	28.5	28.25	1.3	0.081	-13.3	76	8	-21.5	8.2	Failed
160	13-Dec-2005	1	1	N/A	18:48:36	2:50:00	100%	2	1	SPCA Ecowing 26	37.75	29.00	8.0	0.090	-16.8	81	2	-23.0	6.2	Failed
161	13-Dec-2005	1	2	N/A	18:48:56	0:10:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.00	30.00	5.4	0.086	-15.7	79	2	-21.8	6.1	Failed
162	13-Dec-2005	1	3	N/A	18:49:12	0:10:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.00	30.00	5.3	0.086	-15.7	79	2	-22.3	6.6	Failed
163	13-Dec-2005	1	4	N/A	18:49:40	1:09:00	100%	4	1	Clariant Safewing MP IV 2012	35.75	30.00	6.3	0.085	-16.2	79	2	-22.3	6.1	Failed
164	13-Dec-2005	1	5	N/A	18:49:54	1:09:00	100%	4	1	Clariant Safewing MP IV 2012	35.75	30.00	6.3	0.085	-16.2	79	2	-22.1	5.9	Failed
168	13-Dec-2005	1	11	N/A	18:51:34	2:51:00	100%	2	1	SPCA Ecowing 26	37.50	28.50	8.0	0.090	-16.8	81	2	-23.0	6.2	Failed
170	10-Feb-2006	1	1	N/A	18:11:30	6:07:00	100%	2	1	SPCA Ecowing 26	37.50	28.00	11.9	0.094	-13.7	65	4	-19.8	6.1	Failed
171	10-Feb-2006	1	2	N/A	18:11:50	22:40:00	75%	2b	1	SPCA Ecowing 26	29.75	28.25	4.5	0.114	-12.3	56	4	-17.3	5.0	Failed

N/A – Not Available

Table 3.2: Type II/III/IV Tests – Failed (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate (g/dm²/h)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
172	10-Feb-2006	1	3	N/A	18:12:10	21:53:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	28.00	27.75	3.7	0.130	-12.1	53	4	-18.1	6.0	Failed
173	10-Feb-2006	1	4	N/A	18:12:30	2:50:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.25	30.00	8.6	0.094	-13.0	62	4	-20.0	7.0	Failed
174	10-Feb-2006	1	5	N/A	18:12:45	21:45:00	75%	3b	1	Clariant Safewing MP III 2031 ECO	28.25	27.50	3.5	0.130	-12.1	53	4	-18.3	6.2	Failed
175	10-Feb-2006	1	6	N/A	18:13:05	4:53:00	100%	4	1	Clariant Safewing MP IV 2012	36.25	26.50	10.7	0.092	-13.5	64	4	-19.3	5.8	Failed
176	10-Feb-2006	1	9	N/A	18:14:30	21:35:00	75%	4b	1	Clariant Safewing MP IV 2012	29.00	26.25	3.3	0.130	-12.1	53	4	-16.8	4.7	Failed
181	27-Mar-2006	1	3	N/A	19:25:00	0:05:00	100%	3	1	Clariant Safewing MP III 2031 ECO	35.50	6.50	4.7	0.070	2.0	58	6	-5.1	7.1	Failed
182	27-Mar-2006	1	4	N/A	20:34:45	2:42:00	50%	2c	1	Kilfrost ABC 2000	20.00	13.50	6.1	0.146	0.3	66	3	-6.6	6.9	Failed
183	27-Mar-2006	1	5	N/A	19:25:20	0:35:00	75%	3b	1	Clariant Safewing MP III 2031 ECO	29.00	12.00	5.2	0.081	1.5	61	6	-5.2	6.7	Failed
184	27-Mar-2006	1	6	N/A	20:35:20	23:34:00	50%	3c	1	Clariant Safewing MP III 2031 ECO	18.50	8.50	3.0	0.137	1.0	65	5	-5.3	6.3	Failed
186	27-Mar-2006	1	10	N/A	20:36:25	23:50:00	50%	4c	1	Clariant Safewing MP IV 2012	19.50	7.50	3.2	0.137	1.0	65	4	-4.9	5.9	Failed
188	27-Mar-2006	1	12	N/A	20:37:07	1:10:00	50%	4c	1	Octagon Maxflo	19.25	11.00	4.5	0.137	0.4	68	2	-5.6	6.0	Failed
189	27-Mar-2006	2	3	N/A	0:25:34	2:20:00	50%	2c	1	SPCA Ecowing 26	20.00	11.00	1.9	0.152	-1.1	73	2	-7.5	6.4	Failed
190	27-Mar-2006	2	6	N/A	0:26:00	1:50:00	50%	3c	1	Clariant Safewing MP III 2031 ECO	19.00	11.25	1.4	0.148	-0.9	73	2	-6.7	5.8	Failed
191	27-Mar-2006	2	10	N/A	0:27:15	5:45:00	50%	4c	1	Kilfrost ABC-S	20.50	14.00	5.3	0.152	-1.3	73	3	-7.5	6.2	Failed
199	30-Oct-2006	1	9	N/A	20:57:47	0:10:00	50%	4c	1	Octagon Maxflo	19.25	12.25	3.2	0.073	1.1	73	3	-1.0	2.1	Failed
206	24-Nov-2006	1	3	N/A	19:43:50	3:07:00	75%	2b	1	Kilfrost ABC 2000	27.75	21.75	7.4	0.098	-0.5	74	4	-6.2	5.7	Failed
212	24-Nov-2006	1	11	N/A	19:45:45	3:15:00	50%	4c	1	Kilfrost ABC-S	18.5	12.25	7.5	0.098	-0.5	74	4	-6.2	5.7	Failed
215	12-Jan-2008	1	2	N/A	19:58:00	5:15:00	75%	2b	1	Ecowing 26	29.50	18.00	9.3	0.089	-4.1	72	7	-3.6	NA	Failed
216	12-Jan-2008	1	3	N/A	18:31:00	4:23:00	100%	3	1	Clariant Safewing MP III 2031 ECO	35.50	18.00	9.9	0.089	-3.4	71	7	-4.4	1.0	Failed
217	12-Jan-2008	1	4	N/A	19:58:30	1:50:00	75%	3b	1	Clariant Safewing MP III 2031 ECO	28.50	18.00	5.9	0.072	-3.2	70	8	-9.3	6.1	Failed
225	16-Jan-2008	1	1	N/A	18:53:35	4:05:00	100%	2	1	Ecowing 26	37.25	24.75	9.2	0.079	-10.3	74	3	-8.2	NA	Failed
226	16-Jan-2008	1	2	N/A	21:03:30	3:38:00	75%	2b	1	Ecowing 26	31.00	25.00	6.6	0.094	-11.0	78	2	-13.2	2.2	Failed
228	16-Jan-2008	1	4	N/A	21:05:00	2:05:00	75%	3b	1	Clariant Safewing MP III 2031 ECO	28.25	23.25	5.0	0.090	-10.8	76	2	-20.4	9.6	Failed
230	16-Jan-2008	1	6	N/A	21:05:30	3:38:00	75%	2b	1	X'IAN KF-II	28.75	25.50	6.5	0.094	-11.0	78	2	-17.5	6.5	Failed
234	16-Jan-2008	1	12	N/A	21:08:30	7:00:00	75%	2b	1	Newave	29.25	22.75	9.9	0.076	-10.4	76	3	-13.2	2.8	Failed
236	28-Feb-2008	1	1	N/A	19:38:00	6:00:00	100%	2	1	Ecowing 26	37.50	32.25	10.4	0.031	-18.5	52	7	-20.0	1.5	Failed
237	28-Feb-2008	1	2	N/A	19:38:30	6:15:00	100%	2	1	Ecowing 26	37.50	33.00	10.6	0.031	-18.5	52	7	-12.5	NA	Failed

N/A – Not Available

Table 3.3: Type II/III/IV Tests – Not Failed

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate (g/dm^2/h)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
45	8-Dec-2003	1	3	N/A	20:21:40	6:00:00	100%	4	0.5	Clariant Safewing MP IV 2001	35.50	N/A	9.6	0.159	-9.7	88	5	-15.5	5.8	NOT FAILED
46	8-Dec-2003	1	4	N/A	22:50:30	6:00:00	75%	4b	0.5	Clariant Safewing MP IV 2001	26.00	N/A	7.2	0.178	-10.7	92	5	-15.8	5.1	NOT FAILED
47	8-Dec-2003	1	6	N/A	20:30:00	6:00:00	100%	4	0.5	Clariant Safewing MP IV 2030 ECO	35.50	N/A	9.5	0.159	-9.7	88	5	-15.6	5.9	NOT FAILED
48	8-Dec-2003	1	7	N/A	20:30:40	6:00:00	75%	4b	0.5	Clariant Safewing MP IV 2030 ECO	27.50	N/A	9.5	0.159	-9.7	88	5	-15.5	5.8	NOT FAILED
49	8-Dec-2003	1	8	N/A	20:32:20	6:00:00	100%	2	0.5	Clariant Safewing MP II 2025 ECO	35.75	N/A	9.5	0.159	-9.7	88	5	-15.7	6.0	NOT FAILED
51	16-Feb-2004	1	1	N/A	18:38:30	2:30:00	100%	2	0.5	Clariant Safewing MP II 2025 ECO	35.75	37.50	7.9	0.064	-15.0	45	14	-19.2	4.2	NOT FAILED
52	16-Feb-2004	1	2	N/A	18:39:00	2:30:00	100%	4	0.5	Clariant Safewing MP IV 2030 ECO	36.00	37.50	7.9	0.064	-15.0	45	14	-19.2	4.2	NOT FAILED
53	16-Feb-2004	1	3	N/A	18:39:30	2:30:00	100%	4	0.5	Clariant Safewing MP IV 2012	35.50	40.25	7.8	0.064	-15.0	45	14	-19.4	4.4	NOT FAILED
54	16-Feb-2004	1	4	N/A	18:40:00	2:30:00	100%	4	0.5	Clariant Safewing MP IV 2001	35.75	36.50	7.8	0.064	-15.0	45	14	-19.4	4.4	NOT FAILED
55	16-Feb-2004	1	5	N/A	18:40:45	2:30:00	100%	4	0.5	Octagon Maxflight	36.50	38.25	7.8	0.064	-15.0	45	14	-19.5	4.5	NOT FAILED
56	16-Feb-2004	1	6	N/A	18:41:20	2:30:00	100%	2	0.5	SPCA Ecowing 26	35.75	40.25	7.8	0.064	-15.0	45	14	-19.6	4.6	NOT FAILED
57	16-Feb-2004	1	7	N/A	18:42:00	2:30:00	100%	4	0.5	SPCA AD-480	36.50	37.50	7.8	0.064	-15.0	45	14	-19.3	4.3	NOT FAILED
58	16-Feb-2004	1	8	N/A	18:42:30	2:30:00	100%	4	0.5	Dow UCAR Ultra+	41.00	40.75	7.8	0.064	-15.0	45	14	-19.4	4.4	NOT FAILED
59	16-Feb-2004	1	9	N/A	18:43:00	2:30:00	100%	3	0.5	Clariant Safewing MP III 2031 ECO	35.75	37.50	7.8	0.064	-15.0	45	14	-20.0	5.0	NOT FAILED
68	9-Mar-2004	1	1	N/A	19:07:00	6:00:00	100%	4	0.5	Dow UCAR Ultra+	40.50	37.00	10.9	0.112	-4.3	65	5	-10.0	5.7	NOT FAILED
69	9-Mar-2004	1	2	N/A	19:08:00	6:00:00	100%	4	0.5	Clariant Safewing MP IV 2012	35.75	24.50	10.9	0.112	-4.3	65	5	-10.6	6.3	NOT FAILED
70	9-Mar-2004	1	5	N/A	19:11:00	6:00:00	75%	4b	0.5	Clariant Safewing MP IV 2001	28.75	25.50	10.8	0.112	-4.3	65	5	-10.9	6.6	NOT FAILED
71	9-Mar-2004	1	6	N/A	19:12:30	6:00:00	100%	4	0.5	Octagon Maxflight	36.50	29.00	10.8	0.112	-4.3	65	5	-10.3	6.0	NOT FAILED
72	9-Mar-2004	1	12	N/A	19:20:00	6:00:00	75%	2b	0.5	Clariant Safewing MP II 2025 ECO	27.50	26.00	10.7	0.112	-4.3	65	5	-11.0	6.7	NOT FAILED
79	Dec-29-2004	1	1	N/A	17:47:00	7:20:00	100%	2	1	Kilfrost ABC 2000	37.5	28.5	13.6	0.104	-9.3	80	6	-14.2	4.9	NOT FAILED
80	Dec-29-2004	1	2	N/A	17:47:30	7:20:00	100%	4	1	Octagon Maxflight	36.25	34.25	13.5	0.104	-9.3	80	6	-14.0	4.7	NOT FAILED
81	Dec-29-2004	1	3	N/A	17:48:00	7:20:00	100%	4	1	Kilfrost ABC-S	36.5	34	13.5	0.104	-9.3	80	6	-14.2	4.9	NOT FAILED
82	Dec-29-2004	1	4	N/A	17:48:30	7:20:00	100%	4	1	Dow UCAR Ultra+	40	37.5	13.5	0.104	-9.3	80	6	-13.5	4.2	NOT FAILED
83	Dec-29-2004	1	5	N/A	17:49:00	7:20:00	100%	4	1	Clariant Safewing MP IV 2030 ECO	35.5	33.25	13.5	0.104	-9.3	80	6	-14.8	5.5	NOT FAILED
85	Dec-29-2004	1	7	N/A	17:50:00	7:20:00	100%	2	1	Kilfrost ABC II+	28.5	27.75	13.5	0.104	-9.3	80	6	-14.3	5.0	NOT FAILED
86	Dec-29-2004	1	8	N/A	18:04:00	7:20:00	100%	2	1	Clariant Safewing MP II 2025 ECO	35.25	37	13.3	0.104	-9.3	80	6	-15.2	5.9	NOT FAILED

N/A – Not Available

Table 3.3: Type II/III/IV Tests – Not Failed (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate (g/dm²/h)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
87	Dec-29-2004	1	9	N/A	18:04:10	7:20:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27.5	26.5	13.3	0.104	-9.3	80	6	-15.2	5.9	NOT FAILED
88	Dec-29-2004	1	10	N/A	18:04:40	7:20:00	75%	4b	1	Clariant Safewing MP IV 2030 ECO	28	27.25	13.3	0.104	-9.3	80	6	-14.9	5.6	NOT FAILED
89	Dec-29-2004	1	11	N/A	18:05:00	7:20:00	75%	2b	1	Kilfrost ABC II+	35.75	25.5	13.3	0.104	-9.3	80	6	-14.9	5.6	NOT FAILED
90	Dec-29-2004	1	12	N/A	18:05:30	7:20:00	75%	4b	1	Clariant Safewing MP IV 2001	28	25	13.2	0.104	-9.3	80	6	-15.0	5.7	NOT FAILED
91	Jan-27-2005	1	3	N/A	18:24:00	7:00:00	100%	2	1	Clariant Safewing MP II 2025 ECO	N/A	35.5	12.6	0.048	-20.5	60	11	-22.7	2.2	NOT FAILED
92	Jan-27-2005	1	4	N/A	18:25:00	7:00:00	100%	2	1	Kilfrost ABC 2000	N/A	37	12.6	0.048	-20.5	60	10	-22.9	2.4	NOT FAILED
93	Jan-27-2005	1	5	N/A	18:25:30	7:00:00	100%	2	1	Kilfrost ABC II+	N/A	36.75	12.6	0.048	-20.5	60	11	-23.5	3.0	NOT FAILED
96	Jan-27-2005	1	10	N/A	18:30:00	7:00:00	100%	4	1	Kilfrost ABC-S	N/A	35.5	12.5	0.048	-20.5	60	11	-23.5	3.0	NOT FAILED
97	Jan-27-2005	1	11	N/A	18:31:00	7:00:00	100%	4	1	Dow UCAR Ultra+	N/A	40.5	12.5	0.048	-20.5	60	11	-23.3	2.8	NOT FAILED
98	Jan-27-2005	1	12	N/A	18:31:30	7:00:00	100%	4	1	Clariant Safewing MP IV 2001	N/A	34.75	12.5	0.048	-20.5	60	11	-23.8	3.3	NOT FAILED
99	Jan-28-2005	1	3	N/A	18:24:30	7:00:00	100%	3	1	Clariant Safewing MP III 2031 ECO	N/A	30.5	12.6	0.039	-14.5	63	10	-19.4	4.9	NOT FAILED
100	Jan-28-2005	1	4	N/A	18:19:30	7:00:00	100%	2	1	Kilfrost ABC II+	N/A	32	12.7	0.039	-14.5	63	10	-19.1	4.6	NOT FAILED
101	Jan-28-2005	1	5	N/A	18:18:30	7:00:00	100%	2	1	Clariant Safewing MP II 2025 ECO	N/A	33.25	12.7	0.039	-14.5	63	10	-19.6	5.1	NOT FAILED
102	Jan-28-2005	1	6	N/A	18:15:30	7:00:00	100%	4	1	Clariant Safewing MP IV 2030 ECO	N/A	34	12.7	0.039	-14.5	63	10	-19.6	5.1	NOT FAILED
103	Jan-28-2005	1	9	N/A	17:56:00	7:00:00	100%	4	1	Dow UCAR Ultra+	N/A	39	13.1	0.039	-14.5	63	10	-20.8	6.3	NOT FAILED
104	Jan-28-2005	1	10	N/A	18:06:00	7:00:00	100%	4	1	Kilfrost ABC-S	N/A	34.25	12.9	0.039	-14.5	63	10	-19.3	4.8	NOT FAILED
105	Jan-28-2005	1	11	N/A	18:08:00	7:00:00	100%	4	1	Octagon Maxflight	N/A	34.5	12.9	0.039	-14.5	63	10	-18.8	4.3	NOT FAILED
110	Jan-31-2005	1	5	N/A	18:03:00	6:50:00	100%	4	1	Dow UCAR Ultra+	N/A	39	12.8	0.120	-12.7	81	4	-17.7	5.0	NOT FAILED
111	Jan-31-2005	1	6	N/A	18:05:00	6:50:00	100%	2	1	Clariant Safewing MP II 2025 ECO	35.5	30.5	12.8	0.120	-12.7	81	4	-17.8	5.1	NOT FAILED
113	Jan-31-2005	1	10	N/A	18:07:00	6:50:00	100%	4	1	Kilfrost ABC-S	37	31.5	12.7	0.120	-12.7	81	4	-19.0	6.3	NOT FAILED
120	Jan-31-2005	3	2	N/A	23:41:45	7:00:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.75	29	7.3	0.092	-14.2	86	5	-19.2	5.0	NOT FAILED
123	Jan-31-2005	3	12	X	2:14:00	7:00:00	75%	4b	1	Octagon Maxflight	28.5	29.5	4.8	0.098	-14.6	87	6	-20.4	5.8	NOT FAILED
127	Feb-02-2005	1	3	N/A	17:53:30	6:45:00	100%	2	1	Kilfrost ABC II+	N/A	28	12.9	0.098	-7.1	80	8	-9.3	2.2	NOT FAILED
128	Feb-02-2005	1	4	N/A	17:58:00	6:45:00	75%	2b	1	Kilfrost ABC II+	26.5	25	12.8	0.098	-7.1	80	8	-9.4	2.3	NOT FAILED
129	Feb-02-2005	1	5	N/A	17:59:00	6:45:00	100%	2	1	Clariant Safewing MP II 2025 ECO	N/A	30.5	12.8	0.098	-7.1	80	8	-9.0	1.9	NOT FAILED
130	Feb-02-2005	1	6	N/A	18:00:30	6:45:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	N/A	26.5	12.7	0.098	-7.1	80	8	-8.7	1.6	NOT FAILED

N/A – Not Available

Table 3.3: Type II/III/IV Tests – Not Failed (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate (g/dm²/h)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
131	Feb-02-2005	1	9	N/A	18:09:00	6:45:00	100%	4	1	Kilfrost ABC-S	N/A	34	12.6	0.098	-7.1	80	8	-8.7	1.6	NOT FAILED
132	Feb-02-2005	1	10	N/A	18:07:30	6:45:00	75%	4b	1	Kilfrost ABC-S	30	31.5	12.6	0.098	-7.1	80	8	-9.3	2.2	NOT FAILED
133	Feb-02-2005	1	11	N/A	18:04:00	6:45:00	100%	4	1	Dow UCAR Ultra+	N/A	22.5	12.7	0.098	-7.1	80	8	-8.7	1.6	NOT FAILED
135	Feb-02-2005	2	2	N/A	1:18:00	6:45:00	75%	2b	1	Kilfrost ABC 2000	28	27.25	5.5	0.117	-9.3	86	8	-11.8	2.5	NOT FAILED
136	Feb-04-2005	1	1	N/A	17:46:30	6:40:00	100%	2	1	Kilfrost ABC II+	35.5	26	12.9	0.080	-4.8	74	6	-7.3	2.5	NOT FAILED
137	Feb-04-2005	1	2	N/A	17:46:40	6:40:00	75%	2b	1	Kilfrost ABC II+	27.5	26	12.9	0.080	-4.8	74	6	-7.4	2.6	NOT FAILED
138	Feb-04-2005	1	3	N/A	17:46:55	6:40:00	100%	4	1	Kilfrost ABC-S	35.75	33.5	12.9	0.080	-4.8	74	6	-8.3	3.5	NOT FAILED
139	Feb-04-2005	1	4	N/A	17:47:45	6:40:00	75%	4b	1	Kilfrost ABC-S	28.5	28	12.9	0.080	-4.8	74	6	-8.0	3.2	NOT FAILED
140	Feb-04-2005	1	5	N/A	17:47:55	6:40:00	100%	4	1	Clariant Safewing MP IV 2030 ECO	35.5	31	12.9	0.080	-4.8	74	6	-8.7	3.9	NOT FAILED
141	Feb-04-2005	1	6	N/A	17:48:10	6:40:00	75%	4b	1	Clariant Safewing MP IV 2030 ECO	28	26.5	12.9	0.080	-4.8	74	6	-8.5	3.7	NOT FAILED
143	Feb-04-2005	1	10	N/A	17:49:24	6:40:00	100%	4	1	Dow UCAR Ultra+	40	31.5	12.8	0.080	-4.8	74	6	-7.9	3.1	NOT FAILED
144	Feb-04-2005	1	11	N/A	17:49:40	6:40:00	100%	2	1	Clariant Safewing MP II 2025 ECO	35.5	29	12.8	0.080	-4.8	74	6	-8.4	3.6	NOT FAILED
145	Feb-04-2005	1	12	N/A	17:49:55	6:40:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27	25	12.8	0.080	-4.8	74	6	-8.3	3.5	NOT FAILED
148	Feb-25-2005	1	3	N/A	18:47:10	6:25:00	100%	2	1	Clariant Safewing MP II 2025 ECO	35.25	31.5	11.6	0.065	-13.6	73	5	-19.6	6.0	NOT FAILED
152	Feb-25-2005	1	9	X	18:48:50	6:25:00	100%	4	1	Clariant Safewing MP IV 2030 ECO	35.5	31.5	11.6	0.065	-13.6	73	5	-19.0	5.4	NOT FAILED
154	Feb-25-2005	1	11	N/A	18:48:30	6:25:00	100%	4	1	Kilfrost ABC-S	36.5	33.5	11.6	0.065	-13.6	73	5	-19.2	5.6	NOT FAILED
165	13-Dec-2005	1	6	N/A	18:50:18	6:55:00	100%	4	1	Clariant Safewing MP IV 2030 ECO	36.00	29.50	12.1	0.096	-17.1	83	3	-22.4	5.3	NOT FAILED
166	13-Dec-2005	1	9	N/A	18:51:03	6:55:00	100%	4	1	Octagon Maxflo	36.50	30.25	12.1	0.096	-17.1	83	3	-23.0	5.9	NOT FAILED
167	13-Dec-2005	1	10	N/A	18:51:18	6:55:00	100%	4	1	Kilfrost ABC-S	36.50	31.50	12.1	0.096	-17.1	83	3	-23.2	6.1	NOT FAILED
169	13-Dec-2005	1	12	N/A	18:51:50	6:55:00	100%	4	1	Octagon Maxflo	36.50	30.50	12.1	0.096	-17.1	83	3	-22.5	5.4	NOT FAILED
177	10-Feb-2006	1	10	N/A	18:14:00	7:00:00	100%	4	1	Octagon Maxflo	37.00	n/a	12.8	0.096	-13.9	66	5	-19.8	5.9	NOT FAILED
178	10-Feb-2006	1	11	N/A	18:13:35	7:00:00	100%	4	1	Kilfrost ABC-S	37.00	n/a	12.8	0.096	-13.9	66	5	-20.3	6.4	NOT FAILED
179	27-Mar-2006	1	1	N/A	19:24:30	7:00:00	100%	2	1	Kilfrost ABC 2000	36.00	23.00	11.6	0.118	0.1	67	5	-7.3	7.4	NOT FAILED
180	27-Mar-2006	1	2	N/A	19:24:45	7:00:00	75%	2b	1	Kilfrost ABC 2000	28.00	21.00	11.6	0.118	0.1	67	5	N/A	N/A	NOT FAILED
185	27-Mar-2006	1	9	N/A	19:25:45	7:00:00	100%	4	1	Clariant Safewing MP IV 2012	35.50	25.00	11.6	0.118	0.1	67	5	-3.1	3.2	NOT FAILED
187	27-Mar-2006	1	11	N/A	19:26:00	7:00:00	100%	4	1	Octagon Maxflo	36.25	32.00	11.6	0.118	0.1	67	5	-6.6	6.7	NOT FAILED

N/A – Not Available

Table 3.3: Type II/III/IV Tests – Not Failed (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate ($g/dm^2/h$)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
192	27-Mar-2006	2	12	N/A	1:16:30	7:00:00	50%	4c	1	Clariant Safewing MP IV 2030 ECO	20.00	17.50	5.7	0.156	-1.5	74	3	-8.3	6.8	NOT FAILED
193	30-Oct-2006	1	1	N/A	20:11:00	7:00:00	100%	4	1	Kilfrost ABC-S	35.5	33	10.8	0.043	1.5	73	8	-3.0	4.5	NOT FAILED
194	30-Oct-2006	1	2	N/A	20:56:10	7:00:00	75%	4b	1	Kilfrost ABC-S	27.5	24.25	10.1	0.043	1.3	74	8	-4.4	5.7	NOT FAILED
195	30-Oct-2006	1	3	N/A	20:56:30	7:00:00	50%	4c	1	Kilfrost ABC-S	20.75	18.5	10.1	0.043	1.3	74	8	-3.3	4.6	NOT FAILED
196	30-Oct-2006	1	4	N/A	20:11:50	7:00:00	100%	4	1	Clariant Safewing MP IV 2012	34.75	32.25	10.8	0.043	1.5	73	8	-2.7	4.2	NOT FAILED
197	30-Oct-2006	1	5	N/A	20:57:00	7:00:00	75%	4b	1	Clariant Safewing MP IV 2012	27.75	25.75	10.1	0.043	1.3	74	8	-2.6	3.9	NOT FAILED
198	30-Oct-2006	1	6	N/A	20:57:20	7:00:00	50%	4c	1	Clariant Safewing MP IV 2012	20.25	19.25	10.0	0.043	1.3	74	8	-2.8	4.1	NOT FAILED
200	30-Oct-2006	1	10	N/A	20:12:17	7:00:00	100%	2	1	Kilfrost ABC 2000	36	28.25	10.8	0.043	1.5	73	8	-2.8	4.3	NOT FAILED
201	30-Oct-2006	1	11	N/A	20:58:05	7:00:00	75%	2b	1	Kilfrost ABC 2000	28	24.75	10.0	0.043	1.3	74	8	-3.2	4.5	NOT FAILED
202	30-Oct-2006	1	12	N/A	20:58:20	7:00:00	50%	2c	1	Kilfrost ABC 2000	19.50	19.25	10.0	0.043	1.3	74	8	-2.9	4.2	NOT FAILED
203	30-Oct-2006	2	9	N/A	0:27:00	7:00:00	50%	4c	1	Clariant Safewing MP IV 2012	20.25	18.75	6.6	0.020	1.3	76	10	-5.0	6.3	NOT FAILED
204	24-Nov-2006	1	1	N/A	18:58:40	7:20:00	100%	2	1	Kilfrost ABC 2000	36.00	25.50	12.4	0.105	-1.0	77	5	-6.1	5.1	NOT FAILED
205	24-Nov-2006	1	2	N/A	19:43:20	7:20:00	75%	2b	1	Kilfrost ABC 2000	27.75	21.75	11.6	0.113	-1.3	78	5	N/A	N/A	NOT FAILED
207	24-Nov-2006	1	4	N/A	18:59:15	7:20:00	100%	2	1	Clariant Safewing MP II 2025 ECO	34.75	30.25	12.3	0.105	-1.0	77	5	-6.2	5.2	NOT FAILED
208	24-Nov-2006	1	5	N/A	19:44:15	7:20:00	75%	2b	1	Clariant Safewing MP II 2025 ECO	27.50	24.50	11.6	0.113	-1.3	78	5	-5.7	4.4	NOT FAILED
209	24-Nov-2006	1	6	N/A	19:44:40	7:20:00	50%	2c	1	Clariant Safewing MP II 2025 ECO	21.50	15.25	11.6	0.113	-1.3	78	5	-8.6	7.3	NOT FAILED
210	24-Nov-2006	1	9	N/A	18:59:50	7:20:00	100%	4	1	Kilfrost ABC-S	35.50	32.00	12.3	0.105	-1.0	77	5	N/A	-1.0	NOT FAILED
211	24-Nov-2006	1	10	N/A	19:45:15	7:20:00	75%	4b	1	Kilfrost ABC-S	29.75	27.25	11.6	0.113	-1.3	78	5	-5.1	3.8	NOT FAILED
213	24-Nov-2006	1	12	N/A	19:00:15	7:20:00	100%	4	1	Dow UCAR Ultra+	39.75	32.50	12.3	0.105	-1.0	77	5	-4.6	3.6	NOT FAILED
214	12-Jan-2008	1	1	N/A	18:30:30	7:00:00	100%	2	1	Ecowing 26	37.00	25.00	12.5	0.089	-4.1	71	8	-4.1	NA	NOT FAILED
218	12-Jan-2008	1	5	N/A	18:31:30	7:00:00	100%	4	1	UCAR EG 106	32.00	29.00	12.5	0.089	-4.1	71	8	-8.4	4.3	NOT FAILED
219	12-Jan-2008	1	6	N/A	18:32:00	7:00:00	75%	2b	1	X'IAN KF-II	28.50	23.00	12.5	0.089	-4.1	71	8	-8.2	4.1	NOT FAILED
220	12-Jan-2008	1	9	N/A	18:32:30	7:00:00	100%	4	1	Octagon Maxflo	36.50	33.00	12.5	0.089	-4.1	71	8	-8.3	4.2	NOT FAILED
221	12-Jan-2008	1	10	N/A	19:59:00	7:00:00	75%	4b	1	Octagon Maxflo	31.3	28.00	11.0	0.086	-4.5	72	8	-8.4	3.9	NOT FAILED
222	12-Jan-2008	1	11	N/A	18:33:00	7:00:00	100%	2	1	X'IAN KF-II	36.00	28.50	12.4	0.089	-4.1	71	8	-7.1	3.0	NOT FAILED
223	12-Jan-2008	1	12	N/A	18:33:30	7:00:00	75%	2b	1	X'IAN KF-II	28.50	21.75	12.4	0.089	-4.1	71	8	-8.0	3.9	NOT FAILED

N/A – Not Available

Table 3.3: Type II/III/IV Tests – Not Failed (cont'd)

Test No.	Date	Run No.	Plate No.	Chart Completed	Start Time (local)	End Time (local)	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix (Initial)	Fluid Brix (Final)	Endurance Time (hrs)	Average Rate (g/dm²/h)	Average OAT (°C)	Average RH (%)	Average Wind Speed (km/h)	Average Plate Temperature (°C)	ΔT (°C)	Comments
227	16-Jan-2008	1	3	N/A	18:54:15	7:00:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.00	24.25	12.1	0.069	-10.0	74	4	-14.8	4.8	NOT FAILED
229	16-Jan-2008	1	5	N/A	18:55:00	7:00:00	100%	4	1	UCAR EG 106	32.50	30.25	12.1	0.069	-10.0	74	4	-14.6	4.6	NOT FAILED
231	16-Jan-2008	1	9	N/A	18:55:40	7:00:00	100%	4	1	Octagon Maxflo	36.50	30.75	12.1	0.069	-10.0	74	4	-16.0	6.0	NOT FAILED
232	16-Jan-2008	1	10	N/A	21:07:30	7:00:00	75%	4b	1	Octagon Maxflo	31	26.75	9.9	0.076	-10.4	76	3	-14.6	4.2	NOT FAILED
233	16-Jan-2008	1	11	N/A	18:56:20	7:00:00	100%	2	1	Newave	37.50	24.00	12.1	0.069	-10.0	74	4	-8.0	NA	NOT FAILED
235	16-Jan-2008	2	4	N/A	3:10:00	7:00:00	75%	3b	1	Clariant Safewing MP III 2031 ECO	28.00	26.50	3.8	0.059	-10.0	75	4	-13.4	3.4	NOT FAILED
238	28-Feb-2008	1	3	N/A	19:39:00	7:00:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.00	35.25	11.3	0.028	-18.7	54	7	-3.6	NA	NOT FAILED
239	28-Feb-2008	1	4	N/A	19:39:30	7:00:00	100%	3	1	Clariant Safewing MP III 2031 ECO	36.00	35.25	11.3	0.028	-18.7	54	7	-24.9	6.2	NOT FAILED
240	28-Feb-2008	1	5	N/A	19:40:00	7:00:00	100%	4	1	UCAR EG 106	32.50	33.00	11.3	0.028	-18.7	54	7	-24.6	5.9	NOT FAILED
241	28-Feb-2008	1	6	N/A	19:40:30	7:00:00	100%	4	1	UCAR EG 106	32.50	33.25	11.3	0.028	-18.7	54	7	-24.5	5.8	NOT FAILED
242	28-Feb-2008	1	9	N/A	19:41:00	7:00:00	100%	4	1	Octagon Maxflo	36.75	33.00	11.3	0.028	-18.7	54	7	-19.3	0.6	NOT FAILED
243	28-Feb-2008	1	11	N/A	19:41:30	7:00:00	100%	2	1	X'IAN KF-II	36.3	33.25	11.3	0.028	-18.7	54	7	-23.7	5.0	NOT FAILED
244	28-Feb-2008	1	12	N/A	19:42:00	7:00:00	100%	2	1	Newave	37.00	36.00	11.3	0.028	-18.7	54	7	-20.4	1.7	NOT FAILED

N/A – Not Available

3.2 Detailed Temperature Profiles

Several parameters were documented during each fluid endurance time test conducted in frost conditions. Data collected pertaining to fluid dilution (fluid Brix) was measured at the beginning and end of each test, while plate surface temperature and outside ambient air temperature was logged on an ongoing basis. These parameters were used to construct charts to better illustrate the test plate cooling profile, the differential in temperature between the plate and OAT, and fluid dilution.

Figure 3.1, Figure 3.2, and Figure 3.3 are examples of the charts constructed for Type II, Type III, and Type IV fluids. The charts graphically demonstrate the plate temperature profiles, the OAT, and the fluid Brix. For the purpose of this report, charts were completed for all 2003-04 and 2004-05 Type II, Type III, and Type IV tests which demonstrated fluid failure (ice formation covering one third of the test plate surface), as listed in Table 3.2. Charts were not compiled for tests conducted after 2004-05. The completed charts are included in Appendix C.

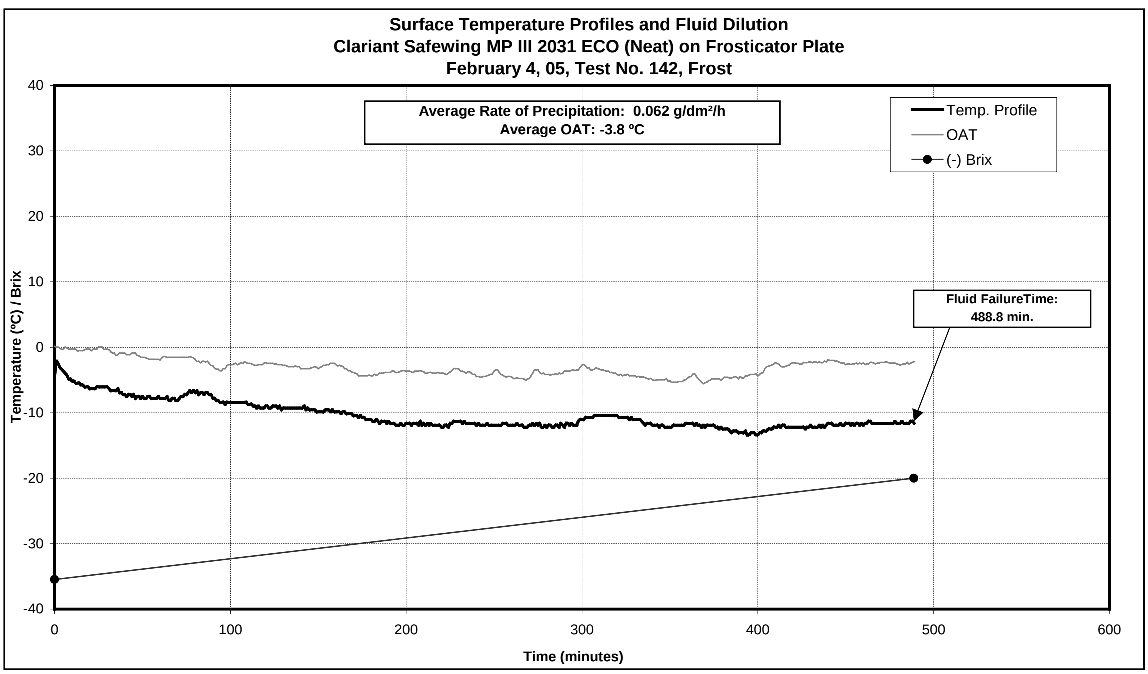

Figure 3.1: Type II Fluid Test Surface Profiles

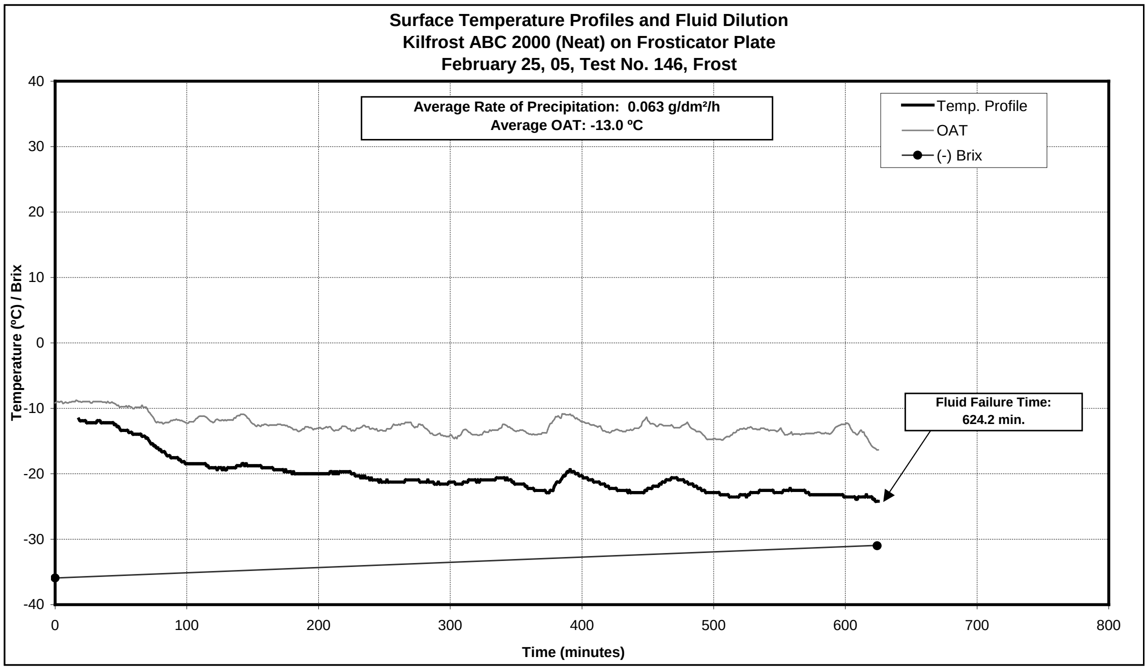

Figure 3.2: Type III Fluid Test Surface Profiles

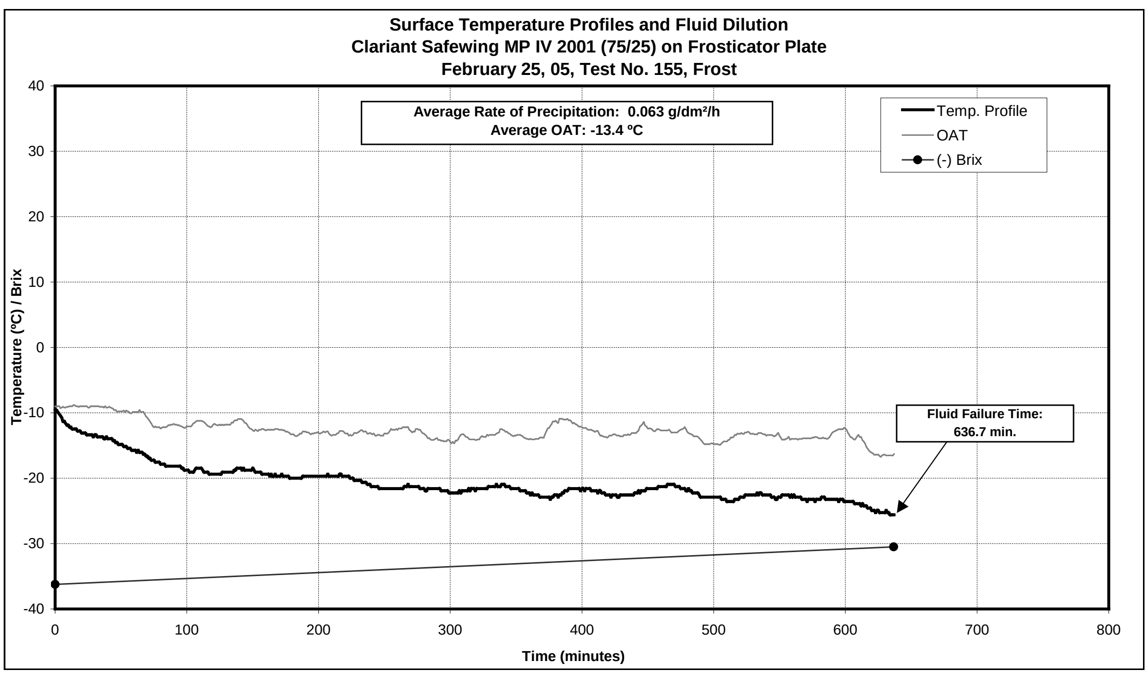

Figure 3.3: Type IV Fluid Test Surface Profiles

3.3 Type I Fluid Endurance Time Data

In Figure 3.4, Type I endurance times have been plotted against icing intensity. A trend line (power law) was generated and superimposed on the dataset. The dataset was grouped according to test session; the individual test sessions are identified in the legend. The results demonstrate how the fluid endurance time decreases exponentially with respect to the rate of precipitation.

The same dataset is plotted in Figure 3.5 grouped according to RH, temperature differential between the plate surface and OAT (ΔT), and fluid brand. The intent of this exercise was to isolate the different parameters to identify any influential factors on endurance time. The results obtained do not show any clear separation in the dataset; therefore, it can be concluded that these parameters do not significantly influence fluid endurance time in frost conditions.

Figure 3.6 demonstrates the Type I endurance time tests conducted at the APS test site as well as Type I endurance time tests that had been previously conducted indoors at the IREQ laboratory. By superimposing the two datasets, it was clear that the IREQ data points demonstrated significantly lower endurance times measured in the laboratory environment in comparison to those measured in natural frost. The reason for the reduced endurance times is not apparent, as the test parameters are common to both datasets. This is one of the reasons that led to the recommendation to conduct tests outdoors where the relationship with wing surfaces is well understood and well correlated.

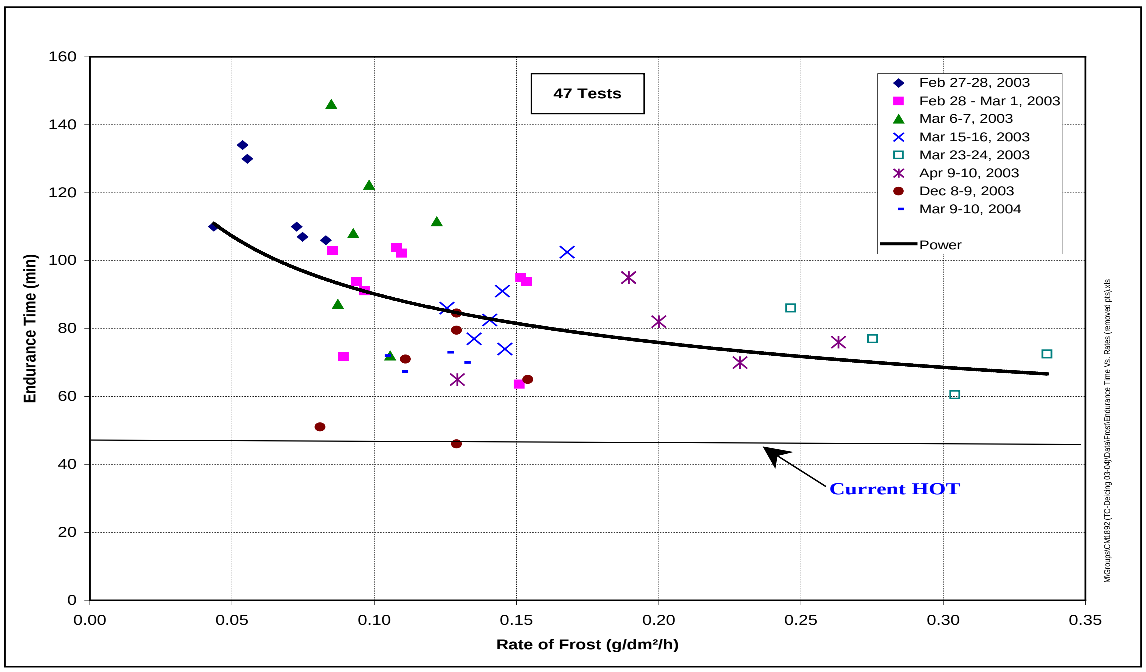

Figure 3.4: Endurance Time vs. Icing Intensity Sorted by Test Session – Type I Fluids

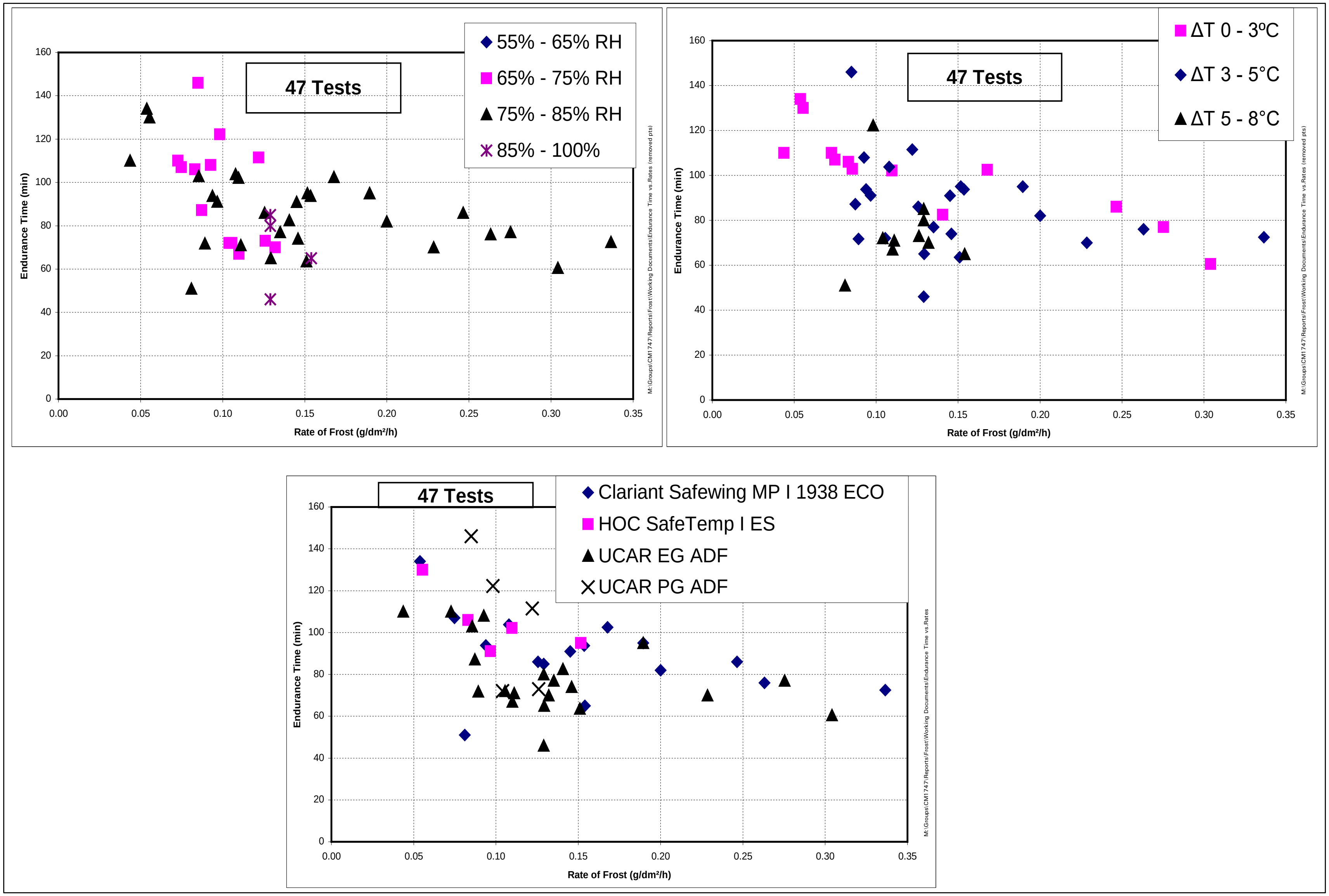

Figure 3.5: Endurance Time vs. Icing Intensity by Sorted by RH, ΔT, Fluid Brand – Type I Fluids

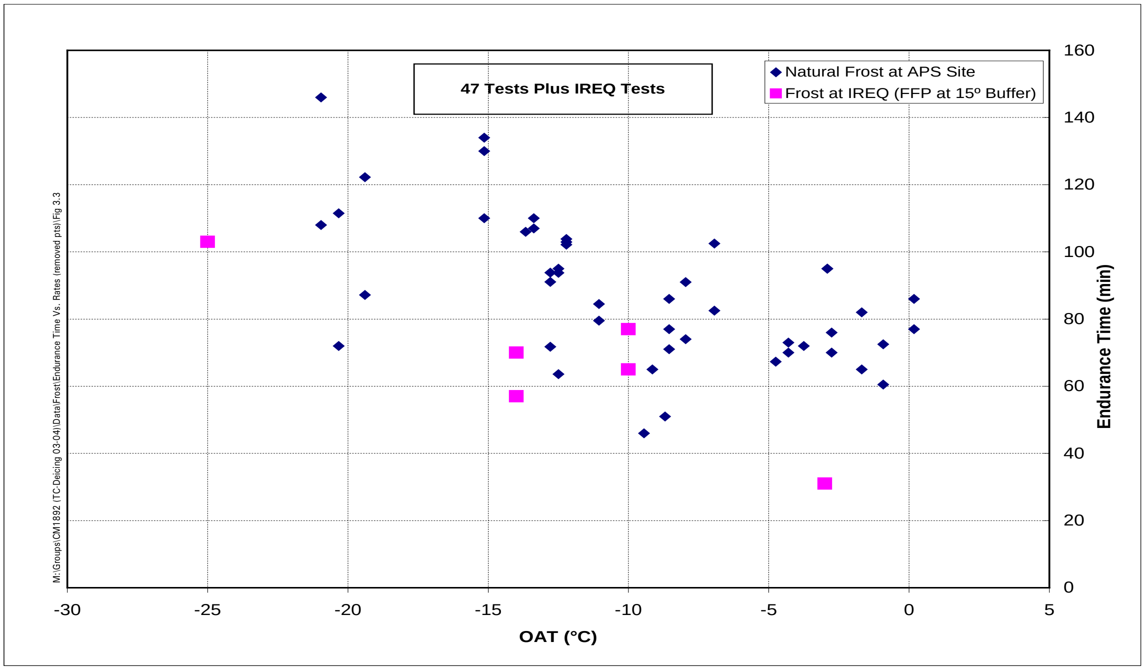

Figure 3.6: Endurance Times vs. OAT – Type I Fluids

3.4 Validity of Type I Fluid Endurance Time Data

To validate the Type I fluid endurance time data collected, the test conditions were analysed to determine whether the results obtained were representative and relative to actual operational conditions. For example, if all or most of the tests were carried out during low relative humidity (RH) conditions that resulted in low icing intensities, then the question would arise as to whether the data was valid. This section isolates and examines each prominent test condition in an attempt to determine whether the Type I data collected is valid and sufficient.

3.4.1 Type I Fluid Brands

Four Type I fluids were tested over a two-year period from 2001 to 2003. The majority of tests were conducted with Dow Union Carbide Corporation (UCAR) ADF-EG and Clariant MP I 1938-PG (see Table 3.4). While there are 27 fluid brands that are certified according to Aerospace Material Specification (AMS) 1424 standards, it was not economically possible to test all of the brands.

Table 3.4: Distribution of Type I Fluid Tests by Fluid Brand

Brand	APS Type I Fluid Endurance Time Tests	
	(#)	(%)
MP 1938-PG	16	34%
Safetemp HOC – PG	5	11%
UCAR ADF – EG	21	44%
UCAR ADF – PG	5	11%
	47	**100**

3.4.2 Relative Humidity (RH)

The Type I fluid data collected by APS was sorted according to range of RH. In addition, data collected at Montreal and La Grande from 1990-2001 during periods with conditions prone to frost accretion was also sorted according to range of RH. These results are shown in Table 3.5. The results showed that the majority of the frost tests were conducted by APS during RH conditions ranging between 60 percent and 90 percent. Results from the Montreal and La Grande dataset demonstrated that the majority of the frost occurrences were also during periods with RH ranging between 60 percent and 90 percent. From these results, it was concluded that the RH conditions during the tests conducted by APS were representative of frost occurrences.

Table 3.5: Distribution of Type I Tests by Relative Humidity

Relative Humidity Range	APS Type I Fluid Endurance Time Tests		Montreal and La Grande Frost Conditions from 1990 - 2001
(%)	(#)	(%)	(%)
0 to 50	0	0%	4%
51 to 60	0	0%	15%
61 to 70	10	21%	30%
71 to 80	22	47%	24%
81 to 90	11	23%	20%
91 to 100	4	9%	7%
	47	**100%**	**100%**

3.4.3 Wind Speed

Table 3.6 shows the distribution of air velocity for the Type I fluid tests. As expected, the majority of the tests were conducted in low wind or calm conditions. From these results, it was concluded that the wind conditions during the tests conducted by APS were representative of frost occurrences.

Table 3.6: Distribution of Air Velocity of Type I Tests

Wind Speed	APS Type II/III/IV Fluid Endurance Time Tests	
(km/h)	(#)	(%)
0 to 3	1	2%
4 to 6	12	26%
7 to 9	30	64%
>9	4	9%
	47	**100%**

3.4.4 Air Temperature

The Type I fluid data collected by APS was sorted according to a range of OAT. In addition, data collected at Montreal and La Grande from 1990-2001 during expected frost periods was also sorted according to range of OAT. These results are demonstrated in Table 3.7. In general, the tests conducted by APS adequately represented typical frost occurrences. However, in locations such as London and Paris, where frost is the prevalent cause for deicing, OAT temperature distributions may trend towards warmer air temperatures near or above 0°C.

Table 3.7: Distribution of Air Temperature of Type I Tests

OAT	APS Type I Fluid Endurance Time Tests		Montreal and La Grande (Wind <10 km/h from 1990-2001)
(%)	(#)	(%)	(%)
>0	2	4%	24%
0 to -5	12	26%	15%
-6 to -10	10	21%	17%
-11 to -15	14	30%	13%
-16 to -20	5	11%	19%
Below -20	4	9%	12%
	47	**100%**	**100%**

3.4.5 OAT and Plate Surface Temperature Differential (ΔT)

In 2001-02 and 2002-03, data was collected to determine the temperature differential between the OAT and plate surface temperature. This database comprised data measured on white aluminum plates. Data was collected in all operational temperature ranges.

The data collected is shown in Figure 3.7; the temperature differential is plotted against the OAT. In addition, the temperature differential collected as part of the Type I fluid endurance time testing during the winter of 2002-03 and 2003-04 was superimposed over the historical database; this is shown in Figure 3.8. It can be seen that several of the points in Figure 3.8 are directly superimposed because some of the data from 2002-03 was shared by both data sets.

The results demonstrate that during frost conditions, the temperature differential can be as high as 8°C. Although the proposed ARP5485 test procedure conditions recommended a temperature differential of 3°C between the OAT and the plate surface temperature, it can be seen that in more severe natural frost conditions, the temperature differential is likely to be more than 3°C; this will have adverse effects on fluid endurance time.

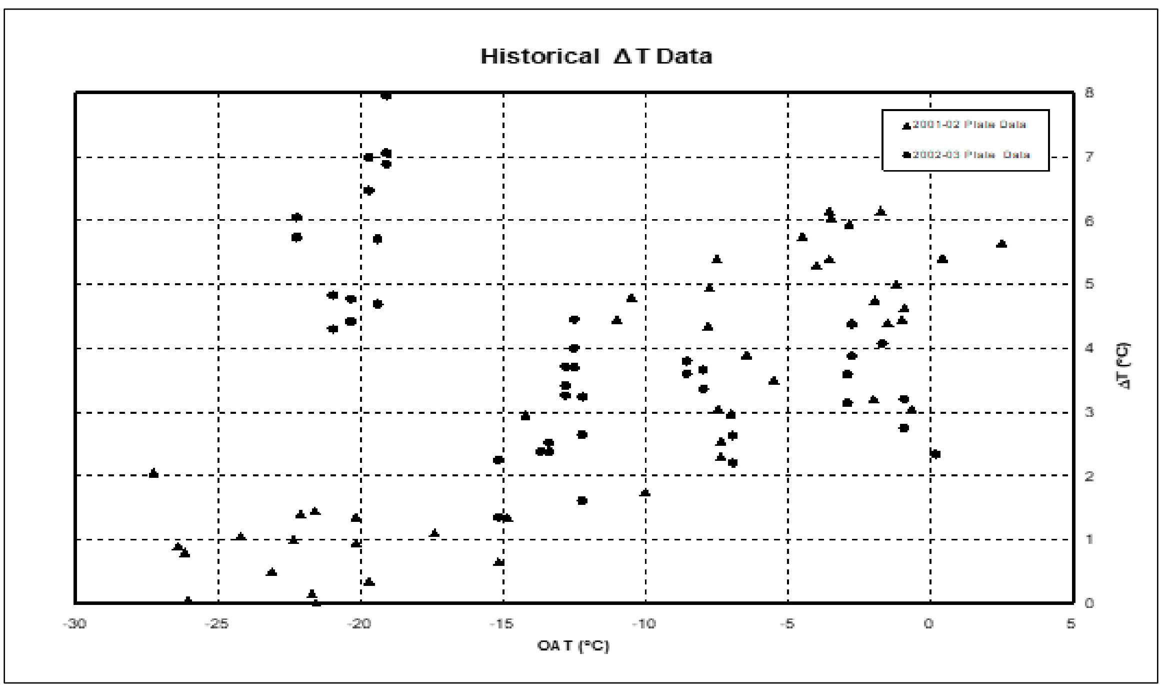

Figure 3.7: Historical ΔT Data

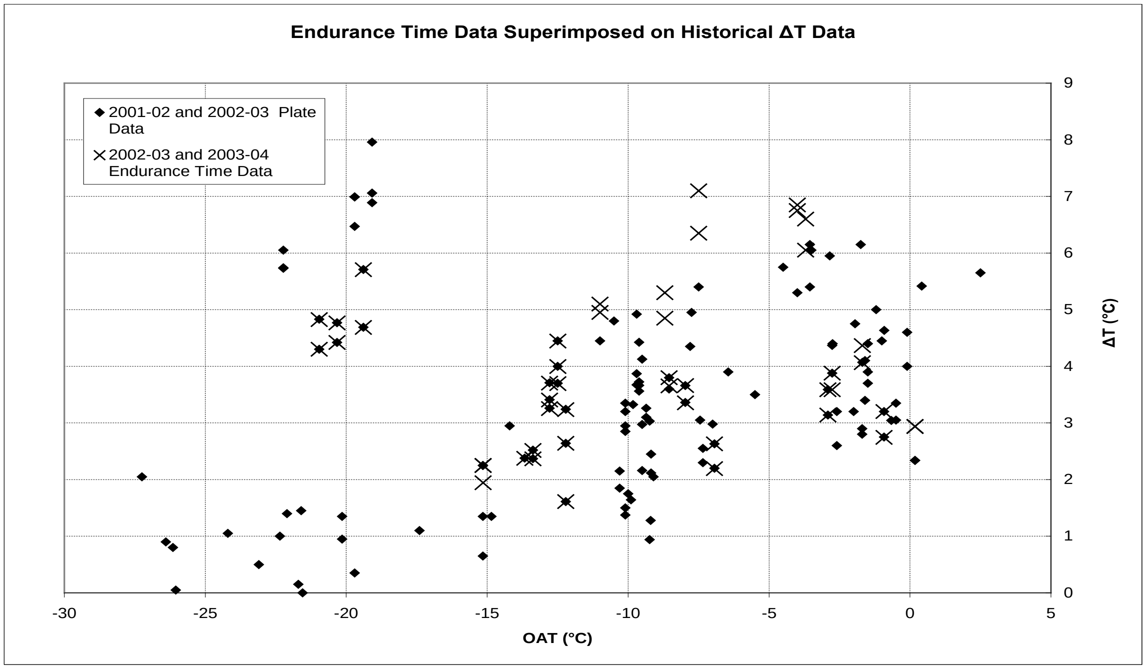

Figure 3.8: ET Data Superimposed on Historical ΔT Data

3.4.6 Icing Intensity

In 2001-02 and 2002-03, data was collected to determine the expected icing intensities during natural frost conditions. This database comprised data measured on white aluminum plates. Data was collected in all operational temperature ranges.

The data collected is shown in Figure 3.9; the rate of precipitation is plotted against the OAT. In addition, 47 test points collected during the winter of 2002-03 and 2003-04 were superimposed over the same data in Figure 3.10; the collective dataset is shown in Figure 3.10.

The results demonstrated that the icing intensity increases with increasing OAT; the same trend was evident in the ARP5485 test procedure, but the values are different.

Examination of Figure 3.9 and Figure 3.10 suggests that perhaps data is lacking in the OAT range of 0°C to +3°C. This is an operationally important temperature zone that is often concurrent with high levels of RH, often experienced at airports in London and Paris.

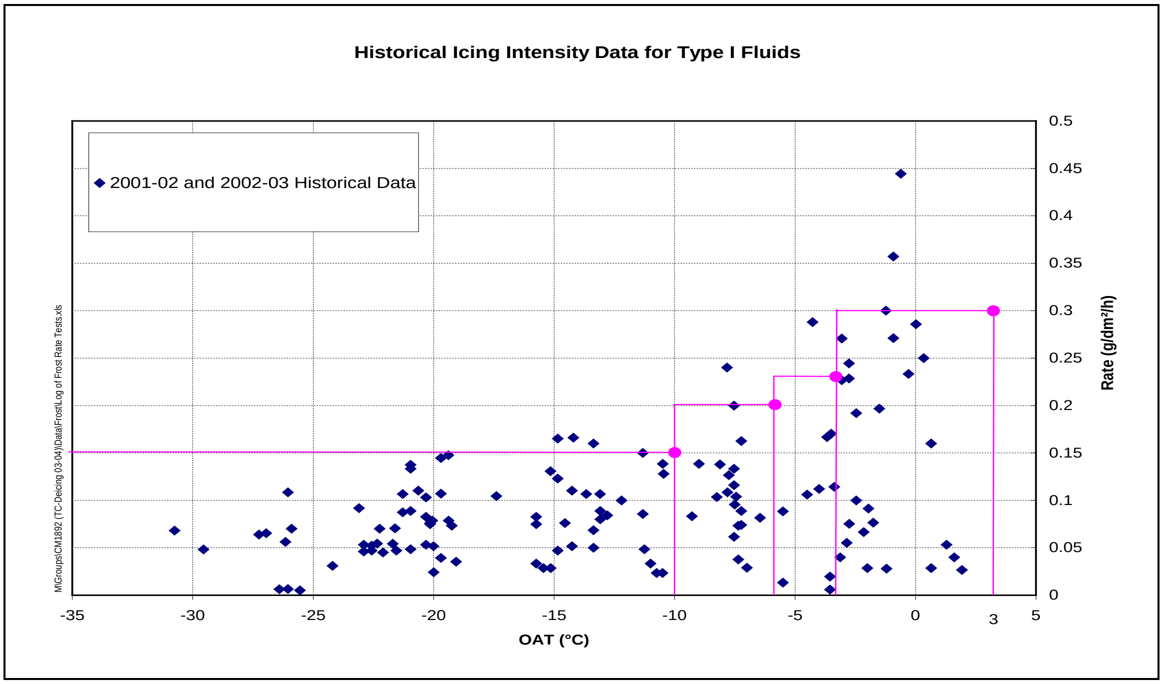

Figure 3.9: Historical Icing Intensity Data for Type I Fluids

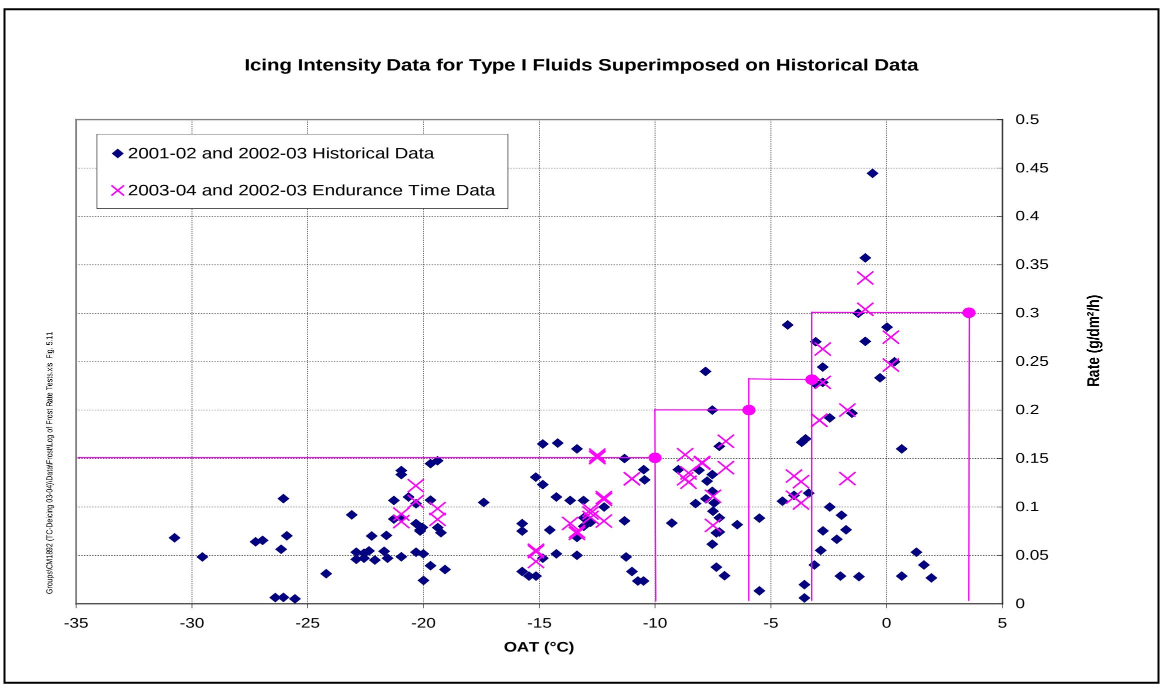

Figure 3.10: Icing Intensity Data for Type I Fluids Superimposed on Historical Data

3.5 Type II/III/IV Fluid Endurance Time Data

For analysis purposes the following fluid groupings were used when examining the Type II/III/IV fluid endurance time data:

- Type II Neat;
- Type II 75/25;
- Type II 50/50;
- Type III Neat;
- Type III 75/25;
- Type III 50/50;
- Type IV Neat;
- Type IV 75/25; and
- Type IV 50/50.

Note: Type II 50/50, Type IV 50/50, Type III 75/25, and Type III 50/50 data was only collected during the winter of 2005-06 onwards.

Endurance times were plotted versus icing intensity for each of the fluid groupings. The fluid endurance time currently published in the HOT guidelines was also plotted. A differentiation was made between the tests that failed and those that did not; the individual datasets are identified in the legend. Figure 3.11 to Figure 3.19 demonstrate the results obtained for each of the fluid groupings.

To verify the effect of OAT on fluid endurance time, endurance times were plotted versus OAT for each of the fluid groupings. The fluid endurance time currently published in the HOT guidelines was also plotted. A differentiation was made between the tests that failed and those that did not; the datasets are identified in the legend. Figure 3.20 to Figure 3.28 demonstrate the results obtained for each of the fluid groupings.

3.6 Validity of Type II/III/IV Fluid Endurance Time Data

To validate the Type II/III/IV fluid endurance time data collected, the test conditions were analysed to determine whether the results obtained were representative and relative to actual operational conditions. This section isolates and examines each prominent test condition in an attempt to determine whether the data collected is valid and sufficient.

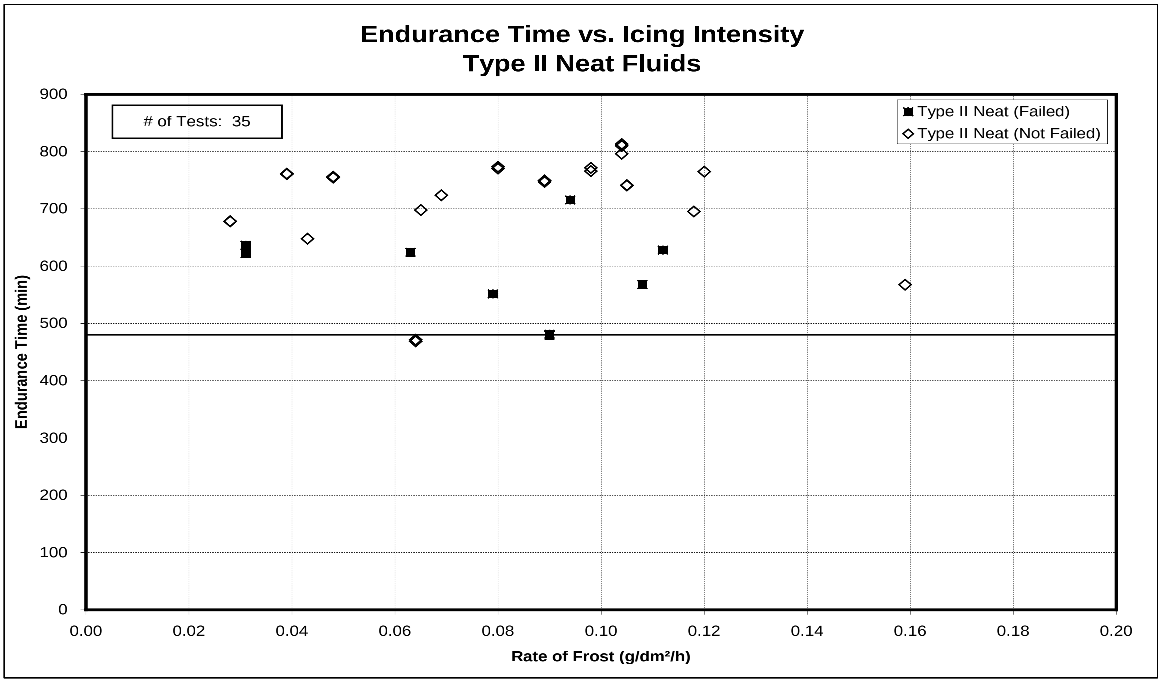

Figure 3.11: Endurance Time vs. Icing Intensity – Type II Neat

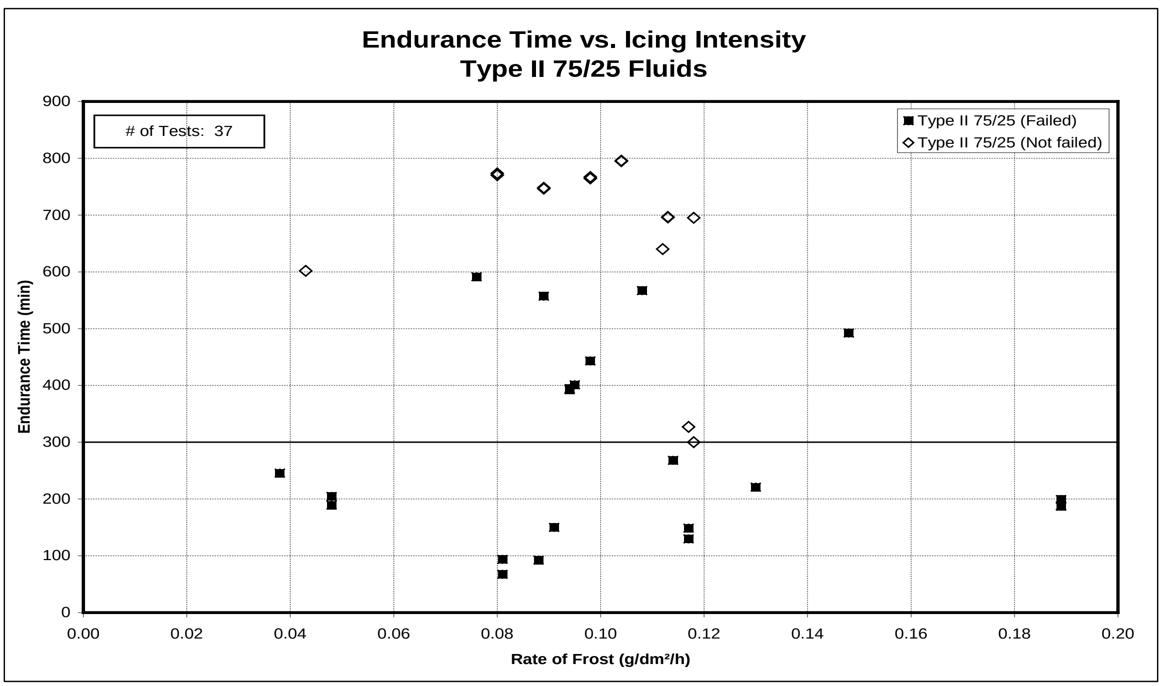

Figure 3.12: Endurance Time vs. Icing Intensity – Type II 75/25

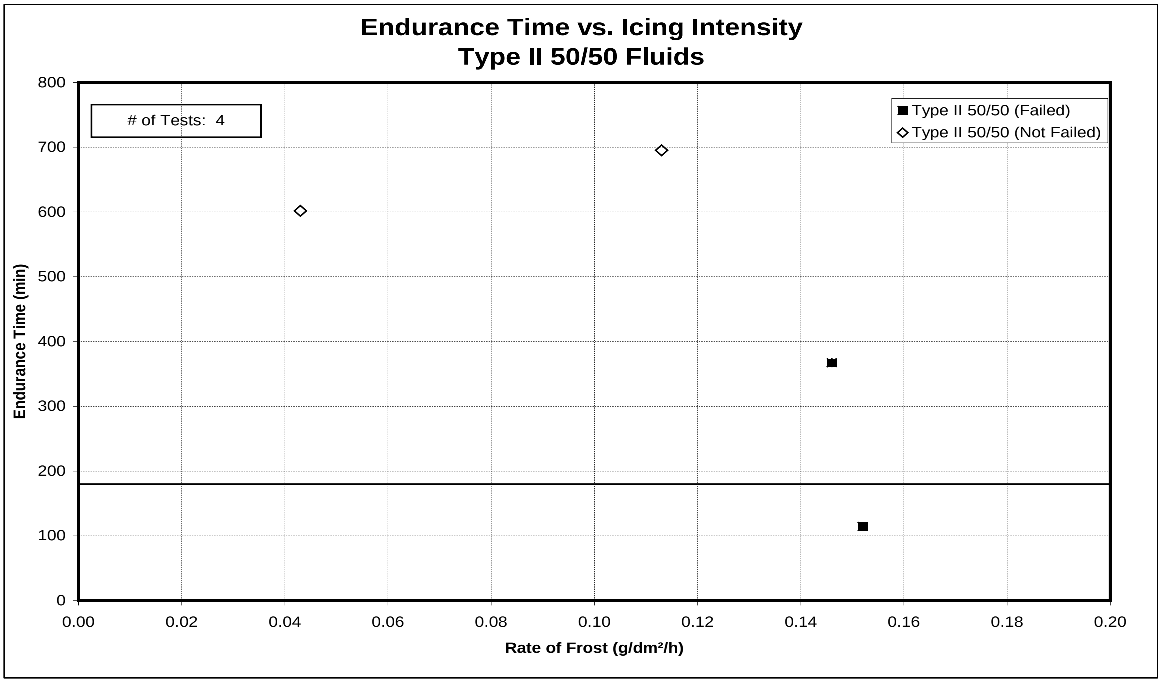

Figure 3.13: Endurance Time vs. Icing Intensity – Type II 50/50

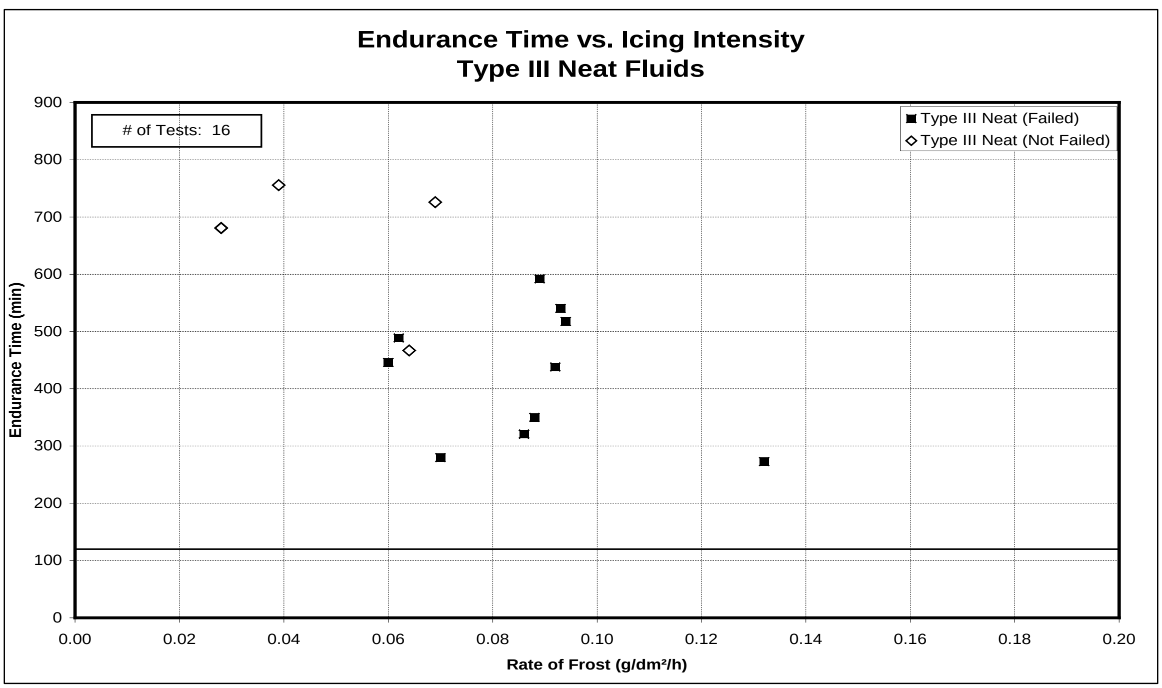

Figure 3.14: Endurance Time vs. Icing Intensity – Type III Neat

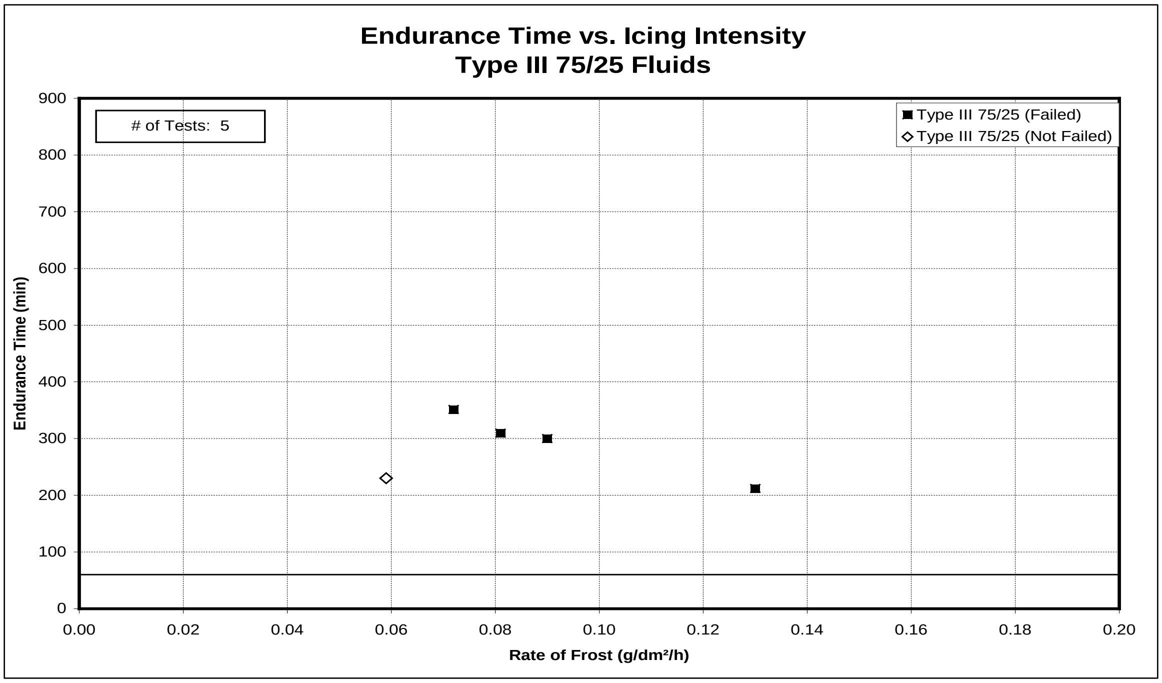

Figure 3.15: Endurance Time vs. Icing Intensity – Type III 75/25

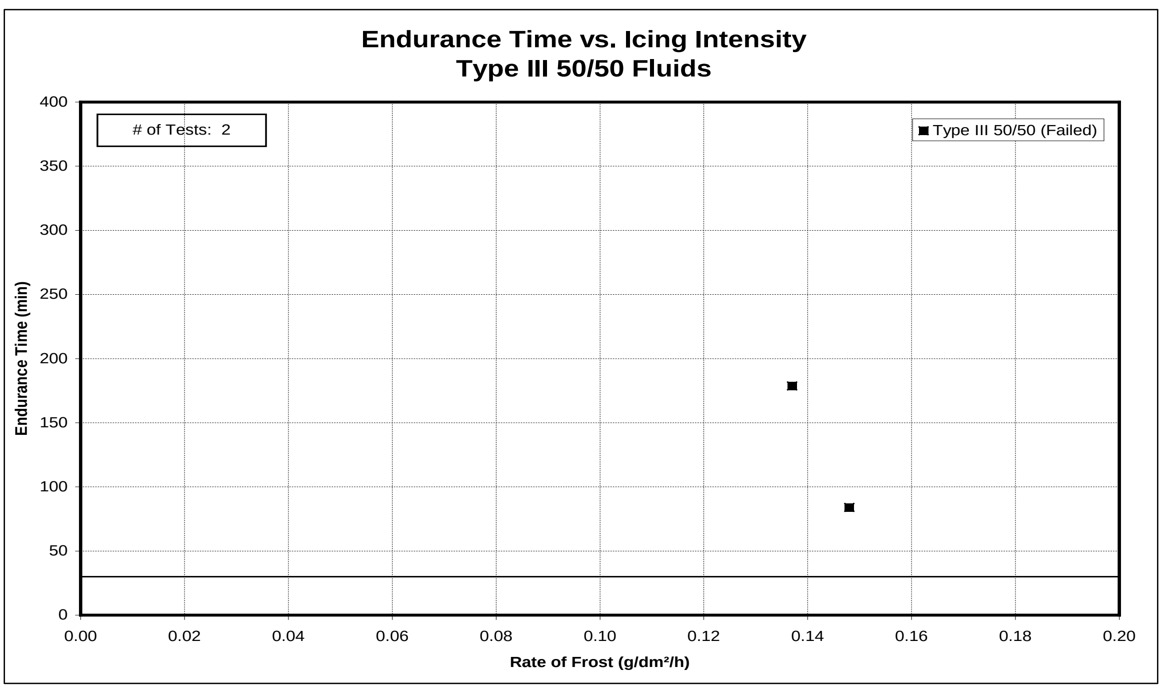

Figure 3.16: Endurance Time vs. Icing Intensity – Type III 50/50

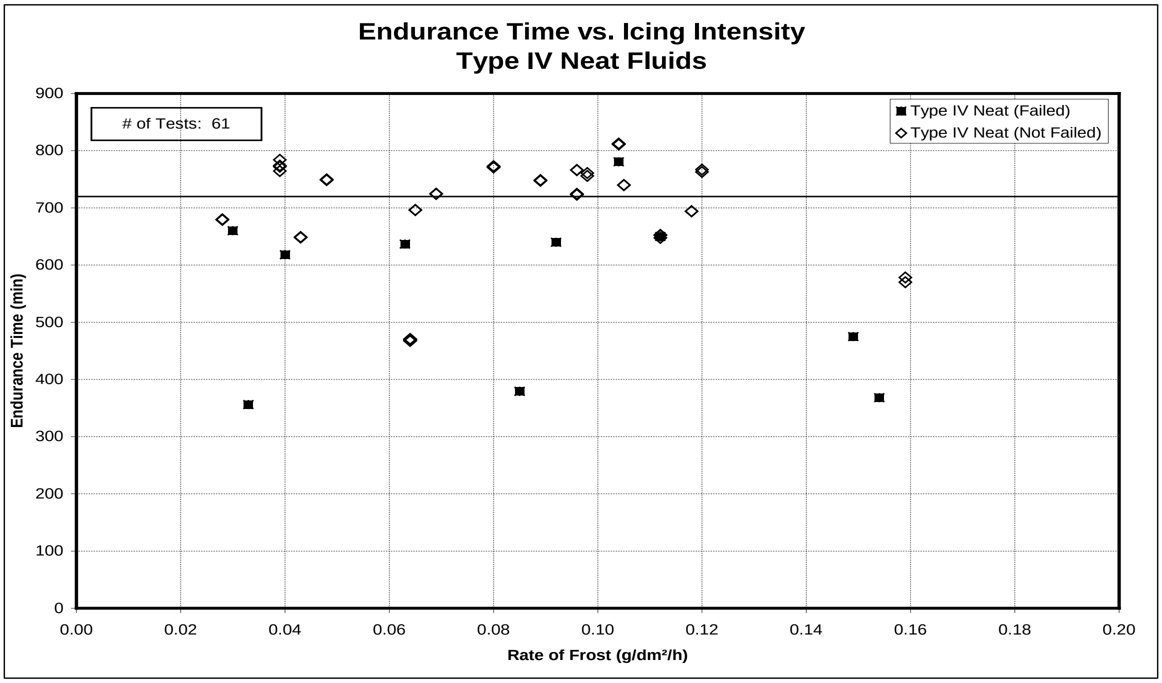

Figure 3.17: Endurance Time vs. Icing Intensity – Type IV Neat

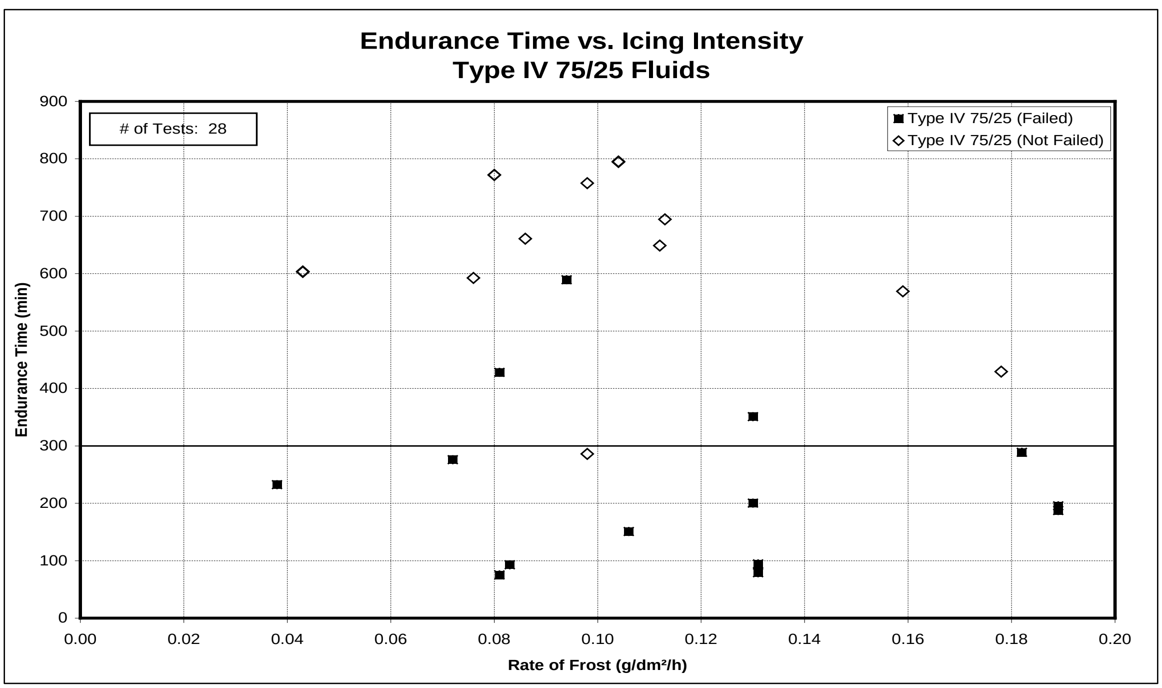

Figure 3.18: Endurance Time vs. Icing Intensity – Type IV 75/25

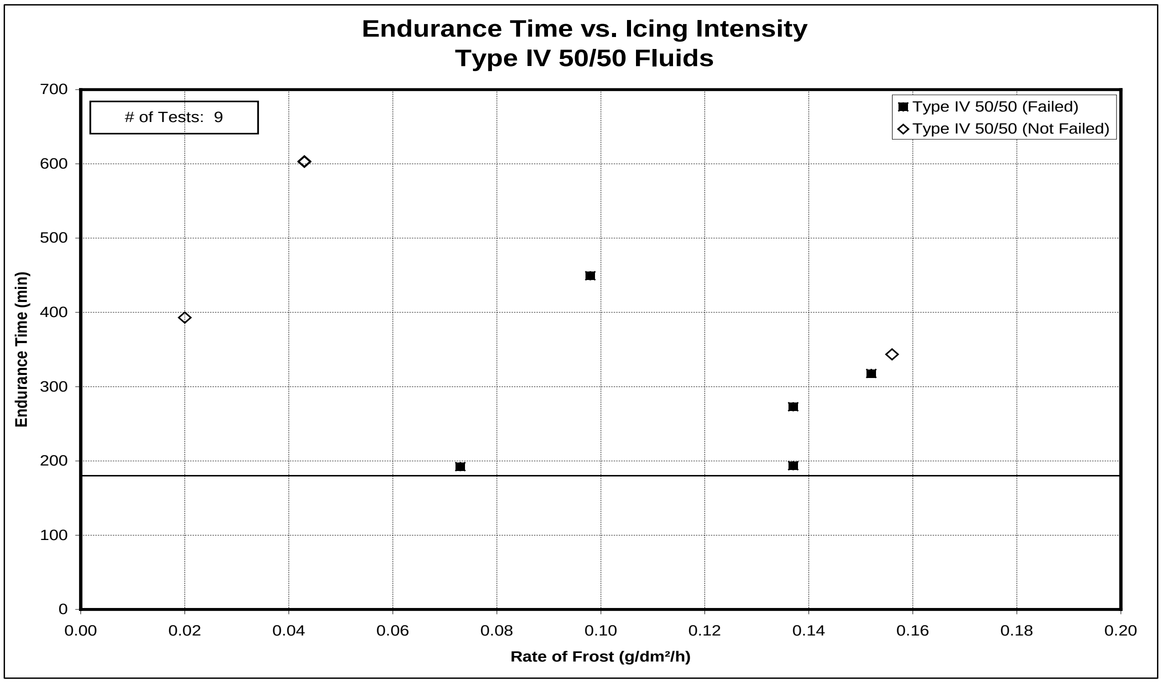

Figure 3.19: Endurance Time vs. Icing Intensity – Type IV 50/50

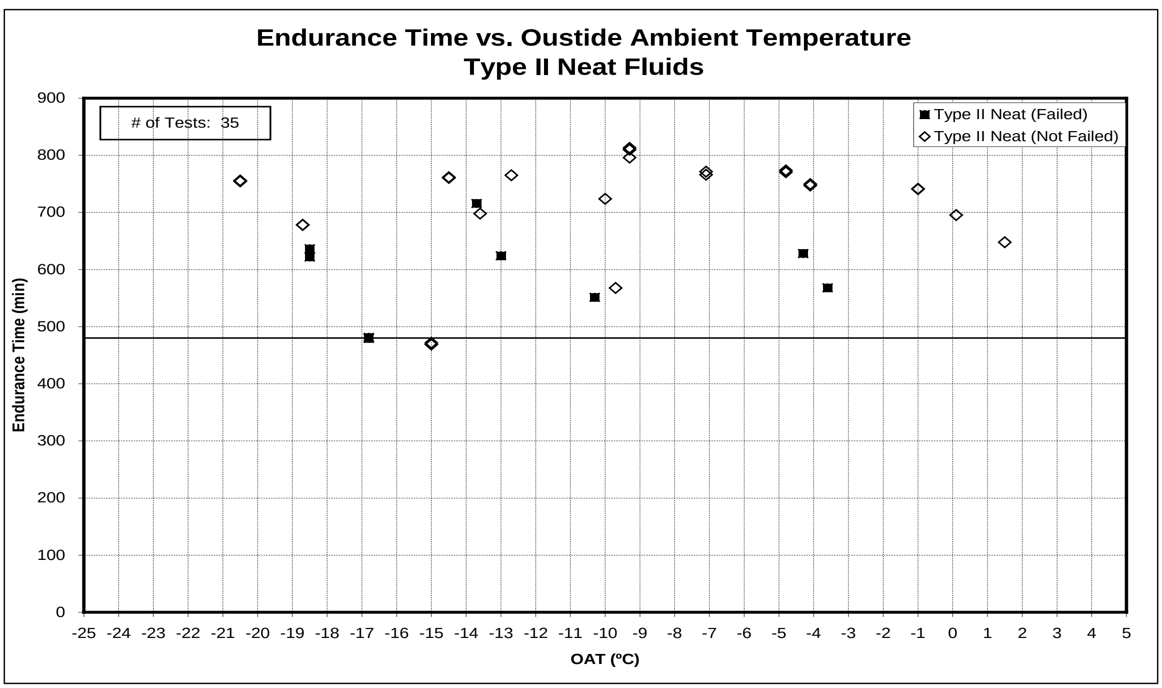

Figure 3.20: Endurance Time vs. OAT – Type II Neat

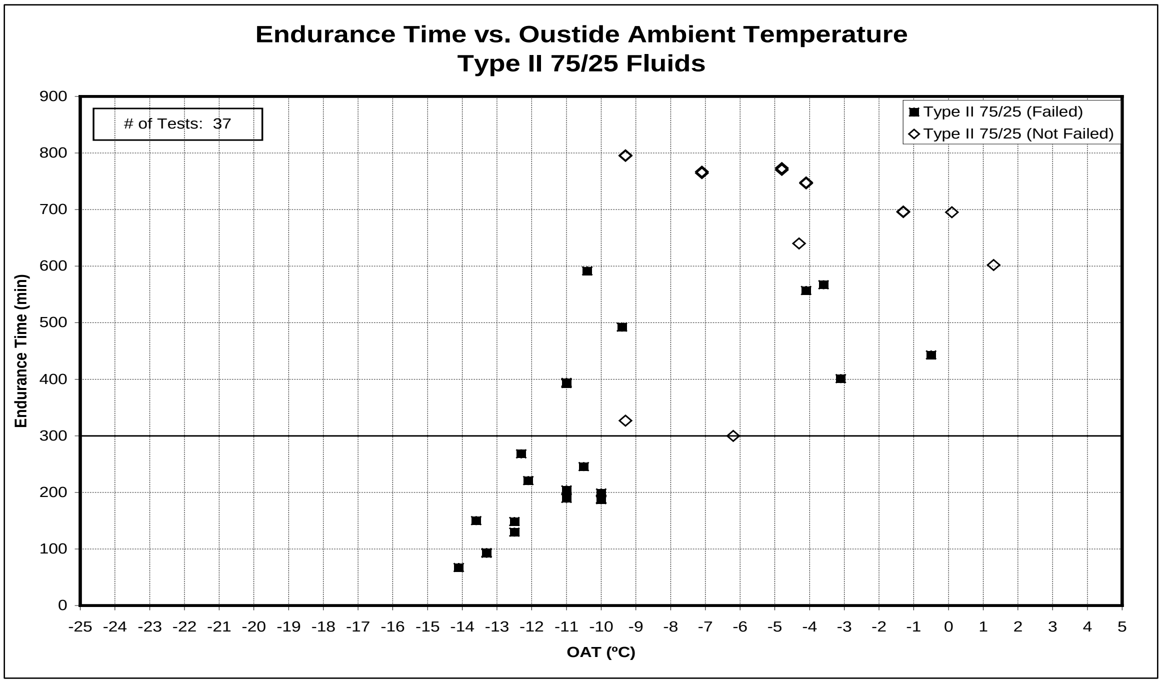

Figure 3.21: Endurance Time vs. OAT – Type II 75/25

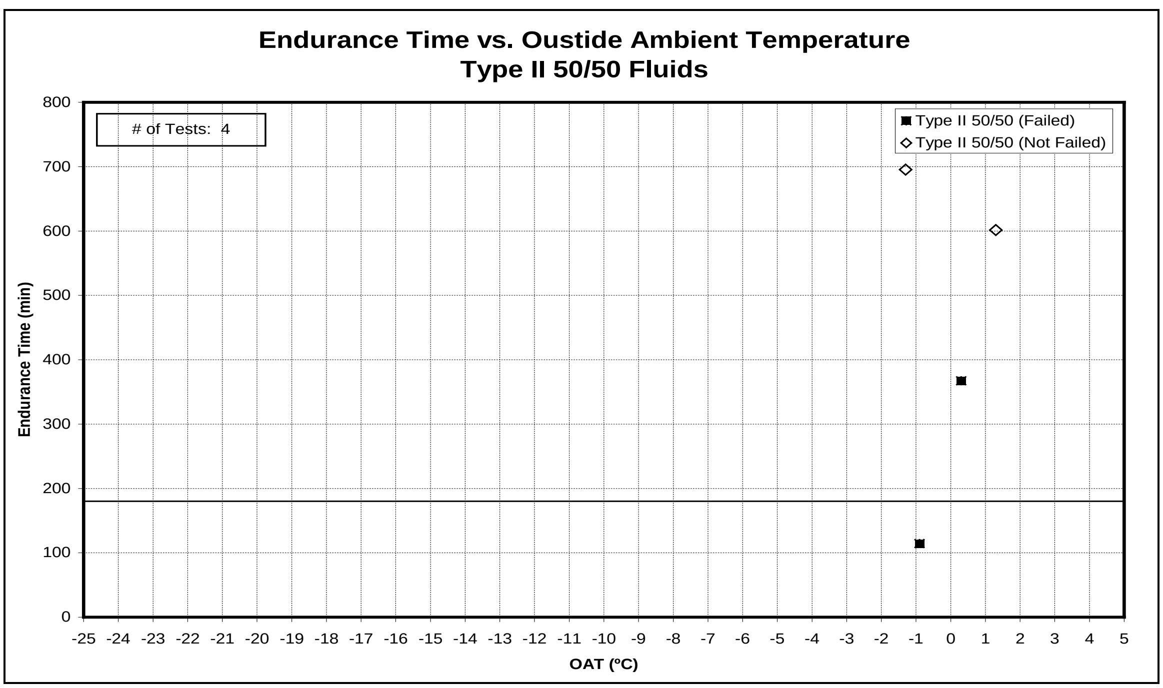

Figure 3.22: Endurance Time vs. OAT – Type II 50/50

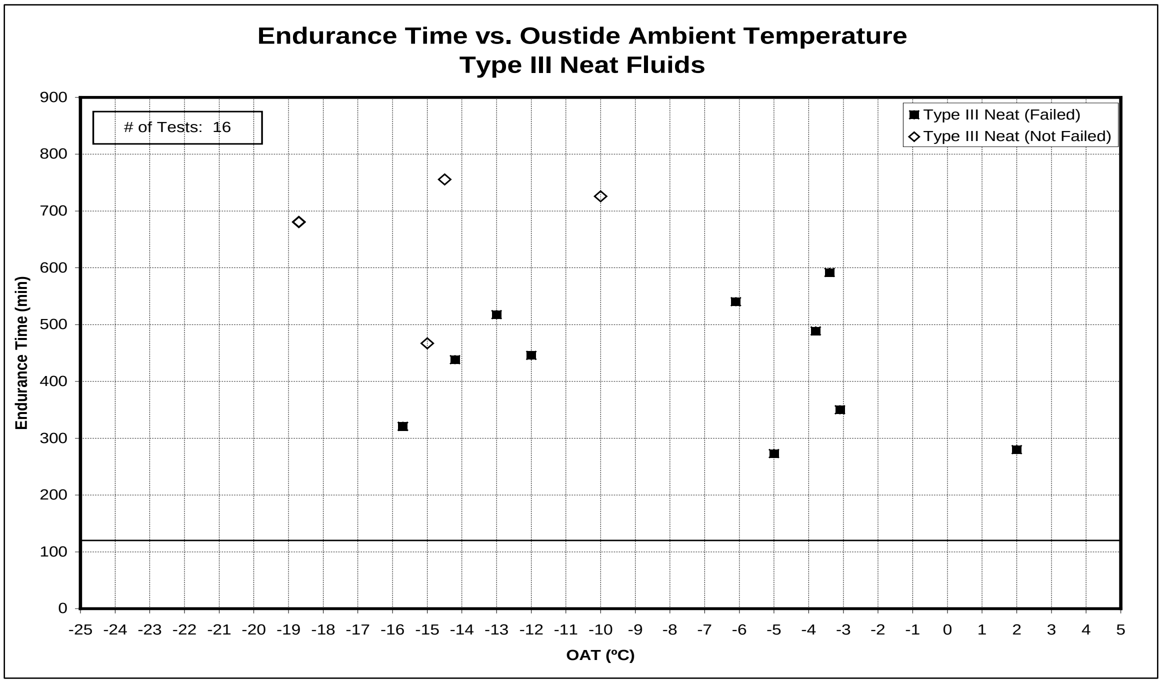

Figure 3.23: Endurance Time vs. OAT – Type III Neat

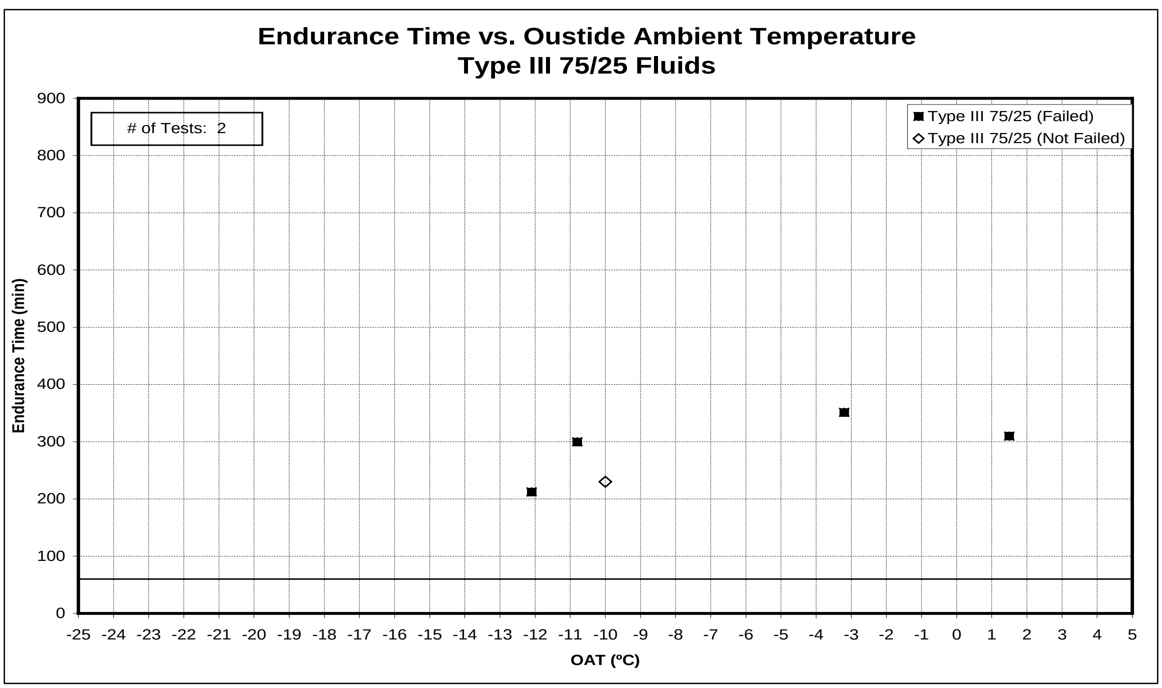

Figure 3.24: Endurance Time vs. OAT – Type III 75/25

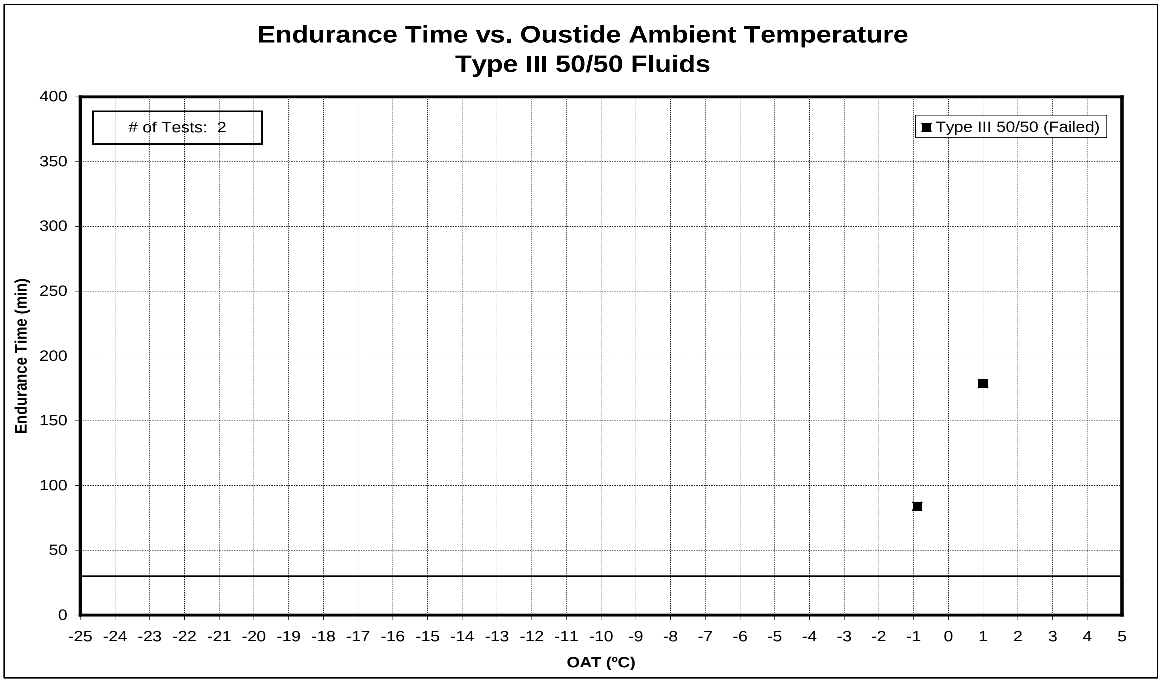

Figure 3.25: Endurance Time vs. OAT – Type III 50/50

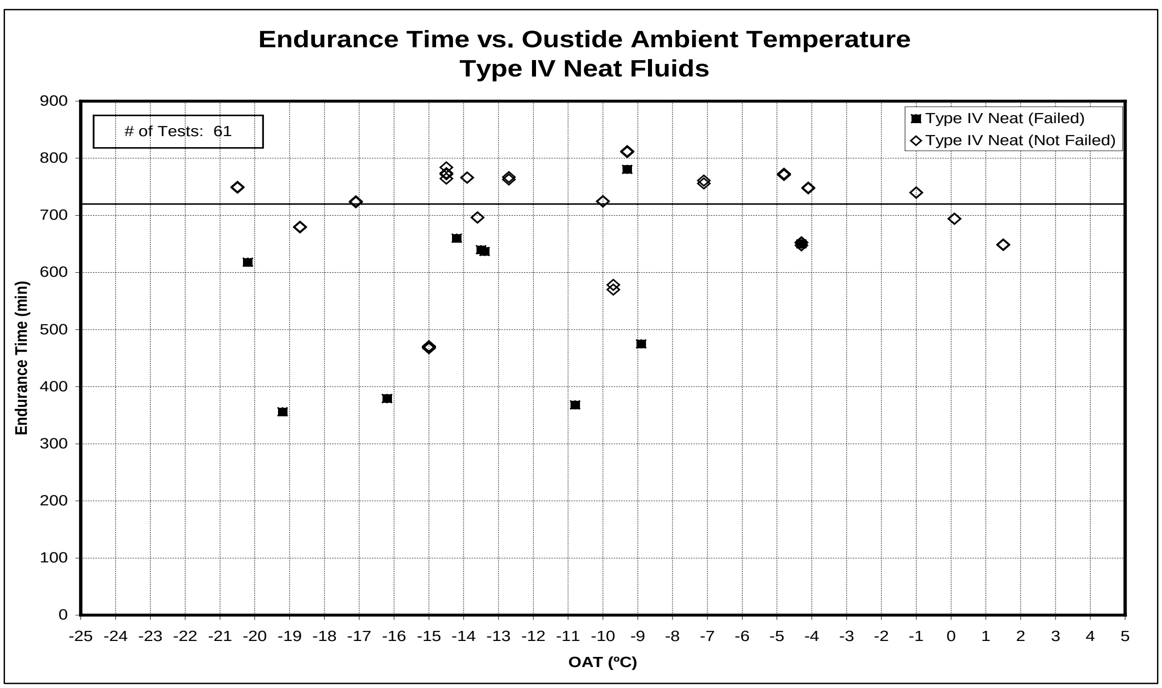

Figure 3.26: Endurance Time vs. OAT – Type IV Neat

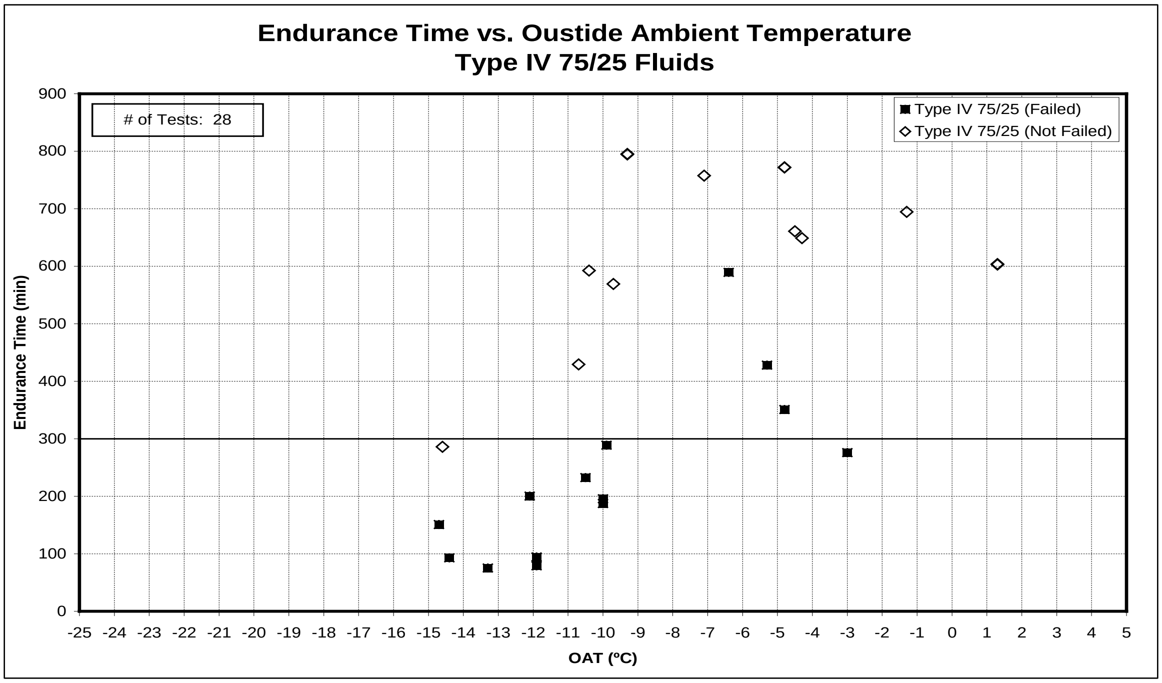

Figure 3.27: Endurance Time vs. OAT – Type IV 75/25

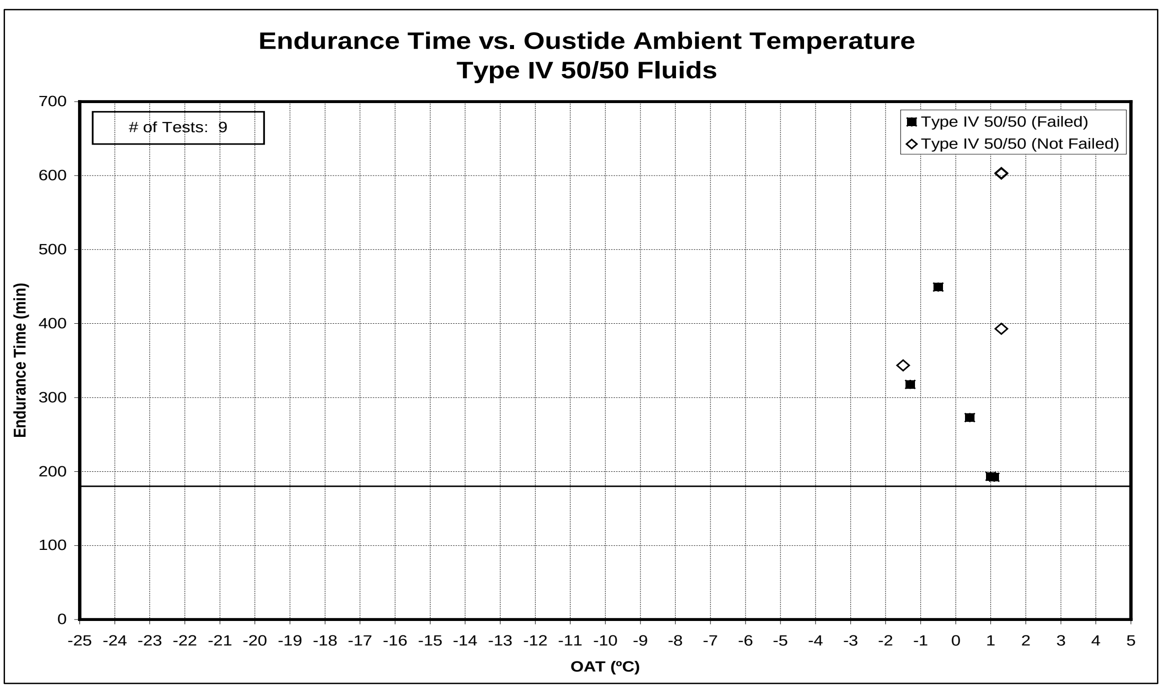

Figure 3.28: Endurance Time vs. OAT – Type IV 50/50

3.6.1 Type II/III/IV Fluid Brands

Fourteen Type II, Type III, and Type IV fluids were tested during the winters of 2003-04 to 2007-08. A list of the fluids tested is given in Table 3.8. In total, 36 percent of the tests were conducted using Type II fluids, 11 percent of the tests were conducted using Type III fluids, and 53 percent of the tests were conducted using Type IV fluids. The selection of fluids was chosen to best represent the currently certified fluids; as the testing objective was to substantiate the current HOT's, not all fluids were tested.

Table 3.8: Distribution of Type III/III/IV Fluid Tests by Fluid Brand

Fluid Brand Name	Fluid Type	APS Type II/III/IV Fluid Endurance Time Tests	
		(#)	(%)
Clariant Safewing MP II 2025 ECO	II	22	11%
ABAX Ecowing 26	II	14	7%
Kilfrost P1491	II	2	1%
Kilfrost ABC 2000	II	17	9%
Aviation Xi'an KHF-II	II	6	3%
Newave FCY-2	II	3	2%
Kilfrost ABC II+	II	12	6%
Clariant Safewing MP III 2031 ECO	III	23	12%
Clariant Safewing MP IV 2012	IV	23	12%
Clariant Safewing MP IV 2001	IV	9	5%
Clariant Safewing MP IV 2030 ECO	IV	14	7%
Octagon Max-Flight	IV	6	3%
Octagon MaxFlo	IV	11	6%
ABAX AD-480	IV	1	1%
Dow UCAR Ultra+	IV	9	5%
Dow UCAR Endurance EG106	IV	4	2%
Kilfrost ABC-S	IV	21	11%
		197	**100%**

3.6.2 Relative Humidity (RH)

The Type II, III, and IV data collected by APS was sorted according to range of RH. In addition, data collected at Montreal and La Grande from 1990-2001 during periods with wind conditions with conditions prone to frost accretion was also sorted according to range of RH. These results are shown in Table 3.9. The results demonstrated that the majority of the frost tests were conducted by APS during RH conditions ranging between 61 percent and 90 percent. Results from the Montreal and La Grande dataset demonstrated that the majority of the frost occurrences were also during periods with RH ranging between 61 percent and 90 percent. From these results, it was concluded that the RH conditions during the tests conducted by APS were representative of frost occurrences.

Table 3.9: Distribution of Type III/III/IV Fluid Tests by Relative Humidity

Relative Humidity Range	APS Type II/III/IV Fluid Endurance Time Tests		Montreal and La Grande Frost Conditions from 1990-2001
(%)	(#)	(%)	(%)
0 to 50	9	5%	4%
51 to 60	23	12%	15%
61 to 70	42	21%	30%
71 to 80	101	51%	24%
81 to 90	20	10%	20%
91 to 100	2	1%	7%
	197	**100%**	**100%**

3.6.3 Wind Speed

Table 3.10 shows the distribution of air velocity for the Type II, III, and IV fluid tests. As expected, the majority of the tests were conducted in low wind or calm conditions. From these results, it was concluded that the wind conditions during the tests conducted by APS were representative of frost occurrences.

Table 3.10: Distribution of Type III/III/IV Fluid Tests by Wind Speed

Wind Speed	APS Type II/III/IV Fluid Endurance Time Tests	
(km/h)	(#)	(%)
0 to 3	30	15%
4 to 6	98	50%
7 to 9	43	22%
>9	26	13%
	197	**100%**

3.6.4 Outside Air Temperature

The Type II, III, and IV data collected by APS was sorted according to range of OAT. In addition, data collected at Montreal and La Grande from 1990-2001 during expected frost periods was also sorted according to range of OAT. These results are shown in Table 3.11. The results suggest that additional testing is required in the above 0°C range and in the below -16°C range. The above 0°C range is particularly important in locations such as London and Paris, where frost is the prevalent cause of deicing and occurs during warmer air temperatures near or above 0°C. It is also important to collect Type II/III/IV fluid endurance time data in below -16°C weather where data is lacking. It is necessary to explore the behaviour of these fluids during these conditions to have a complete dataset ranging through all operational temperatures.

Table 3.11: Distribution of Air Temperature of Type II/III/IV Tests

OAT	APS Type II/III/IV Fluid Endurance Time Tests		Montreal and La Grande Frost Conditions from 1990-2001
(°C)	(#)	(%)	(%)
>0	21	11%	24%
0 to -5	49	25%	15%
-6 to -10	48	24%	17%
-11 to -15	54	27%	13%
-16 to -20	18	9%	19%
Below -20	7	4%	12%
	197	**100%**	**100%**

3.6.5 OAT and Plate Surface Temperature Differential (ΔT)

OAT and test plate surface temperature were constantly monitored during each test. The data collected is presented in Figure 3.29; the temperature differential is plotted against the OAT. The recommended temperature differential of 6°C (based on the 2001-02 and 2002-03 research to establish test parameters for frost) has also been plotted.

The results demonstrate that during frost conditions the temperature differential can increase to almost 9°C. Although the 2001-02 and 2002-03 research to establish test parameters for frost recommends a temperature differential of 6°C between the OAT and the plate surface temperature, it can be seen that in natural frost conditions the temperature differential is likely to rise well above 6°C.

The dataset demonstrates that the updated proposed 6ºC temperature differential for indoor endurance time testing during frost conditions was reasonable and representative of the temperature differential experienced during natural frost conditions. It should be noted that the option to proceed with simulated indoor frost testing was dismissed in favour of the option to substantiate the current frost HOT's through outdoor endurance time testing in natural frost conditions.

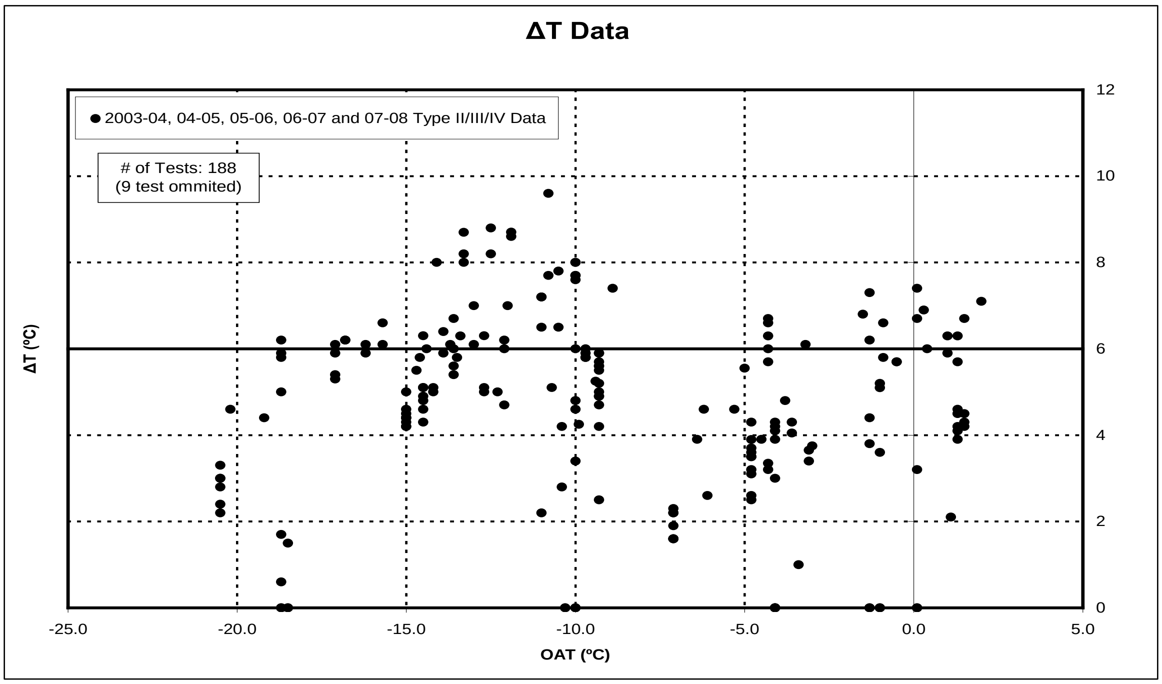

Figure 3.29: ΔT Data

3.6.6 Icing Intensity

Icing intensity was measured using two frosticator test plates weighed at half-hour intervals. The data collected is shown in Figure 3.30; the rate of precipitation is plotted against the OAT. The recommended icing intensities for each temperature range have also been plotted.

Examination of Figure 3.22 suggests that perhaps data is lacking in the above -3ºC temperature range. This temperature range is particularly important due to the high levels of RH experienced. Airport deicing operations are prominent during these conditions in airports such as London and Paris.

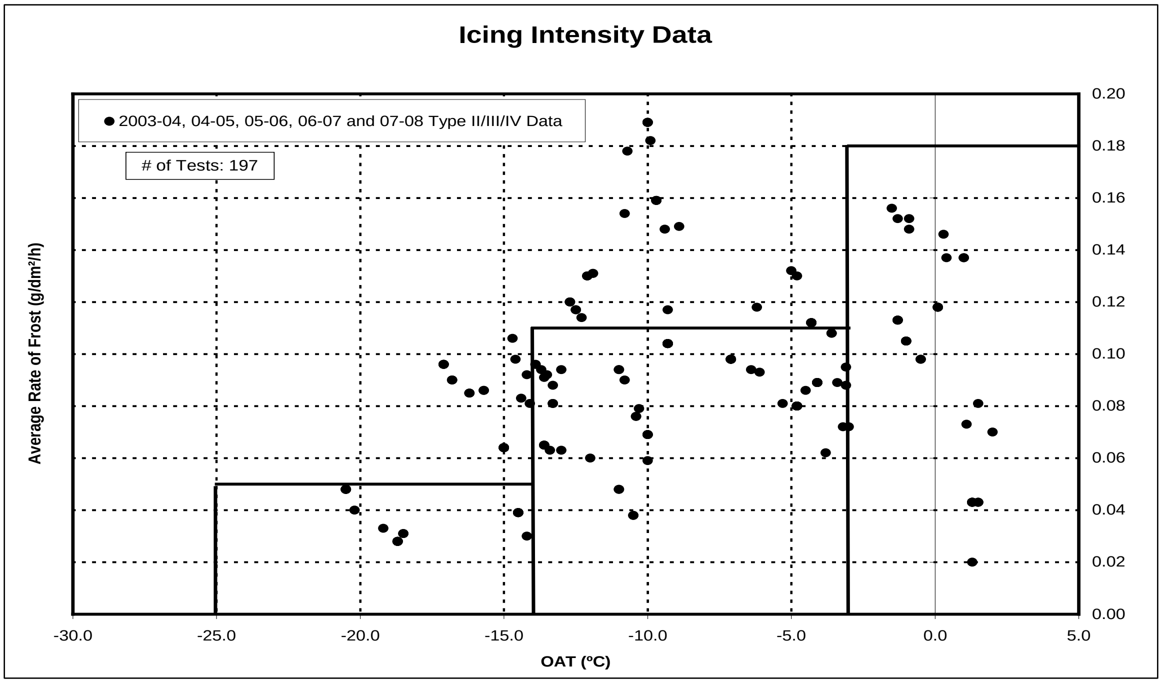

Figure 3.30: Icing Intensity Data

The dataset demonstrates that the updated proposed icing intensities for indoor endurance time testing during frost conditions was reasonable and representative of the icing intensities experienced during natural frost conditions. It should be noted that the option to proceed with simulated indoor frost testing was dismissed in favour of the option to substantiate the current frost HOT's through outdoor endurance time testing in natural frost conditions.

3.7 Aircraft Wing Temperature Differential during Frost

Previous work was conducted as part of a separate project to study the wing skin temperature differentials of operational aircraft. The following data has been included to support the wing skin temperature differentials measured on flat plates.

3.7.1 Data from Aircraft Wing Surfaces

Testing was conducted at Montreal-Trudeau Airport on three overnight occasions in typical frost conditions during the winter of 2001-02. A team of two observers recorded wing skin temperatures on aircraft parked at the passenger terminal and near the Air Canada Maintenance Hangar.

Table 3.12 is a log of data collected from these sessions showing aircraft types and dates. The boxes represent separate logs by aircraft type and date. The wing skin temperature and OAT are shown, along with an indication of whether frost was existent at the measured points when the temperatures were taken. In the analysis, the only data that were used were those collected when frost had formed at the measurement location.

Temperature differentials between wing surface and OAT were calculated from logged data and are charted as shown in Figure 3.31. In this chart, the horizontal axis scale represents ΔT intervals. The vertical axis is the frequency of occurrence of observations within each of these intervals.

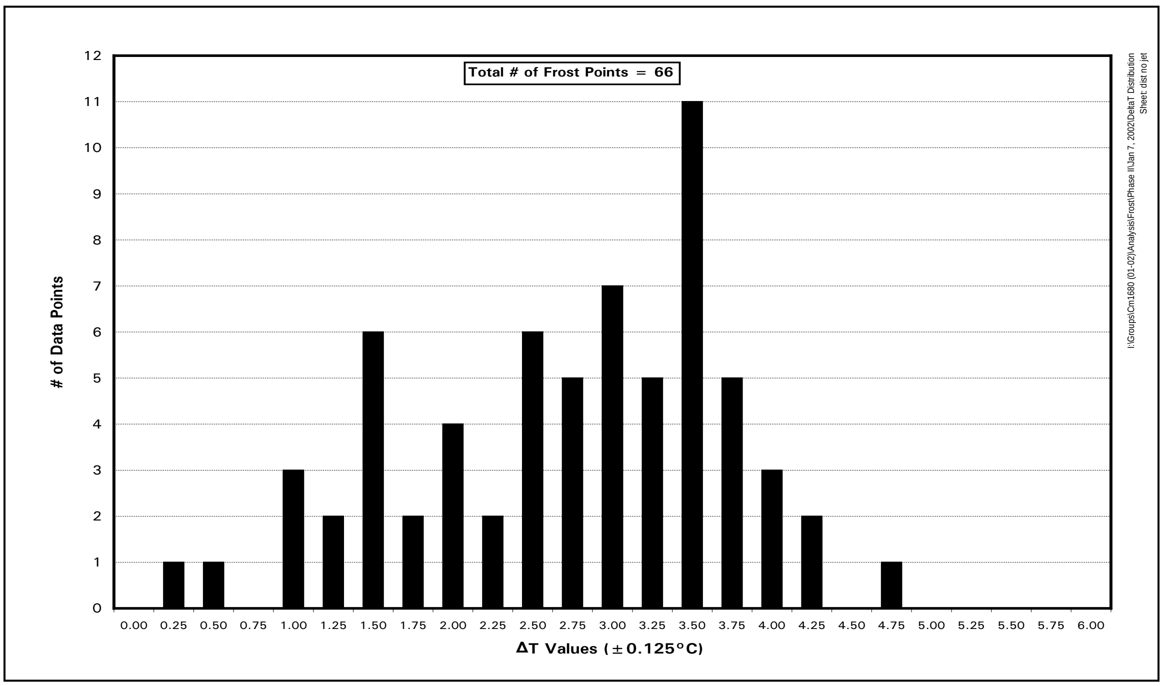

Figure 3.31: Frequency Distribution of ΔT Measured on Overnight Operational Aircraft

Additional data on aircraft wing temperatures were recorded during the tests (February 19, 2002) conducted on a B 737 aircraft. This test data is of particular interest because the wings were covered in fluid when the temperature data were recorded. Therefore, this represents the normal operational situation when fluid has been applied to protect against frost formation. During these tests, it was observed that the fluid layer caused different types of surfaces (such as the unpainted aluminum leading edge and the painted main wing) to take on similar temperature profiles, whereas when dry, their profiles were quite different.

Table 3.12: Log of Tests to Measure ΔT – Phase II

B-737, 30 Oct. 2001

Test #	Temp	OAT	ΔT	Frost
1	1.5	0.6	**-0.9**	
2	0.3	0.6	**0.3**	
3	-0.6	0.6	**1.2**	
4	-2	0.6	**2.6**	
5	-1	0.6	**1.6**	
6	-0.7	0.6	**1.3**	
7	1	0.6	**-0.4**	
1	-0.8	-1.6	**-0.8**	
2	-1.9	-1.6	**0.3**	
3	-1.8	-1.6	**0.2**	
4	-3.4	-1.6	**1.8**	
5	-3.5	-1.6	**1.9**	
6	-2.4	-1.6	**0.8**	
7	-0.8	-1.6	**-0.8**	
1	-0.6	-1.6	**-1**	
2	-1.5	-1.6	**-0.1**	
3	-2.3	-1.6	**0.7**	
4	-3.5	-1.6	**1.9**	
above 4	-5.7	-1.6	**4.1**	X
5	-3	-1.6	**1.4**	
6	-2.8	-1.6	**1.2**	
7	0	-1.6	**-1.6**	
wing tip	-5	-1.6	**3.4**	X
1	-1.3	-1.7	**-0.4**	
2	-2.7	-1.7	**1**	
3	-2.8	-1.7	**1.1**	
4	-3.6	-1.7	**1.9**	
5	-3.4	-1.7	**1.7**	
6	-3.4	-1.7	**1.7**	
7	-0.8	-1.7	**-0.9**	
1	-1.8	-2.5	**-0.7**	
2	-2.6	-2.5	**0.1**	
3	-3.6	-2.5	**1.1**	
4	-4.9	-2.5	**2.4**	
5	-4.3	-2.5	**1.8**	
6	-3.3	-2.5	**0.8**	
7	-1.5	-2.5	**-1**	
1	-3	-2.6	**0.4**	
2	-3.7	-2.6	**1.1**	
3	-4.1	-2.6	**1.5**	
4	-5.2	-2.6	**2.6**	X
5	-5.8	-2.6	**3.2**	X
6	-4.1	-2.6	**1.5**	
7	-1.6	-2.6	**-1**	

Full Scale , 19 Feb. 2002
Wet Wing B-737

Wing	Temp	OAT	ΔT	Frost
Port	-14	-9.7	3.87	
Port	-13	-9.7	3.67	
Port	-15	-9.7	4.92	X
Stbd	-12	-9.5	2.97	
Stbd	-12	-9.5	2.16	
Stbd	-14	-9.5	4.13	

Saab 340, 30 Oct. 2001

Therm	Temp	OAT	ΔT	Frost
1	-0.3	-1.9	**-1.6**	
2	-2	-1.9	**0.1**	
3	-3.8	-1.9	**1.9**	
4	-4.6	-1.9	**2.7**	X
5	-4.2	-1.9	**2.3**	X
6	-4.2	-1.9	**2.3**	
7	-0.6	-1.9	**-1.3**	
1	-2.7	-1.5	**1.2**	
2	-3.4	-1.5	**1.9**	
3	-5.2	-1.5	**3.7**	X
4	-4.6	-1.5	**3.1**	X
5	-4.8	-1.5	**3.3**	X
6	-5.4	-1.5	**3.9**	X
7	-1.9	-1.5	**0.4**	

DC-9, 7 Jan. 2002

Test #	Temp	OAT	ΔT	Frost
1	-5.3	-8.9	**-3.6**	
2	-5.1	-8.9	**-3.8**	
3	-12	-8.9	**2.9**	X
4	-12	-8.9	**2.9**	X
5	-10	-8.9	**1.3**	
6	-13	-8.9	**3.7**	X
7	-9.8	-8.9	**0.9**	
1	-8.2	-8.9	**-0.7**	
2	-8.4	-8.9	**-0.5**	
3	-12	-8.9	**3**	X
4	-12	-8.9	**3.1**	X
5	-11	-8.9	**2.1**	X
6	-13	-8.9	**4.2**	X
7	-10	-8.9	**1.4**	X
1	-7.9	-8.5	**-0.6**	
2	-8	-8.5	**-0.5**	
3	-11	-8.5	**2.5**	X
4	-10	-8.5	**1.7**	X
5	-9.4	-8.5	**0.9**	X
6	-11	-8.5	**2.5**	X
7	-10	-8.5	**1.8**	X
1	-7.5	-8.1	**-0.6**	
2	-8	-8.1	**-0.1**	
3	-11	-8.1	**3.3**	X
4	-11	-8.1	**2.7**	X
5	-9.6	-8.1	**1.5**	X
6	-12	-8.1	**3.5**	X
7	-10	-8.1	**2**	X
1	-7.6	-10	**-2.8**	
2	-8.1	-10	**-2.3**	
3	-11	-10	**0.9**	X
4	-11	-10	**0.8**	X
5	-10	-10	**-0.3**	X
6	-12	-10	**1.4**	X
7	-11	-10	**0.1**	X
1	-8.5	-10	**-1.8**	
2	-9.2	-10	**-1.1**	
3	-12	-10	**2.1**	X
4	-12	-10	**1.5**	X
5	-11	-10	**0.5**	X
6	-13	-10	**2.9**	X
7	-11	-10	**1.1**	X

DC-9, 25 March, 2002

1	-6.9	-6.2	**0.7**	
2	-7.8	-6.2	**1.6**	
3	-9.2	-6.2	**3**	
4	-9.9	-6.2	**3.7**	
5	-12	-6.2	**5.4**	
6	-8.4	-6.2	**2.2**	
1	-7.6	-9	**-1.4**	
2	-8.2	-9	**-0.8**	
3	-11	-9	**2**	
4	-10	-9	**1.4**	
5	-12	-9	**3**	
6	-9.3	-9	**0.3**	
1	-6.4	-9	**-2.6**	
2	-7.9	-9	**-1.1**	
3	-9.3	-9	**0.3**	
4	-10	-9	**1.4**	
5	-11	-9	**1.6**	X
6	-8.7	-9	**-0.3**	
1	-7.2	-9	**-1.8**	
2	-8.2	-9	**-0.8**	
3	-10	-9	**1.1**	
4	-11	-9	**2**	
5	-11	-9	**2**	X
6	-9.6	-9	**0.6**	
1	-7.4	-8.5	**-1.1**	
2	-8	-8.5	**-0.5**	
3	-9.8	-8.5	**1.3**	
4	-9.6	-8.5	**1.1**	
5	-12	-8.5	**3.3**	X
6	-8.9	-8.5	**0.4**	
1	-7.7	-10	**-2.3**	
2	-8.1	-10	**-1.9**	
3	-10	-10	**0**	
4	-11	-10	**0.8**	
5	-11	-10	**1.3**	X
6	-9.7	-10	**-0.3**	

RJ Wing, 30 Oct. 2001

Test #	Temp	OAT	ΔT	Frost
1	1.4	1	**-0.4**	
2	0.6	1	**0.4**	
3	-0.8	1	**1.8**	
4	0	1	**1**	
5	-0.1	1	**1.1**	
6	-0.8	1	**1.8**	
7	2.1	1	**-1.1**	
1	-1.5	-0.9	**0.6**	
2	-1.8	-0.9	**0.9**	
3	-4.4	-0.9	**3.5**	
4	-3.2	-0.9	**2.3**	
5	-3.4	-0.9	**2.5**	
6	-4.7	-0.9	**3.8**	
7	-1.2	-0.9	**0.3**	
8	-4.1	-0.9	**3.2**	X
9	-4.9	-0.9	**4**	X
1	-2.4	-0.1	**2.3**	
2	-3	-0.1	**2.9**	
3	-4.7	-0.1	**4.6**	X
4	-2.6	-0.1	**2.5**	
5	-2.8	-0.1	**2.7**	
6	-4.1	-0.1	**4**	X
7	-1.7	-0.1	**1.6**	
8	-3	-0.1	**2.9**	X
9	-2.8	-0.1	**2.7**	X
1	-3	-7.5	**-4.5**	
2	-3	-7.5	**-4.5**	
3	-9.3	-7.5	**1.8**	
4	-10	-7.5	**2.8**	
5	-11	-7.5	**3.6**	X
6	-11	-7.5	**3.4**	X
7	-5.5	-7.5	**-2**	
1	-9.4	-8.9	**0.5**	
2	-10	-8.9	**1.1**	
3	-12	-8.9	**3.4**	X
4	-12	-8.9	**3.2**	
5	-13	-8.9	**3.6**	X
6	-12	-8.9	**3.4**	X
7	-6.9	-8.9	**-2**	
1	-10	-9.8	**0.2**	
2	-11	-9.8	**0.7**	
3	-13	-9.8	**3.2**	X
4	-13	-9.8	**2.8**	
5	-14	-9.8	**3.7**	X
6	-13	-9.8	**3.3**	X
7	-7.4	-9.8	**-2.4**	
1	-11	-11	**0.5**	
2	-12	-11	**1.1**	X
3	-14	-11	**3.4**	X
4	-12	-11	**1.9**	X
5	-13	-11	**2.5**	X
6	-13	-11	**2.9**	X
7	-8.4	-11	**-2.1**	
1	-12	-10	**1.5**	X
2	-13	-10	**2.6**	X
3	-13	-10	**3.3**	X
4	-13	-10	**2.4**	X
5	-13	-10	**2.9**	X
6	-13	-10	**2.5**	X
7	-9	-10	**-1.1**	

RJ Wing, 25 March 2002

1	-6.2	-9	**-2.8**	
2	-7.4	-9	**-1.6**	
3	-8.3	-9	**-0.7**	
4	-7.4	-9	**-1.6**	
5	-9	-9	**0**	
6	-5.1	-9	**-3.9**	
1	-5.4	-5	**0.4**	
2	-6	-5	**1**	
3	-12	-5	**6.5**	
4	-6.7	-5	**1.7**	
5	-7.5	-5	**2.5**	
6	-6.3	-5	**1.3**	
1	-6.7	-6.5	**0.2**	
2	-7.1	-6.5	**0.6**	
3	-8.7	-6.5	**2.2**	
4	-7.6	-6.5	**1.1**	
5	-7.5	-6.5	**1**	
6	-7	-6.5	**0.5**	
1	-8	-6	**2**	
2	-8.8	-6	**2.8**	
3	-10	-6	**4**	
4	-8.3	-6	**2.3**	
5	-9	-6	**3**	
6	-7.1	-6	**1.1**	

Jet Star Wing 25 March, 2002

Test #	Temp	OAT	ΔT	Frost
1	-8.6	-7.2	**1.4**	
2	-9	-7.2	**1.8**	
3	-	-7.2		
4	-9.6	-7.2	**2.4**	
5	-10.7	-7.2	**3.5**	
6	-10.7	-7.2	**3.5**	
7	-10.7	-7.2	**3.5**	
1	-9	-9	**0**	
2	-10.3	-9	**1.3**	
3	-10.2	-9	**1.2**	
4	-11.5	-9	**2.5**	
5	-12.3	-9	**3.3**	
6	-12.5	-9	**3.5**	
7	-11.6	-9	**2.6**	
1	-10	-9.1	**0.9**	
2	-19	-9.1	**9.9**	
3	-11.2	-9.1	**2.1**	
4	-12.8	-9.1	**3.7**	X
5	-12.6	-9.1	**3.5**	X
6	-12.9	-9.1	**3.8**	X
7	-12	-9.1	**2.9**	X
1	-10.8	-11.1	**-0.3**	
2	-11.5	-11.1	**0.4**	
3	-12	-11.1	**0.9**	
4	-13.3	-11.1	**2.2**	X
5	-14	-11.1	**2.9**	X
6	-14	-11.1	**2.9**	X
7	-13.9	-11.1	**2.8**	X

Jet Star Wing, 7 Jan. 2002

1	-			
2	-7.1	-7.6	**-0.5**	
3	-11.5	-7.6	**3.9**	X
4	-11.4	-7.6	**3.8**	X
5	-11.1	-7.6	**3.5**	X
6	-11.3	-7.6	**3.7**	X
7	-9.6	-7.6	**2**	
1	-			
2	-5	-7.2	**-2.2**	
3	-13.7	-7.2	**6.5**	X
4	-13.7	-7.2	**6.5**	X
5	-13.5	-7.2	**6.3**	X
6	-13.6	-7.2	**6.4**	X
7	-9.6	-7.2	**2.4**	X
1	-			
2	-10.7	-8.2	**2.5**	
3	-14.6	-8.2	**6.4**	X
4	-14.3	-8.2	**6.1**	X
5	-14.2	-8.2	**6**	X
6	-13.6	-8.2	**5.4**	X
7	-11.5	-8.2	**3.3**	X
1	-			
2	-12.5		**-1**	
3	-15.9	-13.5	**2.4**	X
4	-14.6	-13.5	**1.1**	X
5	-14.9	-13.5	**1.4**	X
6	-15.2	-13.5	**1.7**	X
7	-12.4	-13.5	**-1.1**	X
1	-			
2	-12.2	-11.1	**1.1**	X
3	-15.3	-11.1	**4.2**	X
4	-13.9	-11.1	**2.8**	X
5	-13.7	-11.1	**2.6**	X
6	-14.2	-11.1	**3.1**	X
7	-12.5	-11.1	**1.4**	X
1	-			
2	-11.1	-9	**2.1**	X
3	-13.9	-9	**4.9**	X
4	-13.6	-9	**4.6**	X
5	-13.7	-9	**4.7**	X
6	-13.7	-9	**4.7**	X
7	-11.3	-9	**2.3**	X
1	-			
2	-11.1	-10	**1.1**	X
3	-14.1	-10	**4.1**	X
4	-13	-10	**3**	X
5	-12.4	-10	**2.4**	X
6	-12.4	-10	**2.4**	X
7	-11.7	-10	**1.7**	X
1	-			
2	-11.5	-10.3	**1.2**	X
3	-13.3	-10.3	**3**	X
4	-11.7	-10.3	**1.4**	X
5	-11.9	-10.3	**1.6**	X
6	-12.7	-10.3	**2.4**	X
7	-11.8	-10.3	**1.5**	X

X : Indicates Presence of Frost

M:\Groups\Cm1680 (01-02)\Reports\Frost 2001 - 2002\Working Documents\Tables 3.2-3.4

JetStar test wing temperature data and local air temperature data were also gathered during the overnight test sessions on a continual basis, providing a further source of data. In Figure 3.32, the data collected from the JetStar test wing and the tests on the Boeing 737 aircraft have been added to Figure 3.31.

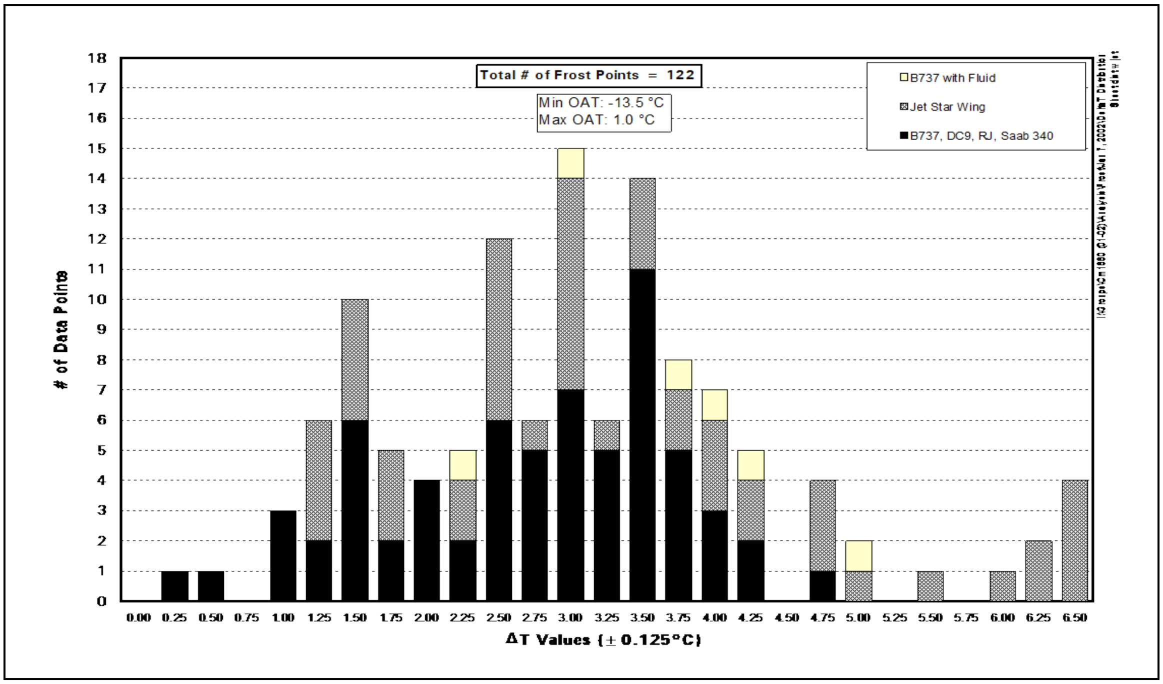

Figure 3.32: Frequency Distribution of ΔT Measured on Overnight Aircraft, JetStar Wing and Full-Scale Test

All data points are plotted as a scatter-diagram in Figure 3.33 with ΔT as the ordinate and OAT as the abscissa. This chart shows that OAT ranged from 0 to -14ºC during the data-gathering sessions. The maximum ΔT recorded was approximately 6.5ºC.

3.8 United Postal Service (UPS) Aircraft Skin Temperature Monitoring during Active Frost Conditions

UPS has put in place a protocol to monitor wing skin temperature versus OAT differentials during potential active frost conditions. This data has been reviewed and is described below. The results support the observed temperature differentials recorded during the flat plate endurance time tests.

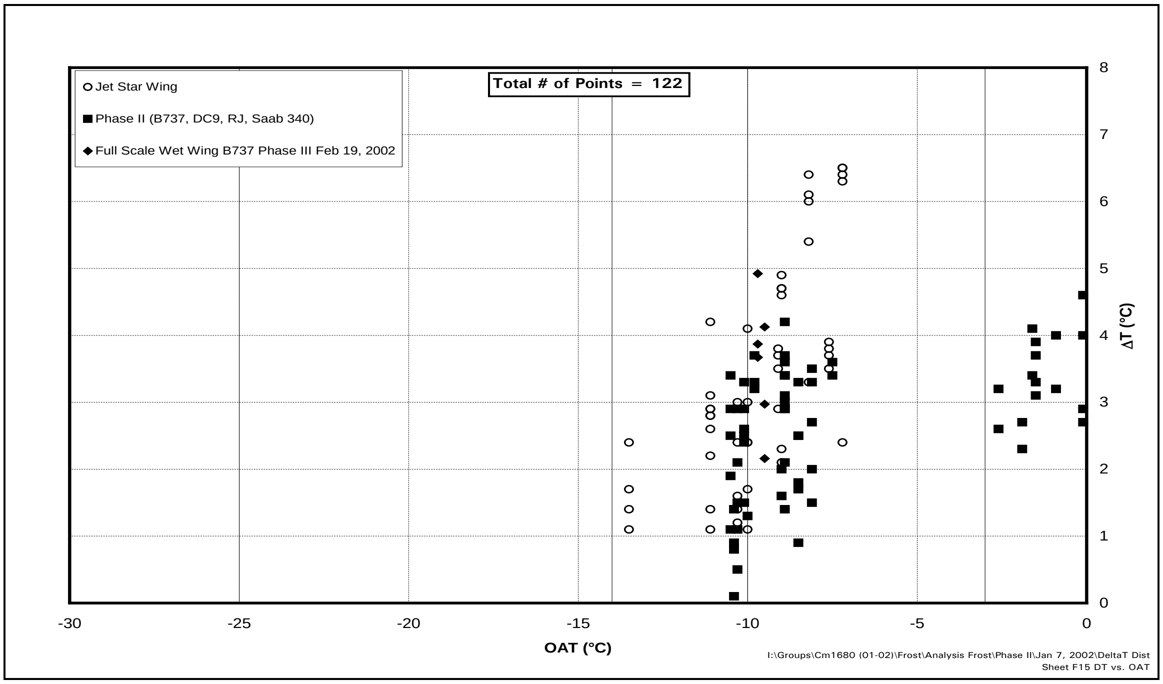

Figure 3.33: ΔT vs. OAT for All Wing Tests

In order to monitor active frost conditions at Louisville International Airport (SDF), UPS setup a frost monitoring system consisting of a leaf wetness indicator (Photo 3.1) to monitor frost accretion, and a representative aircraft surface (Photo 3.2) to monitor aircraft skin to air temperature differentials. The leaf wetness indicator measures the electrical resistance of a water or ice film on the sensor surface, which is in turn converted into an intensity level. The representative aircraft surface has a temperature probe attached to the underside of the unpainted aluminum surface. The mock wing airfoil measures approximately 1.2m x 0.9m, has a curvature representative of an aircraft wing, and is mounted on a wooden frame insulated from the ground using several sheets of insulating foam.

Data was continually logged by UPS between October and December 2007; information is recorded by the sensors on a 5-minute interval. This data was provided to APS courtesy of the UPS Meteorology Department. During this three month period, 24 events were recorded as having frozen dew or frost. During these events, a maximum radiative cooling of 8.4°C between the outside ambient temperature and the representative aircraft surface was recorded during active frost conditions; the general trend was within 2-3°C of this maximum. The results obtained by UPS are in accordance with the plate temperature differential data collected by APS.

Photo 3.1: UPS Leaf Wetness Indicator

Photo 3.2: UPS Representative Aircraft Wing Surface

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4. ANALYSIS AND OBSERVATIONS

4.1 Type I Fluid Endurance Tests in Natural Frost

Type I endurance time testing in natural frost conditions was conducted using white-painted aluminum test surfaces (frosticator plate setup). Section 3.4 demonstrates that the Type I data was collected during weather conditions representative of actual operations. In Figure 3.4, a chart of Type I endurance times was plotted versus the measured icing intensity. It was clear that the positioning of the data points followed an upward trend to the left, as illustrated by the superimposed trend line. The expected relationship between icing intensity and endurance times is produced wherein endurance times increase with lowered rates.

In the Type I dataset collected, none of the natural frost endurance times fell below the currently published Type I fluid HOT of 45 minutes. However, two cases occurred where endurance times came close to the 45 minute limit. Based on the data collected, the Type I HOTs have been substantiated.

4.2 Type II/III/IV Fluid Endurance Tests in Natural Frost

Generic HOT's are issued for Type II, III, and IV fluids. Table 4.1 demonstrates the issued HOT's (for winter 2008-09) along with the endurance times measured during the 2003-04, 2004-05, and 2005-06 winters. The data indicates the potential reductions based on the data collected if the current HOT table format were to be maintained. In addition, the average OAT during each test is included in brackets next to each endurance time result. The endurance time results were sorted into two groups:

- Failed Tests: Tests that were completed (fluid failure occurred); and
- Stopped Tests: Tests that were not completed (fluid failure did not occur).

In the following subsections, assessments are made based on the results obtained with each fluid Type.

Table 4.1: Option 1: Issue Reduced HOT's in Current HOT Tables
Frost HOT Values and Endurance Time Test Results

Times [hours]														
		Type II					Type IV					Type III		
OAT [ºC]	Conc.	Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)		Stopped Tests [hours] (OATºC,ΔTºC)		Current HOT Time [hours]	Failed Tests [hours] (OAT ºC,ΔTºC)		Stopped Tests [hours] (OAT ºC,ΔTºC)		Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)	Stopped Tests [hours] (OATºC,ΔTºC)
Above -3	100/0	8.0			11.6[14] (0.1,7) 10.8[15] (1.5,4)	12.3[16] (-1.0,5) 12.4[16] (-1.0,5)	12.0			11.6[14] (0.1,3) 11.6[14] (0.1,7)	10.8[15] (1.5,5) 10.8[15] (1.5,4) 12.3[16] (-1.0,NA) 12.3[16] (-1.0,4)	2.0	4.7 (2.0,7)	
	75/25	5.0	7.4 (-0.5,6)		11.6[14] (0.1,NA) 10.0[15] (1.3,5)	11.6[16] (-1.3,4) 11.6[16] (-1.3,NA)	5.0	4.6 (-3.0,4)		10.1[15](1.3,6)	10.1[15] (1.3,4) 11.6[16] (-1.3,4)	1.0	5.2 (1.5,7)	
	50/50	3.0	6.1 (0.3,7) 1.9 (-1.1,7)		10.0[15] (1.3,4) 11.6[16] (-1.3,7)		3.0	3.2 (1.0,6) 4.5 (0.4,6) 5.3 (-1.3,6)	3.2 (1.1,2) 7.5 (-0.5,6)	5.7[14] (-1.5,7) 10.1[15](1.3,5)	10.0[15](1.3,4) 6.6[15](1.3,6)	0.5	3.0 (1.0,6) 1.4 (-0.9,6)	
Below -3 to -14	100/0	8.0	9.5 (-3.6,4) 10.5 (-4.3,3) 10.4 (-13.0,6) 11.9 (-13.7,6) 9.2 (-10.3,NA)		9.5[1] (-9.7,6) 13.6[4] (-9.3,5) 13.5[4] (-9.3,5) 13.3[4] (-9.3,6) 12.8[7] (-12.7,5) 12.9[9] (-7.1,2) 12.8[9] (-7.1,2) 12.9[10] (-4.8,3) 12.8[10] (-4.8,4) 11.6[11] (-13.6,6)	12.5[20] (-4.1,NA) 12.4[20] (-4.1,3) 12.1[19] (-10.0,NA)	12.0	7.9 (-10.1,7) 10.8 (-4.3,3) 13.0 (-9.3,5) 6.1 (-10.8,8) 10.6 (-13.4,6) 10.7 (-13.5,6) 11.0 (-14.2,5)		9.6[1] (-9.7,6) 9.5[1] (-9.7,6) 10.9[3] (-4.3,6) 10.9[3] (-4.3,6) 10.8[3] (-4.3,6) 13.5[4] (-9.3,5) 13.5[4] (-9.3,5) 13.5[4] (-9.3,4) 13.5[4] (-9.3,6) 12.8[7] (-12.7,5) 12.7[7] (-12.7,6)	12.6[9] (-7.1,2) 12.7[9] (-7.1,2) 12.9[10] (-4.8,4) 12.9[10] (-4.8,4) 12.8[10] (-4.8,3) 11.6[11] (-13.6,5) 11.6[11] (-13.6,6) 12.8[13] (-13.9,6) 12.8[13] (-13.9,6) 12.5[20] (-4.1,4) 12.5[20] (-4.1,4) 12.1[19] (-10.0,5) 12.1[19] (-10.0,6)	2.0	5.8 (-3.1,4) 4.6 (-5.0,6) 9.0 (-6.1,3) 8.1 (-3.8,5) 7.4 (-12.0,7) 8.6 (-13.0,7) 9.9 (-3.4,1)	12.1[17] (-10.0,5)
	75/25	5.0	8.2 (-9.4,5) 9.5 (-3.6,4) 6.7 (-3.1,3) 3.3 (-10.1,8) 3.1 (-10.1,8) 3.1 (-10.1,8) 2.2 (-12.5,9) 2.5 (-12.5,8) 9.3(-4.1,NA) 6.6(-11.0,2) 6.5(-11.0,7) 9.9(-10.4,3)	2.5 (-13.6,7) 3.4 (-11.0,7) 4.1 (-10.5,8) 3.2 (-11.0,7) 1.6 (-13.3,9) 1.5 (-13.3,8) 1.1 (-14.1,8) 4.5 (-12.3,5) 3.7 (-12.1,6)	10.7[3] (-4.3,7) 13.3[4] (-9.3,6) 13.3[4] (-9.3,6) 12.8[9] (-7.1,2) 12.7[9] (-7.1,2) 5.5[9] (-9.3,3) 12.9[10] (-4.8,3) 12.8[10] (-4.8,4) 12.5[20](-4.1,4) 12.4[20] (-4.1,4) 5.0[20] (-6.2,5)		5.0	4.8 (-9.9,4) 5.9 (-4.8,4) 3.3 (-10.1,8) 3.1 (-10.1,8) 1.6 (-11.9,9) 1.3 (-11.9,9) 1.6 (-14.4,6)	2.5 (-14.7,6) 9.8 (-6.4,4) 7.1 (-5.3,5) 3.9 (-10.5,7) 1.3 (-13.3,8) 3.3 (-12.1,5)	7.2[1] (-10.7,5) 9.5[1] (-9.7,6) 13.3[4] (-9.3,6) 13.2[4] (-9.3,6) 10.8[3] (-4.3,7) 4.8[8] (-14.6,6) 12.6[9] (-7.1,2) 12.9[10] (-4.8,3) 12.9[10] (-4.8,4) 11.0[20] (-4.5,4) 9.9[19] (-10.4,4)		1.0	3.5 (-12.1,6) 5.9 (-3.2,6) 5 (-10.8,10)	3.8[19] (-10.0,3)
Below -14 to -25	100/0	8.0	8.0 (-16.8,6) 8.0 (-16.8,6) 10.4(-18.5,2) 10.6(-18.5,NA)		7.9[2] (-15.0,4) 7.8[2] (-15.0,5) 12.6[5] (-20.5,2) 12.6[5] (-20.5,2) 12.6[5] (-20.5,3) 12.7[6] (-14.5,5) 12.7[6] (-14.5,5) 11.3[18](-18.7,5) 11.3[18](-18.7,2)		12.0	5.9 (-19.2,4) 10.3 (-20.2,5) 6.3 (-16.2,6) 6.3 (-16.2,6)		7.9[2] (-15.0,4) 7.8[2] (-15.0,4) 7.8[2] (-15.0,4) 7.8[2] (-15.0,5) 7.8[2] (-15.0,4) 7.8[2] (-15.0,4) 12.5[5] (-20.5,3) 12.5[5] (-20.5,3) 12.5[5] (-20.5,3)	12.7[6] (-14.5,5) 13.1[6] (-14.5,6) 12.9[6] (-14.5,5) 12.9[6] (-14.5,4) 12.1[12] (-17.1,5) 12.1[12] (-17.1,6) 12.1[12] (-17.1,6) 12.1[12] (-17.1,5) 11.3[18] (-18.7,6) 11.3[18] (-18.7,6) 11.3[18] (-18.7,1)	2.0	5.4 (-15.7,6) 5.3 (-15.7,7)	7.8[2] (-15.0,5) 12.6[6] (-14.5,5) 7.3[8] (-14.2,5) 11.4[18](-18.7,NA) 11.3[18](-18.7,6)

Notes

1. Test stopped at 6:00 am – December 8, 2003
2. Test stopped at 2:30 am – February 16, 2004, winds at 14 km/h
3. Test stopped at 6:00 am – March 9, 2004
4. Test stopped at 7:20 am – December 29, 2004
5. Test stopped at 7:00 am – January 27, 2005
6. Test stopped at 7:00 am – January 28, 2005
7. Test stopped at 6:50 am – January 31, 2005
8. Test stopped at 7:00 am – January 31, 2005
9. Test stopped at 6:45 am – February 2, 2005
10. Test stopped at 6:40 am – February 4, 2005
11. Test stopped at 6:25 am – February 25, 2005
12. Test stopped at 6:55 am – December 13, 2005
13. Test stopped at 7:00 am – February 10, 2006
14. Test stopped at 7:00 am – March 27, 2006
15. Test stopped at 7:00 am – October 31, 2006
16. Test stopped at 7:20 am – November 25, 2006
17. Test stopped at 7:00 am – February 16, 2008
18. Test stopped at 7:00 am – February 28, 2008
19. Test stopped at 7:00 am – January 16, 2008
20. Test stopped at 7:00 am – January 12, 2008

4.2.1 Type II Fluids

Some of the measured fluid endurance times for Type II 75/25 fluids were significantly lower than the values issued in the HOT Guidelines. The limited data collected with Type II 50/50 fluids also demonstrated a similar situation. Additional Type II fluid endurance time testing would be beneficial to further substantiate the lower endurance time values measured. It is recommended that reductions to the current frost HOT's for Type II fluids be issued to reflect the data collected to date.

4.2.2 Type IV Fluids

Some of the measured fluid endurance times for Type IV fluids were significantly lower than the values issued in the HOT Guidelines. It is recommended that reductions to the current frost HOT's for Type IV fluids be issued to reflect the data collected to date.

4.2.3 Type III Fluids

The results indicate that the measured fluid HOT for Type III fluids were longer than the values issued in the HOT Guidelines. Based on the data collected, the current Type III HOT's are satisfactory.

4.3 Effect of Fluid Freeze Point on Endurance Time of Type II/III/IV Fluids

A significant reduction in the Type II and Type IV fluid endurance time was observed in a number of tests once the outside ambient temperature began to approach the fluid LOUT (lowest operational use temperature). By exploring further, it was found that the plate surface temperature during these tests was several degrees lower than the OAT. Once the OAT would begin to approach the fluid LOUT, the plate surface temperature would cool to the fluid freeze point.

Figure 4.1 demonstrates the surface temperature profile for Clariant Safewing MP IV 2012 75/25 during frost conditions. The graphical representation shows that the average OAT is approximately -12°C and the plate surface temperature reaches approximately -20°C. The fluid freeze point does not change from time of application to time of failure; fluid dilution due to frost accretion is not the cause of fluid failure. Fluid failure occurs because the surface temperature of the test plate is approaching the stable fluid freeze point. When the surface temperature reaches the equilibrium freeze point, small ice formations slowly begin to form sporadically across the test plate. In comparison, for cases where fluid failure occurred due to fluid dilution and fluid erosion, the failure occurs primarily because the weakening fluid freeze point reaches the surface temperature of the test plate.

This phenomenon was experienced with the Type II and Type IV fluids tested; the Type III fluid was not affected because the current HOT's are conservative enough to provide sufficient protection. Table 4.2 shows the fluid freeze points for generic Type II and Type IV Propylene Glycol (PG) neat and diluted fluids. When experiencing a 7°C temperature differential, the surface temperature will drop to the fluid freeze point (FFP) for the diluted fluids applied at the LOUT, and will approach the FFP in the case of a neat fluid. The HOT table provides operational ranges specifying limits based on OAT. In frost conditions, the skin temperature of an aircraft may be several degrees lower than the OAT. If a pilot were operating with an anti-icing fluid at the LOUT during frost conditions, the skin temperature of the aircraft could reach the fluid freeze point potentially causing ice to form in the fluid; this can lead to slush contamination.

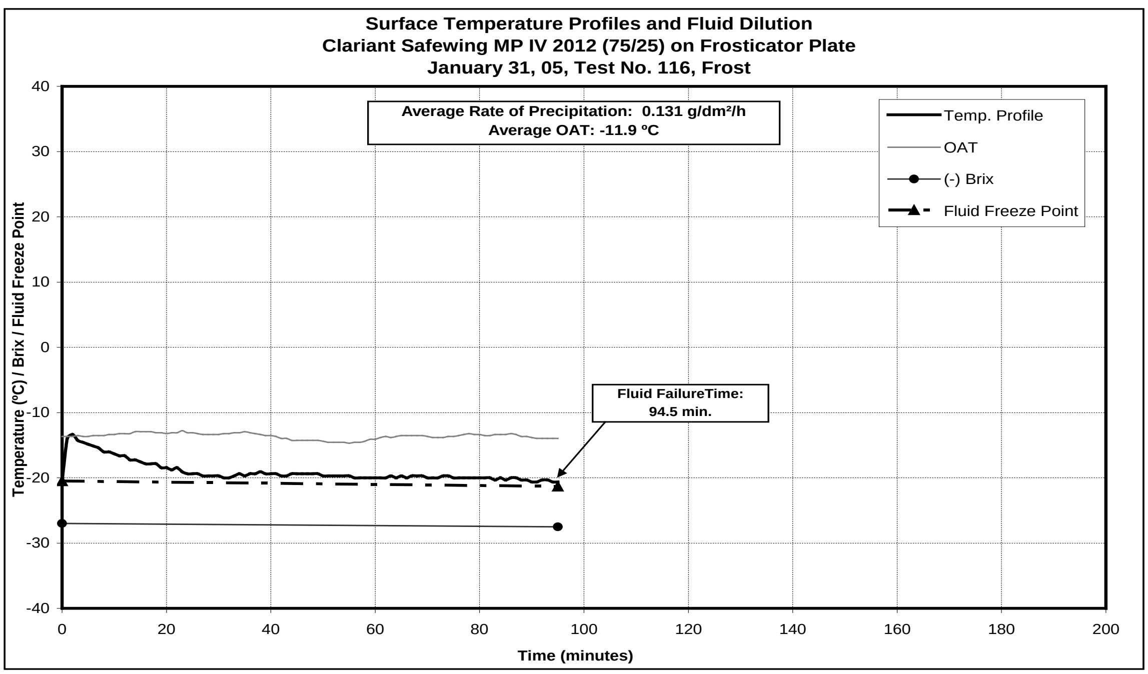

Figure 4.1: Surface Temperature Profile for Clariant Safewing MPIV 2012 75/25 during Frost Conditions

Table 4.2: Example of Fluid Freeze Point Failure in Frost Conditions for Type II and Type IV PG fluids

Type II/IV Dilution	LOUT	Approximate FFP	Possible Surface Temp. During Frost Conditions at LOUT
Neat	-25	-36	-32
75/25	-14	-21	-21
50/50	-3	-10	-10

4.4 Options for Change to Frost HOT Guidelines

As described in Section 4.2, the results of the frost research show that some changes must be made to the frost HOT guidelines. Several options for change have been proposed during industry meetings:

- Option 1: Issue Reduced HOT's in Current HOT Tables;
- Option 2: Issue Temperature Restrictions in Current HOT Tables; and
- Option 3: Issue Separate Frost Table.

These options will be discussed in further detail in Section 7. To facilitate the evaluation of these options, the Type II/III/IV endurance time data has been re-organized according to the proposed changes in each of the options.

- Table 4.1 presents the endurance time data collected in accordance with Option 1, which is the proposal to issue reduced HOT's in the current HOT tables.
- Table 4.3 presents the endurance time data collected in accordance with Option 2, which is the proposal to restrict diluted fluid use as follows: 50/50 fluids restricted to above -1°C and 75/25 fluids restricted to above -10°C. In Table 4.3, the strikethrough data points indicate tests that would no longer be applicable as a result of a temperature restriction for diluted fluids.
- Table 4.4 presents the endurance time data collected in accordance with Option 3, which is the proposal to adopt additional temperature breakdown increments for frost HOTs and to have the frost HOT's issued on a separate frost table.

Table 4.3: Option 2: Issue Temperature Restrictions in Current HOT Tables Frost HOT Values and Endurance Time Test Results

Times [hours]														
		Type II					Type IV					Type III		
OAT [ºC]	Conc.	Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)		Stopped Tests [hours] (OATºC,ΔTºC)		Current HOT Time [hours]	Failed Tests [hours] (OAT ºC,ΔTºC)		Stopped Tests [hours] (OAT ºC,ΔTºC)		Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)	Stopped Tests [hours] (OATºC,ΔTºC)
Above -3	100/0	8.0			11.6[14] (0.1,7) 10.8[15] (1.5,4)	12.3[16] (-1.0,5) 12.4[16] (-1.0,5)	12.0			11.6[14] (0.1,3) 11.6[14] (0.1,7)	10.8[15] (1.5,5) 10.8[15] (1.5,4) 12.3[16] (-1.0,NA) 12.3[16] (-1.0,4)	2.0	4.7 (2.0,7)	
	75/25	5.0	7.4 (-0.5,6)		11.6[14] (0.1,NA) 10.0[15] (1.3,5)	11.6[16] (-1.3,4) 11.6[16] (-1.3,NA)	5.0	4.6 (-3.0,4)		10.1[15](1.3,6)	10.1[15] (1.3,4) ~~11.6[16] (-1.3,4)~~	1.0	5.2 (1.5,7)	
	50/50	3.0	6.1 (0.3,7) ~~1.9 (-1.1,7)~~		10.0[15] (1.3,4) ~~11.6[16] (-1.3,7)~~		3.0	3.2 (1.0,6) 4.5 (0.4,6) ~~5.3 (-1.3,6)~~	3.2 (1.1,2) 7.5 (-0.5,6)	~~5.7[14] (-1.5,7)~~ 10.1[15](1.3,5)	10.0[15](1.3,4) 6.6[15](1.3,6)	0.5	3.0 (1.0,6) 1.4 (-0.9,6)	
Below -3 to -14	100/0	8.0	9.5 (-3.6,4) 10.5 (-4.3,3) 10.4 (-13.0,6) 11.9 (-13.7,6) 9.2 (-10.3,NA)		9.5[1] (-9.7,6) 13.6[4] (-9.3,5) 13.5[4] (-9.3,5) 13.3[4] (-9.3,6) 12.8[7] (-12.7,5) 12.9[9] (-7.1,2) 12.8[9] (-7.1,2) 12.9[10] (-4.8,3) 12.8[10] (-4.8,4) 11.6[11] (-13.6,6)	12.5[20] (-4.1,NA) 12.4[20] (-4.1,3) 12.1[19] (-10.0,NA)	12.0	7.9 (-10.1,7) 10.8 (-4.3,3) 13.0 (-9.3,5) 6.1 (-10.8,8) 10.6 (-13.4,6) 10.7 (-13.5,6) 11.0 (-14.2,5)		9.6[1] (-9.7,6) 9.5[1] (-9.7,6) 10.9[3] (-4.3,6) 10.9[3] (-4.3,6) 10.8[3] (-4.3,6) 13.5[4] (-9.3,5) 13.5[4] (-9.3,5) 13.5[4] (-9.3,4) 13.5[4] (-9.3,6) 12.8[7] (-12.7,5) 12.7[7] (-12.7,6)	12.6[9] (-7.1,2) 12.7[9] (-7.1,2) 12.9[10] (-4.8,4) 12.9[10] (-4.8,4) 12.8[10] (-4.8,3) 11.6[11] (-13.6,5) 11.6[11] (-13.6,6) 12.8[13] (-13.9,6) 12.8[13] (-13.9,6) 12.5[20] (-4.1,4) 12.5[20] (-4.1,4) 12.1[19] (-10.0,5) 12.1[19] (-10.0,6)	2.0	5.8 (-3.1,4) 4.6 (-5.0,6) 9.0 (-6.1,3) 8.1 (-3.8,5) 7.4 (-12.0,7) 8.6 (-13.0,7) 9.9 (-3.4,1)	12.1[17] (-10.0,5)
	75/25	5.0	8.2 (-9.4,5) 9.5 (-3.6,4) 6.7 (-3.1,3) ~~3.3 (-10.1,8)~~ ~~3.1 (-10.1,8)~~ ~~3.1 (-10.1,8)~~ ~~2.2 (-12.5,9)~~ ~~2.5 (-12.5,8)~~ 9.3(-4.1,NA) ~~6.6(-11.0,2)~~ ~~6.5(-11.0,7)~~ ~~9.9(-10.4,3)~~	~~2.5 (-13.6,7)~~ ~~3.4 (-11.0,7)~~ ~~4.1 (-10.5,8)~~ ~~3.2 (-11.0,7)~~ ~~1.6 (-13.3,9)~~ ~~1.5 (-13.3,8)~~ ~~1.1 (-14.1,8)~~ ~~4.5 (-12.3,5)~~ ~~3.7 (-12.1,6)~~	10.7[3] (-4.3,7) 13.3[4] (-9.3,6) 13.3[4] (-9.3,6) 12.8[9] (-7.1,2) 12.7[9] (-7.1,2) 5.5[9] (-9.3,3) 12.9[10] (-4.8,3) 12.8[10] (-4.8,4) 12.5[20](-4.1,4) 12.4[20] (-4.1,4) 5.0[20] (-6.2,5)		5.0	4.8 (-9.9,4) 5.9 (-4.8,4) ~~3.3 (-10.1,8)~~ ~~3.1 (-10.1,8)~~ ~~1.6 (-11.9,9)~~ ~~1.3 (-11.9,9)~~ ~~1.6 (-14.4,6)~~	~~2.5 (-14.7,6)~~ 9.8 (-6.4,4) 7.1 (-5.3,5) ~~3.9 (-10.5,7)~~ ~~1.3 (-13.3,8)~~ ~~3.3 (-12.1,5)~~	~~7.2[1] (-10.7,5)~~ 9.5[1] (-9.7,6) 13.3[4] (-9.3,6) 13.2[4] (-9.3,6) 10.8[3] (-4.3,7) ~~4.8[8] (-14.6,6)~~ 12.6[9] (-7.1,2) 12.9[10] (-4.8,3) 12.9[10] (-4.8,4) 11.0[20] (-4.5,4) ~~9.9[19] (-10.4,4)~~		1.0	~~3.5 (-12.1,6)~~ 5.9 (-3.2,6) ~~5 (-10.8,10)~~	3.8[19] (-10.0,3)
Below -14 to -25	100/0	8.0	8.0 (-16.8,6) 8.0 (-16.8,6) 10.4(-18.5,2) 10.6(-18.5,NA)		7.9[2] (-15.0,4) 7.8[2] (-15.0,5) 12.6[5] (-20.5,2) 12.6[5] (-20.5,2) 12.6[5] (-20.5,3) 12.7[6] (-14.5,5) 12.7[6] (-14.5,5) 11.3[18](-18.7,5) 11.3[18](-18.7,2)		12.0	5.9 (-19.2,4) 10.3 (-20.2,5) 6.3 (-16.2,6) 6.3 (-16.2,6)		7.9[2] (-15.0,4) 7.8[2] (-15.0,4) 7.8[2] (-15.0,4) 7.8[2] (-15.0,5) 7.8[2] (-15.0,4) 7.8[2] (-15.0,4) 12.5[5] (-20.5,3) 12.5[5] (-20.5,3) 12.5[5] (-20.5,3)	12.7[6] (-14.5,5) 13.1[6] (-14.5,6) 12.9[6] (-14.5,5) 12.9[6] (-14.5,4) 12.1[12] (-17.1,5) 12.1[12] (-17.1,6) 12.1[12] (-17.1,6) 12.1[12] (-17.1,5) 11.3[18] (-18.7,6) 11.3[18] (-18.7,6) 11.3[18] (-18.7,1)	2.0	5.4 (-15.7,6) 5.3 (-15.7,7)	7.8[2] (-15.0,5) 12.6[6] (-14.5,5) 7.3[8] (-14.2,5) 11.4[18](-18.7,NA) 11.3[18](-18.7,6)

Notes

1. Test stopped at 6:00 am – December 8, 2003
2. Test stopped at 2:30 am – February 16, 2004, winds at 14 km/h
3. Test stopped at 6:00 am – March 9, 2004
4. Test stopped at 7:20 am – December 29, 2004
5. Test stopped at 7:00 am – January 27, 2005
6. Test stopped at 7:00 am – January 28, 2005
7. Test stopped at 6:50 am – January 31, 2005
8. Test stopped at 7:00 am – January 31, 2005
9. Test stopped at 6:45 am – February 2, 2005
10. Test stopped at 6:40 am – February 4, 2005
11. Test stopped at 6:25 am – February 25, 2005
12. Test stopped at 6:55 am – December 13, 2005
13. Test stopped at 7:00 am – February 10, 2006
14. Test stopped at 7:00 am – March 27, 2006
15. Test stopped at 7:00 am – October 31, 2006
16. Test stopped at 7:20 am – November 25, 2006
17. Test stopped at 7:00 am – February 16, 2008
18. Test stopped at 7:00 am – February 28, 2008
19. Test stopped at 7:00 am – January 16, 2008
20. Test stopped at 7:00 am – January 12, 2008

Table 4.4: Option 3: Issue Separate Frost Table Frost HOT Values and Endurance Time Test Results

		Times [hours]								
OAT [ºC]	Conc.	Type II			Type IV			Type III		
		Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)	Stopped Tests [hours] (OATºC,ΔTºC)	Current HOT Time [hours]	Failed Tests [hours] (OAT ºC,ΔTºC)	Stopped Tests [hours] (OAT ºC,ΔTºC)	Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)	Stopped Tests [hours] (OATºC,ΔTºC)
Above -1	100/0	8.0		11.61[4] (0.1,7) 10.81[5] (1.5,4) 12.31[6] (-1.0,5) 12.41[6] (-1.0,5)	12.0		11.6[14] (0.1,3) 11.6[14] (0.1,7) 10.8[15] (1.5,5) 10.8[15] (1.5,4) 12.3[16] (-1.0,NA) 12.3[16] (-1.0,4)	2.0	4.7 (2.0,7)	
	75/25	5.0	7.4 (-0.5,6)	11.6[14] (0.1,NA) 10.0[15] (1.3,5)	5.0		10.1[15] (1.3,4) 10.1[15] (1.3,6)	1.0	5.2 (1.5,7)	
	50/50	3.0	6.1 (0.3,7)	10.0[15] (1.3,4)	3.0	3.2 (1.0,6) 4.5 (0.4,6) 3.2 (1.1,2) 7.5 (-0.5,6)	10.1[15] (1.3,5) 10.0[15] (1.3,4) 6.6[15] (1.3,6)	0.5	3.0 (1.0,6) 1.4 (-0.9,6)	
Below - 1 to - 3	100/0	8.0			12.0			2.0		
	75/25	5.0		11.6[16] (-1.3,4) 11.6[16] (-1.3,NA)	5.0	4.6 (-3.0,4)	11.6[16] (-1.3,4)	1.0		
	50/50	3.0	1.9 (-1.1,7)	11.6[16] (-1.3,7)	3.0	5.3 (-1.3,6)	5.7[14] (-1.5,7)	0.5		
Below -3 to -10	100/0	8.0	9.5 (-3.6,4) 10.5 (-4.3,3)	9.51 (-9.7,6) 13.6[4] (-9.3,5) 13.5[4] (-9.3,5) 13.3[4] (-9.3,6) 12.9[9] (-7.1,2) 12.8[9] (-7.1,2) 12.9[10] (-4.8,3) 12.8[10] (-4.8,4) 12.5[20] (-4.1,NA) 12.4[20] (-4.1,3) 12.1[19] (-10.0,NA)	12.0	10.8 (-4.3,3) 13.0 (-9.3,5)	9.6[1] (-9.7,6) 9.5[1] (-9.7,6) 10.9[3] (-4.3,6) 10.9[3] (-4.3,6) 10.8[3] (-4.3,6) 13.5[4] (-9.3,5) 13.5[4] (-9.3,5) 13.5[4] (-9.3,4) 13.5[4] (-9.3,6) 12.6[9] (-7.1,2) 12.7[9] (-7.1,2) 12.9[10] (-4.8,4) 12.9[10] (-4.8,4) 12.8[10] (-4.8,3) 12.5[20] (-4.1,4) 12.5[20] (-4.1,4) 12.1[19] (-10.0,5) 12.1[19] (-10.0,6)	2.0	5.8 (-3.1,4) 4.6 (-5.0,6) 9.0 (-6.1,3) 8.1 (-3.8,5) 9.9 (-3.4,1)	12.1[17] (-10.0,5)
	75/25	5.0	8.2 (-9.4,5) 9.5 (-3.6,4) 6.7 (-3.1,3) 9.3(-4.1,NA)	10.7[3] (-4.3,7) 13.3[4] (-9.3,6) 13.3[4] (-9.3,6) 12.8[9] (-7.1,2) 12.7[9] (-7.1,2) 5.5[9] (-9.3,3) 12.9[10] (-4.8,3) 12.8[10] (-4.8,4) 12.5[20](-4.1,4) 12.4[20] (-4.1,4) 5.0[20] (-6.2,5)	5.0	4.8 (-9.9,4) 5.9 (-4.8,4) 9.8 (-6.4,4) 7.1 (-5.3,5)	9.5[1] (-9.7,6) 13.3[4] (-9.3,6) 13.2[4] (-9.3,6) 10.8[3] (-4.3,7) 12.6[9] (-7.1,2) 12.9[10] (-4.8,3) 12.9[10] (-4.8,4) 11.0[20] (-4.5,4)	1.0	5.9 (-3.2,6)	3.8[19] (-10.0,3)

Table 4.4 (cont'd): Option 3: Issue Separate Frost Table Frost HOT Values and Endurance Time Test Results

		Times [hours]								
OAT [ºC]	Conc.	Type II			Type IV			Type III		
		Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)	Stopped Tests [hours] (OATºC,ΔTºC)	Current HOT Time [hours]	Failed Tests [hours] (OAT ºC,ΔTºC)	Stopped Tests [hours] (OAT ºC,ΔTºC)	Current HOT Time [hours]	Failed Tests [hours] (OATºC,ΔTºC)	Stopped Tests [hours] (OATºC,ΔTºC)
Below -1 0 to -14	100/0	8.0	10.4 (-13.0,6) 11.9 (-13.7,6) 9.2 (-10.3,NA)	12.8[7] (-12.7,5) 11.6[11] (-13.6,6)	12.0	7.9 (-10.1,7) 6.1 (-10.8,8) 10.6 (-13.4,6) 10.7 (-13.5,6) 11.0 (-14.2,5)	12.8[7] (-12.7,5) 12.7[7] (-12.7,6) 11.6[11] (-13.6,5) 11.6[11] (-13.6,6) 12.8[13] (-13.9,6) 12.8[13] (-13.9,6)	2.0	7.4 (-12.0,7) 8.6 (-13.0,7)	
	75/25	5.0	3.3 (-10.1,8) 3.1 (-10.1,8) 3.1 (-10.1,8) 2.2 (-12.5,9) 2.5 (-12.5,8) 6.6(-11.0,2) 6.5(-11.0,7) 9.9(-10.4,3) 2.5 (-13.6,7) 3.4 (-11.0,7) 4.1 (-10.5,8) 3.2 (-11.0,7) 1.6 (-13.3,9) 1.5 (-13.3,8) 1.1 (-14.1,8) 4.5 (-12.3,5) 3.7 (-12.1,6)		5.0	3.3 (-10.1,8) 3.1 (-10.1,8) 1.6 (-11.9,9) 1.3 (-11.9,9) 1.6 (-14.4,6) 2.5 (-14.7,6) 3.9 (-10.5,7) 1.3 (-13.3,8) 3.3 (-12.1,5)	7.2[1] (-10.7,5) 4.8[8] (-14.6,6) 9.9[19] (-10.4,4)	1.0	3.5 (-12.1,6) 5 (-10.8,10)	
Below -1 4 to -21	100/0	8.0	8.0 (-16.8,6) 8.0 (-16.8,6) 10.4(-18.5,2) 10.6(-18.5,NA)	7.9[2] (-15.0,4) 7.8[2] (-15.0,5) 12.6[5] (-20.5,2) 12.6[5] (-20.5,2) 12.6[5] (-20.5,3) 12.7[6] (-14.5,5) 12.7[6] (-14.5,5) 11.3[18] (-18.7,5) 11.3[18] (-18.7,2)	12.0	5.9 (-19.2,4) 10.3 (-20.2,5) 6.3 (-16.2,6) 6.3 (-16.2,6)	7.9[2] (-15.0,4) 7.8[2] (-15.0,4) 7.8[2] (-15.0,4) 7.8[2] (-15.0,5) 7.8[2] (-15.0,4) 7.8[2] (-15.0,4) 12.5[5] (-20.5,3) 12.5[5] (-20.5,3) 12.5[5] (-20.5,3) 12.7[6] (-14.5,5) 13.1[6] (-14.5,6) 12.9[6] (-14.5,5) 12.9[6] (-14.5,4) 12.1[12] (-17.1,5) 12.1[12] (-17.1,6) 12.1[12] (-17.1,6) 12.1[12] (-17.1,5) 11.3[18] (-18.7,6) 11.3[18] (-18.7,6) 11.3[18] (-18.7,1)	2.0	5.4 (-15.7,6) 5.3 (-15.7,7)	7.8[2] (-15.0,5) 12.6[6] (-14.5,5) 7.3[8] (-14.2,5) 11.4[18] (-18.7,NA) 11.3[18] (-18.7,6)
Below -2 1 to -25	100/0	8.0			12.0			2.0		

Notes

1. Test stopped at 6:00 am – December 8, 2003
2. Test stopped at 2:30 am – February 16, 2004, winds at 14 km/h
3. Test stopped at 6:00 am – March 9, 2004
4. Test stopped at 7:20 am – December 29, 2004
5. Test stopped at 7:00 am – January 27, 2005
6. Test stopped at 7:00 am – January 28, 2005
7. Test stopped at 6:50 am – January 31, 2005
8. Test stopped at 7:00 am – January 31, 2005
9. Test stopped at 6:45 am – February 2, 2005
10. Test stopped at 6:40 am – February 4, 2005
11. Test stopped at 6:25 am – February 25, 2005
12. Test stopped at 6:55 am – December 13, 2005
13. Test stopped at 7:00 am – February 10, 2006
14. Test stopped at 7:00 am – March 27, 2006
15. Test stopped at 7:00 am – October 31, 2006
16. Test stopped at 7:20 am – November 25, 2006
17. Test stopped at 7:00 am – February 16, 2008
18. Test stopped at 7:00 am – February 28, 2008
19. Test stopped at 7:00 am – January 16, 2008
20. Test stopped at 7:00 am – January 12, 2008

4.5 Separate Frost Table

As discussed in Section 4.2, one option proposed to address the changes required to the frost HOT guidelines is issuing a separate table for frost HOT's. This option was proposed by the HOT working group and has been further developed through industry meetings and working groups; this is discussed further in Section 7.

The option to issue a separate frost table requires the removal of the frost column from the generic and fluid specific tables. The separate frost table would include changes to the temperature ranges to allow greater flexibility for fluid use and to minimize the number of HOT reductions. Use of fluid dilutions would not be restricted; however, HOT reductions would apply when nearing the fluid LOUT. The latest version of the proposed separate frost table is given in Table 4.5. Required reductions to the current frost HOT values have been indicated by a strikethrough with the new proposed value in red. The substantiation, or reduction of the current frost HOT values, is directly linked to the endurance time values recorded in Table 4.4.

Following is a summary of the frost HOT reductions required for the separate frost HOT table:

- ***Type II 50/50 Below -1°C to -3°C***
  - One data point recorded an endurance time of 1.9 hours which is below the current frost HOT value of 3 hours.
- ***Type IV Neat Below -3°C to -10°C***
  - One data point recorded endurance times of and 10.8 hours which is below the current frost HOT value of 12 hours.
- ***Type IV 75/25 Below -3°C to -10°C***
  - Two data points recorded endurance times which are below the current frost HOT value of 5 hours.
- ***Type IV Neat Below -10°C to -14°C***
  - Five data points recorded endurance times of 7.9, 6.1, 10.6, 10.7, and 11.0 hours which are below the current frost HOT value of 12 hours.
- ***Type II Neat Below -10°C to -14°C***
  - Although the endurance times recorded were all above the current frost HOT value of 8 hours, a reduction was required due to the Type IV neat data collected in the same temperature range.

- ***Type II 75/25 Below -10°C to -14°C***
  - 14 data points recorded endurance times of 3.3, 3.1, 3.1, 2.2, 2.5, 2.5, 3.4, 4.1, 3.2, 1.6, 1.5, 1.1, 4.5, and 3.7 hours which are below the current frost HOT value of 5 hours.

- ***Type IV 75/25 Below -10°C to -14°C***
  - Nine data points recorded endurance times of 3.3, 3.1, 1.6, 1.3, 1.6, 2.5, 3.9, 1.3, and 3.3 hours which are below the current frost HOT value of 5 hours.

- ***Type IV Neat Below -14°C to -21°C***
  - Four data points recorded endurance times of 5.9, 10.3, 6.3 and 6.3 hours which are below the current frost HOT value of 12 hours.

- ***Type II Neat Below -14°C to -21°C***
  - Although the endurance times recorded were all above the current frost HOT value of 8 hours, a reduction was required due to the Type IV neat data collected in the same temperature range.

- ***Type IV Neat Below -21°C to -25°C***
  - No endurance time data available. Reductions based on historical IREQ indoor laboratory tests conducted which demonstrated endurance time data of 4.5 hours.

- ***Type II Neat Below -21°C to -25°C***
  - No endurance time data available. Reductions based on historical IREQ indoor laboratory tests conducted which demonstrated endurance time data of 1.9 hours.

4.6 Frost HOT Reduction Sensitivity Analysis

Concerns expressed by the industry regarding the frost protocol employed for the natural frost endurance time testing were based upon the temperature differentials recorded on the test plates. In comparison to the aircraft data, which showed skin temperature to OAT differentials of up to 6.5°C, the plate data collected showed plate temperature to OAT differentials up to 9°C. It was suggested that the larger differentials experienced using the test plates may have been the cause for the premature failures and may have been driving the HOT reductions.

In order to verify the impact of the plate temperature differentials on the fluid endurance times and to satisfy the industry concerns regarding the conservatism of the test surfaces, the current frost HOT's were re-evaluated (using the separate frost table format) by eliminating endurance time data points with recorded skin temperature differentials greater than 6°C. The results of this analysis are shown in Table 4.6. Holdover time increases as compared to Table 4.5 have been circled. In the circled cells, the first value indicates the current frost HOT, the second value indicates the reduction based on the full dataset collected, and the third value indicates the potential increase in HOT as a result of the removal of the data with skin temperature differentials greater than 6°C.

Following is a summary of the frost HOT reductions required for a separate frost HOT table if data with skin temperature differentials greater than 6°C was excluded:

- ***Type IV Neat Below -3°C to -10°C***
  - One data point recorded endurance times of and 10.8 hours which is below the current frost HOT value of 12 hours
- ***Type IV Neat Below -10°C to -14°C***
  - Three data points recorded endurance times of 10.6, 10.7, and 11.0 hours which are below the current frost HOT value of 12 hours.
- ***Type IV 75/25 Below -10°C to -14°C***
  - Three data points recorded endurance times of 1.6, 2.5, and 3.3 hours which are below the current frost HOT value of 5 hours.
- ***Type II 75/25 Below -10°C to -14°C***
  - One data point recorded an endurance time of 3.7 hours which is below the current frost HOT value of 5 hours. A reduction to 1.5 hours was required due to the Type IV 75/25 data collected in the same temperature range.
- ***Type IV Neat Below -14°C to -21°C***
  - Four data points recorded endurance times of 5.9, 10.3, 6.3 and 6.3 hours which are below the current frost HOT value of 12 hours.
- ***Type II Neat Below -14°C to -21°C***
  - Although the endurance times recorded were all above the current frost HOT value of 8 hours, a reduction was required due to the Type IV neat data collected in the same temperature range.
- ***Type IV Neat Below -21°C to -25°C***
  - No endurance time data available. Reductions based on historical IREQ indoor laboratory tests conducted (see TC report TP 13831E, *Endurance*

Time Tests in Simulated Frost Conditions (3)) which demonstrated endurance time data of 4.5 hours.

- ***Type II Neat Below -21°C to -25°C***
    - o No endurance time data available. Reductions based on historical IREQ indoor laboratory tests conducted (see TC report TP 13831E, *Endurance Time Tests in Simulated Frost Conditions* (3)) which demonstrated endurance time data of 1.9 hours.

The results indicate that by removing the endurance time data collected with recorded skin temperature differentials greater than 6°C, five cells would benefit from longer HOT's as compared to the separate frost table analysis conducted using the complete dataset of endurance time tests. The sensitivity analysis demonstrates that even after having eliminated the conservative endurance time data points with skin temperature differentials greater than 6°C, frost HOT reductions are still required.

4.7 Impact of Frost Frequency of Occurrence on HOT Changes

In 2000-01 and 2001-02, TC initiated a survey of airlines at a number of international airports in North America, Europe, and Asia. The responses from the two year survey provided a total number of 62 891 deicing operations (Type I Table) and 53 710 anti–icing operations (Type II/IV Table). The details of this study can be found in the report entitled TP 14146E *Winter Weather Impact on Holdover Time Table Format (1995-2003)* (4).

To investigate the impact of the proposed changes to frost HOT's, the frequency of occurrence of natural frost conditions in various temperature ranges was estimated. The results are shown in Table 4.7 (at the end of this section) using the separate frost table format.

The frequency distribution indicates that the majority of frost events (approximately 80 percent) occur above -3°C; therefore, any changes made to the HOT's in this temperature range could have significant impacts on aircraft operations, especially in Europe where overnight and preventative frost anti-icings are common. The results also indicate that although significant HOT reductions are proposed for Neat Type II and Type IV fluids below -14°C, this is not an operationally significant condition.

Table 4.5: Separate Frost HOT Table

TABLE 0 - Frost

FROST HOLDOVER GUIDELINES FOR WINTER 2009-2010

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

Outside Air Temperature		Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times (hours: minutes)			
			Active Frost			
Degrees Celsius	Degrees Fahrenheit		Type I[1,2]	Type II	Type III	Type IV
above -1	above 30	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 1:30	0:30	3:00
below -3 to -10	below 27 to 14	100/0		8:00	2:00	~~12:00~~ 10:00
		75/25		5:00	1:00	5:00
below -10 to -14	below 14 to 7	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00
below -14 to -21	below 7 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
below -21 to -25	below -6 to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 4:00

NOTES

1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.

2 May be used below -25°C (-13°F) provided the lowest operational use temperature (LOUT) of the fluid is respected.

CAUTIONS

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

Table 4.6: Potential Impact on New Separate Frost HOT Table from Removal of Data with ΔT > 6°C

TABLE 0 - Frost

FROST HOLDOVER GUIDELINES FOR WINTER 2009-2010

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

Outside Air Temperature		Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times (hours: minutes)			
			Active Frost			
Degrees Celsius	Degrees Fahrenheit		Type I[1,2]	Type II	Type III	Type IV
above -1	above 30	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ ~~1:30~~ 3:00	0:30	3:00
below -3 to -10	below 27 to 14	100/0		8:00	2:00	~~12:00~~ 10:00
		75/25		5:00	1:00	5:00
below -10 to -14	below 14 to 7	100/0		~~8:00~~ ~~6:00~~ 8:00	2:00	~~12:00~~ ~~6:00~~ 10:00
		75/25		~~5:00~~ ~~1:00~~ 1:30	1:00	~~5:00~~ ~~1:00~~ 1:30
below -14 to -21	below 7 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
below -21 to -25	below -6 to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 4:00

NOTES

1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.

2 May be used below -25°C (-13°F) provided the lowest operational use temperature (LOUT) of the fluid is respected.

CAUTIONS

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

Table 4.7: Frost Frequency of Occurrence Analysis

TABLE 0 - Frost

FROST HOLDOVER GUIDELINES FOR WINTER 2009-2010

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

Outside Air Temperature		Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times (hours: minutes)				Approximate Percentage of Frost Deicing Operations
			Active Frost				
Degrees Celsius	Degrees Fahrenheit		Type I[1,2]	Type II	Type III	Type IV	
above -1	above 30	100/0	0:45	8:00	2:00	12:00	40%
		75/25		5:00	1:00	5:00	
		50/50		3:00	0:30	3:00	
below -1 to -3	below 30 to 27	100/0		8:00	2:00	12:00	40%
		75/25		5:00	1:00	5:00	
		50/50		~~3:00~~ 1:30	0:30	3:00	
below -3 to -10	below 27 to 14	100/0		8:00	2:00	~~12:00~~ 10:00	20%
		75/25		5:00	1:00	5:00	
below -10 to -14	below 14 to 7	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00	
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00	
below -14 to -21	below 7 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00	0%
below -21 to -25	below -6 to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 4:00	

NOTES

1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.

2 May be used below -25°C (-13°F) provided the lowest operational use temperature (LOUT) of the fluid is respected.

CAUTIONS

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

4.8 United Kingdom (UK) Winter Weather Temperature Analysis

The proposed changes to the frost HOT guidelines have caused some concern, particularly for European operators who conduct overnight preventative anti-icing in frost conditions and who frequently use diluted anti-icing fluid formulations. A UK aircraft operator voiced concerns regarding the significant reductions proposed for the Type II and Type IV 75/25 HOT's in the -10ºC to -14ºC temperature range (proposed HOT reduction from 5:00 to 1:00). A study of winter temperatures typically experienced at three representative UK airports was conducted to evaluate the potential operational impacts of reducing the current Type II and Type IV 75/25 HOT's at the lower end of the temperature range.

An analysis of temperature data from three airports located in the United Kingdom was conducted; airports analysed included Glasgow Airport (GLA), Edinburgh Airport (EDI) and Aberdeen Airport (ABZ). Temperature data was obtained from historical METAR reports provided by www.weatherunderground.com. The minimum daily temperature recorded on each day between November 1st and March 31st was examined for the winters 1998-1999 to 2007-2008. The objective was to determine the total number of days in the last ten years during which the daily temperatures reached below -3°C, -7°C, -10°C and -14°C for each of the airports analysed, and to evaluate potential operational impacts resulting from the reduction of the current Type II and Type IV 75/25 HOT's at the lower end of the temperature range. It should be noted that the study was conducted independent of other meteorological conditions; the data includes minimum daily temperatures regardless of whether or not the minimum daily temperature was recorded during a frost event. The results are shown by airport in Table 4.8 (GLA), Table 4.9 (EDI) and Table 4.10 (ABZ).

The results from the study indicate that all three airports typically experience mild temperatures during the winter months. The number of days during the winter season with minimum daily temperatures below -10ºC represents 0.1 percent (GLA), 0.0 percent (EDI), and 0.3 percent (ABZ) for the three airports studied. Based on these results, it can be concluded that the proposed reductions to the current Type II and Type IV 75/25 HOT's at the lower end of the temperature range (-10ºC to -14ºC range) will not have a significant operational impact on UK operators employing preventative diluted fluid ant-icing procedures.

Table 4.8: Glasgow Airport Minimum Daily Temperature Analysis

Glasgow, United Kingdom Airport (GLA)	#	%
Days Below -3°C	205	13.9%
Days Below -7°C	35	2.4%
Days Below -10°C	2	0.1%
Days Below -14°C	0	0.0%
Total Number of Observations	1475	
Minimum Temperature (°C)	-11.1	

NOTE: Data from February 23, 2000-March 31, 2000 were unavailable

Table 4.9: Edinburgh Airport Minimum Daily Temperature Analysis

Edinburgh, United Kingdom Airport (EDI)	#	%
Days Below -3°C	220	14.9%
Days Below -7°C	31	2.1%
Days Below -10°C	0	0.0%
Days Below -14°C	0	0.0%
Total Number of Observations	1471	
Minimum Temperature (°C)	-10	

NOTE: Data from February 23, 2000-March 31, 2000 and 4 undetermined days were unavailable

Table 4.10: Aberdeen Airport Minimum Daily Temperature Analysis

Aberdeen, United Kingdom Airport (ABZ)	#	%
Days Below -3°C	127	8.6%
Days Below -7°C	22	1.5%
Days Below -10°C	4	0.3%
Days Below -14°C	0	0.0%
Total Number of Observations	1475	
Minimum Temperature (°C)	-13.3	

NOTE: Data from February 23, 2000-March 31, 2000 were unavailable

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5. ALUMINUM VS. COMPOSITE TEST SURFACES

In recent years, there has been an increase in the manufacturing of aircraft wings with non-aluminum materials. The trend has not slowed. In fact, a significant amount of the materials being used in the construction of the Airbus A380 wing are non-aluminum. The benefits of using composite materials in the construction of critical aircraft components include reduced aircraft weight, increased fuel efficiency, and improved maintainability.

As a result of the recent trend towards the use of composite materials in the construction of aircraft, a validation of the current frost HOT values is required. The correlation between fluid endurance times measured on aluminum and non-aluminum surfaces is required to ensure that the guidelines for the use of deicing fluids on aircraft using composite materials is adequate.

This work was conducted as part of a separate project and a summary of the work conducted during the winters of 2004-05 and 2005-06 is included in this report. Details of this research can be found in the TC reports TP 14448E, *Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces* (5) and TP 14720E, *Effect of Heat on Endurance Times Using Composite Surfaces Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces* (7) respectively.

5.1 Previous Work – Winter 2004-05

Preliminary testing to investigate the effect of composite test surfaces on fluid endurance time was conducted during the winter of 2004-05 in conjunction with fluid endurance time testing in frost conditions. Comparative Type I endurance time testing using aluminum and non-aluminum test plates was performed. Testing was conducted with one type of composite material: Carbon Fiber Plain Weave Fabric (Carbon 05). A detailed account of the results is provided in the TC report TP 14448E, *Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces* (5). Results indicated that in natural frost conditions, the Type I endurance time on the composite test plate was generally shorter than the endurance time on the aluminum test plate; Table 5.1 demonstrates the preliminary results obtained. The lower fluid endurance time was linked to the following factors: material conductivity, fluid enrichment, surface temperature stabilization, and fluid dilution. Conclusions were preliminary given that the composite material used was carbon fibre, one of multiple composite materials used in aircraft construction. The structure, material thickness, and finish needed to be explored further in order to verify the validity of the test surface used in comparison to actual composite aircraft configuration.

5.2 Test Results – Winter 2005-06

During the winter of 2005-06 additional endurance time testing using various composite materials used in the construction of aircraft was conducted in conjunction with fluid endurance time testing in frost conditions. Testing was conducted with three different composite materials: Carbon Fiber Plain Weave Fabric (Carbon 05), Carbon Fiber Unidirectional Tape tested with two different thicknesses (Carbon 06 Thin and Carbon 06 Thick), and Glass-Reinforced Fibre Metal Laminate (GLARE). A detailed account of the results is provided in the TC report TP 14720E, *Effect of Heat on Endurance Times Using Composite Surfaces Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces* (7); sections 5.1 and 5.2 discuss the results obtained.

Table 5.1: Comparison of Type I Endurance Time on Aluminum and Composite Test Surfaces

Test #	Comp 05 Plate Endurance Time (min)	White Aluminum Plate Endurance Time (min)	Endurance Time % Ratio (Comp/Alum)
C1-C2	95	131	72%
C3-C4	131	146	89%
C5-C6	178	208	86%
C7-C8	131	151	87%
C9-C10	59	77	76%
C11-C12	79	102	78%

Average:	81%
Standard Deviation:	7%

The recorded endurance times recorded were analysed. The data collected indicated that the endurance time results were similar amongst the four composite materials tested. To correlate the composite plate results to the aluminum plate results, the following analysis was conducted using the white aluminum and one representative composite surface; Comp 05 was chosen as the representative composite sample for this analysis. Table 5.2 contains the test data required for the analysis. The percentage ratio, as well as endurance time difference was calculated for each test.

Results showed that on average, the Type I fluid endurance time on the composite test surface was about 20 percent shorter than the endurance time on the white painted aluminum surface. During four of the six runs conducted, this reduction resulted in a discrepancy of more than 30 minutes.

5.3 Analysis and Observations

Figure 5.1 demonstrates the detailed temperature profiles for comparative tests 1-5 conducted in natural frost conditions. The time scale was reduced to 55 minutes (time when the surface temperature stabilized) to allow for a more detailed view of the increase and decrease in plate temperatures. A complete set of charts is included in the TC report, TP 14720E, *Effect of Heat on Endurance Times Using Composite Surfaces Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces* (7).

Table 5.2: Endurance Time Analysis – Natural Frost

Test #	Comp 05 Plate Endurance Time (min)	White Aluminum Plate Endurance Time (min)	Endurance Time % Ratio (Comp05/ White Alum)
1-5	100	143	70%
6-10	96	144	67%
11-15	99	112	88%
16-20	97	112	86%
21-25	103	133	77%
26-30	86	120.9	71%
		Average:	77%
		Standard Deviation:	9%

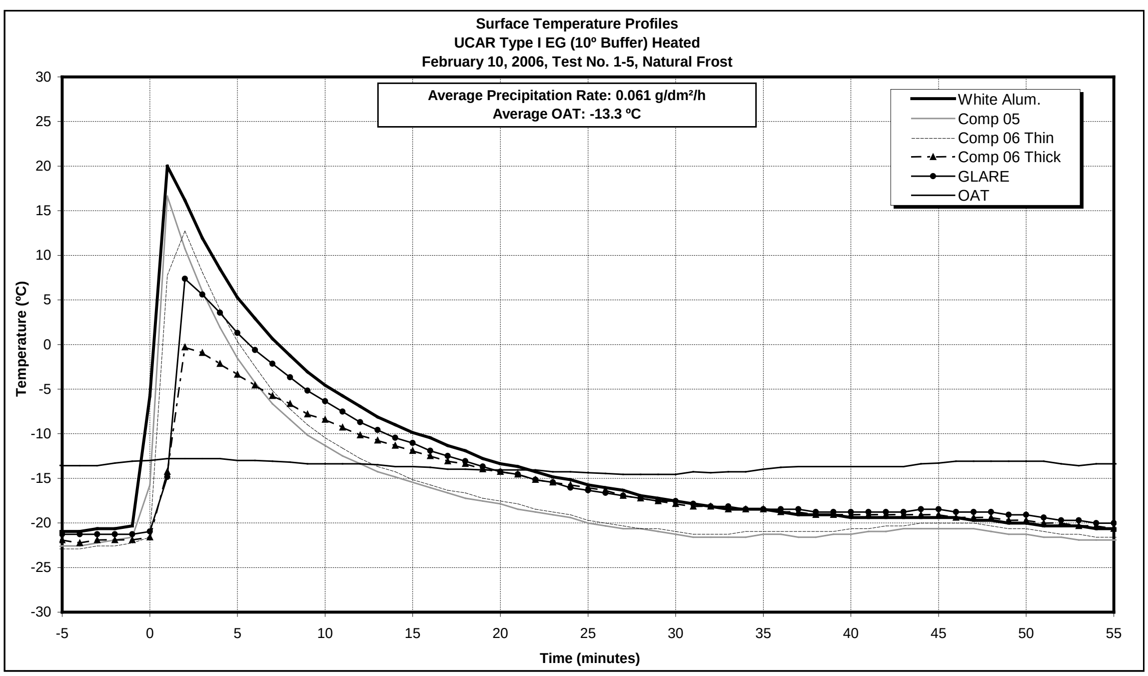

Figure 5.1: Surface Temperature Profiles – Aluminum vs. Composite – Test No. 1-5

In general, the Comp 05 and Comp 06 Thin surface temperatures rose to temperatures slightly less than that of the aluminum test plate. However, they reached their equilibrium temperature faster in comparison to the aluminum plate. The Comp 06 Thick and GLARE test plates reached peak temperatures which were lower in comparison to the white aluminum test plate; however, they required a longer time to reach the equilibrium temperature.

The reduction in fluid endurance time for warm Type I fluids demonstrated by the composite plate was examined. The reduced fluid endurance time was linked to the following factors:

- *Material Thermal Conductivity:* Aluminum materials behave as thermal energy conductors, whereas composite materials behave as thermal energy insulators. The aluminum test plate is subject to absorb a greater amount of heat provided by the warm Type I fluid in comparison to the composite plate; following fluid application, the aluminum test surface will attain a greater peak temperature in comparison to the composite test surfaces. Having absorbed a lesser amount of thermal energy, the composite test plates will cool at a faster rate in comparison to the aluminum plate.

- *Fluid Enrichment:* Previous tests conducted by APS have shown that heated Type I fluids will undergo fluid enrichment when applied to a colder surface. The extent of the fluid enrichment will increase relative to the difference in temperature between the fluid and the surface of application. When conducting aluminum vs. composite Type I fluid endurance tests in natural frost conditions, the surface temperature of the aluminum test plate was observed to rise higher than on the composite plates. Due to the higher temperature differential on the aluminum test plate, following application, the fluid applied to the aluminum surface will undergo a greater amount of fluid enrichment and will consequently be slightly higher in glycol concentration in comparison to the composite plates.

- *Surface Temperature Stabilization: Prior to fluid application, the exposed test* surface temperature in frost conditions will be several degrees below the outside ambient temperature. The heated Type I application will result in a rise in the test plate surface temperature. Following fluid application, the aluminum plate will attain a higher peak temperature in comparison to the composite plate. When cooling begins, the composite plate will stabilize to a temperature below OAT earlier in comparison to the aluminum test plate. As a result, frost accretion, and consequently fluid dilution will begin earlier on the composite test plate.

- In the case of the Comp 06 Thick plate, the greater mass allowed for a greater heat retention, which resulted in a slower cooling process. For the

GLARE test plate, the composite/aluminum hybrid demonstrated a lower peak temperature due to the insulating composite fabric, however retained the heat for longer due to the aluminum layering.

- *Fluid Dilution:* Fluid dilution occurs as frost begins to accrete on the fluid covered test surface. When conducting aluminum vs. composite Type I fluid endurance tests, the glycol concentration following fluid application on the aluminum surface is greater than on the composite surface due to fluid enrichment. As a result, the fluid applied to the aluminum surface will be able to absorb a greater amount of water from the frost accretion without diluting to the fluid freeze point and being subject to fluid failure. The composite test plate surface temperature will stabilize earlier in comparison to the aluminum test plate, and as a result, the composite test plate will begin to undergo frost accretion, and consequently, fluid dilution earlier than the aluminum test plate.

5.4 Conclusions and Recommendations

The lower fluid endurance time for warm Type I fluids on composite test plates was linked to the four factors described above: Material Conductivity, Fluid Enrichment, Surface Temperature Stabilization and Fluid Dilution. A combination of these four factors accounted for the lower fluid endurance time measured on the composite test surface. Additional testing is required in order to investigate the potential operational impact of the lower endurance times observed on composite surfaces, and to develop guidelines specific to composite material aircraft if necessary. This work is being conducted as part of a separate project and is described in the Interim report *Fluid Endurance Times Using Composite Surfaces*.

As testing was only conducted using Type I heated fluid, it is also recommended that additional testing be conducted during the winter of 2009-10 using thickened Type II, Type III, and Type IV fluids applied heated and at ambient temperature. Previous testing showed similar trends amongst the various composite materials tested. It is therefore recommended that the 2009-10 testing be conducted with one representative material to limit the testing required.

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6. FULL-SCALE VALIDATION OF FROST HOT REDUCTIONS

Due to the proposed HOT reductions based on the flat plate endurance time tests conducted, the industry requested full-scale testing to validate the results obtained. The following sections describe the full-scale tests conducted to validate the proposed HOT reductions:

- Full-Scale Endurance Time Testing with the TC JetStar Wing (Section 6.1); and
- Full-Scale Frost Anti-Icing Fluid Freeze Point Failure Simulation in the NRC Open Circuit Wind Tunnel (Section 6.2).

6.1 Full-Scale Endurance Time Testing with the TC JetStar Wing

Concerns expressed by the industry regarding the frost protocol employed for the natural frost endurance time testing were based upon the temperature differentials recorded on the test plates. In comparison to the aircraft data, which showed skin temperature to OAT differentials of up to 6.5ºC, the plate data collected showed plate temperature to OAT differentials up to 9ºC. It was suggested that the larger differentials experienced using the test plates may have been the cause for the premature failures and may have been driving the HOT reductions. It was recommended that full-scale testing with an actual aircraft wing be conducted in order to validate the HOT reductions observed on the test plates. Testing was conducted during the winter of 2008-09 with the TC JetStar wing.

6.1.1 Objective

The objective of this testing was to perform a full-scale validation of the proposed HOT reduction in Type II, III and IV fluids and develop a correlation of plate failure to wing failure for thickened fluids in natural frost conditions. To achieve this objective a series of full-scale endurance time tests were conducted simultaneously with flat plate tests in natural frost conditions. These full-scale endurance time tests were conducted on the JetStar wing surface in conjunction with flat plate testing.

Testing was conducted during four test events with representative Type II, III and IV fluids; fluid samples were lowest on-wing viscosity (LOWV). Testing was geared towards simulating freeze point failure with 75/25 dilutions close to LOUT of -14ºC. A complete description of the procedure used for testing is provided in Appendix D.

6.1.2 Methodology

Prior to each test event, the meteorological conditions were monitored to ensure ideal test conditions: OAT -10ºC to -14ºC, clear skies, low winds, and high relative humidity. The rate of frost accretion was measured using a bare insulated white painted flat plate; testing was only conducted during active frost conditions. To facilitate the test logistics, flat plate tests were conducted at the APS test facility, and the wing tests were conducted at the Aeromag deicing facility; the total distance between the two test locations was approximately 300 m (see Photo 6.1).

Approximately 6 to 10 L of Type II, III, and IV fluids diluted to 75/25 concentrations were poured at OAT on 0.61 m (2 ft.) wide strips the length of the JetStar wing chord (see Photo 6.2). Immediately after each strip of fluid was applied to the wing, one litre of the same fluid and dilution was poured at OAT on an insulated white painted flat plate (see Photo 6.3). During two of these tests, an additional insulated white painted flat plate was positioned directly on the JetStar wing (once bare, and once treated with anti-icing fluid) to investigate any potential differences due to the test locations. Wing surface temperature and plate temperature was monitored using hand-held thermistor probes and mounted thermistors. Endurance times on fluid covered wing surfaces and plate surfaces were measured and compared; fluid dilution (Brix), and fluid thickness were also measured.

6.1.3 Results

Data collected during the four test events is provided in Table 6.1.

During all four test events, fluid freeze point failure was experienced on the test plates with the 75/25 fluids. During three events, on March 3rd, March 4th, and March 13th, the endurance times recorded were lower than the current HOT of five hours for a 75/25 Type II or IV fluid applied below -3°C to -14°C; the recorded endurance times were below five hours. The reduction in endurance time was linked to fluid freeze point failure as crystalline structure was present in the fluid (see Photo 6.4).

Table 6.1: Full-Scale Comparison Test Log

Test No.	Date	Plate/Wing Position	Start Time (Local)	End Time (Local)	Level of Failure	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix Initial	Fluid Brix Final	Endurance Time (hrs.)	Average OAT EC Data (ºC)	Average RH EC Data (%)	Average Wind Speed EC Data (km/h)
1	28-Feb-2009	Plate 9	22:40:50	06:00:00	30%	75%	2b	1	Ecowing 26	29.00	25.25	7.3	-13.3	59	9
2	28-Feb-2009	Wing 1	22:39:00	05:35:00	2%	75%	2b	10	Ecowing 26	28.75	27.90	6.9	-13.3	59	9
3	28-Feb-2009	Plate 10	22:50:20	05:45:00	30%	75%	3b	1	MPIII 2031	28.00	22.75	6.9	-13.3	59	9
4	28-Feb-2009	Wing 2	22:45:00	05:35:00	10%	75%	3b	10	MPIII 2031	27.25	26.50	6.8	-13.3	59	9
5	28-Feb-2009	Plate 11	22:59:00	05:45:00	30%	75%	2b	1	ABC-2000	28.50	23.75	6.8	-13.3	59	9
6	28-Feb-2009	Wing 3	22:56:00	05:35:00	5%	75%	2b	10	ABC-2000	28.00	29.60	6.7	-13.3	59	9
7	28-Feb-2009	Plate 12	23:05:10	06:00:00	No Fail	100%	4	1	ABC-S	36.00	30.25	6.9	-13.3	59	9
8	28-Feb-2009	Wing 4	23:05:00	05:35:00	No Fail	100%	4	10	ABC-S	27.50	33.40	6.5	-13.3	59	9
9	3-Mar-2009	Plate 9	23:18:00	01:50:00	40%	75%	2b	1	Ecowing 26	29.00	28.00	2.5	-12.4	59	8
10	3-Mar-2009	Wing 1	23:17:00	05:00:00	No Fail	75%	2b	6	Ecowing 26	29.25	27.00	5.7	-13.2	61	7
11	3-Mar-2009	Plate 10	23:21:00	01:17:00	100%	75%	3b	1	MPIII 2031	28.50	25.75	1.9	-12.4	59	8
12	3-Mar-2009	Wing 2	23:20:00	05:00:00	No Fail	75%	3b	6	MPIII 2031	28.00	27.50	5.7	-13.2	61	7
13	3-Mar-2009	Plate 11	23:23:00	01:17:00	40%	75%	4b	1	ABC-2000	28.25	27.50	1.9	-12.4	59	8
14	3-Mar-2009	Wing 3	23:22:00	05:00:00	No Fail	75%	2b	6	ABC-2000	28.00	28.00	5.6	-13.2	61	7
15	3-Mar-2009	Plate 12	23:26:00	01:17:00	50%	75%	4b	1	ABC-S	29.00	27.50	1.9	-12.4	59	8
16	3-Mar-2009	Wing 4	23:24:00	05:00:00	No Fail	75%	4b	6	ABC-S	28.00	28.75	5.6	-13.2	61	7
17	5-Mar-2009	Plate 9	00:11:00	04:25:00	15%	75%	2b	1	Ecowing 26	29.00	28.00	4.2	-11.3	62	2
18	5-Mar-2009	Wing 1	00:10:00	05:30:00	0%	75%	2b	6	Ecowing 26	29.00	28.40	5.3	-11.3	62	2
19	5-Mar-2009	Plate 10	00:08:00	02:15:00	100%	75%	3b	1	MPIII 2031	28.00	27.00	2.1	-9.7	50	2

Table 6.1: Full-Scale Comparison Test Log (cont'd)

Test No.	Date	Plate/Wing Position	Start Time (Local)	End Time (Local)	Level of Failure	Fluid Dilution	Fluid Type	Fluid Quantity (L)	Fluid Name	Fluid Brix Initial	Fluid Brix Final	Endurance Time (hrs.)	Average OAT EC Data (ºC)	Average RH EC Data (%)	Average Wind Speed EC Data (km/h)
20	5-Mar-2009	Wing 2	00:07:00	04:15:00	80%	75%	3b	6	MPIII 2031	28.00	27.25	4.1	-11.3	62	2
21	5-Mar-2009	Plate 11	00:15:00	04:20:00	80%	75%	2b	1	ABC-2000	28.50	27.50	4.1	-11.3	62	2
22	5-Mar-2009	Wing 3	00:13:00	04:15:00	40%	75%	2b	6	ABC-2000	28.50	28.00	4.0	-11.3	62	2
23*	5-Mar-2009	Wing Plate 3	00:14:00	04:15:00	90%	75%	2b	1	ABC-2000	28.50	28.00	4.0	-11.3	62	2
24	5-Mar-2009	Plate 12	00:19:00	05:10:00	5%	75%	4b	1	ABC-S	28.25	27.75	4.9	-11.3	62	2
25	5-Mar-2009	Wing 4	00:18:00	04:20:00	70%	75%	4b	6	ABC-S	28.00	28.30	4.0	-11.3	62	2
26	13-Mar-2009	Plate 9	02:24:15	04:00:00	15%	75%	2b	1	Ecowing 26	28.50	29.00	1.6	-11.0	63	6
27	13-Mar-2009	Wing 1	02:17:26	04:45:00	15%	75%	2b	1	Ecowing 26	29.00	28.50	2.5	-11.2	65	5
28	13-Mar-2009	Plate 10	02:20:41	04:00:00	100%	75%	3b	1	MPIII 2031	27.50	27.25	1.7	-11.0	63	6
29	13-Mar-2009	Wing 2	02:19:58	04:45:00	100%	75%	3b	1	MPIII 2031	28.00	27.25	2.4	-11.2	65	5
30	13-Mar-2009	Plate 11	02:18:34	04:00:00	100%	75%	2b	1	ABC-2000	28.25	28.25	1.7	-11.0	63	6
31	13-Mar-2009	Wing 3	02:25:55	04:45:00	100%	75%	2b	1	ABC-2000	29.50	29.00	2.3	-11.2	65	5
32	13-Mar-2009	Plate 12	02:24:45	04:00:00	50%	75%	4b	1	ABC-S	28.00	28.50	1.6	-11.0	63	6
33	13-Mar-2009	Wing 4	02:23:30	04:45:00	50%	75%	4b	1	ABC-S	28.75	28.50	2.4	-11.2	65	5

* Additional plate positioned directly on JetStar wing

During the tests where fluid freeze point failure was experienced on the JetStar wing section, the results were generally comparable to the flat plate results. During two events, February 28th and March 4th, fluid freeze point failure was experienced on the JetStar wing section with the 75/25 fluids. On March 4th, the recorded endurance times for two tests (Type II and Type IV fluid) was lower than the current HOT of five hours for a 75/25 Type II or IV fluid applied below -3 to -14ºC. As was the case during the flat plate tests, the reduction in endurance time was linked to fluid freeze point failure as crystalline structures were present in the fluid (see Photo 6.55). The JetStar endurance times were greater than the proposed 1-hour HOT for Type II/IV 75/25 fluids. However, the JetStar data collected was limited in comparison to the number of flat plate tests conducted (see Section 3). The results indicated a good correlation between the wing and plate, therefore it can be assumed that, had ideally critical conditions been achieved, the endurance time measured on the JetStar wing would be closer to the proposed 1-hour HOT (as has been documented in the past on flat plates).

It should be noted that different lighting conditions and radiant heat from nearby buildings may have caused the differences in results obtained on the JetStar wing versus the flat plates. During the March 4th event, Aeromag reduced their ambient lighting surrounding their building to create similar lighting conditions to the APS test facility, and during this test event, the most comparable results were obtained.

The results from the comparative testing are included in Figure 6.1. The white bars demonstrate the endurance times recorded using the insulated white painted aluminum flat plates, and the black bars demonstrate the endurance times recorded using the JetStar wing; striped black bars indicate JetStar wing tests that did not show signs of failure when testing was stopped. The 75/25 fluid tested is indicated on the x-axis, and the y-axis indicates the endurance time recorded in hours. Each set of comparative tests has been separated by date and the average OAT during the test event has been indicated (listed on the top horizontal axis of the chart). The percentage failed, in terms of surface area, at the end of each test has been added to each of the individual bars. Due to the quick occurrence of fluid freeze point failure, it was often difficult to call failure at 33 percent of test plate surface, as is standard with other HOT testing protocol; the percentage failed at the time of the observation has been indicated for reference purposes. In the case of the wing tests, "first failure" was targeted as the failure call, however, as was the case with the plate tests, the quick occurrence of fluid freeze point failure resulted in failure calls at different levels of contamination. On the right hand axis, the current Type II, III, and IV HOT's have been indicated, in addition to the current proposed reduced HOT for Type II and Type IV 75/25 fluids.

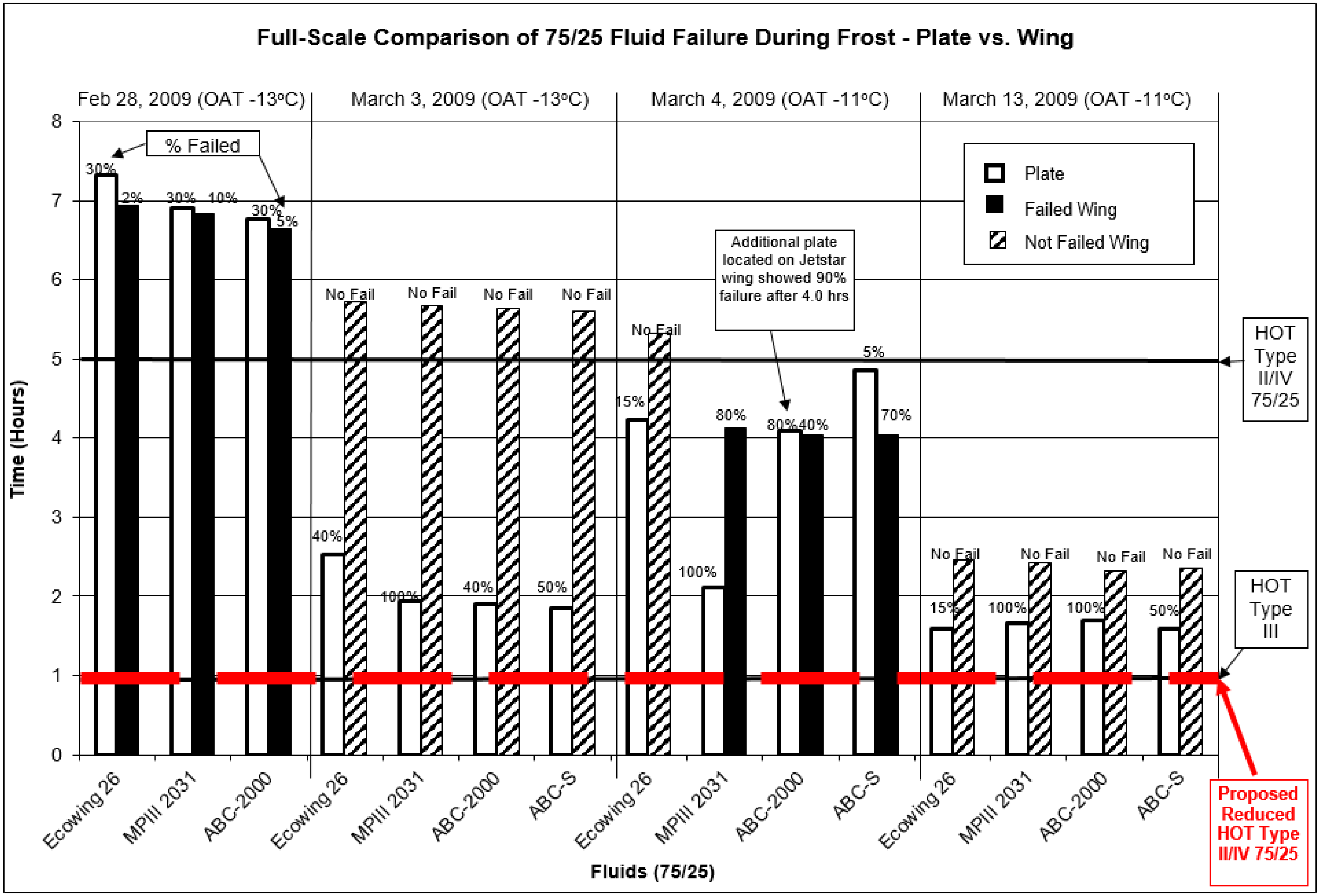

Figure 6.1: Results of Full-Scale Comparison of 75/25 Fluid failure During Frost – Plate vs. JetStar Wing

Figure 6.2 demonstrates the detailed wing temperature profiles recorded during the frost event on March 4-5, 2009. During this event, an additional test plate was positioned directly on the JetStar wing for comparison purposes; the temperature profile is also included in Figure 6.2. The temperature profiles demonstrate that approximately 200 minutes into the test, the OAT and the wing temperatures dropped slightly, and shortly thereafter fluid freeze point failure began to occur on the wing and plate surfaces. The hourly recorded Environment Canada OAT has also been included for reference purposes.

6.1.4 Observations

The results indicate a correlation between the JetStar wing and the white painted insulated flat plates. It was observed that localized ambient conditions can have an effect on results obtained; however, as was observed during the March 4th test event, under similar conditions the results obtained using the white painted insulated flat plates were comparable to the results obtained using the JetStar wing. The radiational cooling observed on the flat plates was representative of the radiational cooling experienced on an actual aircraft wing. The full-scale results supported the previously collected flat plate endurance time data during natural frost conditions which indicates a need for reductions to the current Type II and Type IV HOT's.

6.2 Full-Scale Frost Anti-Icing Fluid Freeze Point Failure Simulation in the NRC Open Circuit Wind Tunnel

Previous flat plate testing conducted in natural frost conditions demonstrated that anti-icing fluids could experience premature failure when the fluid was applied near its LOUT. Due to radiational cooling, the temperature of the test surface approaches the fluid freeze point, causing ice to form sporadically in the fluid. The ice contamination did not seem to adhere to the surface; however, the aerodynamic impact of the failed fluid needed to be investigated.

6.2.1 Objective

The objective of this preliminary testing was to investigate the aerodynamic impact of anti-icing fluid failed during active frost conditions as a result of the surface temperature approaching the fluid freeze point. Two tests were conducted at the NRC open circuit wind tunnel.

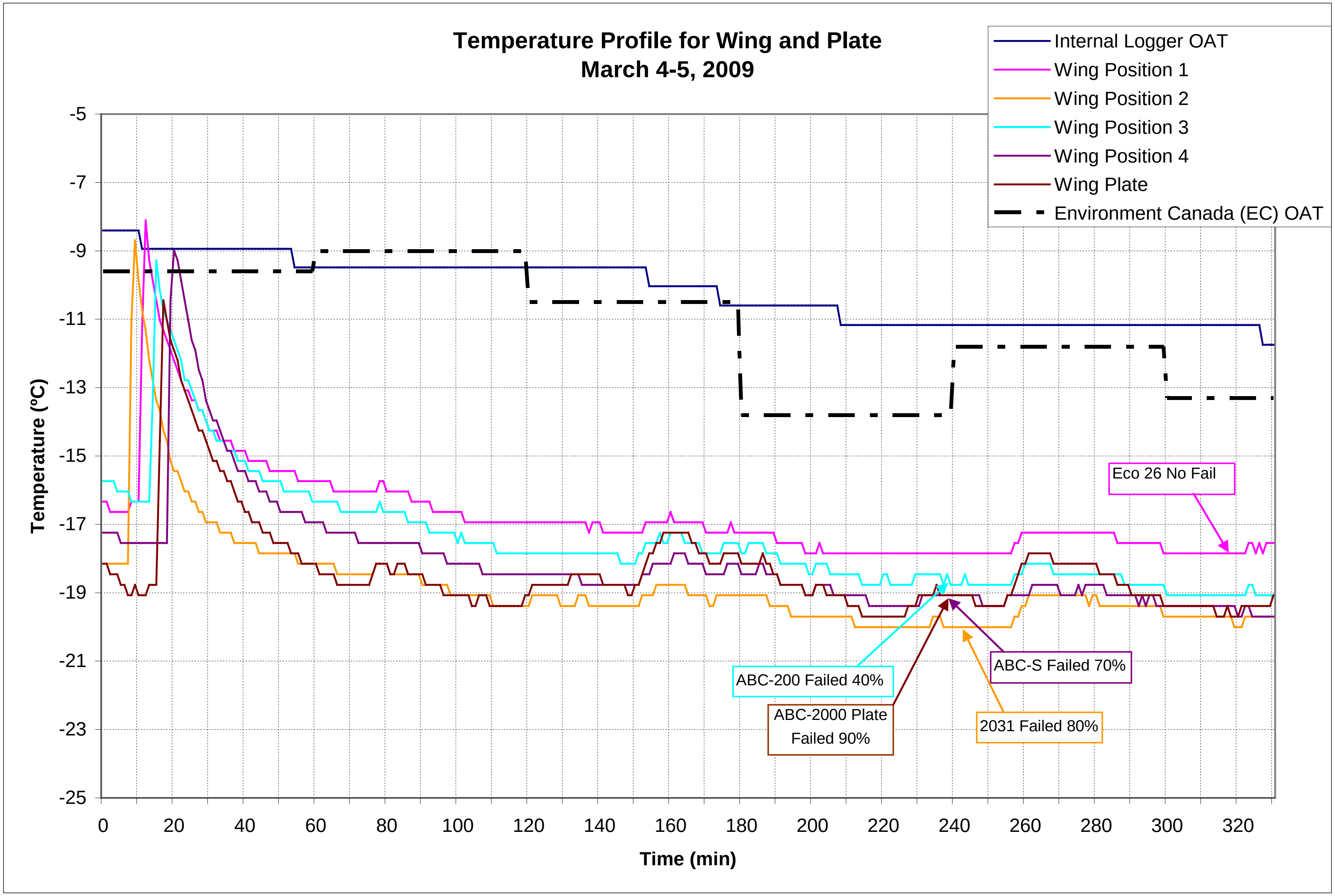

Figure 6.2: Detailed Wing Temperature Profiles for March 4-5, 2009

No official procedure was issued for this work; however a brief description of the procedure used for testing was included in the procedure titled *Wind Tunnel Tests to Examine Fluid Removed from Aircraft Surfaces During Take-off with Mixed Ice Pellet Precipitation Conditions – Winter 2008-09.* Further details of this testing are included in the TC report TP 14939E titled *Exploratory Wind Tunnel Aerodynamic Research Examination of Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09* (6).

6.2.2 Methodology

During the wind tunnel tests, cooling the wing section below ambient temperature to simulate radiational cooling was not feasible. In order to simulate the fluid freeze point failure, diluted Type IV fluid was applied to the wing section with a -7°C buffer (approximately 25/75 mix) for one test, and a 1°C buffer (approximately 50/50 mix) for the second test. The buffers were based on the wing skin temperature. The wing section was cooled to allow the formation of the crystalline structures in the fluid; during the second test, the wind tunnel was then run at idle speed (approximately 30-40 knots) to accelerate wing cooling using cold outside air. When approximately 33 percent of the wing section was contaminated with crystalline formations, the wind tunnel was run through a typical high speed take-off profile.

6.2.3 Results

The test parameters collected during the two tests are shown in Table 6.2.

Table 6.2: Test Log of Simulated Frost Testing at the NRC Wind Tunnel

Run #	Date	Fluid Name	Fluid Type	Fluid Dilution	Approx. Fluid Freeze Point (°C)	Speed Profile	Rotation Angle	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Avg. Wing Temp. Before Test (°C)
89	1-Mar-09	Flight	II	25/75	-4	High (100 knots)	16°	1:07	-16	-13.6	-10.8
90	1-Mar-09	Flight	II	50/50	-11	High (100 knots)	16°	2:42	-16.1	-16.5	-10

During run #89, the 25/75 fluid provided a very thin layer of anti-icing fluid on the wing section. As a result of the -7°C buffer, the fluid began to freeze almost immediately in large sections; ice formations resembled large sheets of ice. The results were not representative of the previous experience during the outdoor endurance time tests conducted on flat plates. Those tests produced ice crystals within the fluid, as opposed to sheets of ice. During the high-speed run, the wing skin temperature was further cooled and ice sheets grew in size; the contamination was not removed by the time of rotation. It was recommended that the test be repeated with a higher glycol content fluid to generate a more representative test.

During run #90, a 50/50 fluid was applied to the wing section; the fluid provided a 1ºC buffer with respect to the wing section. The fluid thickness was greater as compared to run #89 and was more representative of a thickened fluid anti-icing treatment. Crystallization in the fluid did not occur immediately, therefore the wind tunnel was run on idle speed (30-40 knots) to help cool down the wing and accelerate the crystallization process. Once an acceptable level of contamination was achieved (approximately 33 percent of the wing surface) a high-speed test run was simulated (see Photo 6.6).

The ice formations observed during run #90 were similar in shape and appearance to the ice formations observed during outdoor endurance time tests conducted on flat plates. The formations began as small nucleation points and grew outwards to form opaque circular shapes. The growth of these ice formations was rapid once the wing skin temperature dropped below the fluid freeze point.

During the high-speed run, the contamination present did not flow off at time of rotation (see Photo 6.7), contrary to expectations. This was due to the crystallization forming on the interface between the wing skin and the fluid and therefore having greater adhesive forces as compared to other forms of frozen contamination (i.e. snow) which primarily sit on the top layer of the fluid. As the tunnel was run, the wing skin temperature cooled further and the ice formations grew greater in size and were not removed. Contamination was greater by the end of the test run (see Photo 6.8).

It should be noted, however, that these results are conservative due to the limitations of the test protocol. In a typical frost operation, the wing skin temperature would be warmed during taxi and take-off, as the OAT would be several degrees above the wing skin temperature, as compared to the wind tunnel tests, where the OAT was several degrees below the skin temperature. Nevertheless, it is unknown whether the taxi and take-off following a typical overnight frost anti-icing application would provide enough time to melt any ice formations embedded in the fluid.

6.2.4 Observations

The results from the wind tunnel tests demonstrated similar crystalline formations as were observed with the white painted, insulated aluminum plates. Although the contamination did not seem to adhere during the plate tests, the wind tunnel tests demonstrated that the contamination was not removed by the time of rotation, and that the level of contamination worsened by the end of the test. However, during a typical frost operation, the wing skin temperature would be warmed during taxi and takeoff (rather than cooled as in the wind tunnel) and the results may potentially have been less severe.

The visual fluid failure mechanism simulated in the wind tunnel were representative of the fluid freeze point failure experienced on flat plates during the natural frost endurance time testing. The fluid flow off issues observed during the wind tunnel tests support the need for reductions to the current Type II and Type IV HOT's, as recommended based on flat plate endurance time data collected during natural frost conditions.

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Photo 6.1: Relative Locations of APS and Aeromag Facilities

Photo 6.2: JetStar Wing Setup at Aeromag Facility

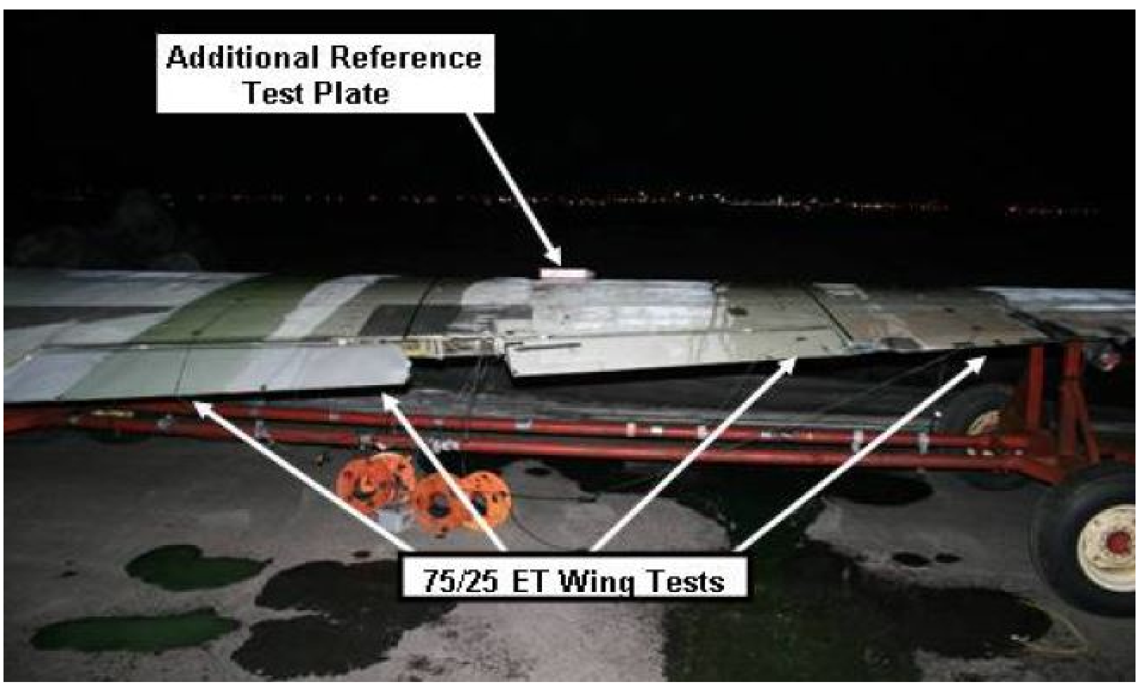

Photo 6.3: White Painted Insulated Flat Plate Setup at APS Test Facility

Photo 6.4: Crystalline Formation in Fluid During Flat Plate Tests

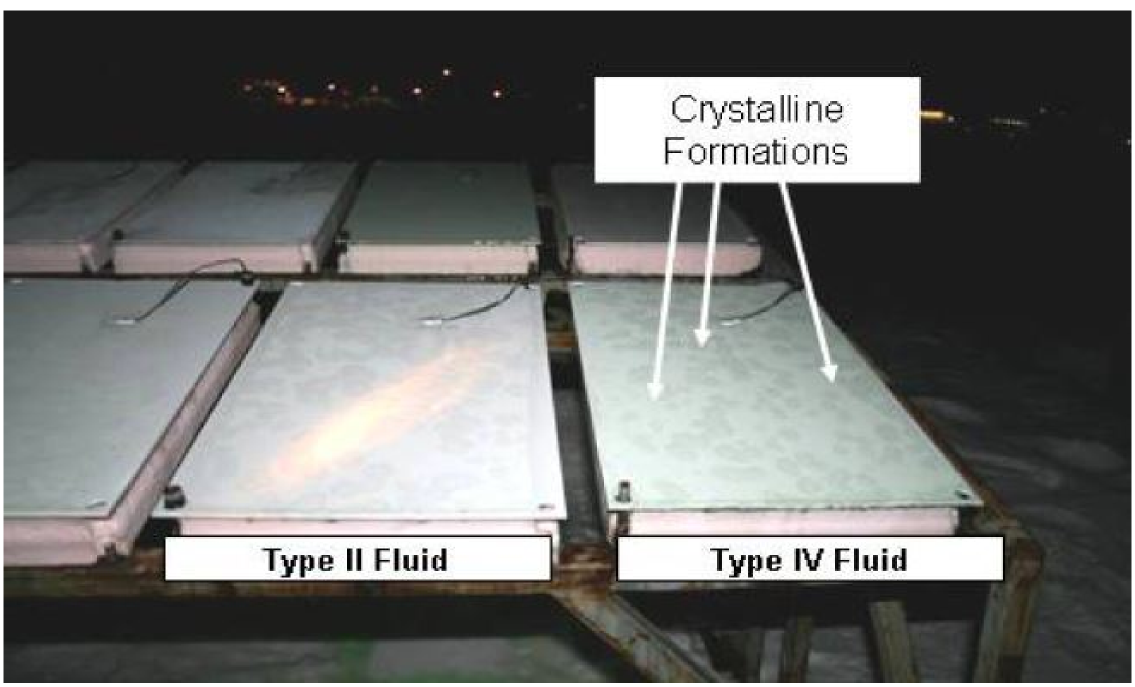

Photo 6.5: Crystalline Formation In Fluid During JetStar Wing Tests

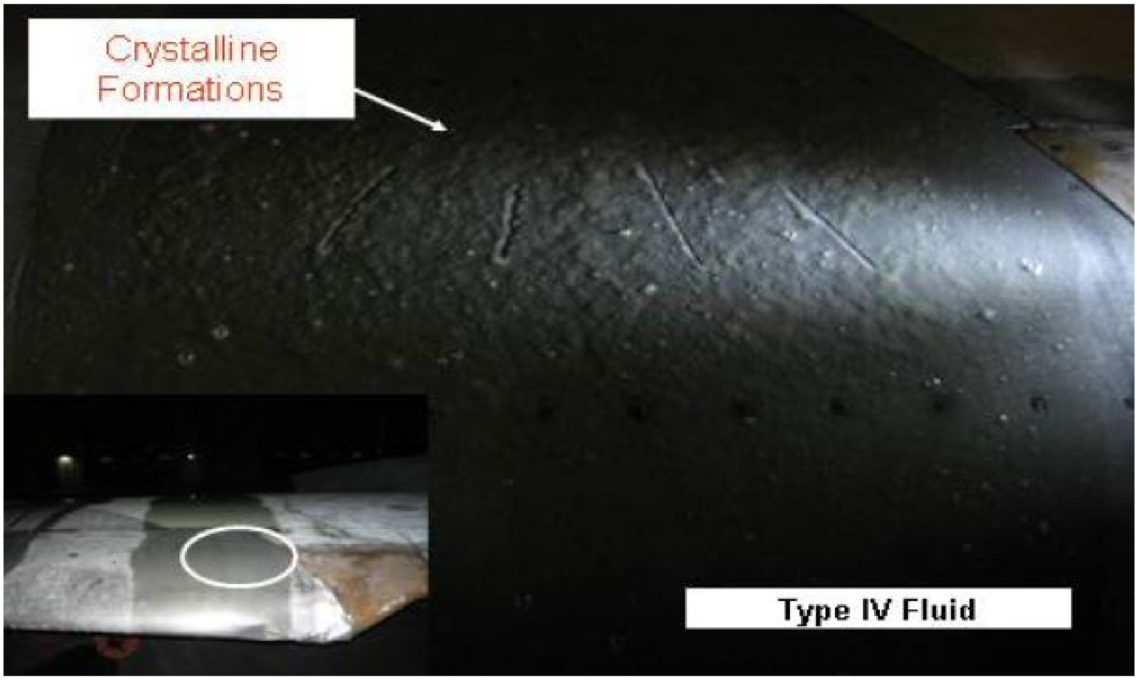

Photo 6.6: Crystalline Formation in Fluid at Start of High Speed Test Run

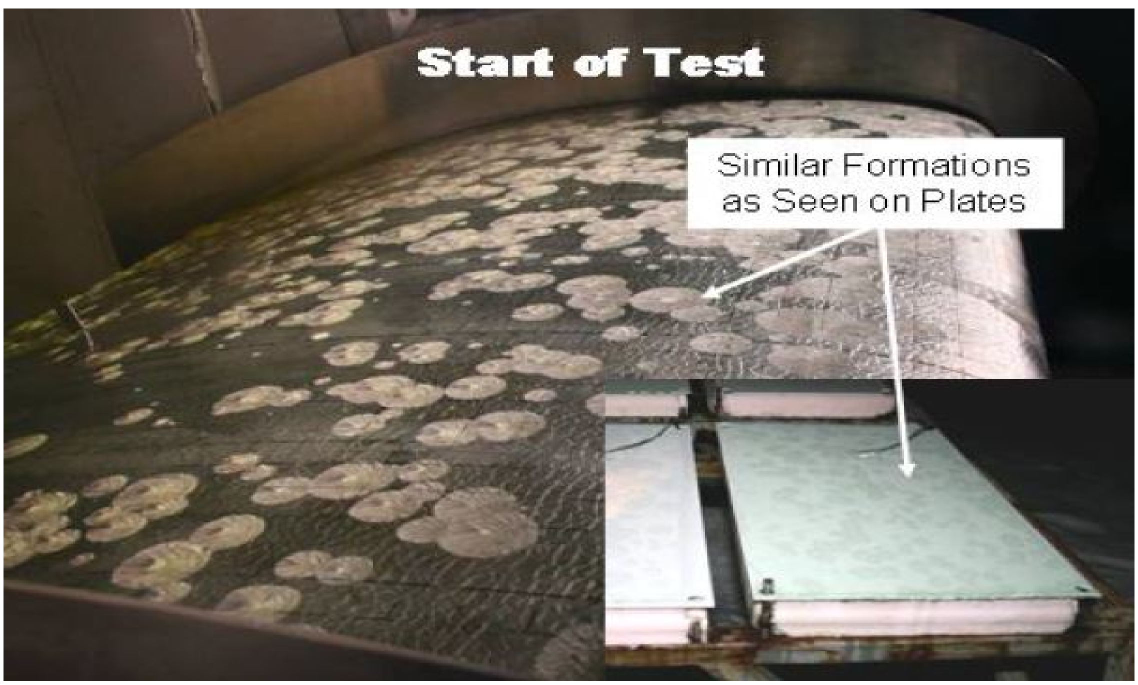

Photo 6.7: Crystalline Formation in Fluid at Time of Rotation

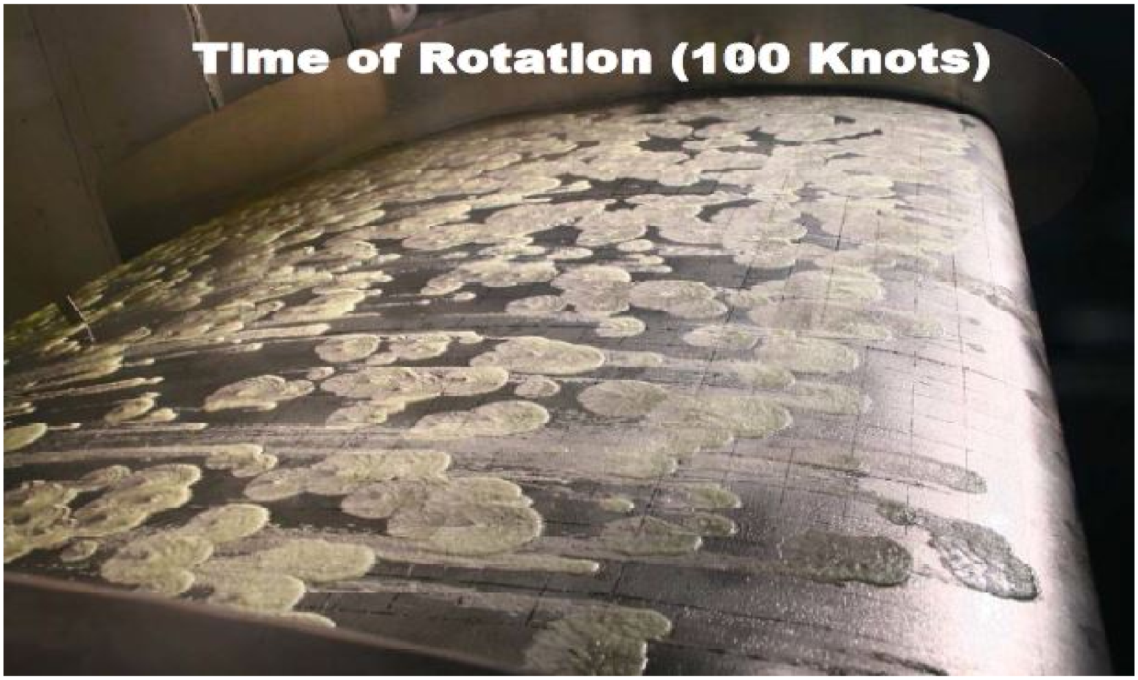

Photo 6.8: Crystalline Formation in Fluid at the End of Test

7. PROPOSED CHANGES TO FROST HOT GUIDELINES

As a result of the endurance time testing results in natural frost conditions, there is a need to implement changes to the current frost HOT's. Premature fluid failure has occurred when operating close to the fluid LOUT; fluid begins to crystallize as the treated surface temperature nears the fluid freeze point due to radiational cooling during natural frost conditions. In addition, reduced HOT's were observed for neat fluids below -3°C indicating that the current frost HOT's are not conservative and require reductions to provide a sufficient safety buffer for operations.

These issues have been presented by APS to the SAE G-12 HOT Subcommittee meeting during five SAE G-12 conferences: San Diego in May 2007, Montreal in November 2007, Warsaw in May 2008, Montreal in November 2008 and Charleston in May 2009. In addition, a Working Group was created following the November 2007 meeting to address the issues regarding the frost HOT changes required. The following sections provide a summary of the discussions and conclusions from these meetings.

7.1 San Diego G-12 HOT Subcommittee Meeting (May 2007)

The data presented by APS at the San Diego G-12 HOT Subcommittee meeting in May 2007 demonstrated that the current HOT's for Type I and Type III fluids had been substantiated and deemed adequate as a result of the flat plate endurance time testing conducted. As for Type II and Type IV fluids, data collected indicated that reductions to the current HOT's were required due to fluid freeze point issues and fluid endurance time results at colder temperatures. The data presentation is included in Appendix E.

Two options for change were proposed to the HOT Subcommittee:

- ***Option 1: Reduced HOT's and Restricted Use of Diluted Fluids***
    - Issue changes in the current HOT tables by reducing the effected cells. In addition, restrict use of diluted fluids to reflect skin temperature differential in frost conditions and to prevent premature fluid failure due to the freeze point issues observed.
- ***Option 2: Issue Separate Frost Table***
    - Issue frost HOT's on a separate table, thereby removing the frost column from the generic and fluid specific tables. The separate frost table would include changes to the temperature ranges to reflect the skin temperature differential in frost conditions and include reduced HOT's for affected cells.

The feedback obtained from the subcommittee indicated reluctance, mostly from European operators, towards restricting the use of diluted fluids, as this would have significant associated costs. In addition, the significant reductions to the frost HOT values, especially at the lower OAT's, would restrict operators from performing overnight protective anti-icing in active frost conditions.

7.2 Montreal G-12 HOT Subcommittee Meeting (November 2007)

The issues presented by APS at the Montreal G-12 HOT Subcommittee meeting in November 2007 served as an update to the San Diego presentation. The purpose was to stimulate discussion amongst the subcommittee in order to achieve appropriate measures to rectify the frost HOT issues. The presentation given is included in Appendix F.

Three options for change were proposed to the HOT Subcommittee:

- ***Option 1: Issue Reduced HOT's in Current HOT Tables***
    - Use current temperature breakdowns for frost HOT's and issue reduced HOT changes in the current HOT table format. Reductions to frost HOT's would affect all Type II and Type IV cells below -3ºC and 50/50 dilutions in -3ºC and above.
- ***Option 2: Issue Separate Frost Table***
    - Issue frost HOT's on a separate table, thereby removing the frost column from the generic and fluid specific tables. The separate frost table would include changes to the temperature ranges to reflect the skin temperature differential in frost conditions and include reduced HOT's for affected cells. Reductions would be more limited when compared to Option 1; however the use of diluted fluids would be restricted.
- ***Option 3: Issue Temperature Restrictions in Current HOT Tables***
    - Use the current format for frost HOT guidelines and issue temperature restrictions to avoid fluid freeze point issues. In addition, neat Type II and Type IV HOT's below -14ºC would be reduced based on data collected.

The feedback obtained from the subcommittee once again indicated some reluctance towards restricting the use of diluted fluids. As a result of this meeting, a working group was assembled to discuss and develop an appropriate means of issuing changes to the frost HOT Guidelines.

7.3 Frost Working Group Meetings (January to October 2008)

Several working group meetings were held between January and October 2008. The ad-hoc working group was assembled by FAA, TC and APS. These meetings were attended by the FAA, TC, APS, two aircraft operators, and one fluid manufacturer. The objective of this working group was to review the current data available and scrutinize the proposed changes to the Frost HOT Guidelines. The working group developed four options for changes to the frost HOT guidelines. The latest document used for discussion purposes during these working group meetings is included in Appendix G.

The four options for change were as follows:

- ***Option 1: Issue Reduced HOT's in Current HOT Tables***
  - Use current temperature breakdowns for Frost HOT's and issue reduced HOT changes in the current HOT table format. Reductions to frost HOT's would affect all Type II and Type IV cells below -3°C and Type II 50/50 dilutions in -3°C and above.
- ***Option 2: Issue Temperature Restrictions in Current HOT Tables***
  - Use current format for frost HOT guidelines and issue temperature restrictions using footnotes to avoid fluid freeze point issues. In addition, Neat Type II and Type IV HOT's below -14°C would be reduced based on data collected.
- ***Option 3: Issue Separate Frost Table***
  - Issue frost HOT's on a separate table, thereby removing the frost column from the generic and fluid specific tables. The separate frost table would include changes to the temperature ranges to allow greater flexibility for fluid use and to minimize the number of HOT reductions. Use of fluid dilutions would not be restricted however HOT reductions would apply when nearing the fluid LOUT.
- ***Option 4: Status Quo with Caution (Short-Term Solution)***
  - No changes would be issued to the frost HOT's in the short term. However, a cautionary note would be added to the tables to advise that radiational cooling may reduce HOT when operating close to the lower end of the OAT range.

As the working group meetings progressed, the Association of European Airlines (AEA) voiced concern regarding the changes to the frost HOT's. The AEA questioned the testing protocol used and indicated that the surfaces used for testing may have been too conservative (i.e. the radiative cooling experienced on the frosticator plates may be greater than what would be experienced on operational aircraft). They requested to review the data collected before any changes to the frost HOT values were issued. In addition, several questions were put forth by the AEA of which a reply was prepared; questions and answers were prepared in an informal document (Appendix H) and discussed with a member of the AEA. Consequently, as an interim solution, the working group agreed that Option 4 would be an adequate short-term solution to address the reduced frost HOT issues. In addition, the working group recommended that full-scale validation of the reduced frost HOT's be conducted during the winter of 2008-09 using operational aircraft.

7.4 Warsaw G-12 HOT Subcommittee Meeting (May 2008)

The frost HOT issues previously presented at the San Diego and Montreal G-12 HOT Subcommittee meetings were summarized at the Warsaw G-12 HOT Subcommittee meeting in May 2008. The results indicated that reductions in fluid endurance times were apparent during natural frost endurance time testing, but further work was required to substantiate the current endurance time testing protocol for natural frost conditions. The purpose of this presentation by APS was to advise the committee of the interim measures being adopted by TC and the FAA to address the reduced frost HOT issues. This presentation is included in Appendix I.

Option 4 from the working group proposed changes was adopted and is described in the following:

- ***Option 4: Status Quo with Caution (Short-Term Solution)***
  - No changes would be issued to the frost HOT's in the short term however, a cautionary note would be added to the Type II and Type IV tables to advise that radiational cooling may reduce HOT when operating close to the lower end of the OAT range.

7.5 Montreal G-12 HOT Subcommittee Meeting (November 2008)

The issues presented by APS at the Montreal G-12 HOT Subcommittee meeting in November 2008 served as an update to the Warsaw presentation. The purpose of the meeting was to stimulate discussion amongst the subcommittee and to obtain feedback regarding the direction for change. This presentation is included in Appendix J.

The feedback from the meeting supported the effort to move forward with the full-scale validation of the HOT reductions observed on flat plates. No decision was made regarding the four proposed options for change; however the comments from the committee indicated that Option 3 (the separate frost table) would likely be the preferred option if changes were necessary.

7.6 Charleston G-12 HOT Subcommittee Meeting (May 2009)

The full-scale wind tunnel and JetStar test results were presented at the G-12 HOT Subcommittee meeting held in Charleston in May 2009. The results supported the need for reductions to the current frost HOT's, as was previously determined with the endurance time testing conducted on white painted insulated plates. The purpose of this presentation by APS was to obtain industry feedback regarding the TC and the FAA initiative to proceed with adopting the separate frost table (Option 3) to address the reduced frost HOT's issues. This presentation is included in Appendix K.

Option 3 from the working group proposed changes was adopted and is described in the following:

- ***Option 3: Issue Separate Frost Table***
  - Issue frost HOT's on a separate table thereby removing the frost column from the generic and fluid specific tables. The separate frost table would include changes to the temperature ranges to allow greater flexibility for fluid use and to minimize the number of HOT reductions. Use of fluid dilutions would not be restricted however HOT reductions would apply when nearing the fluid LOUT.

The industry feedback indicated that due to the reduced HOT's in frost conditions and the associated potential negative effects of fluid freeze point failure on aerodynamic performance, action should be taken to address the issues and that the current advisory note in the HOT tables was not sufficient. A representative from the AEA stated that if changes to the current frost HOT's were to be issued, the separate frost table was preferred amongst the other options as it allowed for the greatest degree of operational flexibility.

The general consensus from the meeting supported the initiative to proceed forward with issuing a separate frost table for the winter of 2009-10 to address the issues with reduced HOT's in active frost conditions.

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8. CONCLUSIONS

8.1 Type I Fluids

Forty-seven tests were conducted outdoors using insulated white-painted aluminum surfaces over two winter seasons. A review of the measured test conditions indicated that the dataset was generally comprehensive and representative of the natural environment.

The test results show that the measured endurance times do not violate the long used HOT of 45 minutes.

8.2 Type II/IV Fluids

Sixty-two Type II tests and Ninety type IV tests were conducted outdoors using insulated white-painted aluminum surfaces over three winter seasons. A review of the measured test conditions indicated that the dataset was generally comprehensive and representative of the natural environment.

The endurance time data collected indicates that several Type II/IV HOT's need to be reduced. During several tests, fluid failure was experienced prematurely and occurred as a result of the fluid and plate temperature reaching the fluid freeze point. Fluid dilution was minimal during these tests.

8.3 Type III Fluids

The endurance time data collected indicates that the current HOT for Type III Neat fluids is substantial and conservative in comparison to the data collected during the endurance time testing.

8.4 Type I Endurance Times in Frost Conditions using Composite Surfaces

The Type I comparative tests conducted during natural frost conditions indicated lower endurance times on composite surfaces as compared to aluminum surfaces. Further work is required to evaluate the potential operational impact, if any, of the lower endurance times observed.

8.5 Wind Tunnel and Full-Scale Validation of Frost HOT Reductions

The results from the wind tunnel tests demonstrated similar crystalline formations as observed with the white painted insulated aluminum plates. These formations were not removed by the time of rotation. The results from the full-scale validation tests indicate a correlation between the JetStar wing and the white painted insulated flat plates; fluid freeze point failure was observed on both surfaces. Both the wind tunnel and the full-scale results support the previously collected flat plate results, which indicate a need for reductions to the current Type II and Type IV frost HOT's.

8.6 Working Group Development of Separate Frost Table

Due to the potential operational impacts resulting from the proposed frost HOT reductions, a working group was created consisting of members from the SAE G-12 HOT Subcommittee to discuss the options for change. Through ongoing discussions with industry members, the working group developed a separate frost table which included the necessary HOT reductions based on the endurance time data collected while minimizing the operational impact.

9. RECOMMENDATIONS

9.1 New Frost Table Format

Through ongoing discussions with industry members, it is recommended that frost HOT's be issued on a separate table and be removed from the generic and fluid specific tables. The separate frost table includes changes to the temperature ranges to allow greater flexibility for fluid use and minimize the impact of HOT reductions. Use of fluid dilutions will not be restricted, however, HOT reductions would apply when nearing the fluid LOUT.

9.2 Changes to ARP5945 and ARP5485

The outdoor procedure for Type I and Type II/III/IV natural frost endurance time testing should be added in a future revision of the currently proposed ARP5945 and ARP5485, respectively, to enable verification of any new Type I and Type II/III/IV non-glycol products. The current generation of Type I and Type II/III/IV fluids have been substantiated and generic HOT table values have been provided. Therefore testing for any newly developed fluids is not required.

9.3 Potential Future Work

9.3.1 Use of OAT for Determining Frost HOT

Future working group discussions should address the use of OAT for determining the holdover time in frost conditions. Significant fluctuations in OAT can occur during active frost conditions. This is particularity true for overnight preventative anti-icing. Discussions should aim at establishing the appropriate use for OAT in determining the HOT available during frost conditions i.e. OAT at start of application, minimum temperature achieved between time of application and time of take-off, or temperature at time of take-off.

9.3.2 Aluminum vs. Composite Test Surfaces

As testing on composite surfaces was only conducted using Type I heated fluid, it is recommended that additional testing be conducted during the winter of 2009-10 using thickened Type II, Type III, and Type IV fluids applied heated and at ambient temperature. Previous testing showed similar trends amongst the various composite materials tested. It is therefore recommended that the 2009-10 testing be conducted with one representative material to limit the testing required.

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REFERENCES

1. Dawson, P., *Laboratory Test Parameters for Frost Endurance Time Tests*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2003, TP 14145E, XX (to be published).

2. Moc, N., *Winter Weather Impact on Holdover Time Table Format (1995-2004),* APS Aviation Inc., Transportation Development Centre, Montreal, December 2004, TP 14375E, XX (to be published).

3. Alwaid, A., *Endurance Time Tests in Simulated Frost Conditions*, APS Aviation Inc., Transportation Development Centre, Montreal, October 2001, TP 13831E, XX (to be published).

4. Moc, N., *Winter Weather Impact on Holdover Time Table Format (1995-2003),* APS Aviation Inc., Transportation Development Centre, Montreal, October 2003, TP 14146E, XX (to be published).

5. Ruggi, M., *Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces*, APS Aviation Inc., Transportation Development Centre, Montreal, September 2005, TP 14448E (to be published).

6. Ruggi M., *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2009, TP 14939E (to be published).

7. Ruggi M., *Effect of Heat on Endurance Times Using Composite Surfaces Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces*, APS Aviation Inc., Transportation Development Centre, Montreal, October 2006, TP 14720E, XX (to be published).

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2008-09

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2008-09

4.2 DE/ATI-ICING FLUIDS RESEARCH (AND HOLDOVER TIME CREATION)

4.2.2 Endurance Time Testing in Frost

a) Conduct endurance time testing in natural frost conditions at the TDC test site at YUL during the 2008-09 winter. Testing will be conducted overnight during suitable frost conditions with representative Type II, III and IV fluids, both ethylene and propylene based. Tests shall be conducted over extended frost forecast periods with all dilutions. Testing will aim at validating the reduced endurance times experienced when measured at temperatures nearing the fluid lower end of the temperature range. Priority will also be given to testing in the above -3°C range;

b) Evaluate previous work and determine data required to support endurance times observed using test surfaces made of composite materials currently used on aircraft lifting surfaces. Low-cost field tests should be conducted with such operationally representative composite material test plates. Testing will be conducted overnight during suitable frost conditions with Type IV ethylene glycol (EG) and propylene glycol (PG) fluids. Fluid viscosity should be verified prior to testing using falling ball methodology;

c) Conduct full scale validation of frost endurance time testing with TDC JetStar wing. Testing will be conducted overnight during suitable frost conditions with representative Type II, III and IV fluids, both ethylene and propylene based. Testing will aim at validating the reduced endurance times experienced when measured at temperatures nearing the fluid lower end of the temperature range;

d) Develop video or photo documentation of frost growth on bare surfaces during the conduct of tests. Particular attention shall be given to frost growth at warm temperatures with emphasis on growth when dew changes to ice;

e) Analyze the data collected as well as data collected from previous winters;

f) Report the findings;

g) Develop and review alternatives for required changes to frost HOT tables and complete a detailed preparation of the proposed changes for each of the alternatives. Detailed changes should be applied to all tables in the HOT Guidelines; this will allow for a better understanding of the possible operational impacts; and

h) Present these and previous results at the SAE G-12 annual meeting.

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APPENDIX B

EXPERIMENTAL PROGRAM
ENDURANCE TIME TESTING IN FROST WITH
TYPE I, II, III AND IV FLUIDS

CM1892.001

EXPERIMENTAL PROGRAM
ENDURANCE TIME TESTING IN FROST
WITH TYPE I, II, III AND IV FLUIDS

Winter 2003-04

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Nicoara Moc

Reviewed by: John D'Avirro

APS Aviation Inc.

November 13, 2003
Version 1.0

EXPERIMENTAL PROGRAM
ENDURANCE TIME TESTING IN FROST WITH TYPE I, II, III AND IV FLUIDS
Winter 2003-04

1. BACKGROUND

This project has been developed to substantiate the HOTs in frost conditions of Type I, Type II, Type III and Type IV fluids.

The SAE G-12 HOT Subcommittee determined the need to test fluids for frost endurance time. During winter 1999-2000, APS conducted preliminary calibration tests in simulated frost conditions at the Institut de Recherche d'Hydro-Québec (IREQ) cold chamber in Varennes.

The tests showed that the environmental conditions specified in AS 5485 were not appropriate for producing the required frost rates, and that further research was necessary. The objective of the subsequent research was to establish test parameters that reflect natural environment conditions for active frost and to document rates of natural frost accretion to enable specifying frost intensity rates for fluid endurance testing in a laboratory.

The research program documented wing-to-air temperature differential (delta T) over a range of temperatures. Historical weather data was reviewed to ascertain a range of values for relative humidity (RH) typically experienced during frost conditions in nature. A field test was conducted on an operational aircraft in natural frost conditions. This test enabled selection of a test surface representative of aircraft surfaces for frost generation purposes. The test also showed that heated Type I fluids enriched substantially after application on the wing due to the evaporation of water from the water/glycol mix. The fluid enrichment contributed greatly to the fluid endurance time, and it was concluded that laboratory test procedures must be redesigned to include this feature. Field measurements of on-wing fluid enrichment following actual frost sprays were conducted.

Frost rates were measured during both winter seasons over a range of conditions and temperatures. Endurance times for Type I fluid were measured in natural frost conditions. All of the times measured exceeded the current HOT values.

From the consolidated data collected over two seasons, a new set of laboratory test parameters for Type I, Type II, Type III and Type IV fluids was recommended.

Based on the findings of the natural frost endurance tests on SAE Type I Fluid, different approaches were considered for finalizing the test process for these fluids. These alternative recommendations were presented at a meeting of the SAE G-12

HOT working group, September 03-04, 2003. The recommendation agreed upon was to supplement the current endurance time data base developed from tests in natural conditions by additional low-cost field tests during the 2003-04 winter, with attention given to testing in mild conditions when high frost intensity rates may occur.

Similar to the potential alternatives discussed for SAE Type I Fluid, different approaches were considered for finalizing the test process for Type II and IV Fluids. The approach agreed upon at the meeting was to substantiate the current frost HOT values through a series of one-time tests, in natural frost. Low-cost testing would be conducted in natural conditions.

2. OBJECTIVES

The objective of this procedure is to substantiate the current frost HOT values for Type I, II, III and IV fluids. To achieve this objective a series of endurance time tests will be conducted in natural frost conditions at the APS test site during the 2003-04 winter. Testing will be conducted overnight during suitable frost conditions with representative Type I, II, III and IV fluids, both ethylene and propylene based. Tests shall be conducted over extended frost forecast periods with all dilutions. Tests on seven nights are anticipated. One run of tests would involve the use of about 12 plates run simultaneously.

Type I endurance time testing in frost will be conducted with attention given to testing in mild conditions when high frost intensity rates are more predominant. The desired relative humidity for this purpose is 80% and above. Data on test surface temperature, ambient temperature and relative humidity will be collected simultaneously.

3. TEST REQUIREMENTS

The following data are to be collected throughout the test session:

a) OAT using three thermistor probes installed in a Stevenson radiation shield attached to the 2-position stand (see Figure 1), and linked to a thermistor logger; and

b) Test surface temperature using a thermistor probe installed on the test plate surface and rate-measuring surface, and linked to a thermistor logger.

A printout of the Environment Canada Weather Trends for the test location covering the test session period (Attachment C) is to be attached to the data sheet. This will provide a record of wind and sky condition, and weather data. The website for

Montreal is:
http://weatheroffice.ec.gc.ca/forecast/24_hour_conditions_e.html?yul&unit=m

As a backup, an alternative method for measuring frost accumulation, outside air temperature and relative humidity can be implemented using the Campbell Scientific system. Using this setup, frost accumulation data from an electronic balance with a digital output, and OAT and RH from the Vaisala meter are recorded by a CR10X datalogger.

The white-painted aluminum test plate will be used as a frost-collecting surface as it has been shown to be a good representation of fluid-covered aircraft wings, for frost generation purposes.

4. PROCEDURE

Two procedures are provided below:

a) Frost rate data collection, and

b) Fluid endurance tests in frost.

4.1 Procedure for Frost Data Collection

1) Monitor weather forecasts to select a time for testing. The ideal conditions for the development of frost are:
   a) OAT near or below 0°C;
   b) Less than 10 km of wind; and
   c) Clear sky overnight.
2) At the beginning of the data gathering session:
   a) Ensure the test surface is clean;
   b) Clear the data logger and ensure that new data is logging. Synchronize time on all data collection devices. Label loggers and computer files indicating date of test;
   c) Initiate the data sheet, recording times when the loggers have been cleared and reset (see Attachment B); and
   d) Zero the scale and record the time on the data sheet.
3) At 30-minute intervals, record data as follows:
   a) Verify the surface temperature from the real time readings displayed on the

computer screen, prior to removing the plate from the stand for weighing;

b) After recording the surface temperature, reweigh the test surface, recording weight and time; and

c) The two surfaces collecting frost will be used in a staggered routine.

4) Every 2 or 3 hours, depending on the frost rate, the surface collecting frost should be replaced by a clean surface that was maintained at ambient temperature.

5) At the end of the data gathering session:

   a) Download the data from data logger to the PC, and check to ensure that data is saved. Label files indicating date of test;

   b) Provide a copy of data files (by diskette or e-mail) to APS for project record where they will be saved to the network;

   c) Download the Environment Canada Weather Trend for the data collection period, print a copy and attach it to the data sheet. Forward a copy from the website to APS for project record;

   d) Complete the data sheet (see Attachment B); and

   e) A complete set of test records for each session includes:

      - Computer files of downloaded surface temperature logger data;
      - Completed data sheets (Attachment B); and
      - Printed copy of the Environment Canada Weather Trend.

4.2 Procedure for Fluid Endurance Tests

Tests will be conducted on white-painted aluminum test surfaces, mounted at a 10º slope on a test stand. Each test surface will have a thermistor probe installed at the 15 cm line, inset 1/3 of the width. The test stand is to be located near the frost rate test setup, as shown in Figure 1.

The temperature channels of the three data loggers used for testing will be labelled in the computer according to the *italic characters* shown in Figure 1.

As mentioned in Section 2, testing will be conducted with representative Type I, II, III and IV fluids, both ethylene and propylene based. Tests on seven nights are anticipated. One run of tests would involve the use of all 12 plates simultaneously. Type I endurance time testing in frost will be conducted with attention given to testing in mild conditions when high frost intensity rates are more predominant. It is recommended that about 15 Type I tests be conducted during several sessions. SAE Type I fluid, EG and PG-based, will be applied at 20°C with the standard 12-hole spreader. Fluids will be mixed to a 10ºC freeze point buffer, and the quantity will be 0.5 L. Fluid strength will be measured and recorded on the fluid dilution data form (Attachment D). The brix value will originally be measured in the container before pouring. The second measurement will be taken at failure time. The sample for the second measurement will be collected at the failure "front" location.

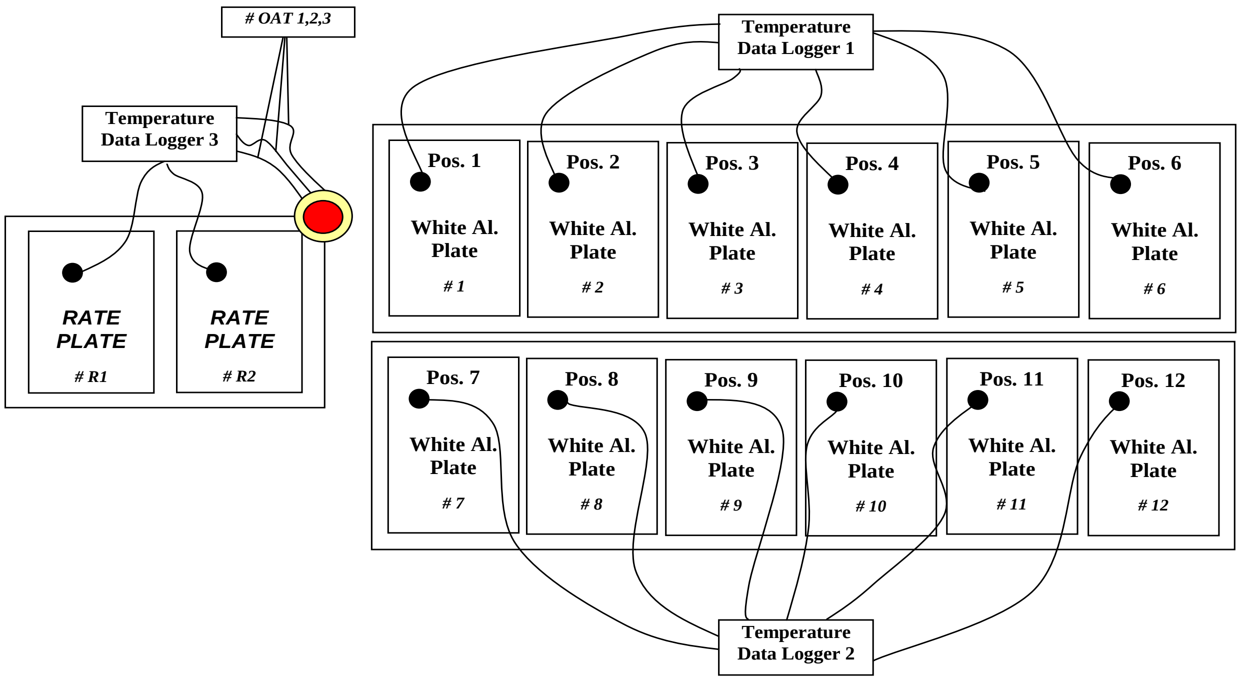


Figure 1: Test Stand Positions

SAE Type II/IV fluids, EG and PG-based, will be applied at outside air temperature by pouring. Fluids will be tested "as ready" at neat, 75/25 and 50/50 concentration, and the recommended quantity is 1.0 L. Fluid strength will be measured and recorded on the fluid dilution data form (Attachment D). The brix value will originally be measured in the container before pouring. The second measurement will be taken at failure time. The sample for the second measurement will be collected at the failure "front" location.

For each test run the following fluid types and dilutions are to be used:

- Type I EG – 10°C Buffer;
- Type I PG – 10°C Buffer;
- Type II PG – Neat;
- Type II PG – 75/25;

- Type II PG – 50/50;
- Type IV EG – Neat;
- Type IV PG – Neat;
- Type IV PG – 75/25; and
- Type IV PG – 50/50.

The fluids to be tested should be taken from the following list of low viscosity fluids: Clariant Safewing Protect 2012, Clariant MP IV 2001, Clariant Safewing MP II 2025, Clariant Safewing MP IV 2030, Kilfrost ABC-II Plus, Kilfrost ABC-S, Kilfrost ABC 2000, Octagon Maxflight, Octagon E Max II, SPCA Ecowing 26, SPCA AD-480, UCAR Ultra+.

The remainder of the stand (3 positions) will be used to conduct tests with either Type II PG (all three dilutions), Type IV PG (all three dilutions), or Type III fluids. Whenever a test is repeated, a different brand name should be used.

The 50/50-dilution fluid shall not be tested if the OAT is forecast to be below -3°C. The 75/25-dilution fluid shall not be tested if the OAT is forecast to be below -14°C.

5. EQUIPMENT

5.1 Equipment for Frost Data Collection

The equipment required to collect frost rates includes:

a) An electronic balance;

b) Two white-painted aluminum test plates with one thermistor probe installed at the 15 cm line, linked to the thermistor logger. The aluminum speed tape used to secure the probes tape is to be painted white to match the emissivity property of the white-painted plates. A small bottle of automotive touch-up paint can be used for this;

c) Three screened thermistor probes to measure air temperature linked to the thermistor logger;

d) An electronic balance with a digital output (optional); and

e) The Vaisala meter (optional) to measure RH and OAT.

5.2 Equipment for Frost Endurance Tests

Standard equipment used for Type I and Type II/IV fluid endurance tests outdoors will be used, with the exception that the test surface will be the white-painted insulated aluminum surface used for frost rates. The surfaces will be instrumented with a thermistor probe installed at the 15 cm line, linked to the logger.

5.3 Equipment List

See Attachment A.

6. DATA FORMS

For frost rate data collection, see Attachments B and C.

For fluid endurance tests in frost, see Attachment D.

7. PERSONNEL

One person required. A second person may be required for initial setup.

ATTACHMENT A
EQUIPMENT LIST

FROST RATE DATA COLLECTION	**Number**
2-position test stand	1
White-painted aluminum test plate with insulated backing	3
Thermistor probes to be installed at the 15 cm line, one on each plate	3
Thermistor probes with shield, for air temperature	3
Thermistor probe logger	1
Thermistor probe logger/PC cable	1
Weigh scale (accuracy of 0.1 g or better)	1
Vaisala meter	1
Data forms	
PC or laptop	1
Electrical extension cord for weigh scale and Vaisala meter	1
FLUID ENDURANCE TESTS IN FROST	
White-painted aluminum test plate with insulated backing	12
6-position test stand	2
Thermistor probes to be installed at the 15 cm line, one on each plate	12
Thermistor probe logger	2
Brixometer	1
SAE Type I fluid, EG and PG-based	
Fluid mixing charts	
Fluid spreader	1
Fluid thermometer	1
SAE Type I, II and IV fluids, EG and PG-based	

ATTACHMENT B
DATA FORM
FROST RATES ON TEST SURFACES

Date ________________ Location ________________

Recorded by ________________ Signature ________________

Logger Start Time____________ Weather Trend Printed at (time)________

Logger Save Time____________

Surface	Time (Hr:min)	Weight (g)
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		

Surface	Time (Hr:min)	Weight (g)
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		

Surface	Time (Hr:min)	Weight (g)
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		
1		
2		

INSTRUCTIONS:

1. Confirm test surface temperature and OAT logging throughout the testing session by checking the real time readings displayed on the computer screen;
2. Check online the availability of Environment Canada weather summary every hour. If unavailable, fill in the form in ATTACHMENT B1; and
3. Weigh one plate at a time.

ATTACHMENT B1
DATA FORM
FROST RATES ON TEST SURFACES

Date ________________ Location ________________

Recorded by ________________ Signature ________________

Surface	Time (Hr:min)	OAT (°C)	RH (%)	Wind Speed (km/h)	Sky Clear (C) or Overcast (O)
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					

INSTRUCTIONS:

1. Measure wind with handheld anemometer at 2 m above ground.
2. Measure OAT and RH with Vaisala instrument.

ATTACHMENT C
SAMPLE OF WEATHER TRENDS FOR MONTRÉAL

[Imperial Units]

Date	Hour	Weather	Temp. (°C)	Humidity (%)	DewPoint (°C)	Wind (km/h)	Pressure (kPa)	Visibility (km)
08 Oct. 2002	06:00 EDT	Clear	2	72	-3	WNW 6	102.4	24
08 Oct. 2002	05:00 EDT	Clear	3	72	-1	W 7	102.3	24
08 Oct. 2002	04:00 EDT	Clear	2	79	-1	WNW 7	102.2	24
08 Oct. 2002	03:00 EDT	Clear	3	74	-1	WNW 11	102.1	24
08 Oct. 2002	02:00 EDT	Clear	4	71	0	NW 11	102.0	24
08 Oct. 2002	01:00 EDT	Mainly Clear	5	68	-1	W 11	102.0	24
08 Oct. 2002	00:00 EDT	Mainly Clear	6	64	-1	W 7	101.9	24
07 Oct. 2002	23:00 EDT	Mainly Clear	6	65	0	NW 13	101.8	24
07 Oct. 2002	22:00 EDT	Mainly Clear	7	59	0	NW 13	101.8	24
07 Oct. 2002	21:00 EDT	Clear	8	59	1	NW 11	101.7	24
07 Oct. 2002	20:00 EDT	Clear	9	54	0	NW 15	101.7	24
07 Oct. 2002	19:00 EDT	Mainly Clear	11	47	0	WNW 20 gusting to 30	101.5	24
07 Oct. 2002	18:00 EDT	Mainly Sunny	13	44	1	WNW 28 gusting to 46	101.4	48

ATTACHMENT D
END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME 2003-04

LOCATION: Dorval Test Site **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:						
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						
FLUID DILUTION (BRIX)	INITIAL	INITIAL	INITIAL	INITIAL	INITIAL	INITIAL
	AT FAILURE	AT FAILURE	AT FAILURE	AT FAILURE	AT FAILURE	AT FAILURE

	Plate 7	Plate 8	Plate 9	Plate 10	Plate 11	Plate 12
Time of Fluid Application:						
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						
FLUID DILUTION (BRIX)	INITIAL	INITIAL	INITIAL	INITIAL	INITIAL	INITIAL
	AT FAILURE	AT FAILURE	AT FAILURE	AT FAILURE	AT FAILURE	AT FAILURE

AMBIENT TEMPERATURE: ________ °C

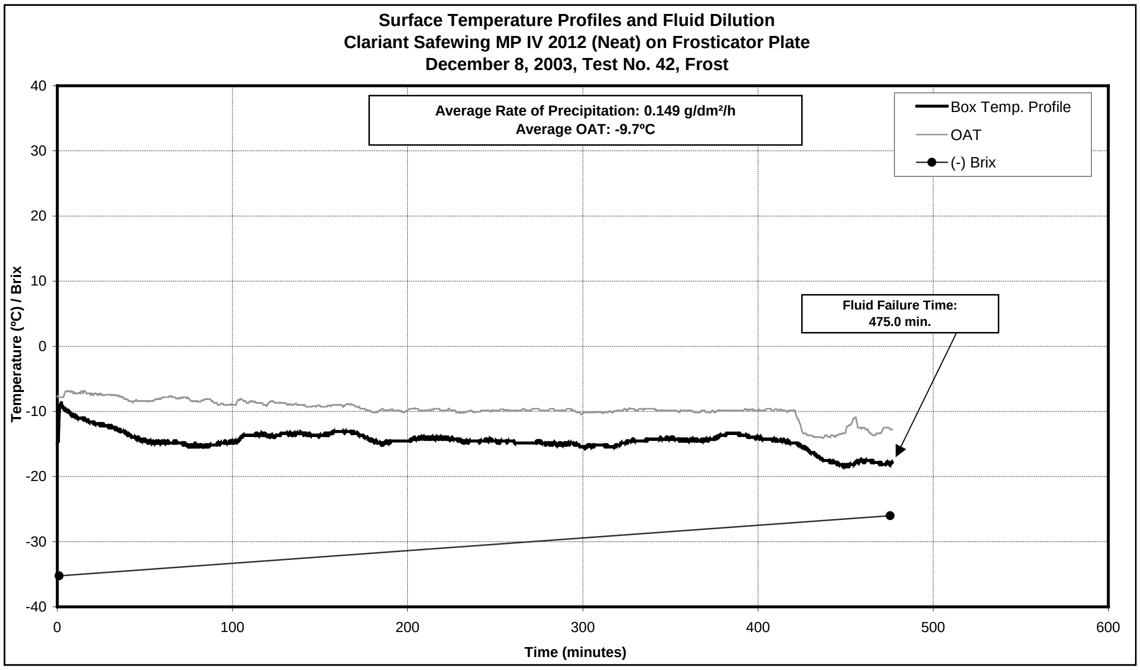
COMMENTS:

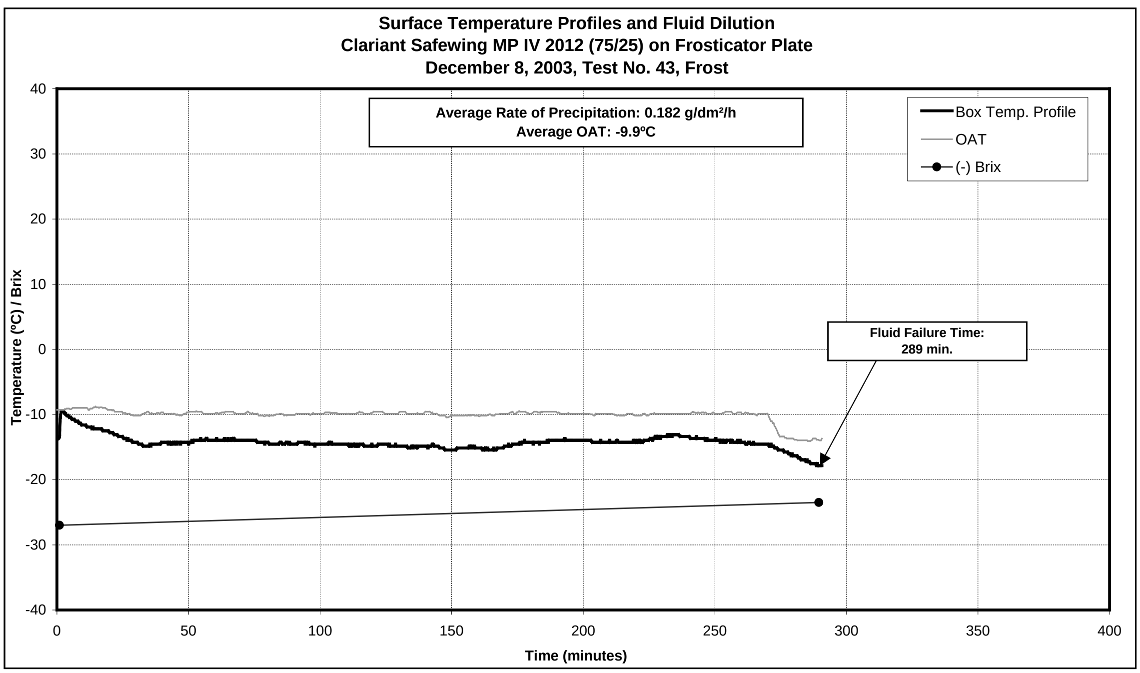
FAILURES CALLED BY: ____________________

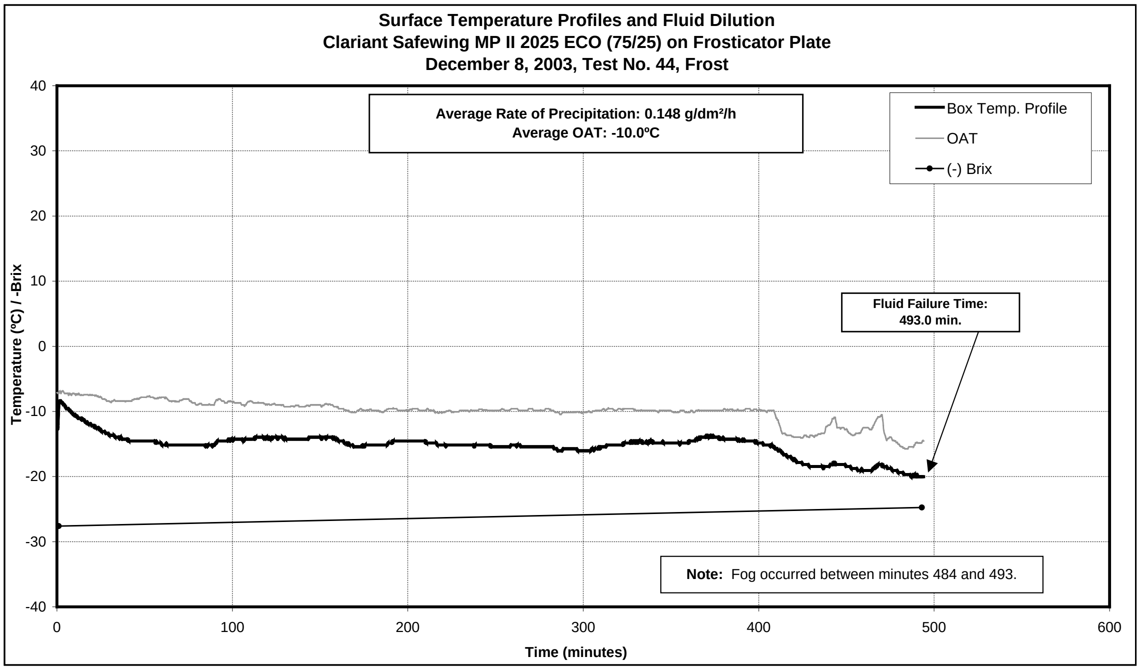
LEADER / MANAGER: ____________________

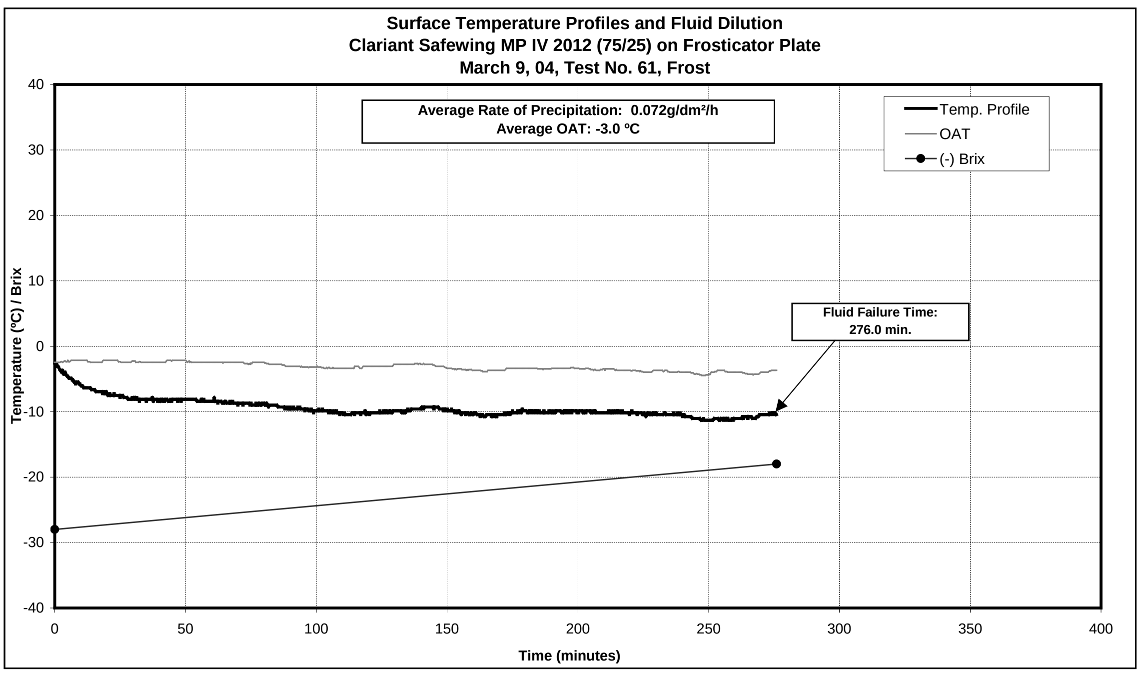
APPENDIX C

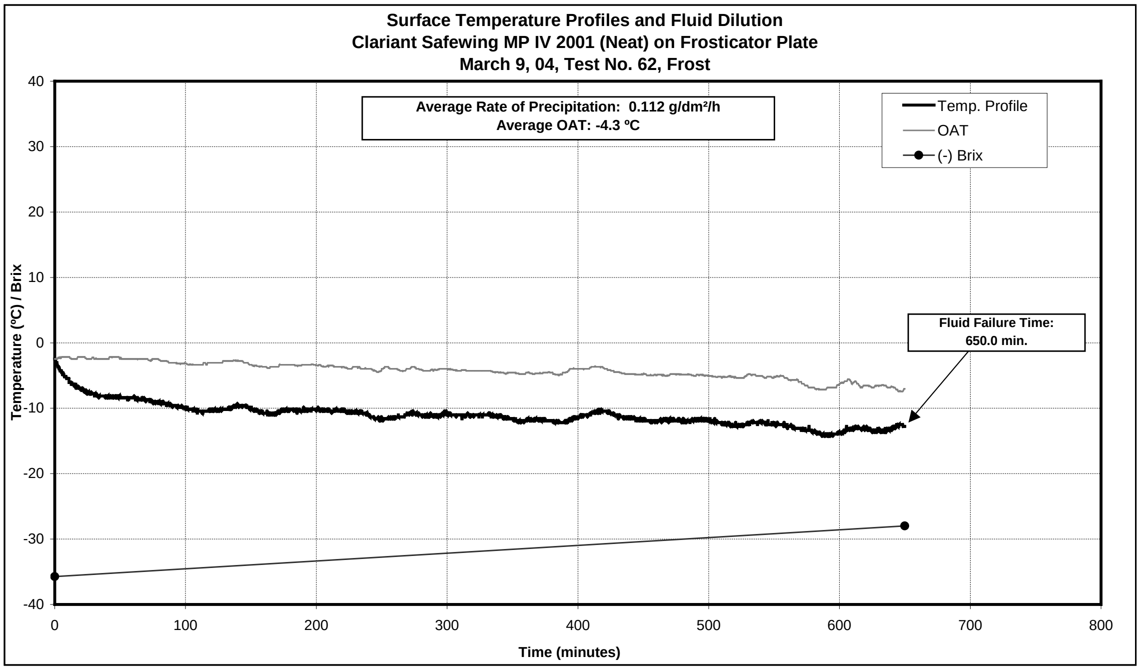
DETAILED TEMPERATURE PROFILES
TESTS CONDUCTED DURING FROST CONDITIONS

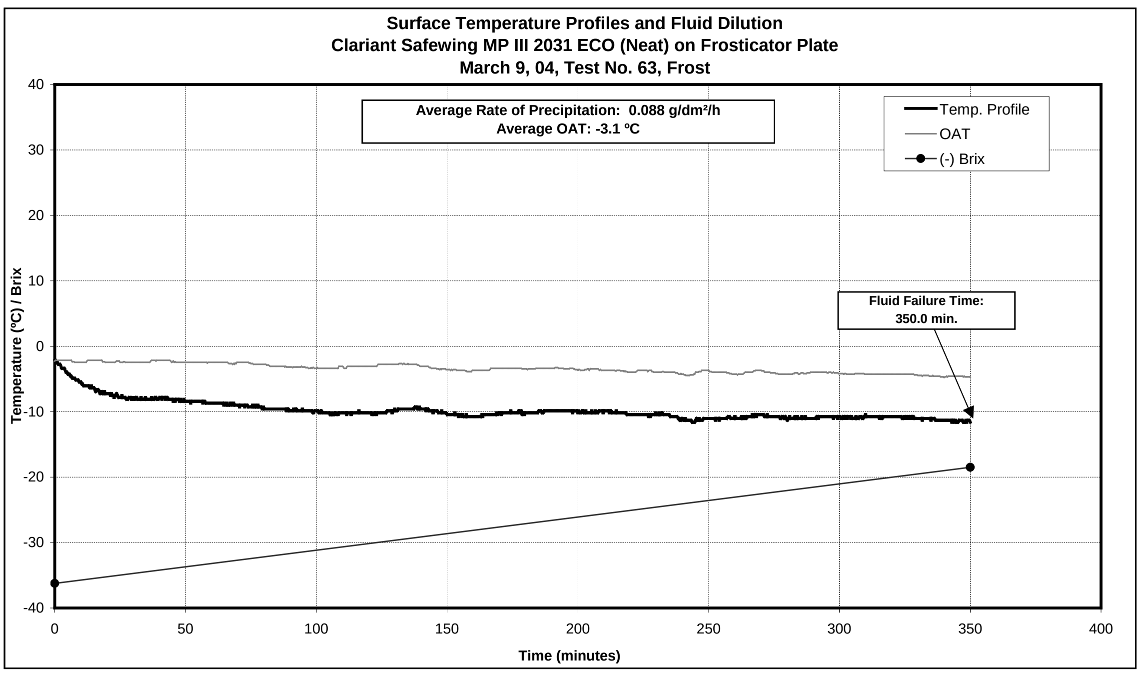

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (Neat) on Frosticator Plate
December 8, 2003, Test No. 42, Frost
Average Rate of Precipitation: 0.149 g/dm²/h
Average OAT: -9.7ºC
Box Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
475.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

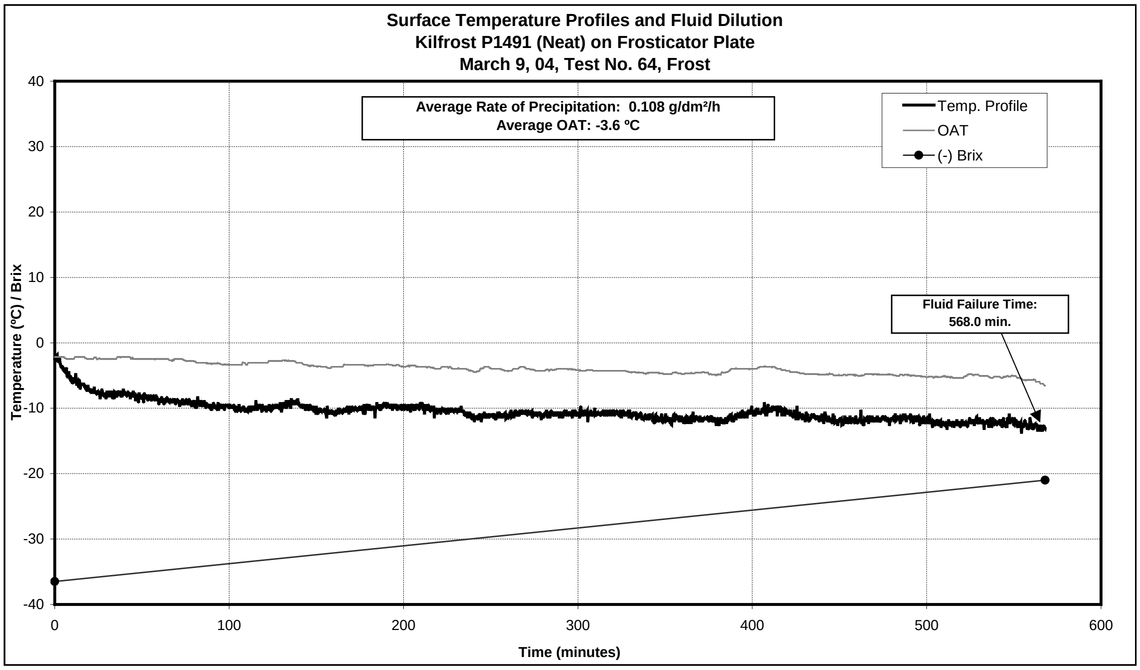

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (75/25) on Frosticator Plate
December 8, 2003, Test No. 43, Frost
Average Rate of Precipitation: 0.182 g/dm²/h
Average OAT: -9.9ºC
Box Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
289 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400


Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP II 2025 ECO (75/25) on Frosticator Plate
December 8, 2003, Test No. 44, Frost
Average Rate of Precipitation: 0.148 g/dm²/h
Average OAT: -10.0ºC
Box Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
493.0 min.
Note: Fog occurred between minutes 484 and 493.
Temperature (ºC) / -Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

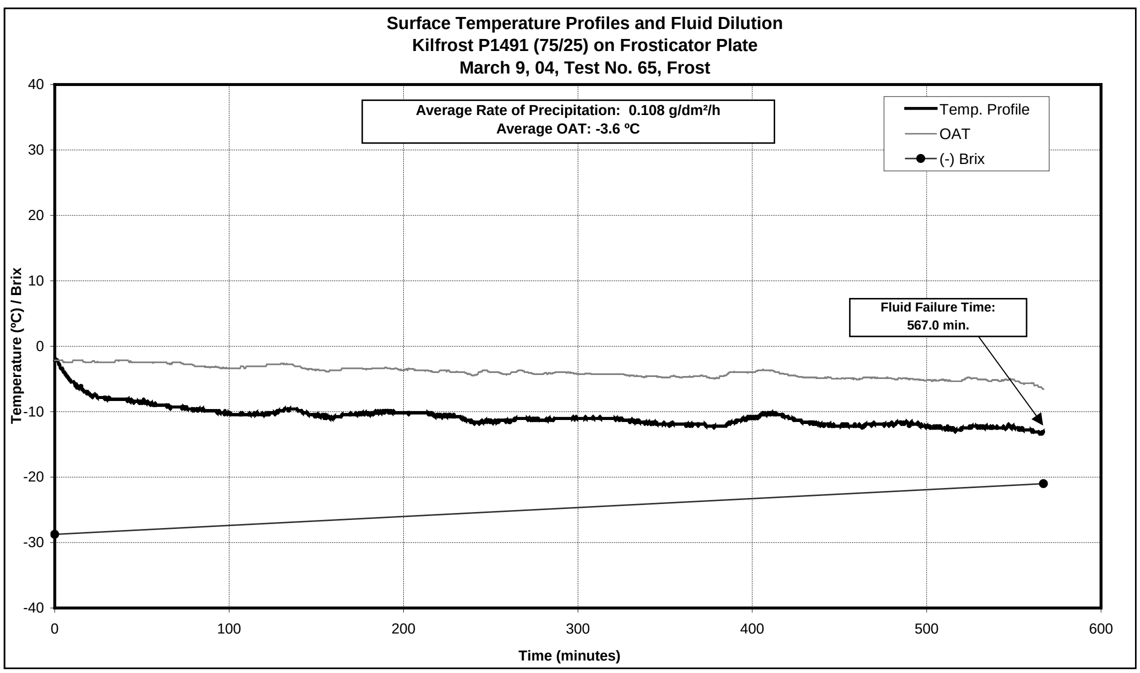

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (75/25) on Frosticator Plate
March 9, 04, Test No. 61, Frost
Average Rate of Precipitation: 0.072g/dm²/h
Average OAT: -3.0 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
276.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400


Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2001 (Neat) on Frosticator Plate
March 9, 04, Test No. 62, Frost
Average Rate of Precipitation: 0.112 g/dm²/h
Average OAT: -4.3 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
650.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800

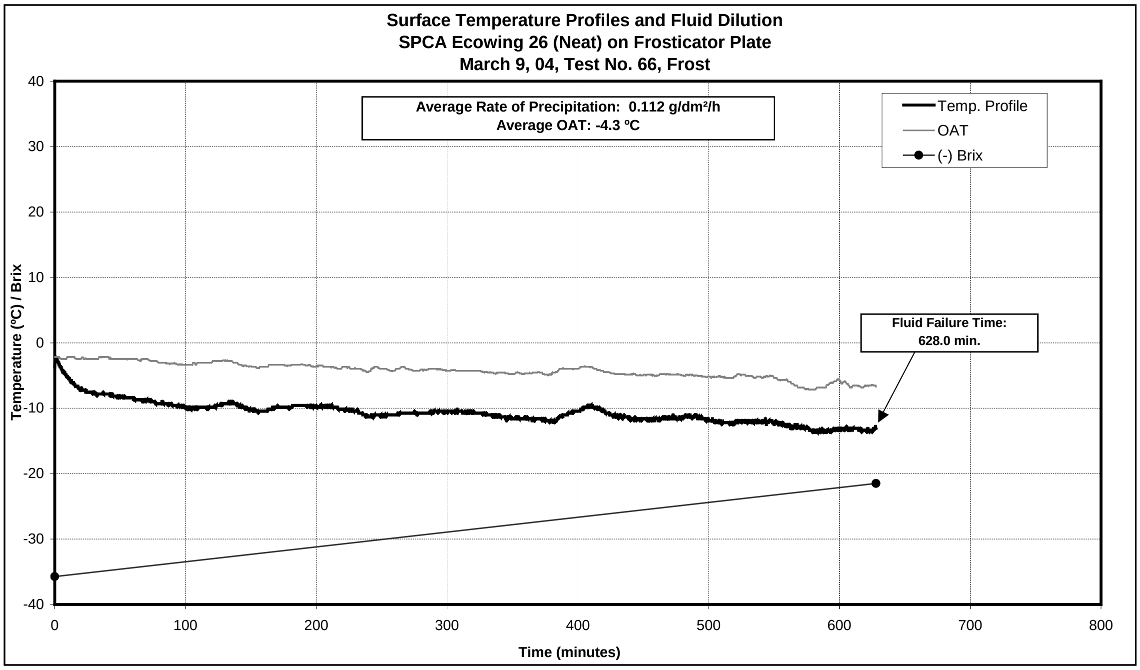

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP III 2031 ECO (Neat) on Frosticator Plate
March 9, 04, Test No. 63, Frost
Average Rate of Precipitation: 0.088 g/dm²/h
Average OAT: -3.1 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
350.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

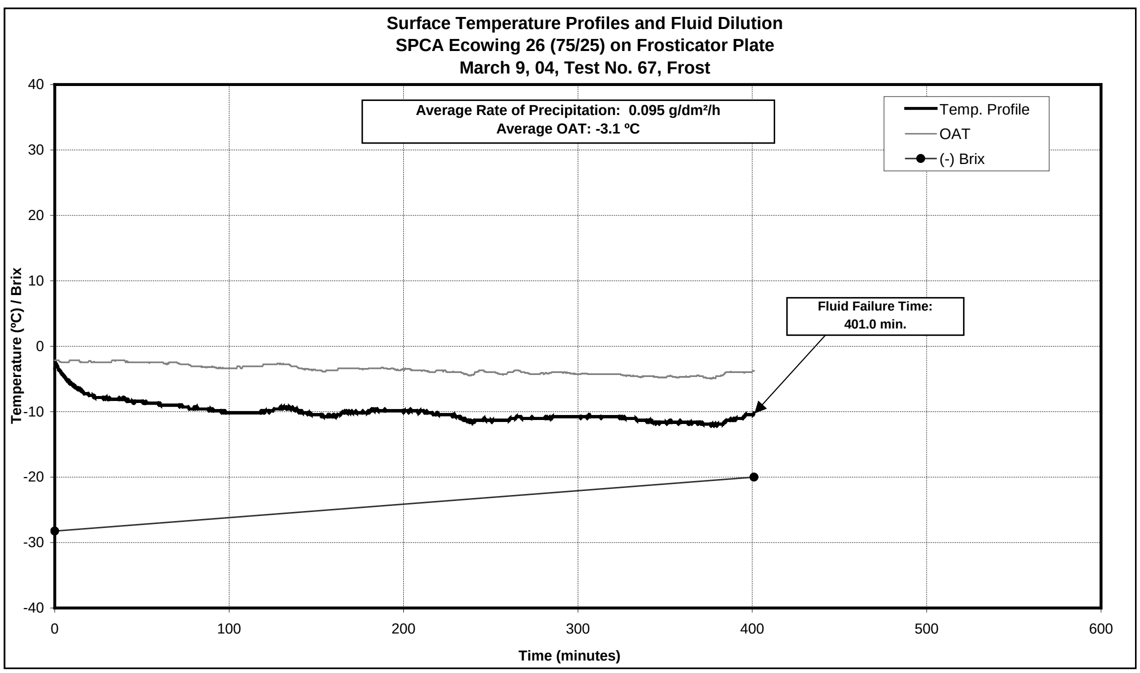


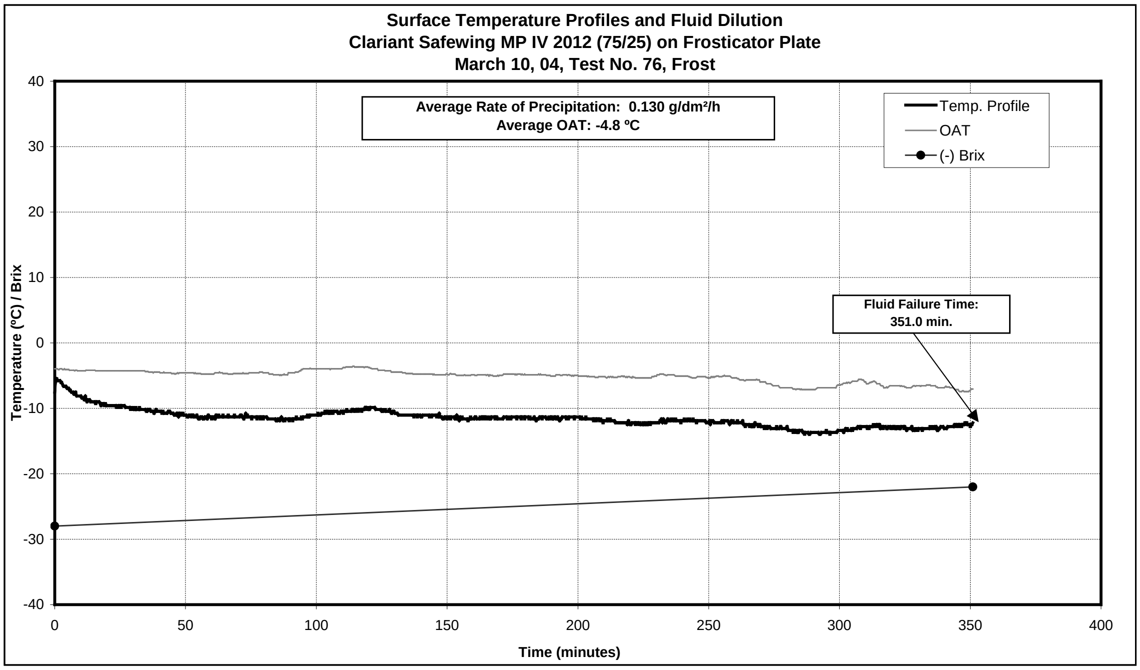
Surface Temperature Profiles and Fluid Dilution
Kilfrost P1491 (Neat) on Frosticator Plate
March 9, 04, Test No. 64, Frost
Average Rate of Precipitation: 0.108 g/dm²/h
Average OAT: -3.6 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
568.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

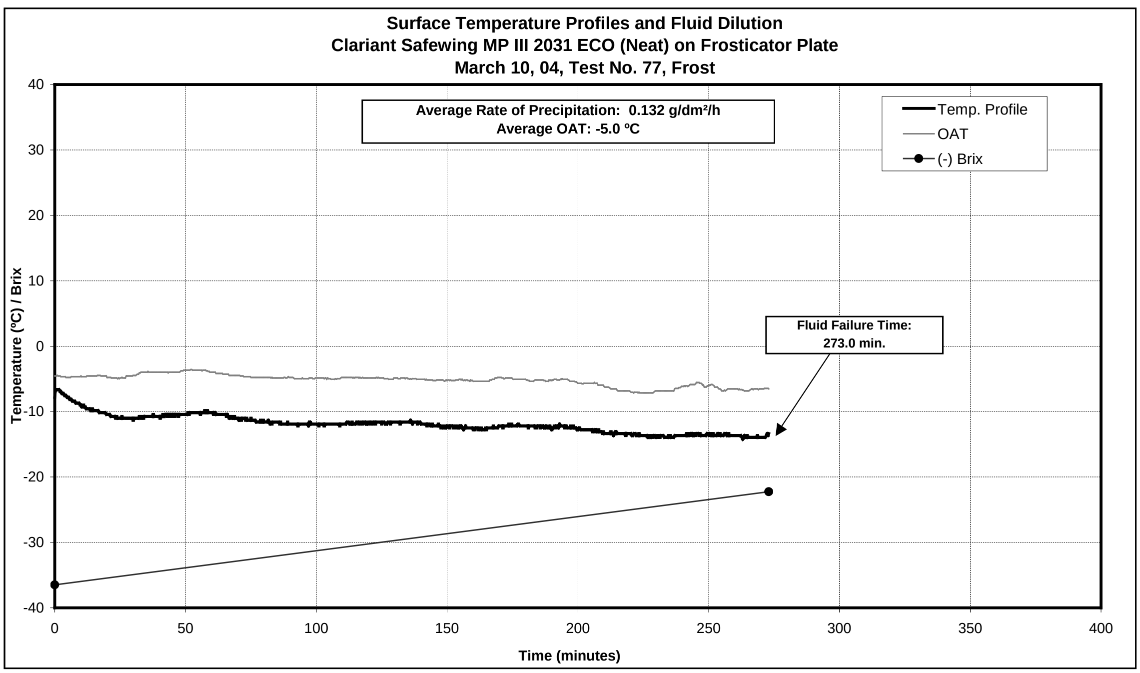


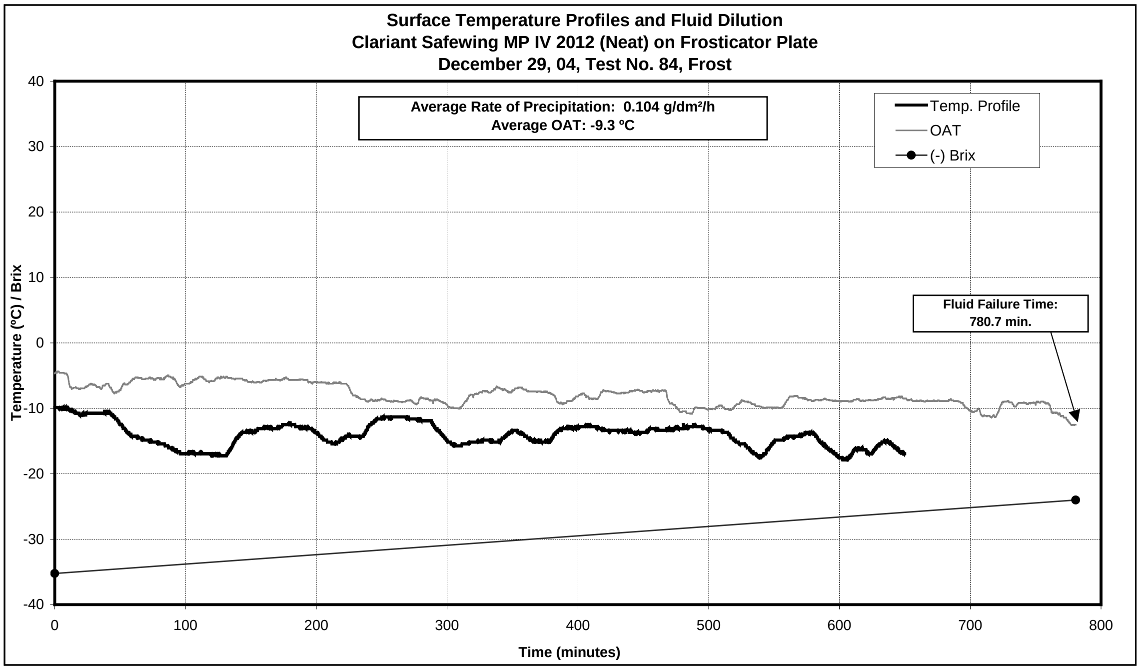
Surface Temperature Profiles and Fluid Dilution
Kilfrost P1491 (75/25) on Frosticator Plate
March 9, 04, Test No. 65, Frost
Average Rate of Precipitation: 0.108 g/dm²/h
Average OAT: -3.6 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
567.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

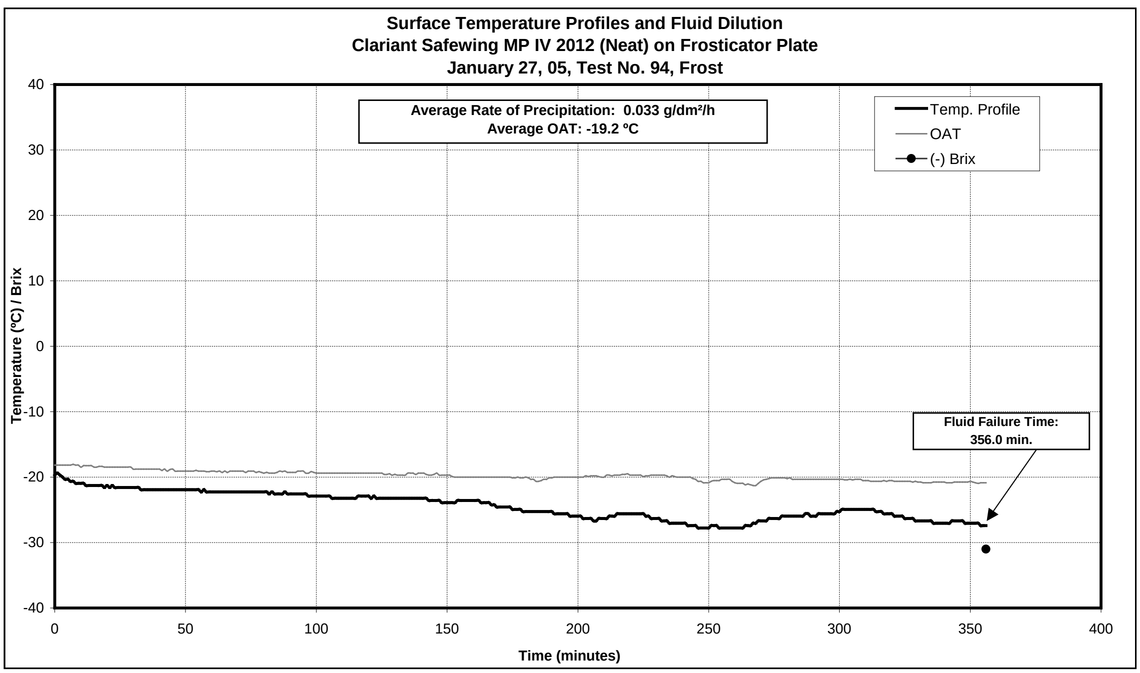

Surface Temperature Profiles and Fluid Dilution
SPCA Ecowing 26 (Neat) on Frosticator Plate
March 9, 04, Test No. 66, Frost
Average Rate of Precipitation: 0.112 g/dm²/h
Average OAT: -4.3 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
628.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800

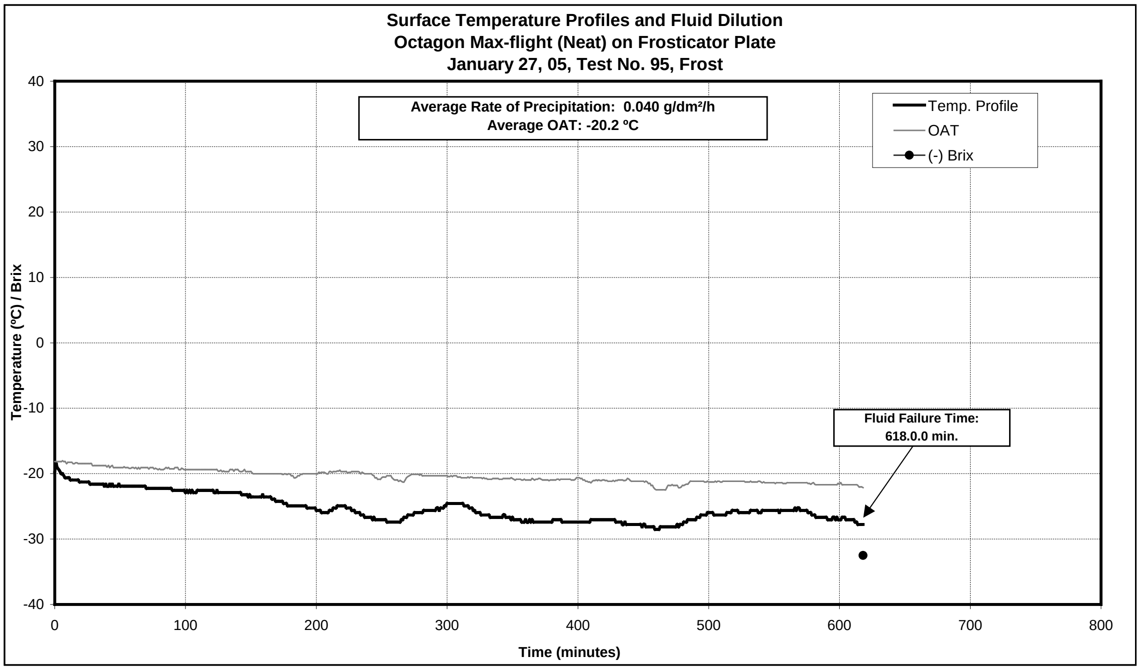

Surface Temperature Profiles and Fluid Dilution
SPCA Ecowing 26 (75/25) on Frosticator Plate
March 9, 04, Test No. 67, Frost
Average Rate of Precipitation: 0.095 g/dm²/h
Average OAT: -3.1 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
401.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

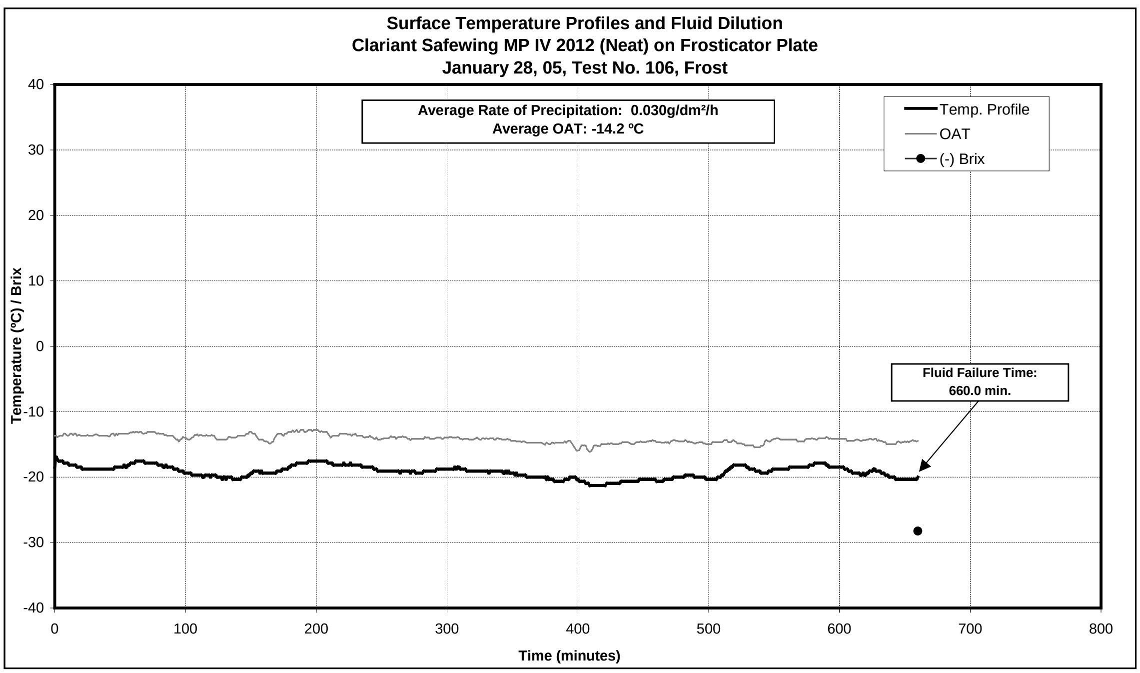

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (75/25) on Frosticator Plate
March 10, 04, Test No. 76, Frost
Average Rate of Precipitation: 0.130 g/dm²/h
Average OAT: -4.8 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
351.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

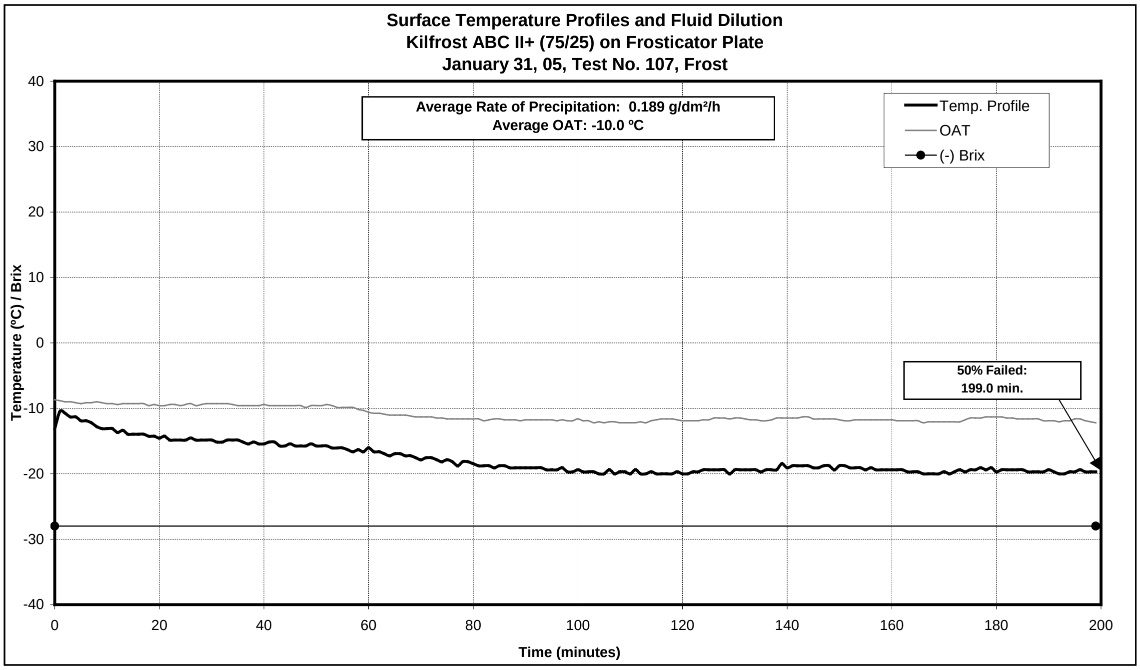

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP III 2031 ECO (Neat) on Frosticator Plate
March 10, 04, Test No. 77, Frost
Average Rate of Precipitation: 0.132 g/dm²/h
Average OAT: -5.0 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
273.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

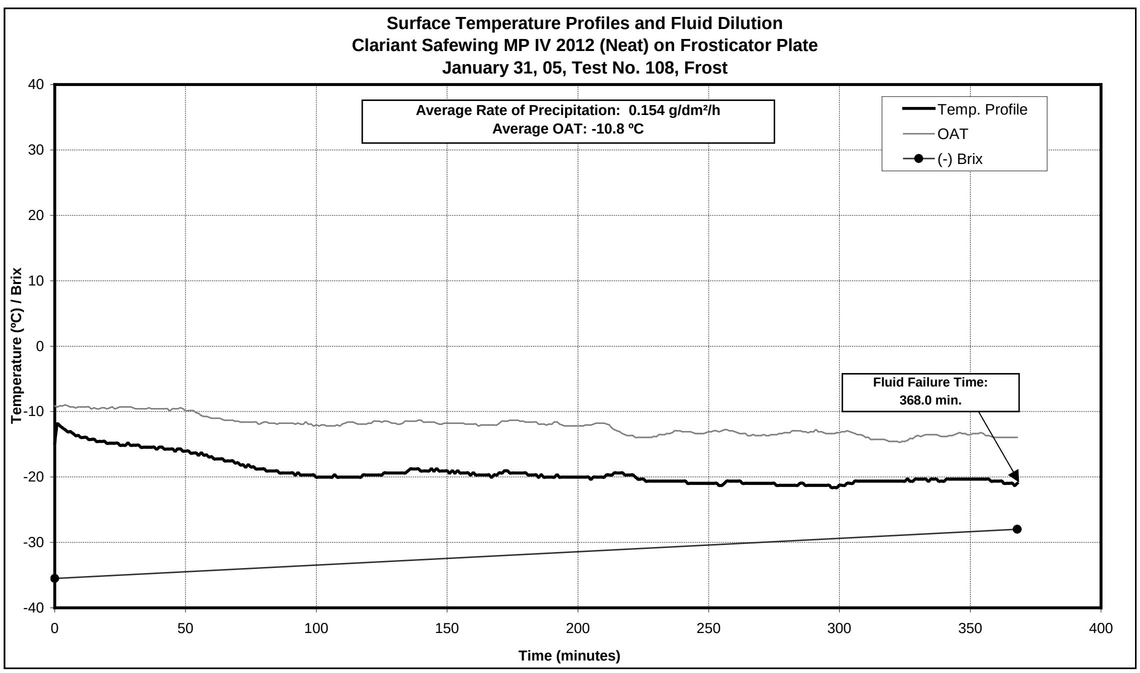

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (Neat) on Frosticator Plate
December 29, 04, Test No. 84, Frost
Average Rate of Precipitation: 0.104 g/dm²/h
Average OAT: -9.3 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
780.7 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800

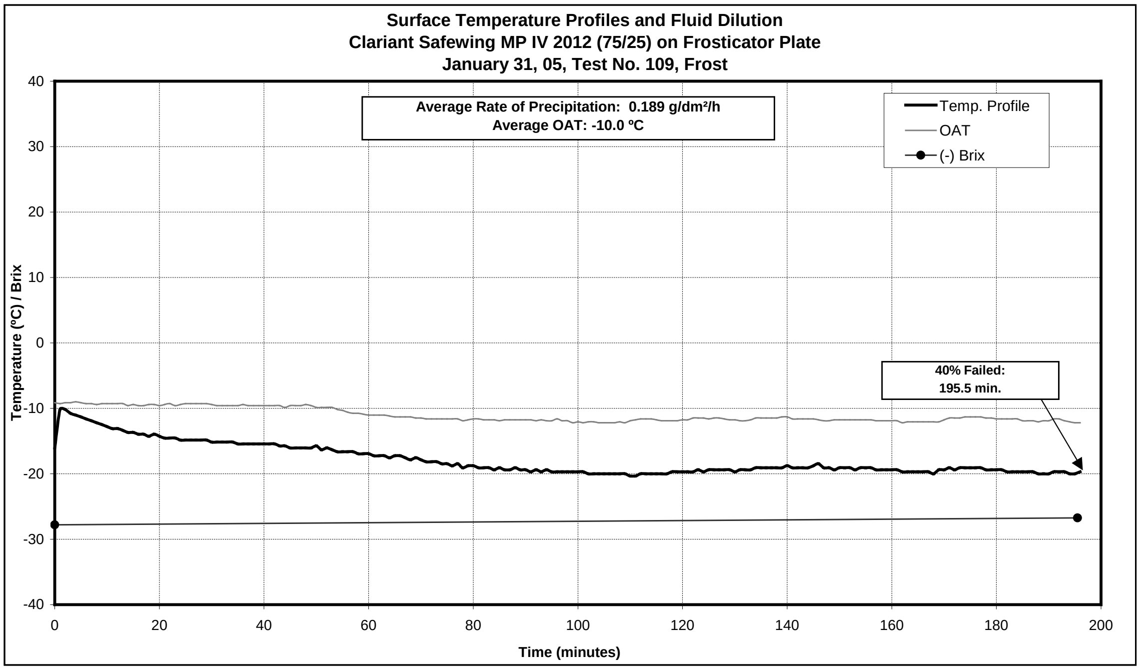

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (Neat) on Frosticator Plate
January 27, 05, Test No. 94, Frost
Average Rate of Precipitation: 0.033 g/dm²/h
Average OAT: -19.2 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
356.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

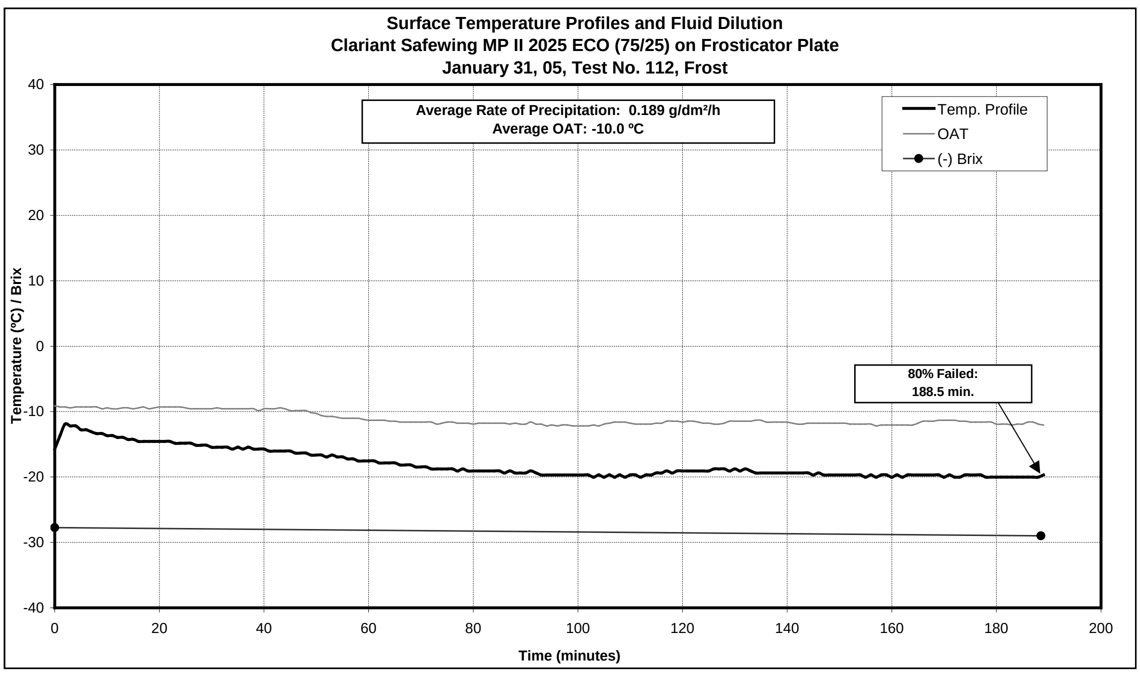

Surface Temperature Profiles and Fluid Dilution
Octagon Max-flight (Neat) on Frosticator Plate
January 27, 05, Test No. 95, Frost
Average Rate of Precipitation: 0.040 g/dm²/h
Average OAT: -20.2 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
618.0.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800

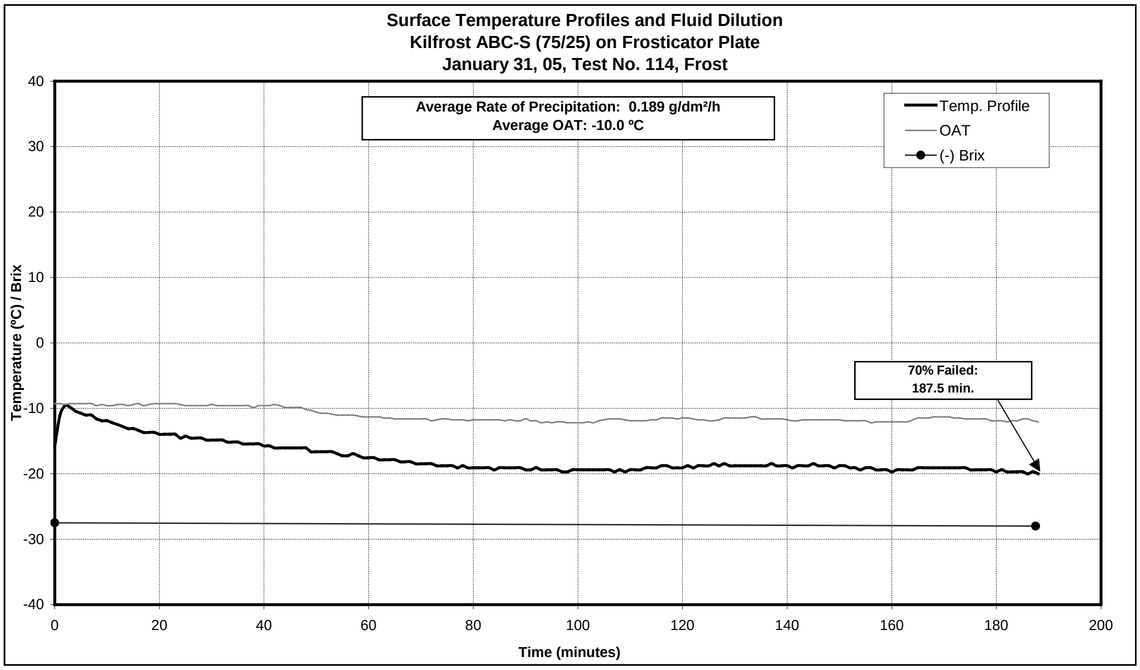

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (Neat) on Frosticator Plate
January 28, 05, Test No. 106, Frost
Average Rate of Precipitation: 0.030g/dm²/h
Average OAT: -14.2 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
660.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800

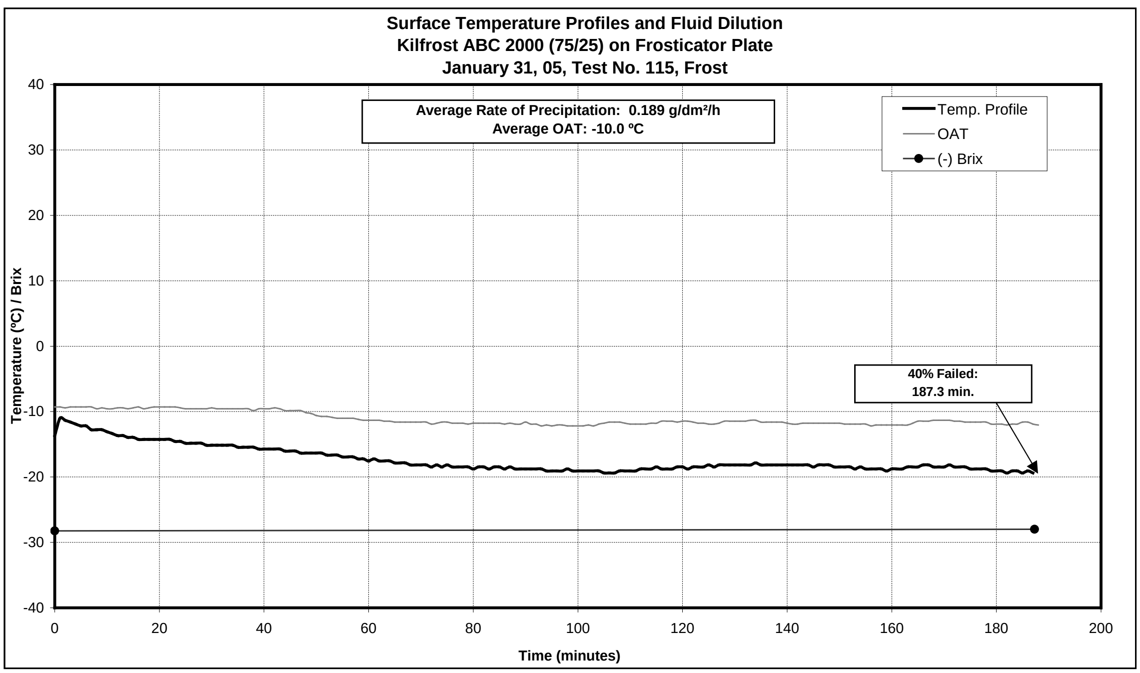

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC II+ (75/25) on Frosticator Plate
January 31, 05, Test No. 107, Frost
Average Rate of Precipitation: 0.189 g/dm²/h
Average OAT: -10.0 ºC
Temp. Profile
OAT
(-) Brix
50% Failed:
199.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

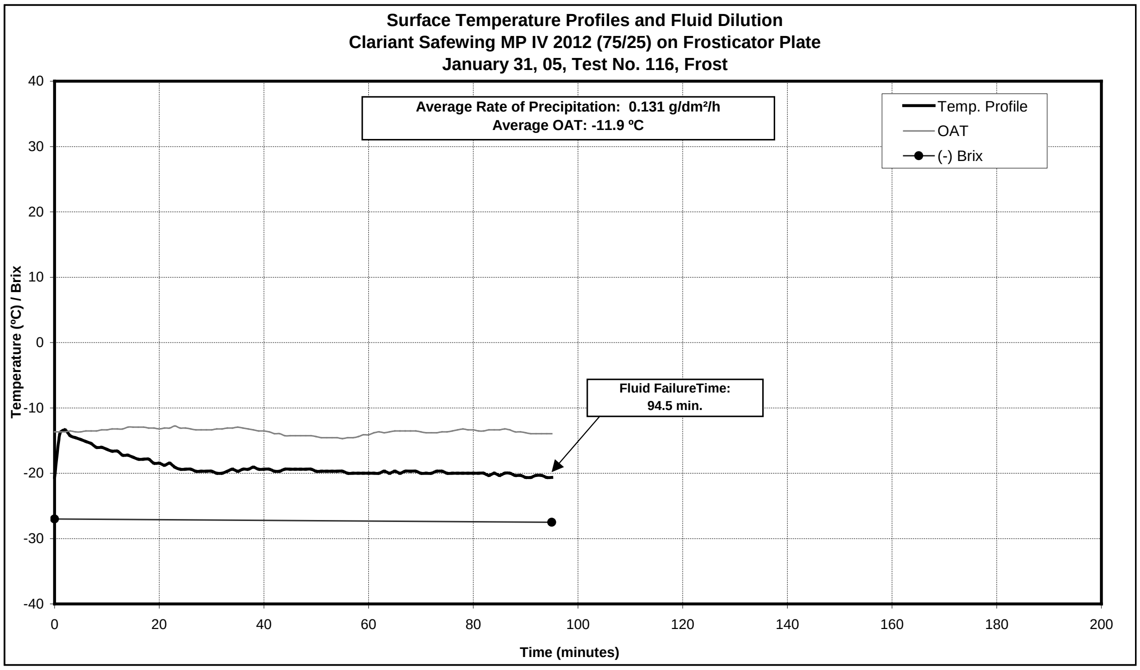

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (Neat) on Frosticator Plate
January 31, 05, Test No. 108, Frost
Average Rate of Precipitation: 0.154 g/dm²/h
Average OAT: -10.8 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
368.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

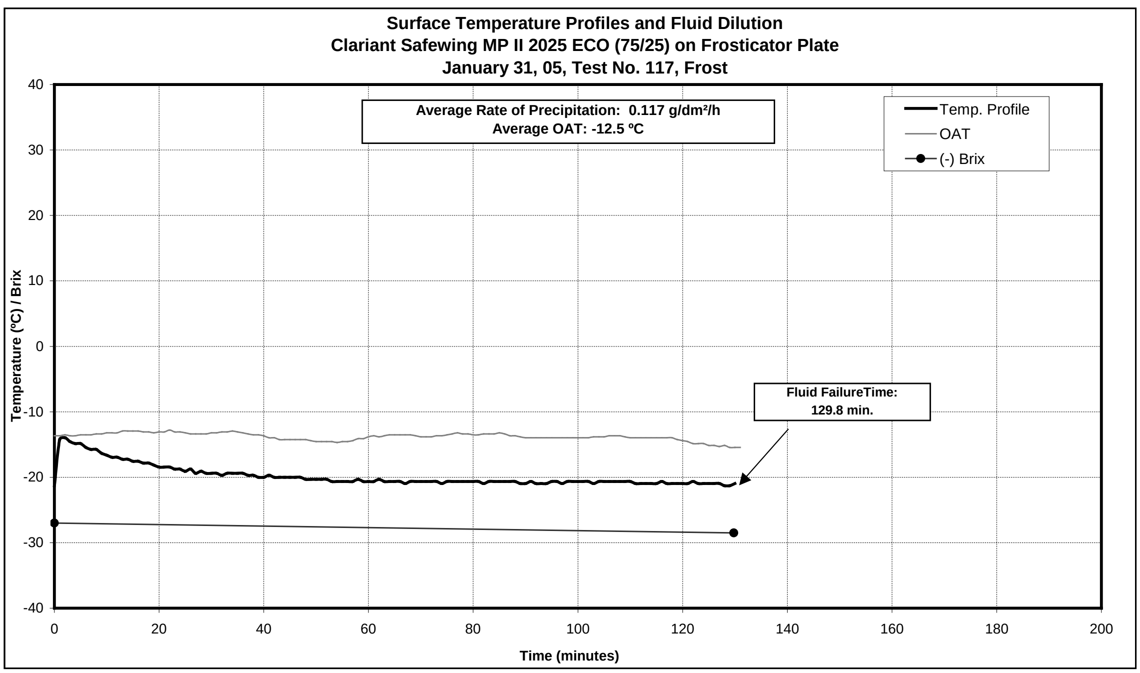

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (75/25) on Frosticator Plate
January 31, 05, Test No. 109, Frost
Average Rate of Precipitation: 0.189 g/dm²/h
Average OAT: -10.0 ºC
Temp. Profile
OAT
(-) Brix
40% Failed:
195.5 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

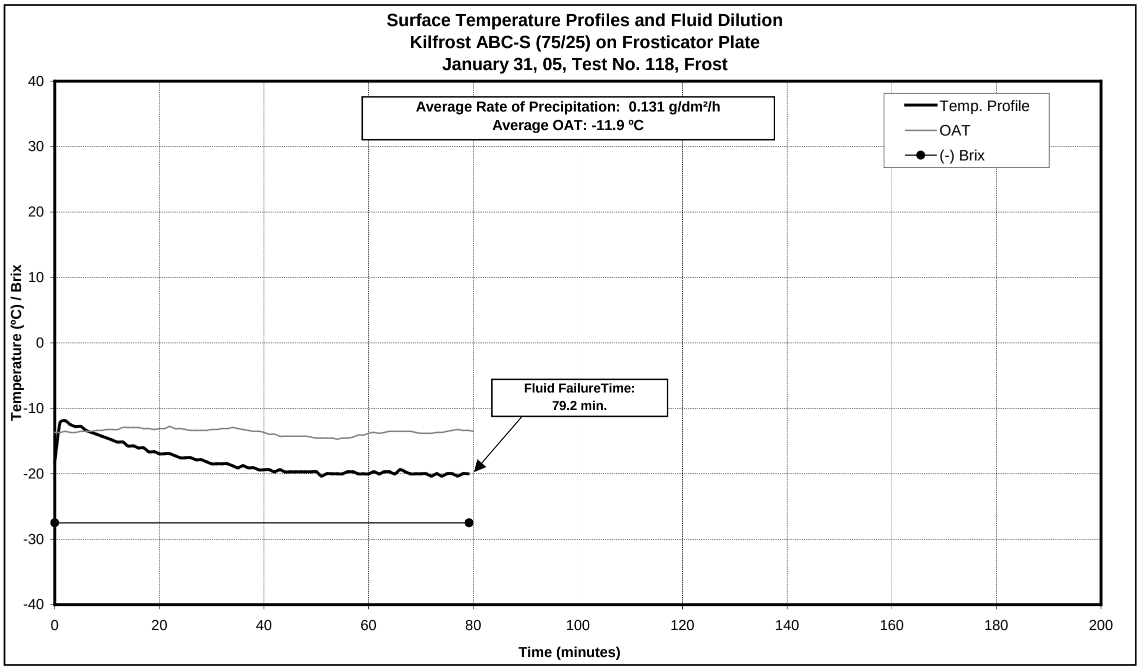

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP II 2025 ECO (75/25) on Frosticator Plate
January 31, 05, Test No. 112, Frost
Average Rate of Precipitation: 0.189 g/dm²/h
Average OAT: -10.0 ºC
Temp. Profile
OAT
(-) Brix
80% Failed:
188.5 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

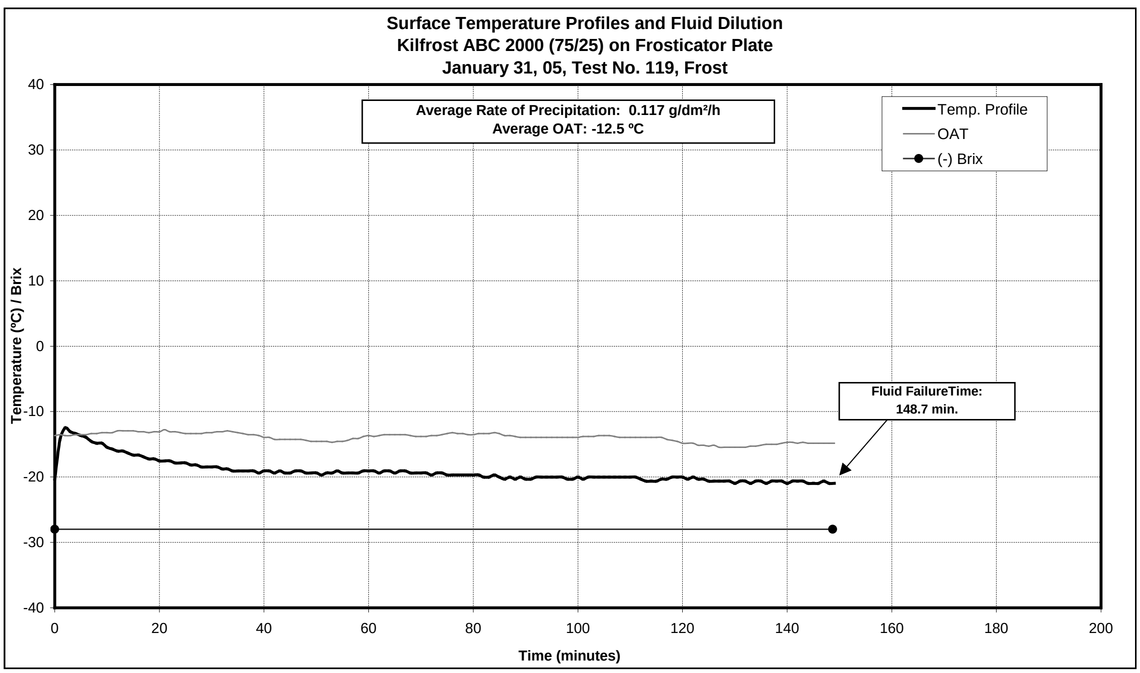

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC-S (75/25) on Frosticator Plate
January 31, 05, Test No. 114, Frost
Average Rate of Precipitation: 0.189 g/dm²/h
Average OAT: -10.0 ºC
Temp. Profile
OAT
(-) Brix
70% Failed:
187.5 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

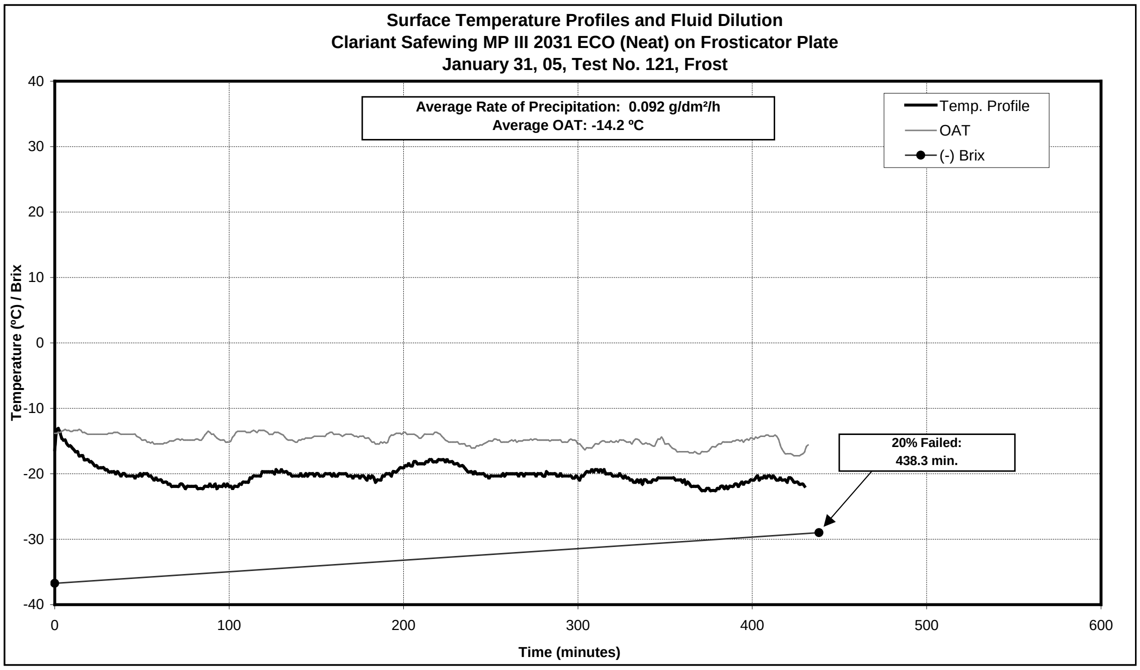

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC 2000 (75/25) on Frosticator Plate
January 31, 05, Test No. 115, Frost
Average Rate of Precipitation: 0.189 g/dm²/h
Average OAT: -10.0 ºC
Temp. Profile
OAT
(-) Brix
40% Failed:
187.3 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

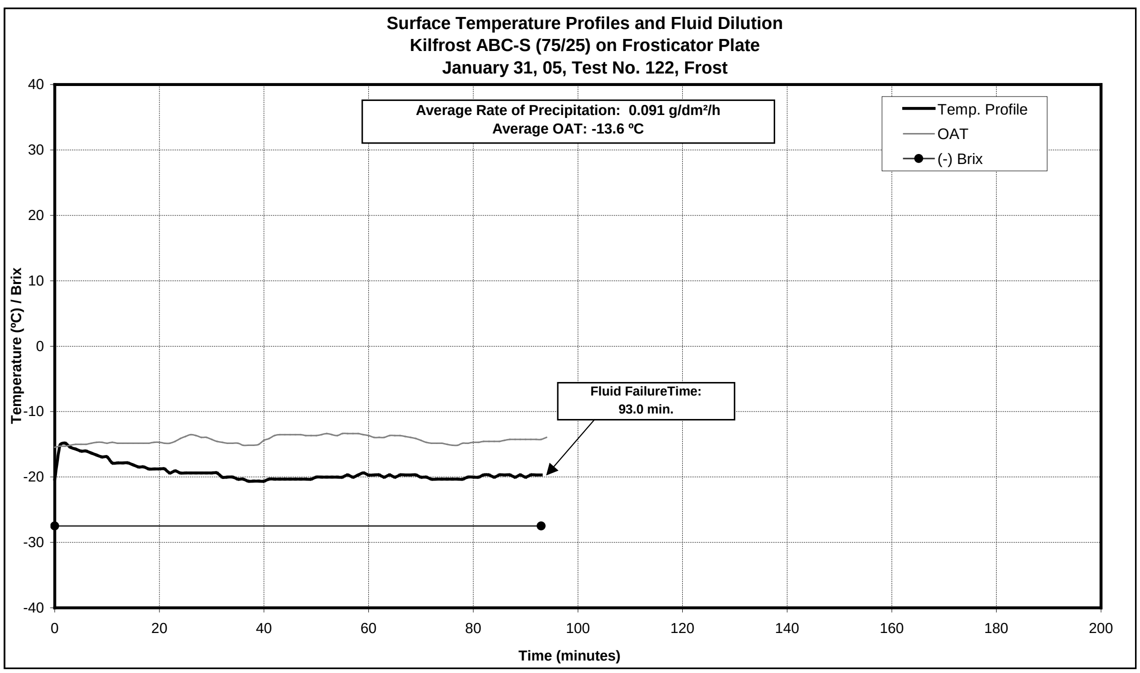

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 (75/25) on Frosticator Plate
January 31, 05, Test No. 116, Frost
Average Rate of Precipitation: 0.131 g/dm²/h
Average OAT: -11.9 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
94.5 min.
Temperature (ºC) / Brix
Time (minutes)

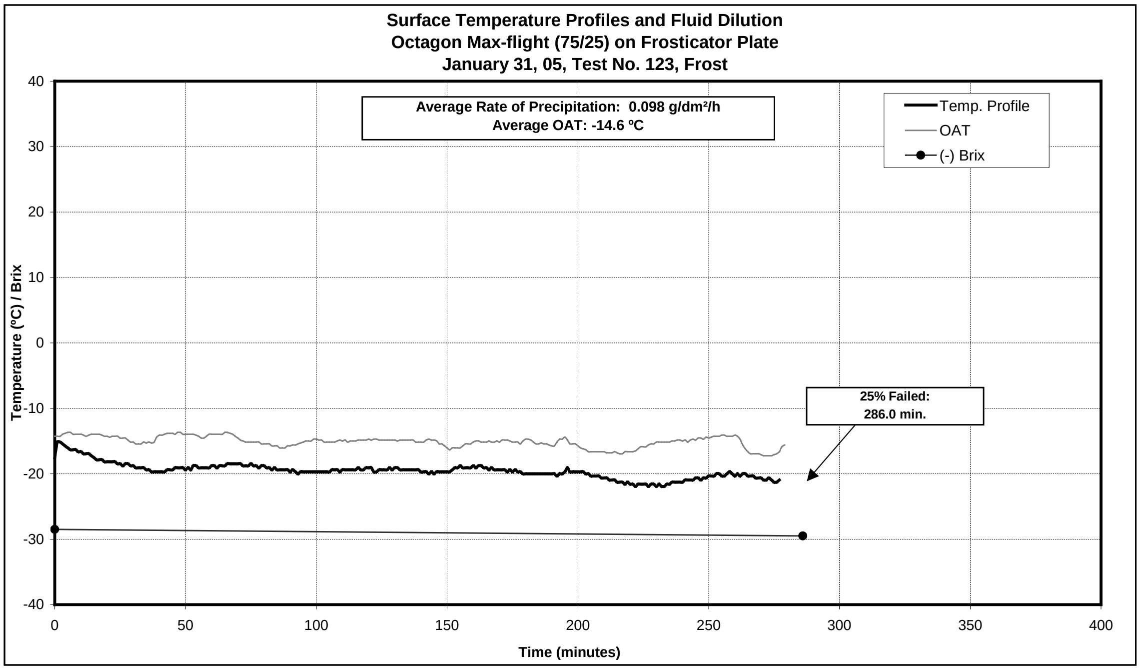

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP II 2025 ECO (75/25) on Frosticator Plate
January 31, 05, Test No. 117, Frost
Average Rate of Precipitation: 0.117 g/dm²/h
Average OAT: -12.5 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
129.8 min.
Temperature (ºC) / Brix
Time (minutes)

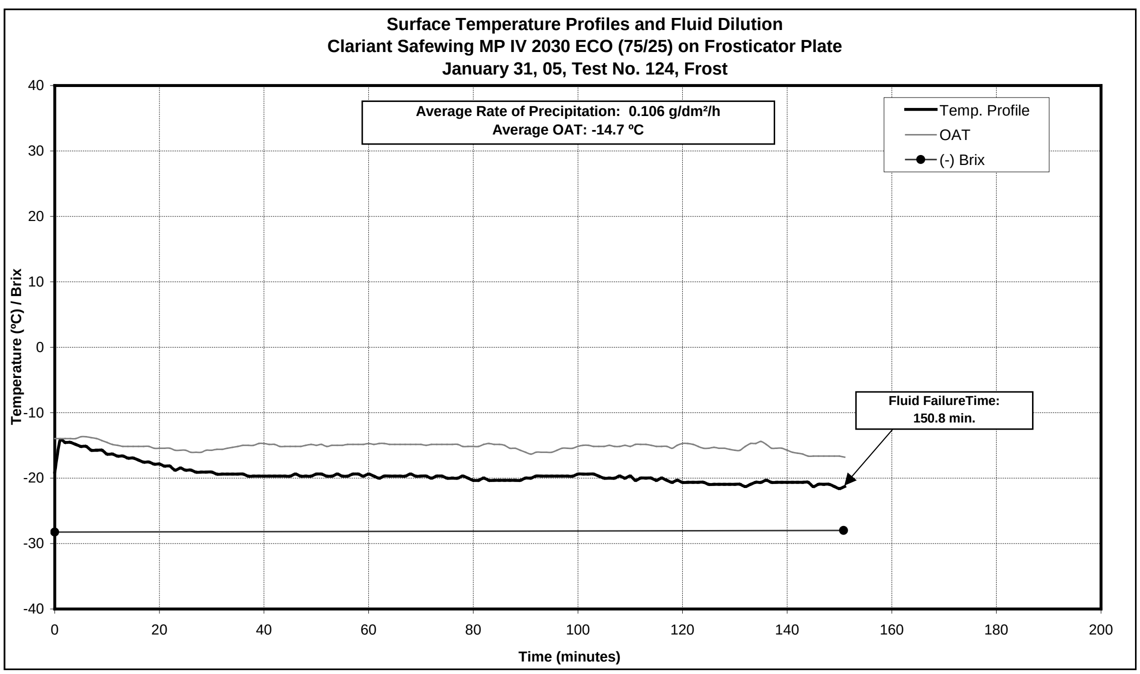

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC-S (75/25) on Frosticator Plate
January 31, 05, Test No. 118, Frost
Average Rate of Precipitation: 0.131 g/dm²/h
Average OAT: -11.9 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
79.2 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

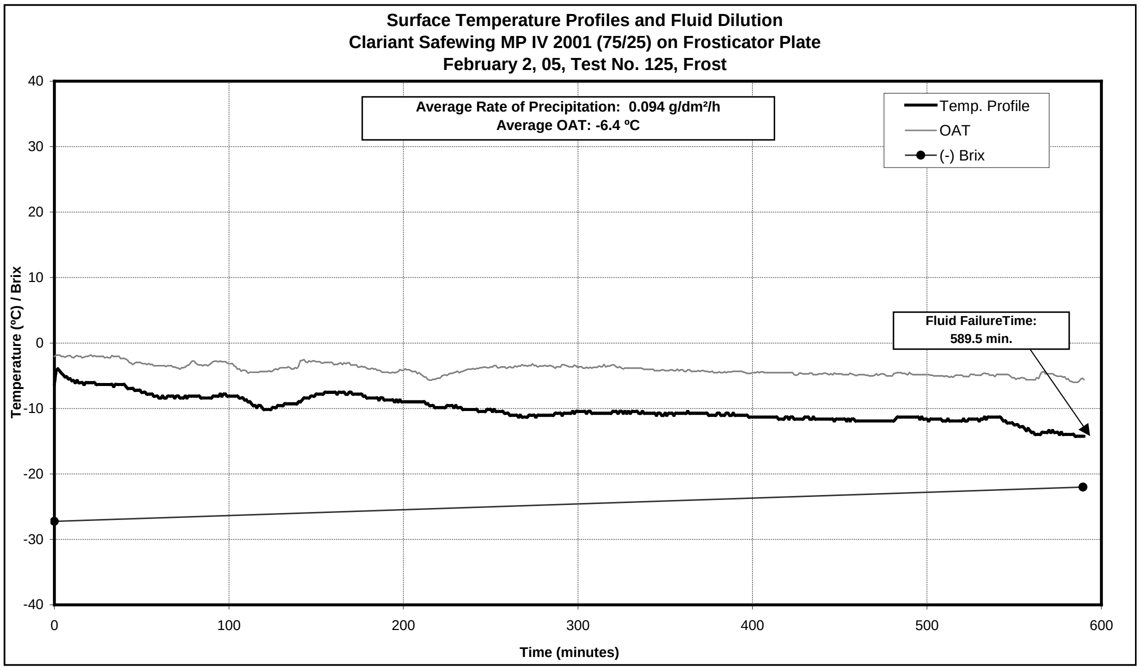

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC 2000 (75/25) on Frosticator Plate
January 31, 05, Test No. 119, Frost
Average Rate of Precipitation: 0.117 g/dm²/h
Average OAT: -12.5 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
148.7 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

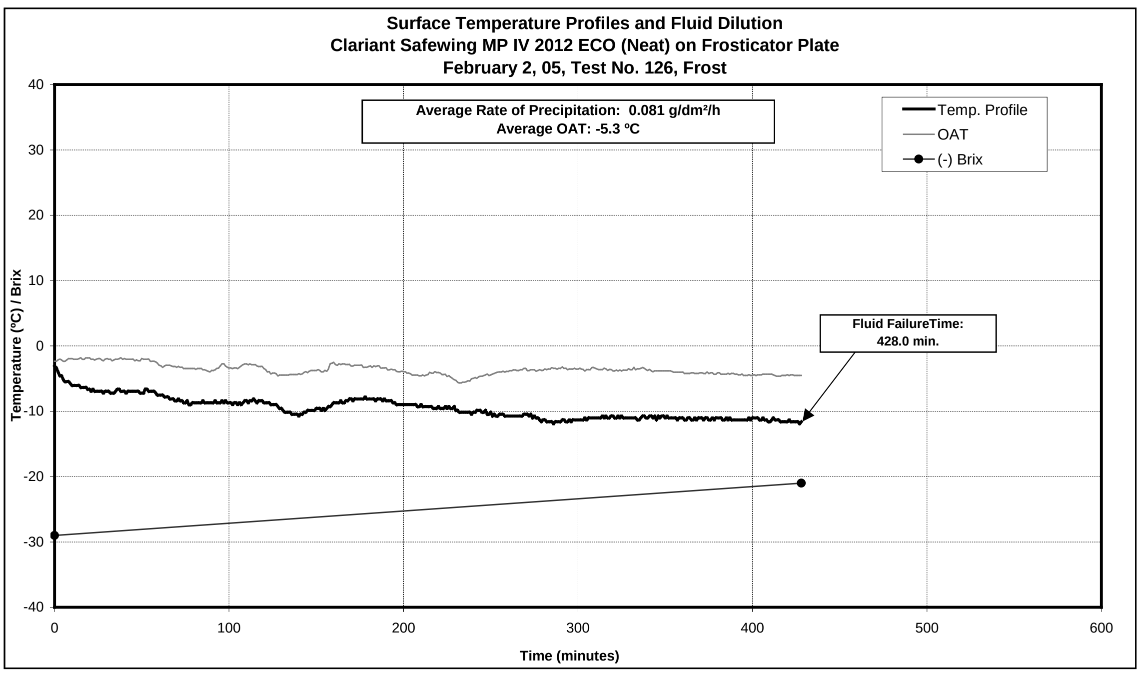

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP III 2031 ECO (Neat) on Frosticator Plate
January 31, 05, Test No. 121, Frost
Average Rate of Precipitation: 0.092 g/dm²/h
Average OAT: -14.2 ºC
Temp. Profile
OAT
(-) Brix
20% Failed:
438.3 min.
Temperature (ºC) / Brix
Time (minutes)

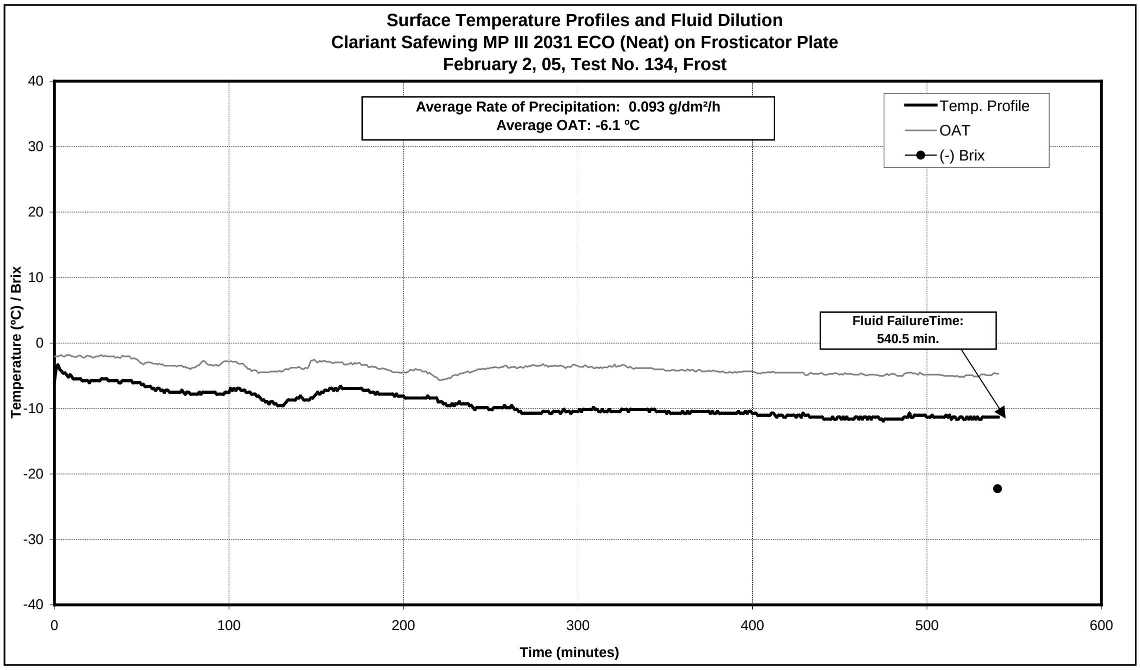

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC-S (75/25) on Frosticator Plate
January 31, 05, Test No. 122, Frost
Average Rate of Precipitation: 0.091 g/dm²/h
Average OAT: -13.6 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
93.0 min.
Temperature (ºC) / Brix
Time (minutes)

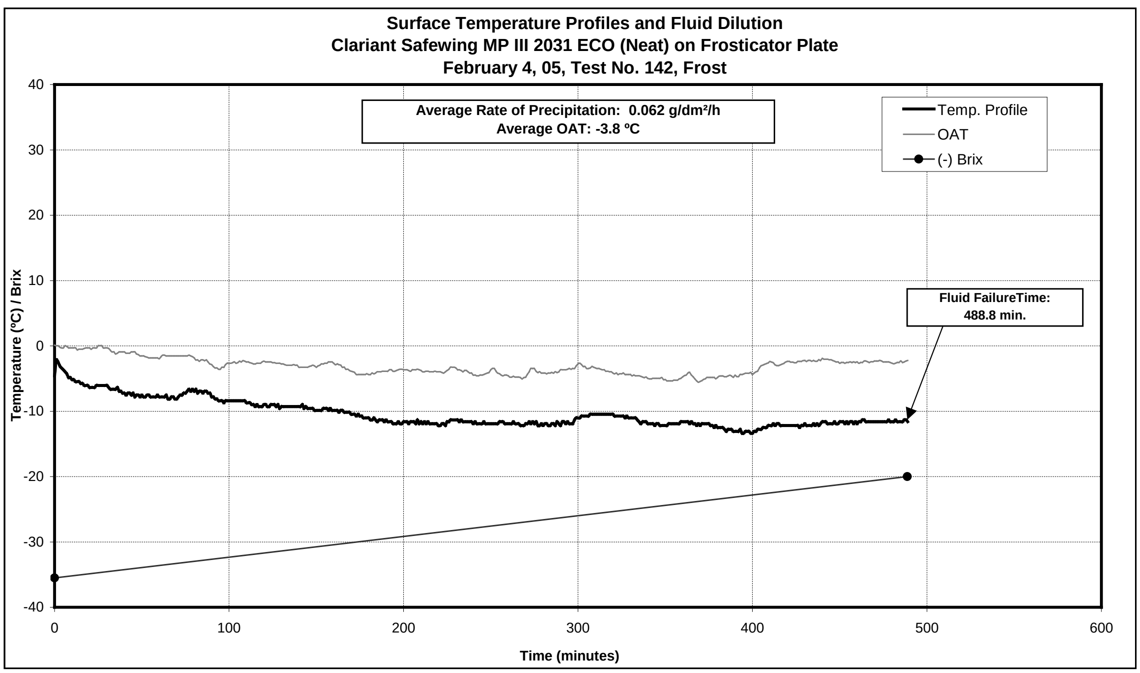

Surface Temperature Profiles and Fluid Dilution
Octagon Max-flight (75/25) on Frosticator Plate
January 31, 05, Test No. 123, Frost
Average Rate of Precipitation: 0.098 g/dm²/h
Average OAT: -14.6 ºC
Temp. Profile
OAT
(-) Brix
25% Failed:
286.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

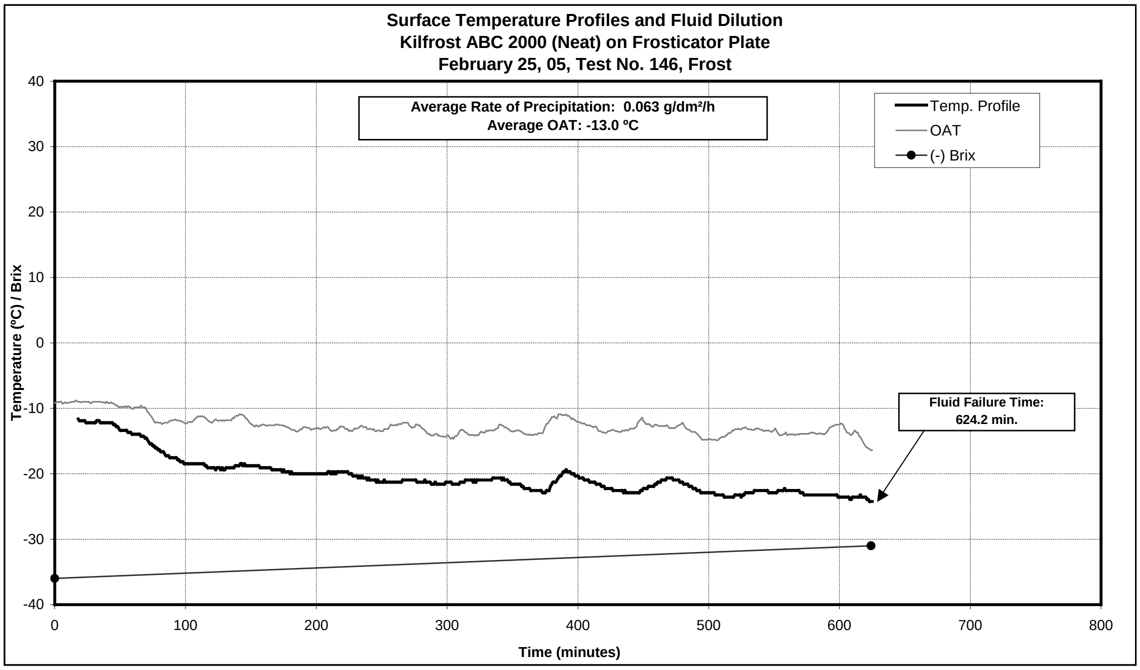

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2030 ECO (75/25) on Frosticator Plate
January 31, 05, Test No. 124, Frost
Average Rate of Precipitation: 0.106 g/dm²/h
Average OAT: -14.7 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
150.8 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

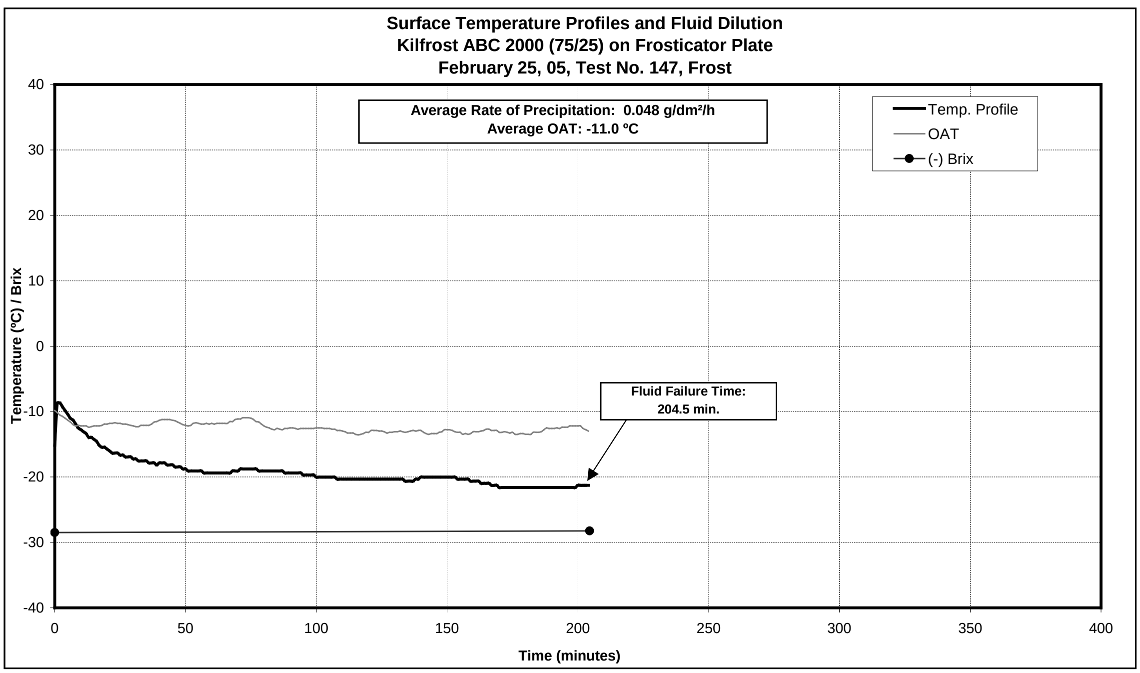

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2001 (75/25) on Frosticator Plate
February 2, 05, Test No. 125, Frost
Average Rate of Precipitation: 0.094 g/dm²/h
Average OAT: -6.4 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
589.5 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

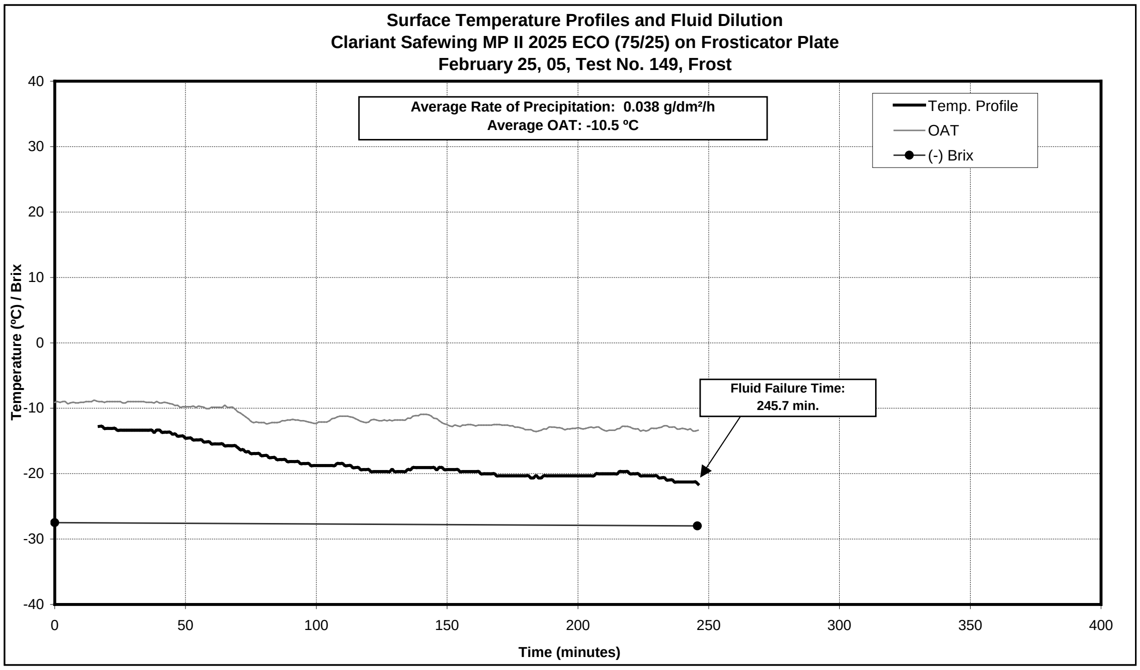

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2012 ECO (Neat) on Frosticator Plate
February 2, 05, Test No. 126, Frost
Average Rate of Precipitation: 0.081 g/dm²/h
Average OAT: -5.3 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
428.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

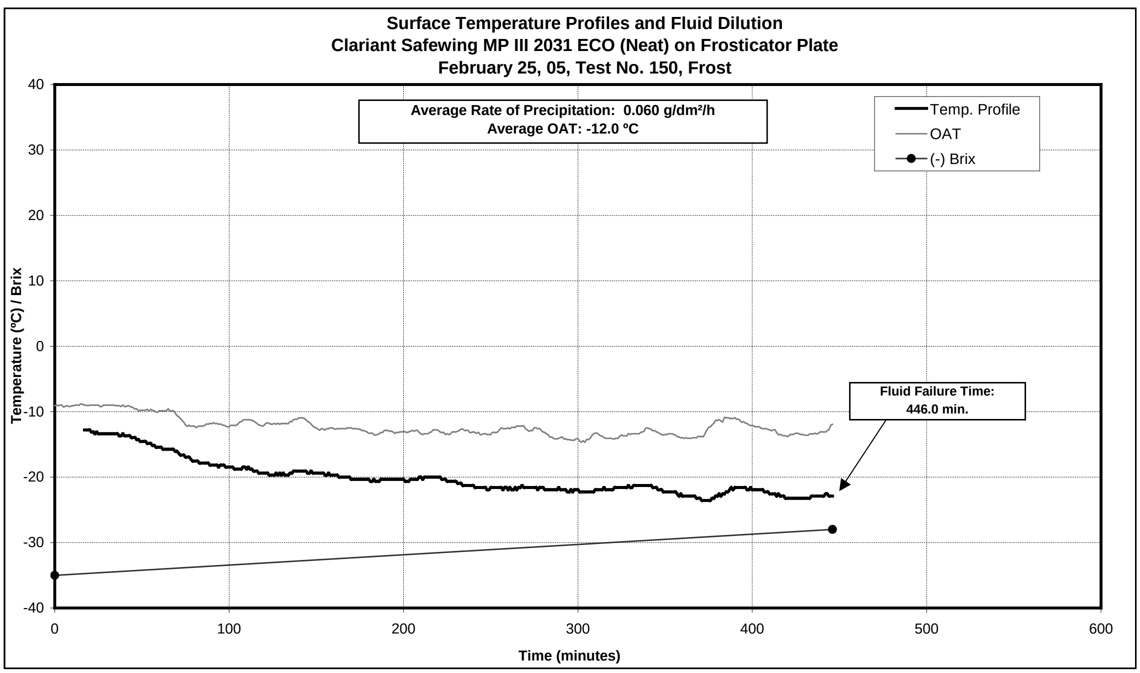

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP III 2031 ECO (Neat) on Frosticator Plate
February 2, 05, Test No. 134, Frost
Average Rate of Precipitation: 0.093 g/dm²/h
Average OAT: -6.1 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
540.5 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

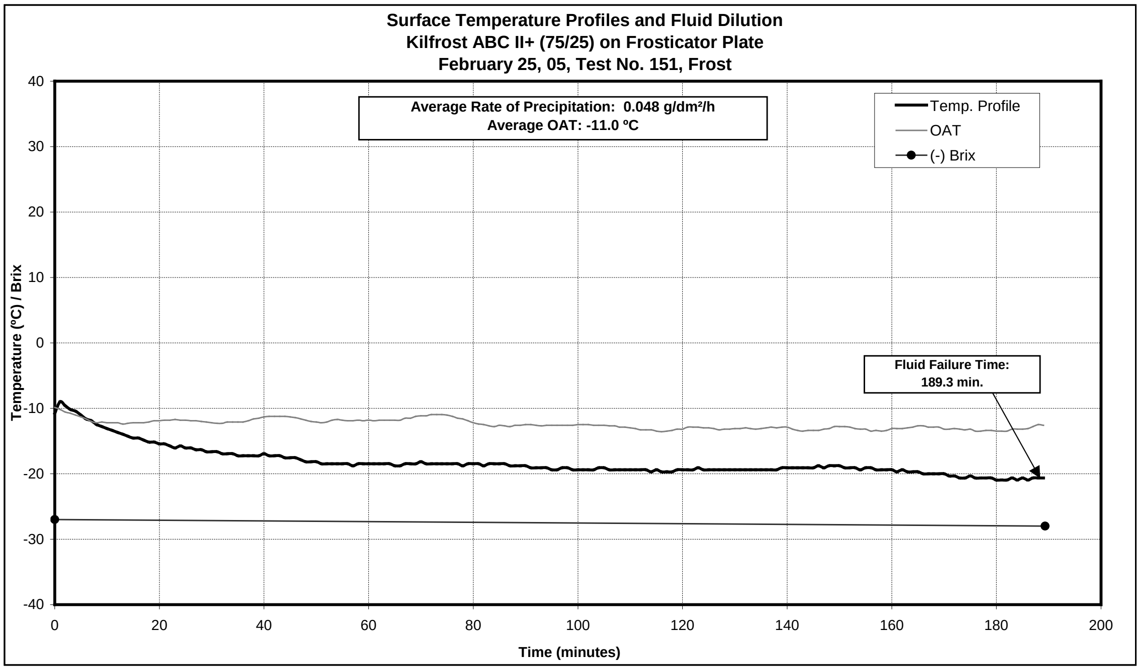

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP III 2031 ECO (Neat) on Frosticator Plate
February 4, 05, Test No. 142, Frost
Average Rate of Precipitation: 0.062 g/dm²/h
Average OAT: -3.8 ºC
Temp. Profile
OAT
(-) Brix
Fluid FailureTime:
488.8 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

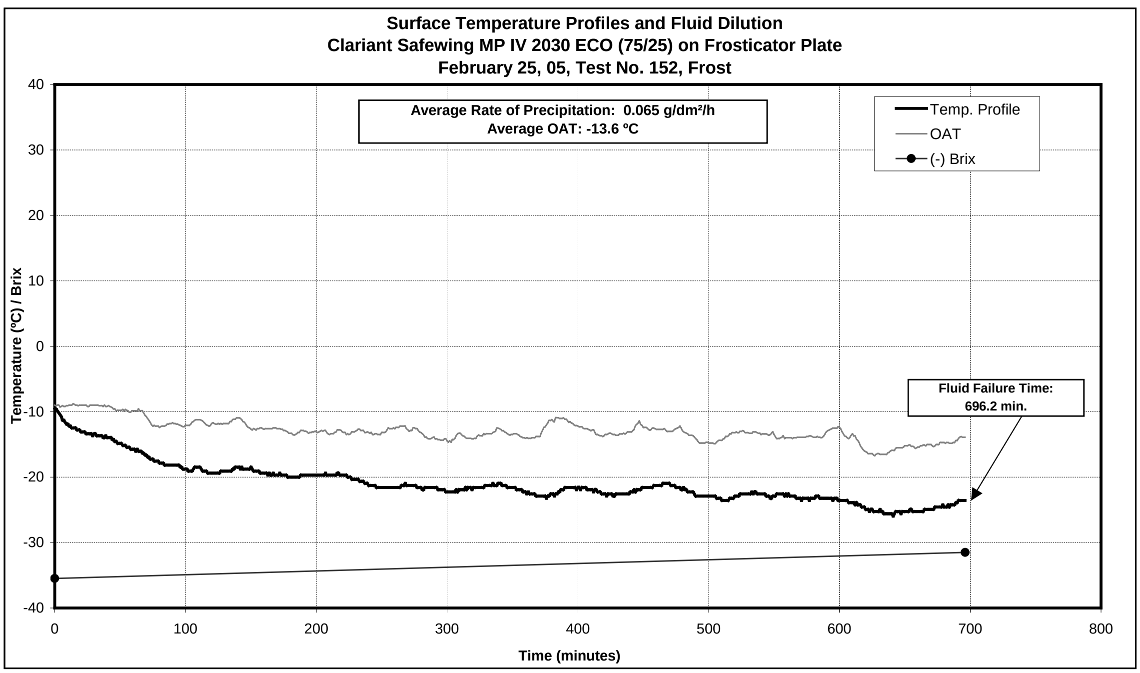

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC 2000 (Neat) on Frosticator Plate
February 25, 05, Test No. 146, Frost
Average Rate of Precipitation: 0.063 g/dm²/h
Average OAT: -13.0 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
624.2 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800

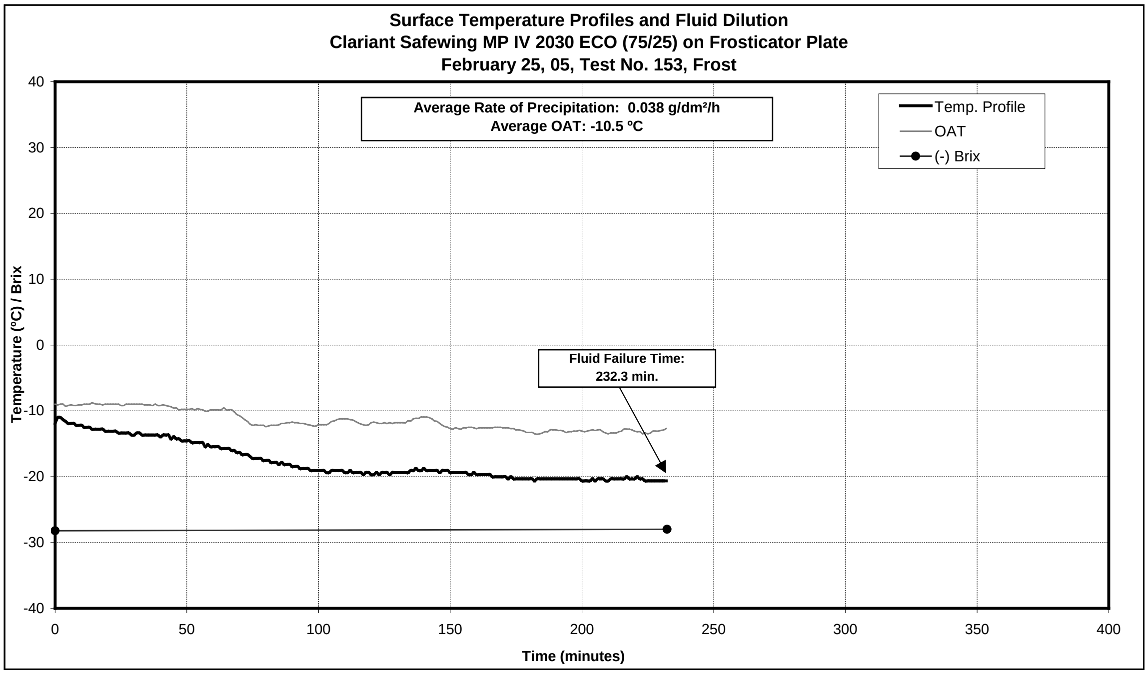

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC 2000 (75/25) on Frosticator Plate
February 25, 05, Test No. 147, Frost
Average Rate of Precipitation: 0.048 g/dm²/h
Average OAT: -11.0 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
204.5 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

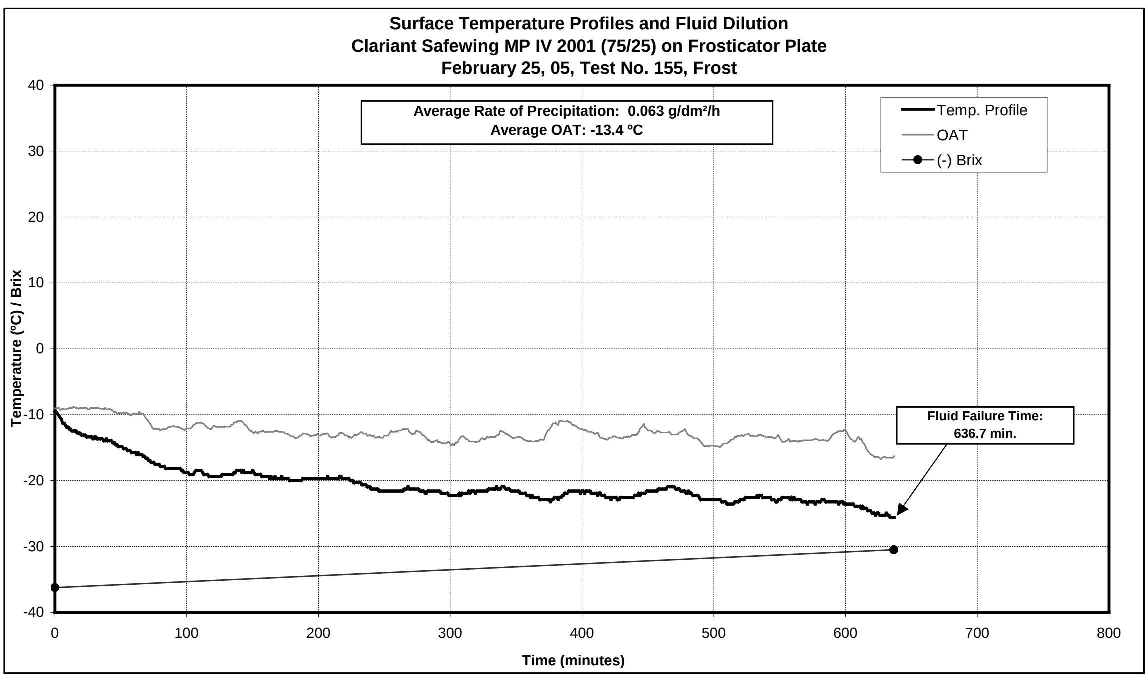

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP II 2025 ECO (75/25) on Frosticator Plate
February 25, 05, Test No. 149, Frost
Average Rate of Precipitation: 0.038 g/dm²/h
Average OAT: -10.5 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
245.7 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

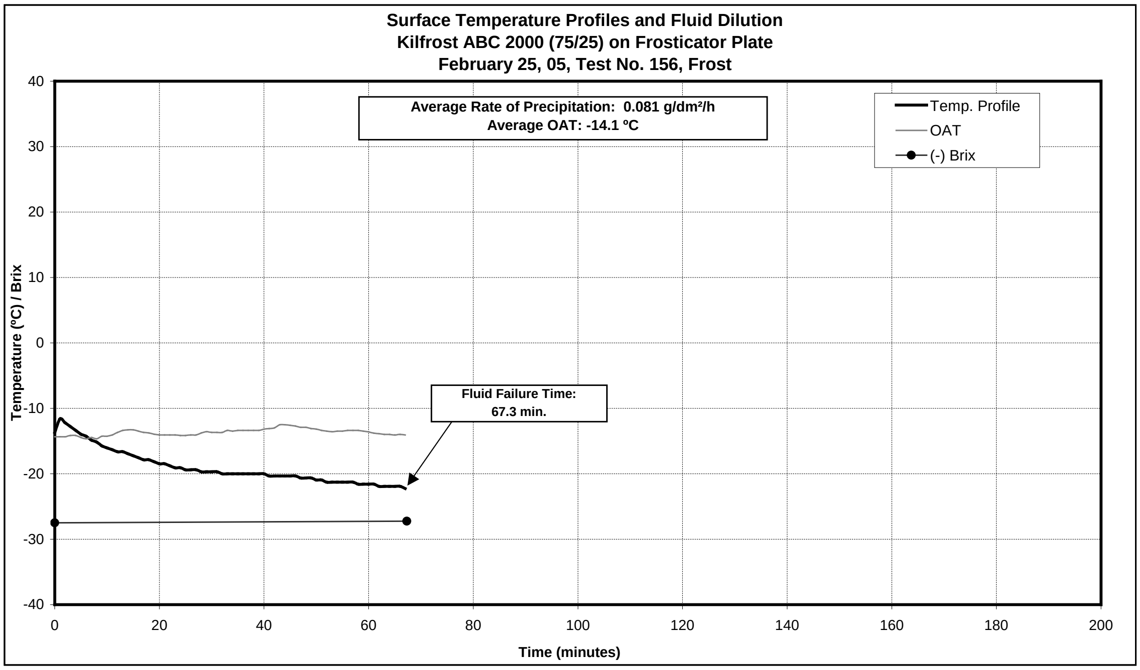

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP III 2031 ECO (Neat) on Frosticator Plate
February 25, 05, Test No. 150, Frost
Average Rate of Precipitation: 0.060 g/dm²/h
Average OAT: -12.0 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
446.0 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600

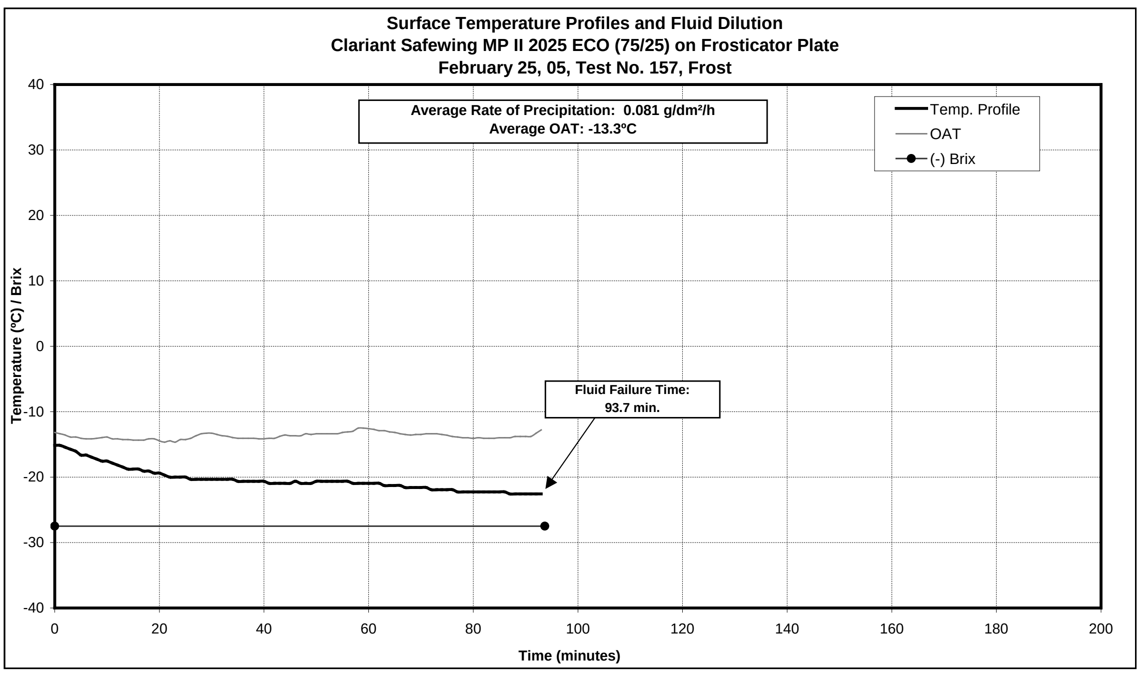

Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC II+ (75/25) on Frosticator Plate
February 25, 05, Test No. 151, Frost
Average Rate of Precipitation: 0.048 g/dm²/h
Average OAT: -11.0 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
189.3 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

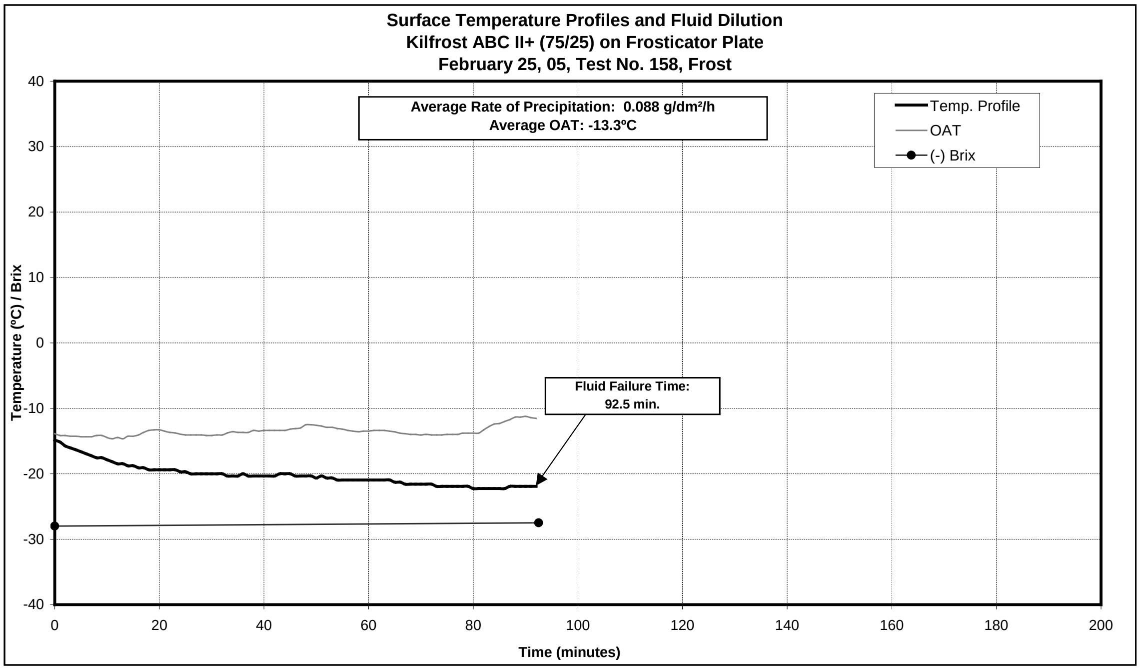

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2030 ECO (75/25) on Frosticator Plate
February 25, 05, Test No. 152, Frost
Average Rate of Precipitation: 0.065 g/dm²/h
Average OAT: -13.6 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
696.2 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800

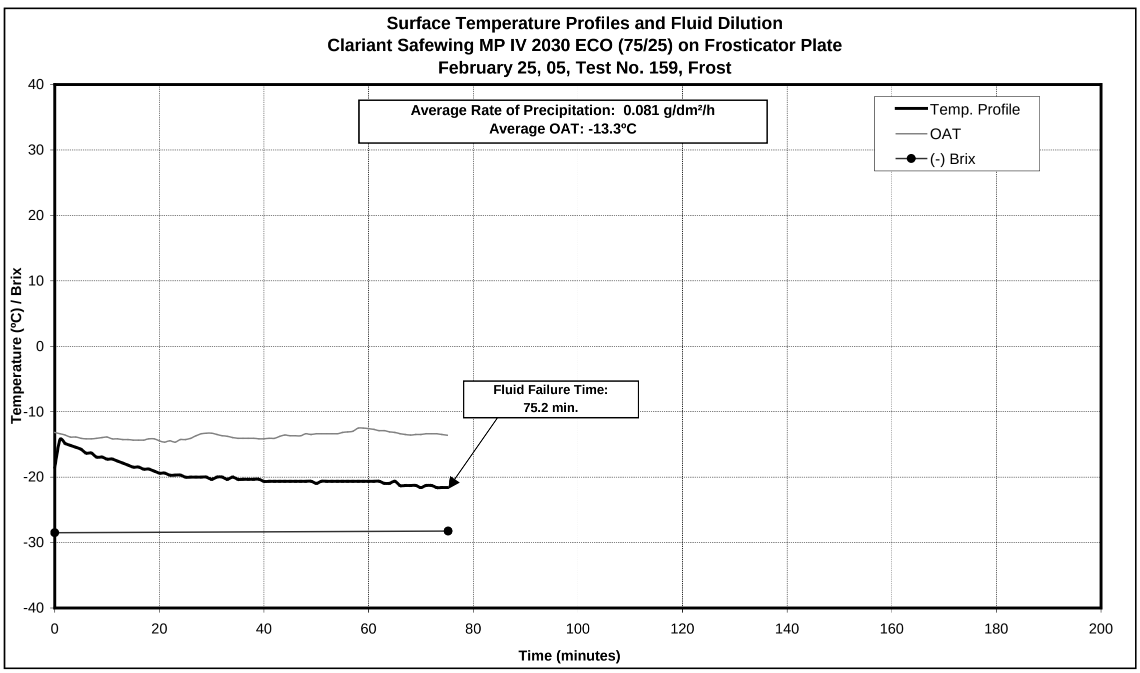

Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2030 ECO (75/25) on Frosticator Plate
February 25, 05, Test No. 153, Frost
Average Rate of Precipitation: 0.038 g/dm²/h
Average OAT: -10.5 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
232.3 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400


Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2001 (75/25) on Frosticator Plate
February 25, 05, Test No. 155, Frost
Average Rate of Precipitation: 0.063 g/dm²/h
Average OAT: -13.4 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
636.7 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
700
800


Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC 2000 (75/25) on Frosticator Plate
February 25, 05, Test No. 156, Frost
Average Rate of Precipitation: 0.081 g/dm²/h
Average OAT: -14.1 ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
67.3 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200


Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP II 2025 ECO (75/25) on Frosticator Plate
February 25, 05, Test No. 157, Frost
Average Rate of Precipitation: 0.081 g/dm²/h
Average OAT: -13.3ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
93.7 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200


Surface Temperature Profiles and Fluid Dilution
Kilfrost ABC II+ (75/25) on Frosticator Plate
February 25, 05, Test No. 158, Frost
Average Rate of Precipitation: 0.088 g/dm²/h
Average OAT: -13.3ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
92.5 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200


Surface Temperature Profiles and Fluid Dilution
Clariant Safewing MP IV 2030 ECO (75/25) on Frosticator Plate
February 25, 05, Test No. 159, Frost
Average Rate of Precipitation: 0.081 g/dm²/h
Average OAT: -13.3ºC
Temp. Profile
OAT
(-) Brix
Fluid Failure Time:
75.2 min.
Temperature (ºC) / Brix
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

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APPENDIX D

PROCEDURE
FULL SCALE VALIDATION OF FLAT PLATE ENDURANCE TIME TESTING IN FROST WITH TYPE II, III AND IV FLUIDS

BM5611.00

FULL SCALE VALIDATION OF FLAT PLATE ENDURANCE TIME TESTING IN FROST WITH TYPE II, III AND IV FLUIDS

Winter 2008-09

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

APS Aviation Inc.

December 29, 2008
Version 1.1

FULL SCALE VALIDATION OF FLAT PLATE ENDURANCE TIME TESTING IN FROST WITH TYPE II, III AND IV FLUIDS

Winter 2008-09

1. BACKGROUND

Frost is an important consideration in aircraft deicing. The irregular and rough frost accretion patterns can result in a significant loss of lift on critical aircraft surfaces. This potential hazard is amplified by the frequent occurrence of frost accretion during winter airport operations.

Ongoing research conducted by APS has led to the substantiation of fluid endurance times currently issued in the HOT Guidelines. The Type I holdover time of 45 minutes has been substantiated, and therefore no further testing is required. However, ongoing further analysis of Type II,III, and IV fluids is required. The procedure "*Experimental Program: Endurance Time Testing in Frost with Type I, II, III and IV Fluids*" has been developed to substantiate the HOTs in frost conditions of Type II, III, and IV fluids.

The endurance time data collected for Type II,III, and IV fluids indicated that several cells of the HOT tables may need to be reduced; this result is not surprising, as the current holdover times have been somewhat based upon high humidity tests, which are conducted at an air temperature of 0ºC. During several outdoor tests, fluid failure was experienced prematurely and occurred as a result of the fluid and plate temperature reaching the fluid freeze point; fluid dilution was minimal during these tests.

The option to issue a separate frost table has been suggested. The separate frost table would include changes to the temperature ranges to allow greater flexibility for fluid use and to minimize the number of HOT reductions. Use of fluid dilutions would not be restricted however HOT reductions would apply when nearing the fluid LOUT. The latest version of the proposed separate frost table, as it would appear in the HOT Guidelines if it were adopted, is demonstrated in Attachment I.

Additional testing is required for Type II, III, and IV fluids to substantiate the reduced endurance times recorded. In addition, it has been recommended that full scale testing be conducted in order to validate the HOT reductions observed during flat plate testing. This document outlines the procedure for a full scale wing correlation to the flat plate testing.

2. OBJECTIVES

The objective of this procedure is to perform a full-scale validation of the proposed HOT reduction in Type II, III and IV fluids. Moreover, the objective is to develop a correlation of plate failure to wing failure for thickened fluids in natural frost conditions. To achieve this objective a series of full-scale endurance time tests will be conducted simultaneously with flat plate tests in natural frost conditions. These full-scale endurance time tests will be completed on the Jetstar wing surface.

Testing will be conducted overnight during suitable frost conditions with representative Type II, III and IV fluids, both ethylene and propylene based. Tests shall be conducted over extended frost forecast periods with all dilutions. Tests on 2 to 3 nights are anticipated. Testing will be geared towards simulating freeze point failure with 75/25 dilutions close to LOUT of -14 °C.

Data on test surface temperature, ambient temperature and relative humidity will be collected simultaneously.

3. TEST REQUIREMENTS

3.1 Test Methodology

As mentioned in Section 2, the objective of this testing is to provide a validation of plate results and a correlation between the full-scale test surface and that of flat plate tests. The methodology used in this test is as follows:

- Ensure active frost conditions and OAT of -10°C to -14 °C;
- Apply fluid to a 2 foot wide chord of the Jetstar Wing;
- Apply same fluid to an insulated white painted flat plates;
- Monitor rate of frost accretion using two insulated white painted plates;
- Monitor wing surface temperature and plate temperature using hand-held thermistor probe or mounted thermistors;
- Measure endurance time on fluid covered plate surfaces and wing surfaces; and
- Measure fluid dilution (Brix), and if necessary fluid thickness.

Compare results obtained using the flat plates to the results obtained using the wing surfaces.

3.2 Test Plan and Location

It is anticipated that 2 to 3 nights of testing will be completed. Based on the location of the wing, testing will either be completed in Montreal or Smiths Falls, Ontario. This procedure will be used regardless of test location.

3.3 Ideal Test Condition

The ideal test condition should meet all of the following conditions:

- OAT near or below -10ºC
- Less than 10 km of wind; and
- Clear sky overnight.

On a given night, there may be up to 14 hours of possible frost. It should be noted that only 5-6 hours of strong active frost is required for this test. The tester should estimate the *best* 5-6 hours of frost on a given evening. In other words, the tester should find the best 5-6 hours that have both a strong frost rate and strong delta T. The suggested frost rate and delta T are as follows:

- *Strong Frost Rate:* Accumulation of 1 gram or more of Frost per hour.
- *Strong Delta T*: Plate Temperature is at least 6 ºC below OAT.

4. TEST SETUP

4.1 Frost Data Collection

Two independent frosticator plates will be setup on a two position stand in close proximity to both the flat-plate test stand and the Jetstar wing. Each frosticator plate will have a thermistor attached. Attached to this stand will be a Stevenson shield with three free-standing thermistors. This will provide OAT measurements throughout the test. A diagram of this setup can been seen in Figure 1.

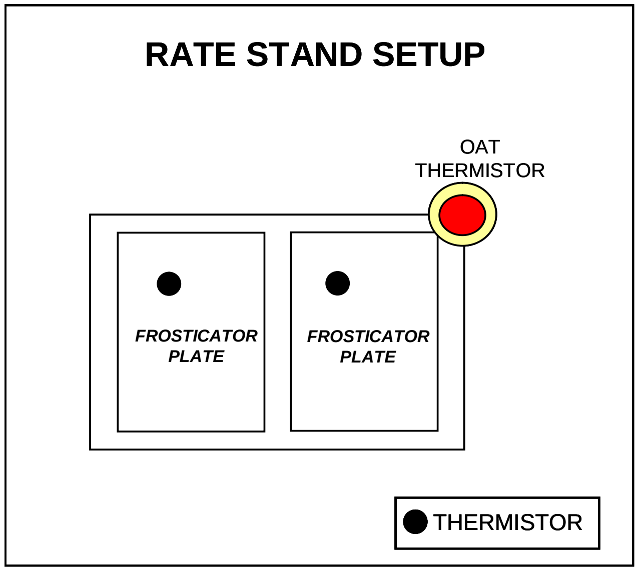


Figure 1: Frost Rate Collection Setup

4.2 Flat Plate Test Stand

Tests will be conducted on white-painted aluminum test surfaces, mounted at a 10º slope on a test stand. Each test surface will have a thermistor probe installed at the 15 cm line, inset 1/3 of the width. The test stand is to be placed in close proximity to the Jetstar wing. A diagram of this setup can be seen in Figure 2.

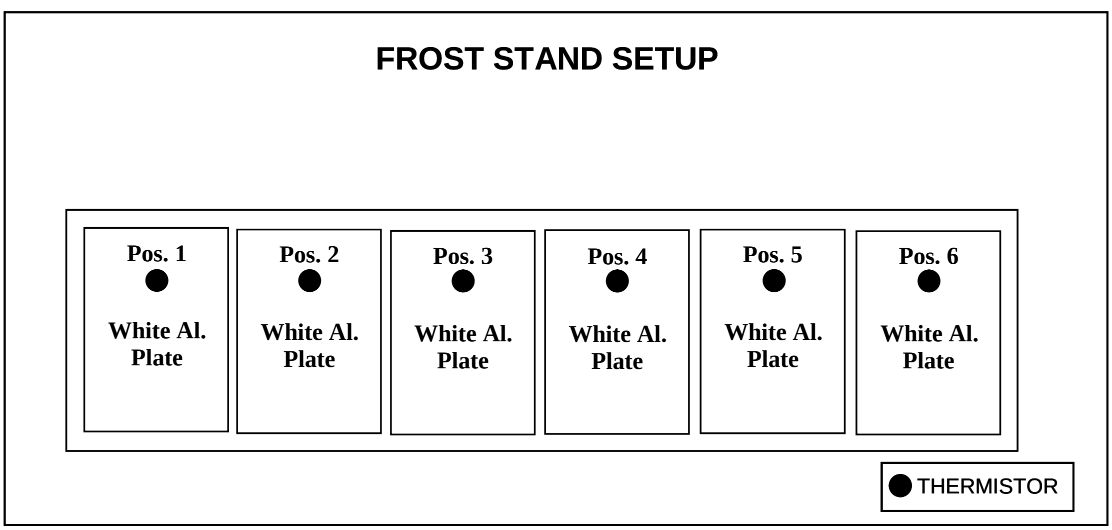


Figure 2: Frost Stand Setup

4.3 Full Scale Setup

Tests will be conducted on the Jetstar test wing. The wing will be divided into 4 main chords. There will be sufficient separation between chords to prevent cross contamination. Approximately 10 litres of fluid will be applied to each chord. A diagram of this setup can be seen in Figure 3.

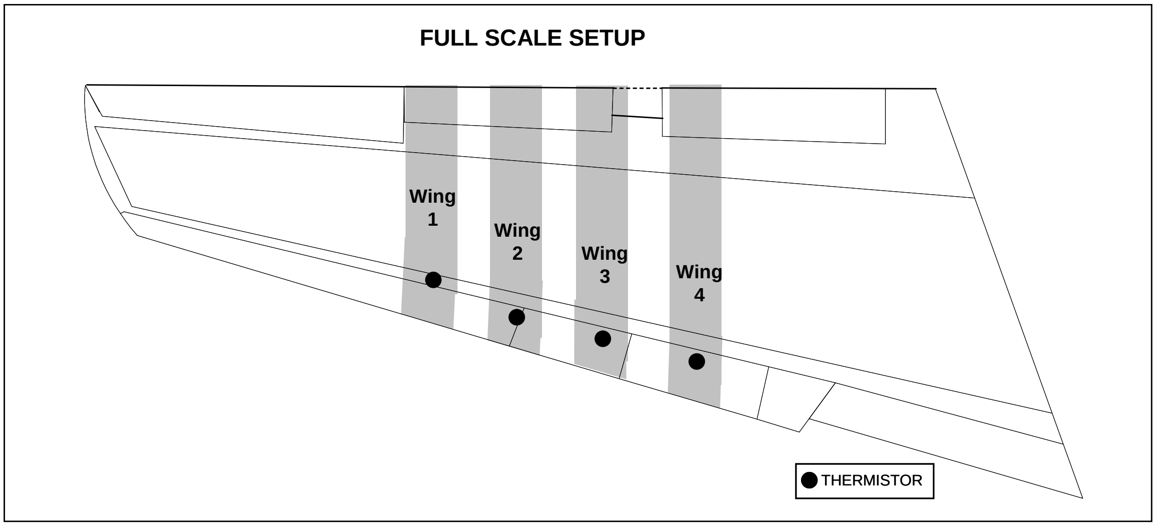


Figure 3: Full Scale Setup

5. PROCEDURE

Two procedures are provided below:

a) Frost rate data collection; and

b) Fluid endurance tests in frost (Flat Plate and Full Scale).

5.1 Procedure for Frost Data Collection

1) Monitor weather forecasts to select a time for testing. The ideal conditions for the development of frost are:

   a) OAT near or below -10ºC and expected to stay above or near -14 ºC;

   b) Less than 10 km of wind; and

   c) Clear sky overnight.

2) At the beginning of the data gathering session:
   a) Ensure the test surface is clean;
   b) Clear the data logger and ensure that new data is logging. Synchronize time on all data collection devices. Label loggers and computer files indicating date of test;
   c) Zero the scale and record the time on the data sheet;
   d) Verify and record initial weight of each frosticator plate; and
   e) Record Time and place plates on stand.
3) At 30-minute intervals, record data as follows:
   a) Verify the surface temperature from the real time readings displayed on the computer screen, prior to removing the plate from the stand for weighing;
   b) Reweigh the test surface, recording weight and time; and
   c) The two surfaces collecting frost will be used in a staggered routine.
4) At the end of the data gathering session:
   a) Download the data from data logger to the PC, and check to ensure that data is saved. Label files indicating date of test; and
   b) Provide a copy of data files (by e-mail) to APS for project record where they will be saved to the network.

5.2 Procedure for Fluid Endurance Tests (Flat Plate and Full Scale)

5.2.1 *Test Matrix*

Tests will be conducted with representative Type II, III and IV fluids. Attachment II depicts this test matrix.

5.2.2 *Procedure*

1. At the beginning of test session:
   a) Ensure all timepieces are synchronized;
   b) Clean and prepare test plates and test wing by wiping down with Isopropyl;
   c) Clear the data logger and ensure that new data is logging. Synchronize time on all data collection devices. Label loggers and computer files indicating date of test; and

d) Indicate initial brix of each fluid.

2. Application of Fluid:

   a) Ensure all timepieces are synchronized;

   b) Apply 1 litre of Fluid to test plate and 10 litres of fluid to corresponding wing chord as prescribed in test Plan; and

   c) Indicate time of Application.

3. End of Test:

   a) Indicate failure on both test surface and wing surface; and

   b) Indicate final brix.

6. EQUIPMENT

6.1 Equipment for Frost Data Collection

The equipment required to collect frost rates includes:

a) An electronic balance;

b) Two white-painted aluminum test plates with one thermistor probe installed at the 15 cm line, linked to the thermistor logger. The aluminum speed tape used to secure the probes tape is to be painted white to match the emissivity property of the white-painted plates. A small bottle of automotive touch-up paint can be used for this;

c) Three screened thermistor probes to measure air temperature linked to the thermistor logger; and

d) An electronic balance with a digital output (optional).

6.2 Equipment for Frost Endurance Tests

Standard equipment used for Type I and Type II/IV outdoor endurance time tests outdoors will be used, with the exception that the test surfaces will be white-painted insulated aluminum plates. The surfaces will be instrumented with a thermistor probe installed at the 15 cm line, linked to the logger.

6.3 Equipment for Full Scale Tests

The JetStar test wing will be used on the full scale setup. The surface will be instrumented with thermistor probes installed at approximately 35 centimetres in from the leading edge.

6.4 Equipment List

See Attachment III.

7. DATA FORMS

For frost rate data collection, see Attachments IV
For fluid endurance tests in frost, see Attachment V

8. PERSONNEL

Two APS personnel will be required. In the event that this test is conducted "airside" in Montreal, escorts will be needed. Security SEA 2000 International will be employed.

Security Escorts
SEA 2000 International
(514) 633-0718

ATTACHMENT I
SAE TYPE I[1], II, III, IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes) — Active Frost			
Degrees Celsius	**Degrees Fahrenheit**		**Type I[2]**	**Type II**	**Type III**	**Type IV**
above -1	above 30	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 1:30	0:30	3:00
below -3 to -7	below 27 to 19	100/0		8:00	2:00	~~12:00~~ 10:00
		75/25		5:00	1:00	5:00
below -7 to -14	below 19 to 7	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00
below -14 to -21	below 7 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
below -21 to -25	below -6 to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 4:00

NOTES (TO BE DEVELOPPED FURTHER)

1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.

2 May be used below -25°C (-13°F) provided the LOUT of the fluid is respected.

CAUTIONS (TO BE DEVELOPPED FURTHER)

- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

ATTACHMENT II
TEST MATRIX

TEST MATRIX		NUMBER OF TESTS	
FLUID	DILUTION	below -10 to -14 ºC	-21 ºC or below
EcoWing 26	100		1
	75	3	
Clariant MPIII 2031	100		1
	75	3	
Kilfrost ABC 2000	100		1
	75	3	
Kilfrost ABC-S	100		1
	75	3	

ATTACHMENT III
EQUIPMENT LIST

FROST RATE DATA COLLECTION	**Number**
2-position test stand	1
White-painted aluminum test plate with insulated backing	2
Thermistor probes to be installed at the 15 cm line, one on each plate	2
Thermistor probes with shield, for air temperature	1
Thermistor probe logger	1
Thermistor probe logger/PC cable	1
Weigh scale (accuracy of 0.1 g or better)	1
Data forms	Sufficient Amount
PC or laptop	1
Electrical extension cord for weigh scale	1
FLUID ENDURANCE TESTS IN FROST	
White-painted aluminum test plate with insulated backing	6
2 x 3-position test stand	1
Thermistor probes to be installed at the 15 cm line, one on each plate	6
Thermistor probe logger	1
FULL SCALE TESTS IN FROST	
Jetstar Wing	1
Ladder	1
Thermistor probes to be installed	6
Thermistor probe logger	1
General Equipment	
Brixometer	1
Fluid thermometer	1
Inclinometer	1
Rate Stand Collection Pans	2
Tarp for Run-off Fluid (Wing Tests)	1
Vacuum for Fluid Cleanup	1

ATTACHMENT IV
DATA FORM
FROST RATES ON TEST SURFACES

Date **Location**
Recorded by **Signature**

Surface	Time Before (Hr:min)	Time After (Hr:min)	Weight Before (g)	Weight After (g)	Computed Rate (g/dm2/h)
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					
1					
2					

INSTRUCTIONS:

1. Measure wind with handheld anemometer at 2 m above ground.
2. Measure OAT and RH with Vaisala instrument.

ATTACHMENT V
DATA FORM
END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH MSC - USE LOCAL TIME

LOCATION:	DATE:	RUN NUMBER:	STAND # :

PLATE TESTS

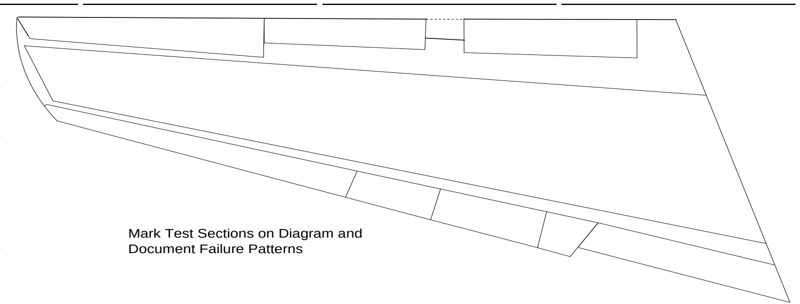
	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Initial Brix						
Time of Fluid Application:						
FLUID NAME/DILUTION						
Final Brix						

FULL SCALE TESTS

	Wing Position 1	Wing Position 2	Wing Position 3	Wing Position 4	Wing Position 5	Wing Position 6
Initial Brix						
Time of Fluid Application:						
FLUID NAME/DILUTION						
Final Brix						

AMBIENT TEMPERATURE: ________ °C

COMMENTS: ______________________



WRITTEN & PERFORMED BY : ______________________

DATE: ______________________

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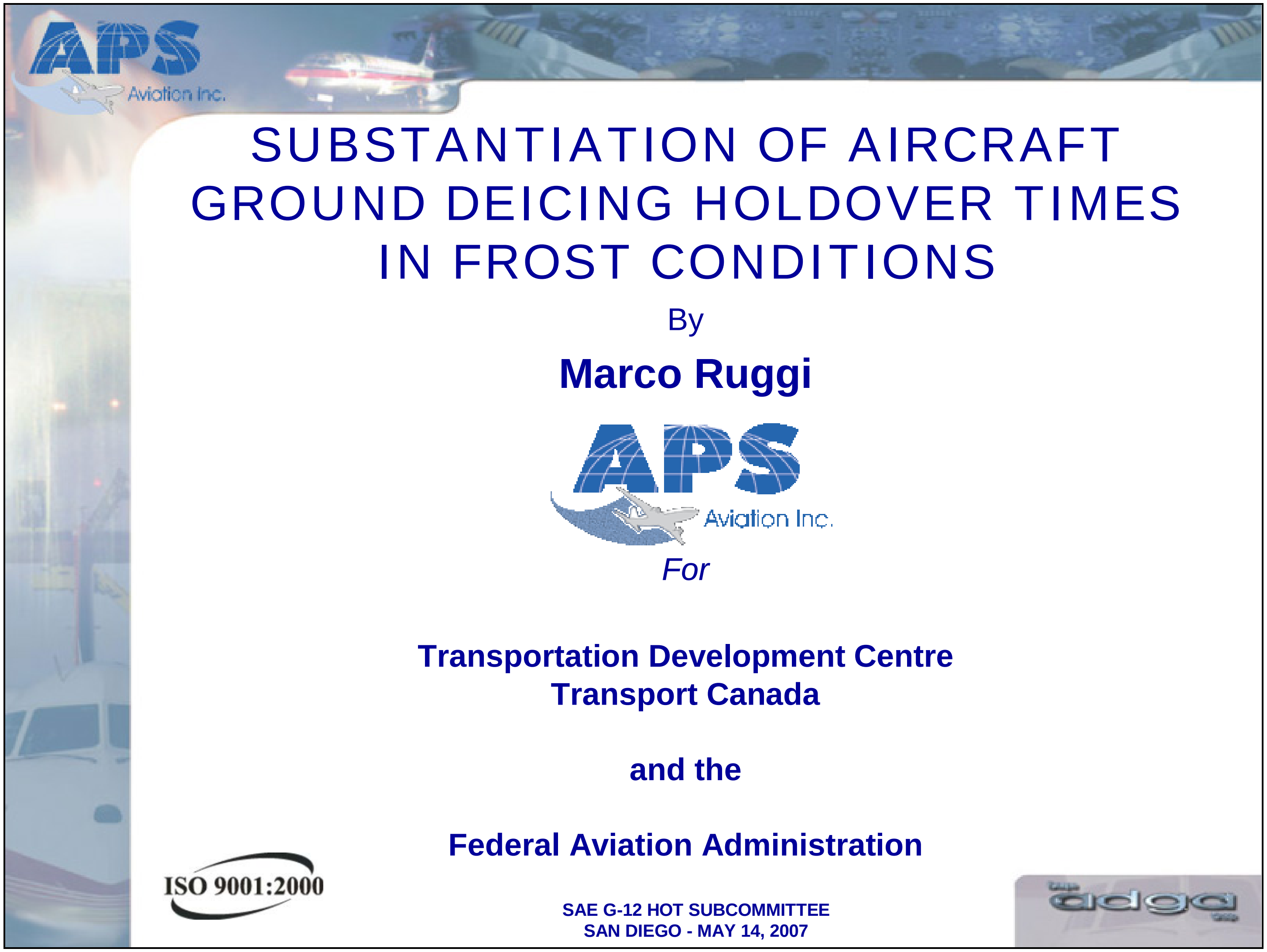
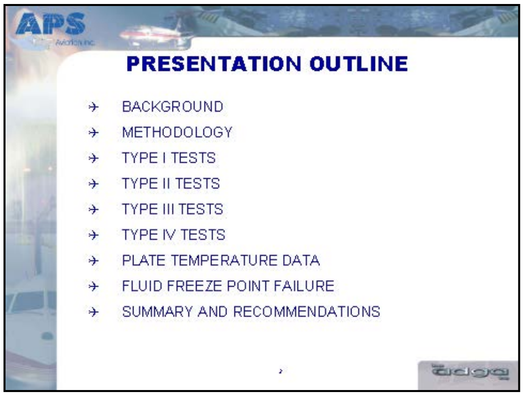
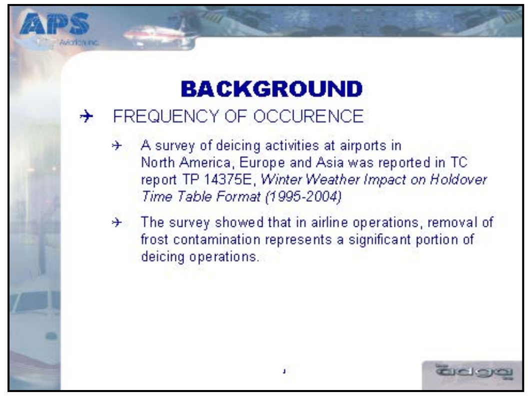
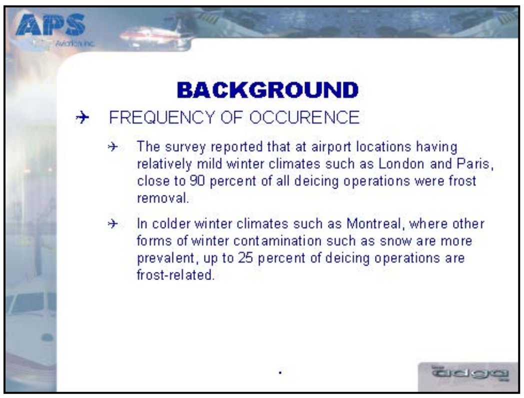
APPENDIX E

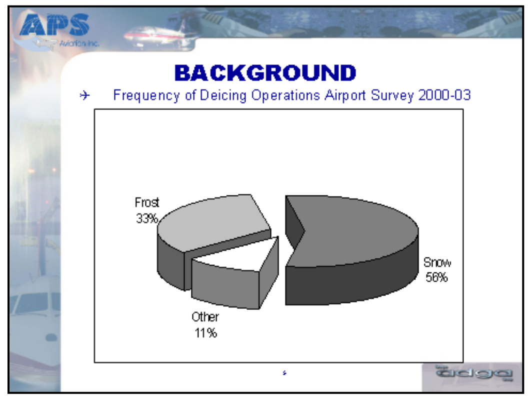
PRESENTATION: SUBSTANTIATION OF AIRCRAFT GROUND DEICING HOLDOVER TIMES IN FROST CONDITIONS – SAN DIEGO, MAY 2007

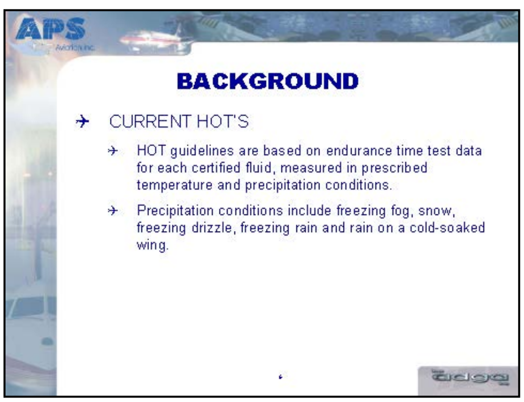

SUBSTANTIATION OF AIRCRAFT GROUND DEICING HOLDOVER TIMES IN FROST CONDITIONS
By
Marco Ruggi
APS Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000
SAE G-12 HOT SUBCOMMITTEE
SAN DIEGO - MAY 14, 2007
adga

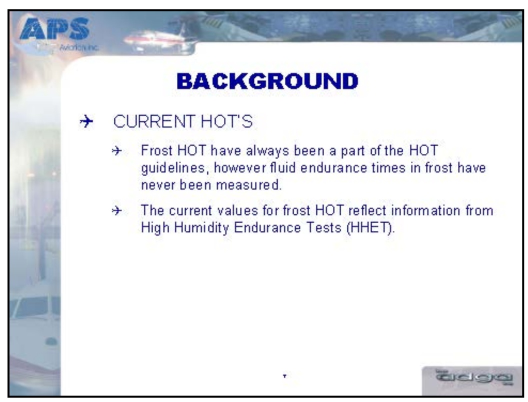

APS
PRESENTATION OUTLINE
BACKGROUND
METHODOLOGY
TYPE I TESTS
TYPE II TESTS
TYPE III TESTS
TYPE IV TESTS
PLATE TEMPERATURE DATA
FLUID FREEZE POINT FAILURE
SUMMARY AND RECOMMENDATIONS


APS
BACKGROUND
FREQUENCY OF OCCURENCE
A survey of deicing activities at airports in North America, Europe and Asia was reported in TC report TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004)*
The survey showed that in airline operations, removal of frost contamination represents a significant portion of deicing operations.


APS
BACKGROUND
FREQUENCY OF OCCURENCE
The survey reported that at airport locations having relatively mild winter climates such as London and Paris, close to 90 percent of all deicing operations were frost removal.
In colder winter climates such as Montreal, where other forms of winter contamination such as snow are more prevalent, up to 25 percent of deicing operations are frost-related.


APS
BACKGROUND
Frequency of Deicing Operations Airport Survey 2000-03
Frost
33%
Snow
56%
Other
11%


APS
BACKGROUND
CURRENT HOT'S
HOT guidelines are based on endurance time test data for each certified fluid, measured in prescribed temperature and precipitation conditions.
Precipitation conditions include freezing fog, snow, freezing drizzle, freezing rain and rain on a cold-soaked wing.


APS
BACKGROUND
CURRENT HOT'S
Frost HOT have always been a part of the HOT guidelines, however fluid endurance times in frost have never been measured.
The current values for frost HOT reflect information from High Humidity Endurance Tests (HHET).

BACKGROUND

- CURRENT HOT'S

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water	Approximate Holdover Times Under Various (hours:minutes)			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Active Frost			
			Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -3 to -14	below 27 to 7	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
below -14 to -25	below 7 to -13	100/0		8:00	2:00	12:00

BACKGROUND

- CURRENT HOT'S
  - Previous indoor laboratory attempts to substantiate current HOT showed some questionable discrepancies in the results
    - Testing conducted at Institut de Recherche d'Hydro-Québec (IREQ)
  - It was recommended that outdoor testing in natural frost conditions be conducted for Type I,II,III,IV fluids

PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

METHODOLOGY

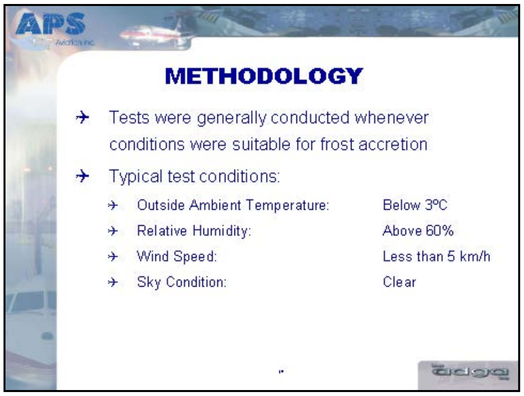
- Fluid endurance time testing in frost conditions was conducted using standard aluminum test plates painted white using aircraft grade paint.
- An insulation backing was mounted onto each white-painted test plate to avoid heat exchange via the underside
- Testing frost production on this surface was found to be representative of aircraft wing surfaces, where only the skin surface is exposed.
  - Previous full-scale validation of the test surfaces was conducted by APS

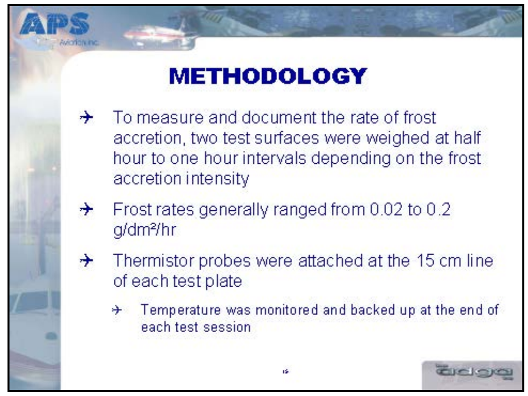
METHODOLOGY

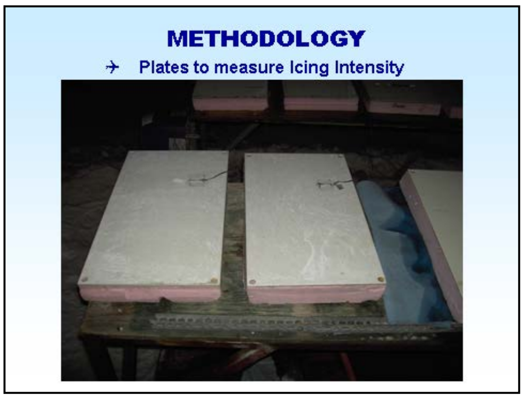
- Frost Plate with Insulated Backing

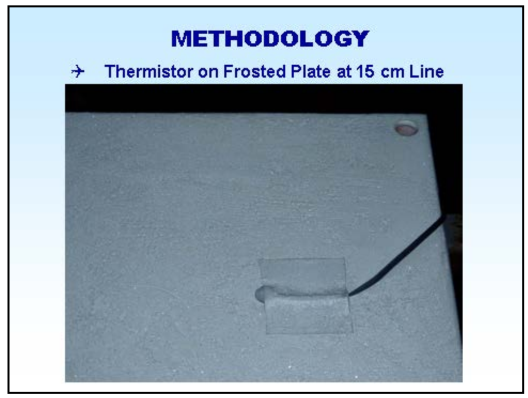
METHODOLOGY

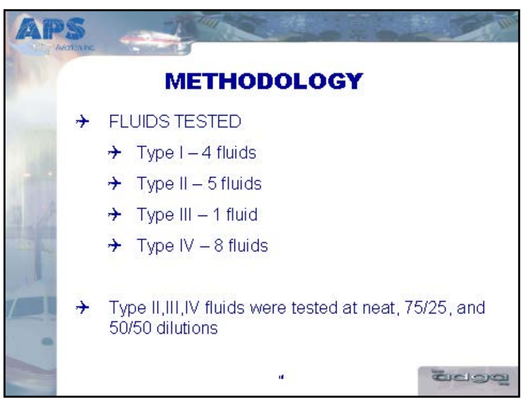
- Test Stand with Insulated Frost Test Plates

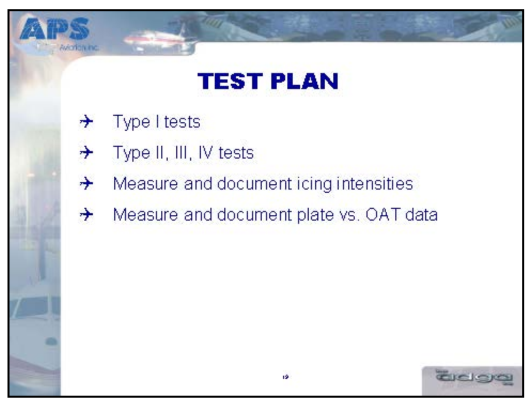

APS
METHODOLOGY
Tests were generally conducted whenever conditions were suitable for frost accretion
Typical test conditions:
Outside Ambient Temperature: Below 3ºC
Relative Humidity: Above 60%
Wind Speed: Less than 5 km/h
Sky Condition: Clear


APS
METHODOLOGY
To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity
Frost rates generally ranged from 0.02 to 0.2 g/dm²/hr
Thermistor probes were attached at the 15 cm line of each test plate
Temperature was monitored and backed up at the end of each test session


METHODOLOGY
Plates to measure Icing Intensity


METHODOLOGY
Thermistor on Frosted Plate at 15 cm Line


APS
METHODOLOGY
FLUIDS TESTED
Type I – 4 fluids
Type II – 5 fluids
Type III – 1 fluid
Type IV – 8 fluids
Type II,III,IV fluids were tested at neat, 75/25, and 50/50 dilutions


APS
TEST PLAN
Type I tests
Type II, III, IV tests
Measure and document icing intensities
Measure and document plate vs. OAT data

PRESENTATION OUTLINE

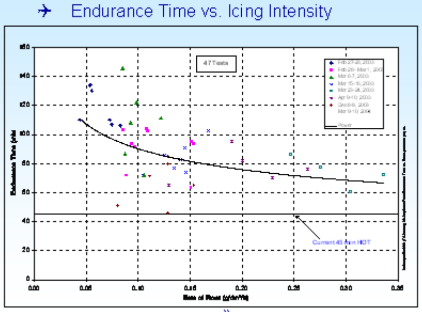
- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

TYPE I TESTS

- Forty-seven tests were conducted outdoors using insulated white-painted aluminum surfaces during two winter seasons
- Testing was conducted with 4 Type I fluids
- A review of the measured test conditions indicated that the data set was generally comprehensive and representative of the natural environment.

TYPE I TESTS

- Endurance Time vs. Icing Intensity



TYPE I TESTS

- CONCLUSION
  - The test results show that the measured endurance times do not violate the long used HOT of 45 minutes.
  - Two tests produced endurance times that came close to 45 minutes
  - Based on the data collected, the Type I HOTs have been substantiated.
  - A note will be included in ARP 5945 indicating that testing is not required for frost if the fluid meets the certification requirements

PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

TYPE II TESTS

- 62 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 26 tests were stopped due to fluid failure
  - 36 tests were stopped prior to fluid failure
    - 34 tests did not fail before sunrise
    - 2 tests stopped due to rising wind conditions
- Testing was conducted with 5 Type II fluids

TYPE II TESTS

- Frost HOT Values and Endurance Time Test Results

OAT (°C)	Concentration	Type II		
		Current HOT Time (hours)	Failed Tests (hours)	Stopped Tests (hours)
Above -3	100/0	8.0		11.6, 10.8, 12.2, 12.4
	75/25	5.0	7.4	11.6, 10.0, 11.8, 11.8
	50/50	3.0	6.1, 1.9	10.0, 11.8
Below -3 to -14	100/0	8.0	9.5, 10.5, 10.4, 11.9	9.5, 13.6, 13.5, 13.3, 12.8, 12.9, 12.8, 12.9, 12.8, 11.6
	75/25	5.0	8.2, 9.5, 6.7, 3.3, 3.1, 3.1, 2.2, 2.5, 2.5, 3.4, 4.1, 3.2, 1.6, 1.5, 1.1, 4.5, 3.7	10.7, 13.3, 13.3, 12.8, 12.7, 5.5, 12.9, 12.8
Below -14 to -25	100/0	8.0	8.0, 8.0	7.9, 7.8, 12.8, 12.8, 12.8, 12.7, 12.7

TYPE II TESTS

- Frost HOT Values and Endurance Time Test Results

OAT (°C)	Concentration	Type II		
		Current HOT Time (hours)	Failed Tests (hours)	Stopped Tests (hours)
Above -3	100/0	8.0		11.6, 10.8, 12.2, 12.4
	75/25	5.0	7.4	11.6, 10.0, 11.8, 11.8
	50/50	3.0	6.1, 1.9	10.0, 11.8
Below -3 to -14	100/0	8.0	9.5, 10.5, 10.4, 11.9	9.5, 13.6, 13.5, 13.3, 12.8, 12.9, 12.8, 12.9, 12.8, 11.6
	75/25	5.0	8.2, 9.5, 6.7, 3.3, 3.1, 3.1, 2.2, 2.5, 2.5, 3.4, 4.1, 3.2, 1.6, 1.5, 1.1, 4.5, 3.7	10.7, 13.3, 13.3, 12.8, 12.7, 5.5, 12.9, 12.8
Below -14 to -25	100/0	8.0	8.0, 8.0	7.9, 7.8, 12.8, 12.8, 12.8, 12.7, 12.7

APS Aviation Inc.

TYPE II TESTS

- OBSERVATIONS
  - 15 tests showed reductions in comparison to current Type II frost values issued in the HOT Guidelines
  - Discrepancy in endurance times was attributed to fluid freeze point issues for 14 of the 15 tests
    - To be discussed in detail later in the presentation
  - Indoor laboratory frost tests previously conducted also indicated reduced endurance times at colder temperatures

APS Aviation Inc.

PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

APS Aviation Inc.

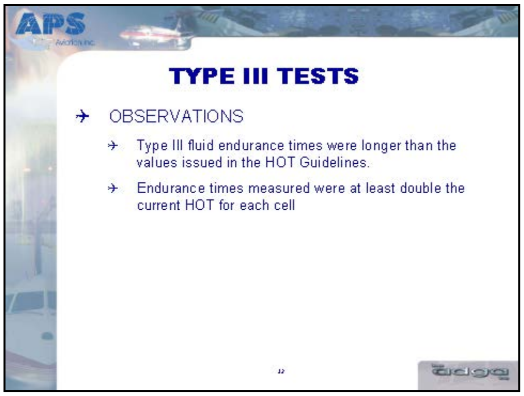
TYPE III TESTS

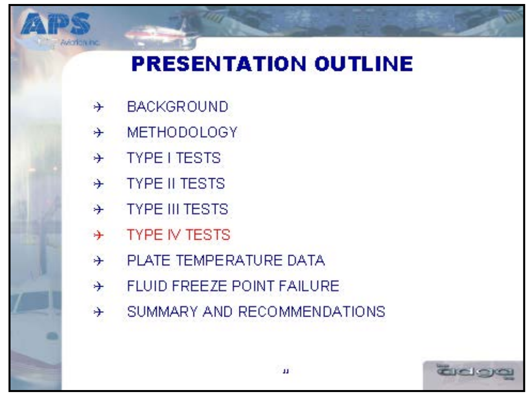
- 16 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 13 tests were stopped due to fluid failure
  - 3 tests were stopped prior to fluid failure
    - 2 tests did not fail before sunrise
    - 1 test stopped due to rising wind conditions
- Testing was conducted with 1 Type III fluid

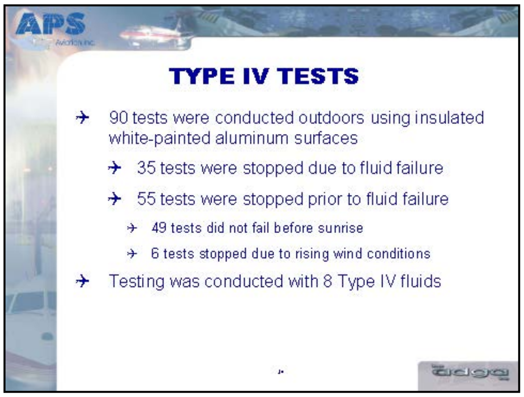
TYPE III TESTS

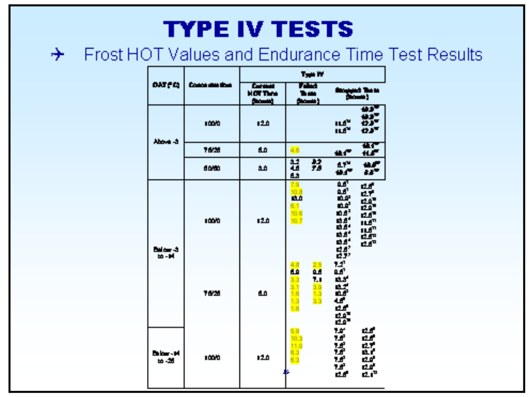
- Frost HOT Values and Endurance Time Test Results

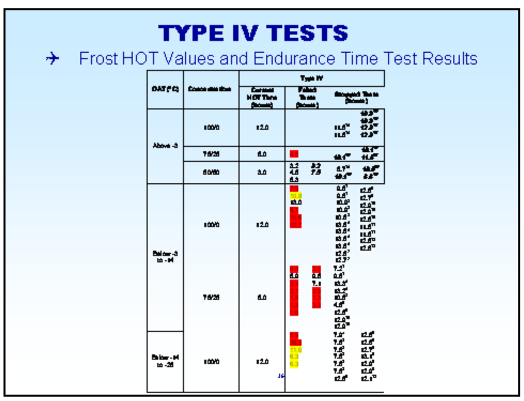
OAT (°C)	Concentration	Type III		
		Current HOT Time (hours)	Failed Tests (hours)	Stopped Tests (hours)
Above -3	100/0	2.0	4.7	
	75/25	1.0	5.2	
	50/50	0.5	3.0, 1.4	
Below -3 to -14	100/0	2.0	5.8, 4.6, 9.0, 8.1, 7.4, 8.6	
	75/25	1.0	3.5	
Below -14 to -25	100/0	2.0	5.4, 5.3	7.8, 12.6, 7.3

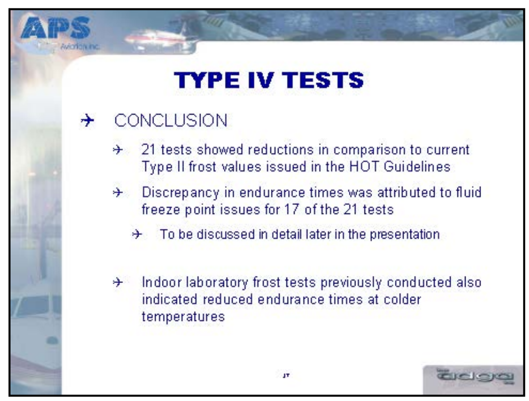

APS
TYPE III TESTS
OBSERVATIONS
Type III fluid endurance times were longer than the values issued in the HOT Guidelines.
Endurance times measured were at least double the current HOT for each cell


APS
PRESENTATION OUTLINE
BACKGROUND
METHODOLOGY
TYPE I TESTS
TYPE II TESTS
TYPE III TESTS
TYPE IV TESTS
PLATE TEMPERATURE DATA
FLUID FREEZE POINT FAILURE
SUMMARY AND RECOMMENDATIONS


APS
TYPE IV TESTS
90 tests were conducted outdoors using insulated white-painted aluminum surfaces
35 tests were stopped due to fluid failure
55 tests were stopped prior to fluid failure
49 tests did not fail before sunrise
6 tests stopped due to rising wind conditions
Testing was conducted with 8 Type IV fluids


TYPE IV TESTS
Frost HOT Values and Endurance Time Test Results


TYPE IV TESTS
Frost HOT Values and Endurance Time Test Results


APS
TYPE IV TESTS
CONCLUSION
21 tests showed reductions in comparison to current Type II frost values issued in the HOT Guidelines
Discrepancy in endurance times was attributed to fluid freeze point issues for 17 of the 21 tests
To be discussed in detail later in the presentation
Indoor laboratory frost tests previously conducted also indicated reduced endurance times at colder temperatures

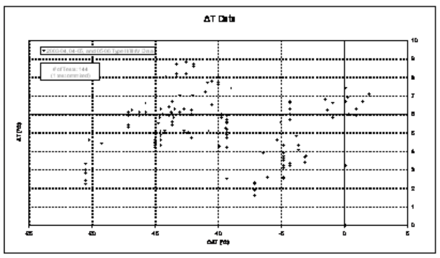
PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

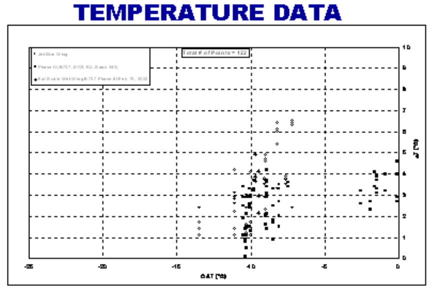
PLATE TEMPERATURE DATA

- OAT and test plate surface temperature were constantly monitored during each test
- Data collected demonstrated that during frost conditions the plate and OAT temperature differential could range from 2ºC to 9ºC.
- Full-scale aircraft wing surface temperatures collected by APS in frost conditions showed temperature differentials that reached up to 6.5ºC

PLATE TEMPERATURE DATA



AIRCRAFT SKIN TEMPERATURE DATA



PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

FLUID FREEZE POINT FAILURE

- A reduction in the Type II and Type IV fluid endurance was experienced when approaching fluid LOUT
  - Occurred with neat and diluted fluids
- Once the OAT would begin to approach fluid LOUT , the plate surface temperature would cool closer to the fluid freeze point
- Fluid failure occurred primarily because the surface temperature of the test plate reached the fluid freeze point
  - Fluid dilution and erosion did not significantly contribute to the failure

FLUID FREEZE POINT FAILURE

- EXAMPLE OF FLUID FREEZE POINT FAILURE IN FROST
  - Type IV 75/25 Fluid
  - OAT = **-13.9°C**
  - Plate Temperature = -13.9°C – (9°C) = **-22. 9°C**
  - Fluid Freeze Point = **-21°C**
    - Fluid would be designed with 7°C buffer based on LOUT of -14°C
  - **Fluid experiences contamination as ice crystals begin to form sporadically in fluid**

FLUID FREEZE POINT FAILURE

- EXAMPLE OF FLUID FREEZE POINT FAILURE IN FROST

Type II/IV Dilution	LOUT	Approximate FFP	Possible Surface Temp. During Frost Conditions at LOUT
Neat	-25	-36	-34
75/25	-14	-21	-23
50/50	-3	-10	-12

FLUID FREEZE POINT FAILURE

- The HOT table provides operational ranges specifying limits based on OAT.
- In frost conditions, the skin temperature of an aircraft may be several degrees lower than the OAT
- If operating with a fluid close to the LOUT during frost conditions, the skin temperature of the aircraft could reach the fluid freeze point potentially causing ice to form in the fluid

PRESENTATION OUTLINE

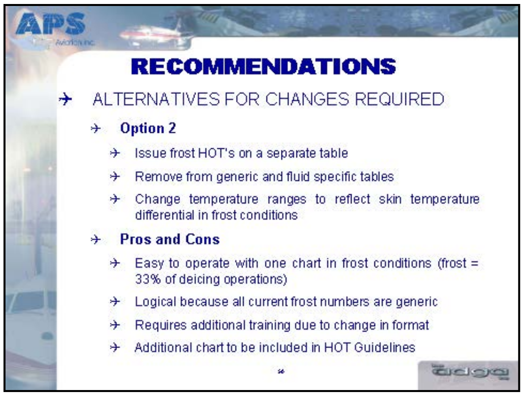
- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

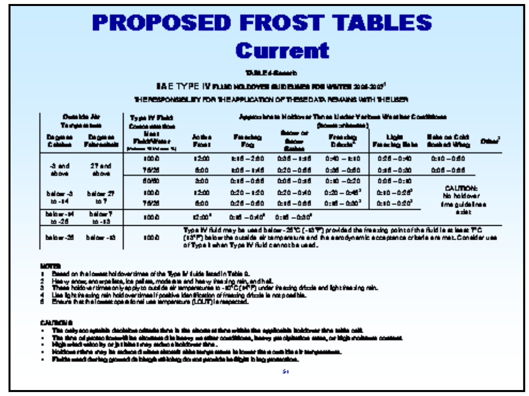
SUMMARY OF RESULTS

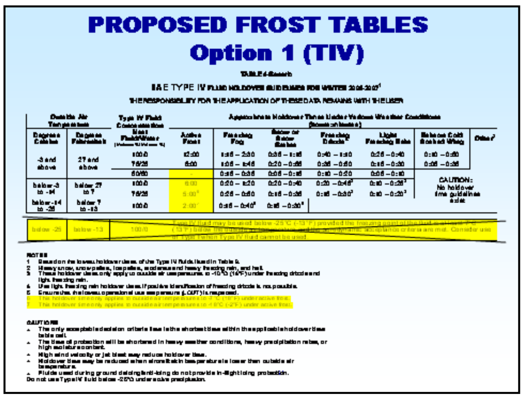
- TYPE I HOT's
  - Substantiated and deemed adequate
- TYPE II HOT's
  - Reduce HOT due to FFP issues
- TYPE III HOT's
  - Substantiated and deemed adequate
- TYPE IV HOT's
  - Reduce HOT due to FFP issues

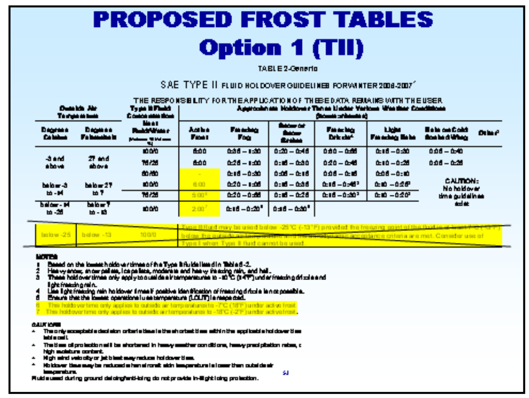
RECOMMENDATIONS

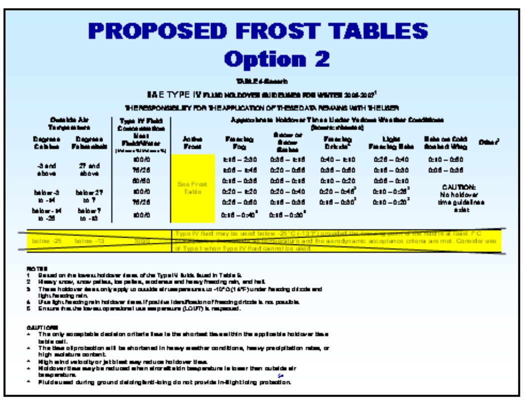
- ALTERNATIVES FOR CHANGES REQUIRED
  - **Option 1**
    - Make changes in current HOT tables
    - Restrict use of diluted fluids to reflect skin temperature differential in frost conditions
    - Include notes to describe temperature restrictions
  - **Pros and Cons**
    - No change in table format required
    - Allows for fluid specific frost numbers to be easily incorporated in the event that this was needed
    - Requires more notes, therefore tables become cluttered
    - Requires additional training due to temperature restrictions

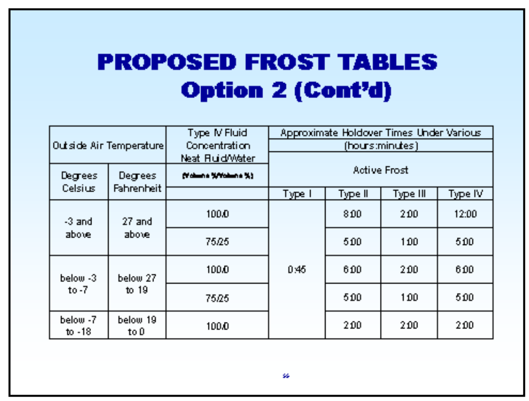

APS
Aviation Inc.
RECOMMENDATIONS
ALTERNATIVES FOR CHANGES REQUIRED
Option 2
Issue frost HOT's on a separate table
Remove from generic and fluid specific tables
Change temperature ranges to reflect skin temperature differential in frost conditions
Pros and Cons
Easy to operate with one chart in frost conditions (frost = 33% of deicing operations)
Logical because all current frost numbers are generic
Requires additional training due to change in format
Additional chart to be included in HOT Guidelines

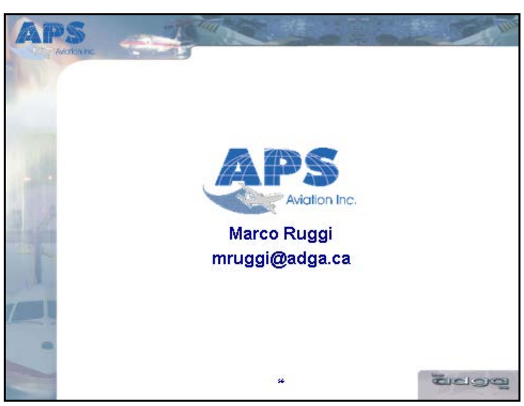

PROPOSED FROST TABLES
Current


PROPOSED FROST TABLES
Option 1 (TIV)


PROPOSED FROST TABLES
Option 1 (TII)
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007


PROPOSED FROST TABLES
Option 2


PROPOSED FROST TABLES
Option 2 (Cont'd)
Outside Air Temperature
Type IV Fluid Concentration Neat Fluid/Water
Approximate Holdover Times Under Various
(hours:minutes)
Degrees Celsius
Degrees Fahrenheit
Active Frost
Type I
Type II
Type III
Type IV
-3 and above
27 and above
100/0
8:00
2:00
12:00
75/25
5:00
1:00
5:00
below -3 to -7
below 27 to 19
100/0
0:45
6:00
2:00
6:00
75/25
5:00
1:00
5:00
below -7 to -18
below 19 to 0
100/0
2:00
2:00
2:00


APS
Aviation Inc.
Marco Ruggi
mruggi@adga.ca

APPENDIX F

PRESENTATION: SUBSTANTIATION OF AIRCRAFT GROUND DEICING HOLDOVER TIMES IN FROST CONDITIONS – MONTREAL, NOVEMBER 2007

SUBSTANTIATION OF AIRCRAFT GROUND DEICING HOLDOVER TIMES IN FROST CONDITIONS

By

Marco Ruggi

APS Aviation Inc.

For

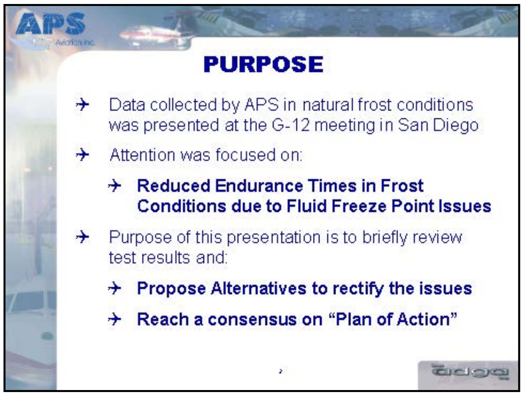
Transportation Development Centre
Transport Canada

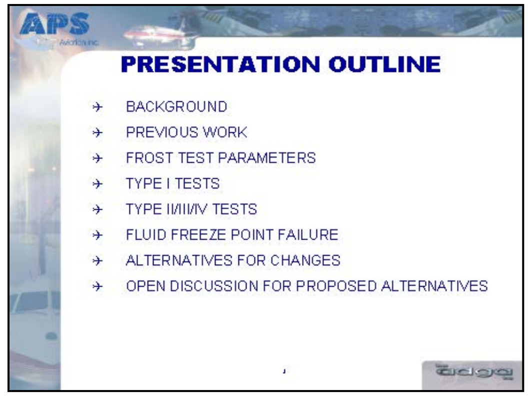
and the

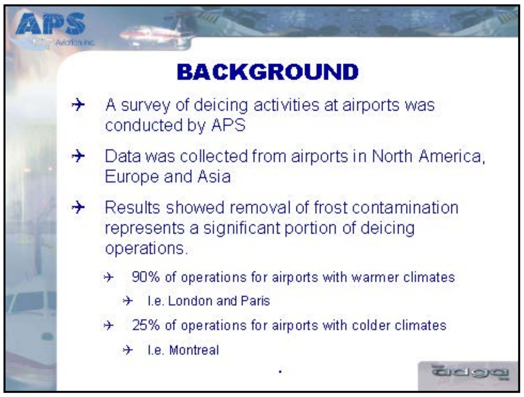
Federal Aviation Administration

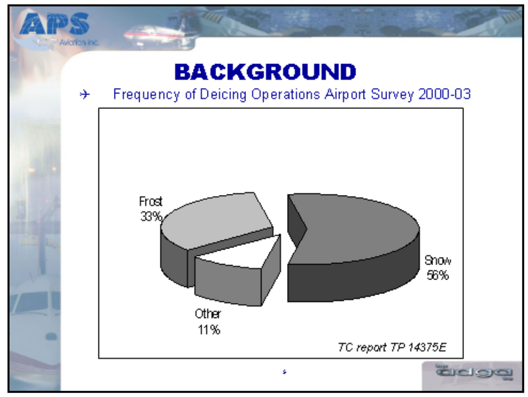
ISO 9001:2000

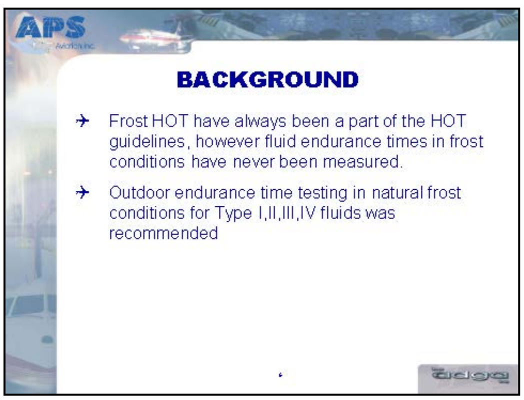
SAE G-12 HOT SUBCOMMITTEE
MONTREAL - NOVEMBER 14, 2007

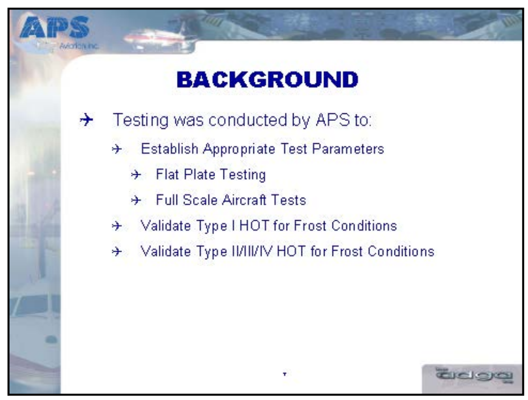

APS
PURPOSE
Data collected by APS in natural frost conditions was presented at the G-12 meeting in San Diego
Attention was focused on:
Reduced Endurance Times in Frost Conditions due to Fluid Freeze Point Issues
Purpose of this presentation is to briefly review test results and:
Propose Alternatives to rectify the issues
Reach a consensus on "Plan of Action"

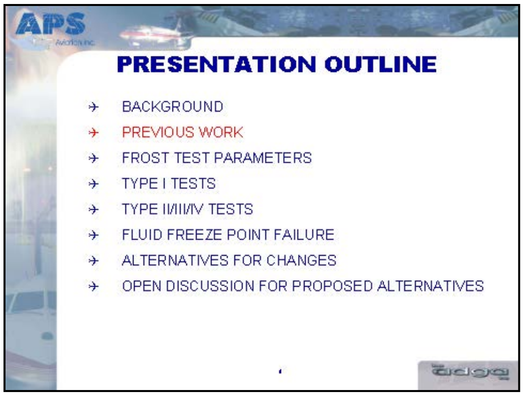

APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST TEST PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
OPEN DISCUSSION FOR PROPOSED ALTERNATIVES

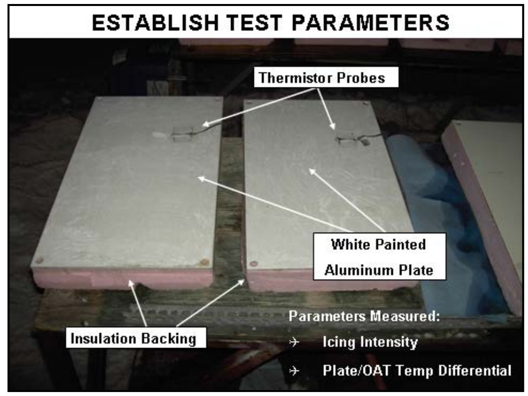

APS
BACKGROUND
A survey of deicing activities at airports was conducted by APS
Data was collected from airports in North America, Europe and Asia
Results showed removal of frost contamination represents a significant portion of deicing operations.
90% of operations for airports with warmer climates
I.e. London and Paris
25% of operations for airports with colder climates
I.e. Montreal

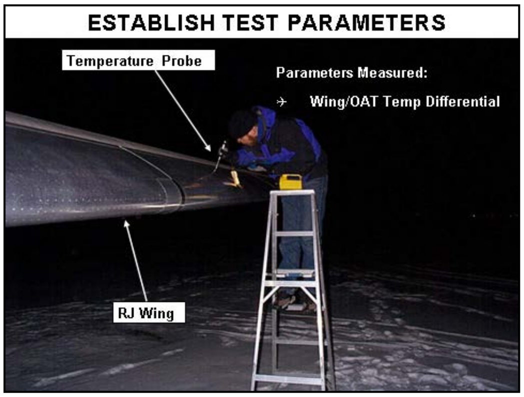

APS
BACKGROUND
Frequency of Deicing Operations Airport Survey 2000-03
Frost 33%
Snow 56%
Other 11%
TC report TP 14375E

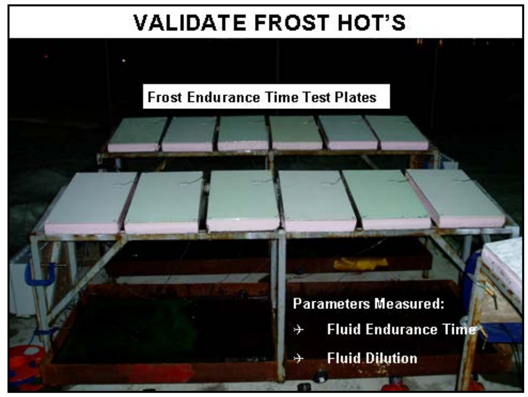

APS
BACKGROUND
Frost HOT have always been a part of the HOT guidelines, however fluid endurance times in frost conditions have never been measured.
Outdoor endurance time testing in natural frost conditions for Type I,II,III,IV fluids was recommended

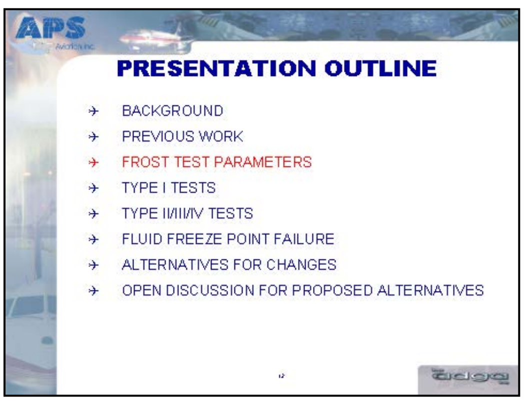

APS
BACKGROUND
Testing was conducted by APS to:
Establish Appropriate Test Parameters
Flat Plate Testing
Full Scale Aircraft Tests
Validate Type I HOT for Frost Conditions
Validate Type II/III/IV HOT for Frost Conditions


APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST TEST PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
OPEN DISCUSSION FOR PROPOSED ALTERNATIVES


ESTABLISH TEST PARAMETERS
Thermistor Probes
White Painted Aluminum Plate
Insulation Backing
Parameters Measured:
Icing Intensity
Plate/OAT Temp Differential


ESTABLISH TEST PARAMETERS
Temperature Probe
Parameters Measured:
Wing/OAT Temp Differential
RJ Wing


VALIDATE FROST HOT'S
Frost Endurance Time Test Plates
Parameters Measured:
Fluid Endurance Time
Fluid Dilution


APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST TEST PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
OPEN DISCUSSION FOR PROPOSED ALTERNATIVES

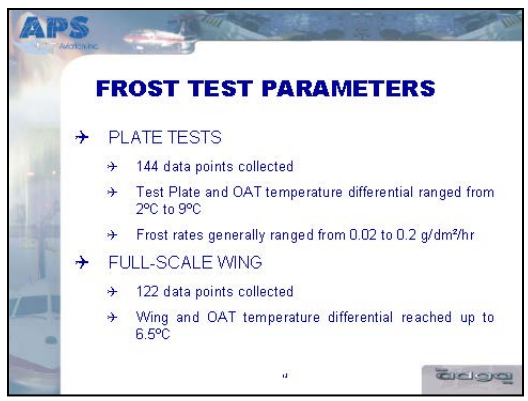
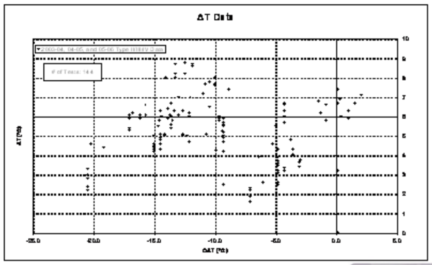
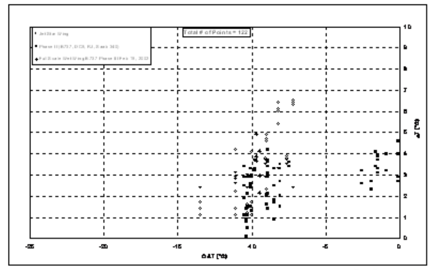

APS
FROST TEST PARAMETERS
PLATE TESTS
144 data points collected
Test Plate and OAT temperature differential ranged from 2ºC to 9ºC
Frost rates generally ranged from 0.02 to 0.2 g/dm²/hr
FULL-SCALE WING
122 data points collected
Wing and OAT temperature differential reached up to 6.5ºC

PLATE TEMPERATURE DATA



WING TEMPERATURE DATA



PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS WORK
- FROST TEST PARAMETERS
- TYPE I TESTS
- TYPE II/III/IV TESTS
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
- OPEN DISCUSSION FOR PROPOSED ALTERNATIVES

TYPE I TESTS

- 47 tests were conducted with 4 Type I fluids
  - The measured endurance times did not violate the long used HOT of 45 minutes.
  - Based on the data collected, the Type I HOTs have been substantiated.
  - *It is recommended that a note be included in ARP 5945 indicating that testing is not required for frost if the fluid meets the certification requirements*

PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS WORK
- FROST TEST PARAMETERS
- TYPE I TESTS
- TYPE II/III/IV TESTS
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
- OPEN DISCUSSION FOR PROPOSED ALTERNATIVES

TYPE II/III/IV TESTS

- 62 tests were conducted with 5 Type II fluids
- 16 tests were conducted with 1 Type III fluid
- 90 tests were conducted with 8 Type IV fluids
- Type II,III,IV fluids were tested at neat, 75/25, and 50/50 dilutions

TYPE II/III/IV TESTS

- 15 Type II tests and 21 Type IV tests generated reduced endurance times in comparison to the current frost values issued in the HOT Guidelines
- Discrepancy in endurance times was attributed to fluid freeze point issues for 86% of the cases

PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS WORK
- FROST TEST PARAMETERS
- TYPE I TESTS
- TYPE II/III/IV TESTS
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
- OPEN DISCUSSION FOR PROPOSED ALTERNATIVES

FLUID FREEZE POINT FAILURE

- Reduced fluid endurance times were experienced when OAT approached fluid LOUT
- The plate surface temperature would cool closer to the fluid freeze point causing fluid failure
- Fluid dilution and erosion did not significantly contribute to the failure

FLUID FREEZE POINT FAILURE

- EXAMPLE
  - Type IV 75/25 Fluid
  - OAT = **-13.9°C** (within operational limit)
  - Plate Temperature = -13.9°C – (7°C) = **-20. 9°C**
  - Fluid Freeze Point = **-21°C**
    - Fluid would be designed with 7°C buffer based on LOUT of -14°C
  - **Plate temperature is cooled to LOUT**
  - **Fluid experiences contamination as ice crystals begin to form sporadically in fluid**

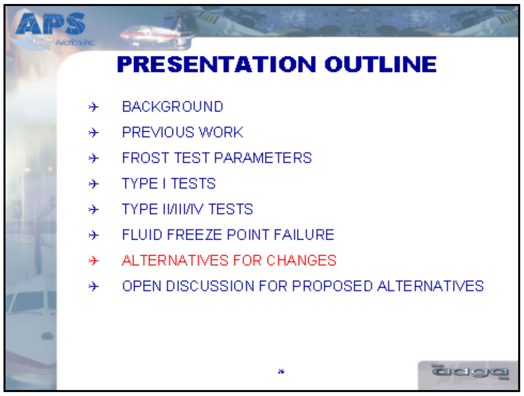
FLUID FREEZE POINT FAILURE

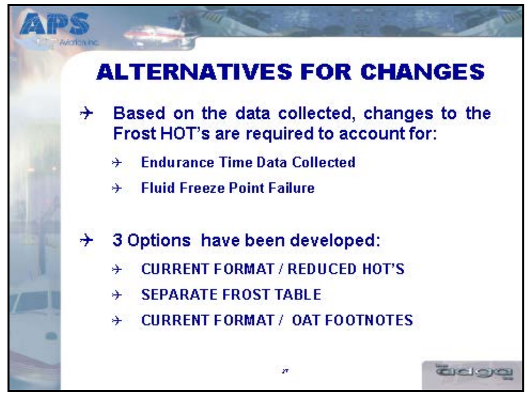
- Fluid freeze point failure can be experienced with dilutions when operating close to the LOUT
  - *Assuming ΔT=9°C*

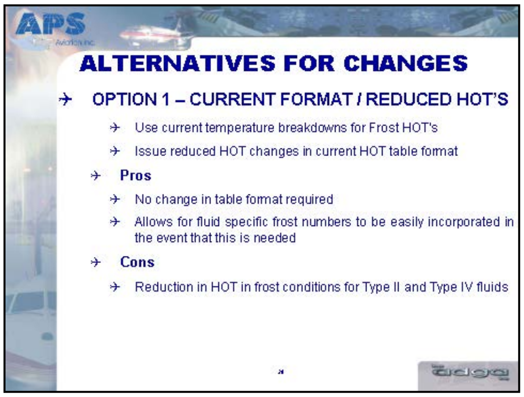
Type II/IV Dilution	LOUT	Approximate FFP	Possible Surface Temp. During Frost Conditions at LOUT
Neat	-25	-36	-32
75/25	-14	-21	-21
50/50	-3	-10	-10

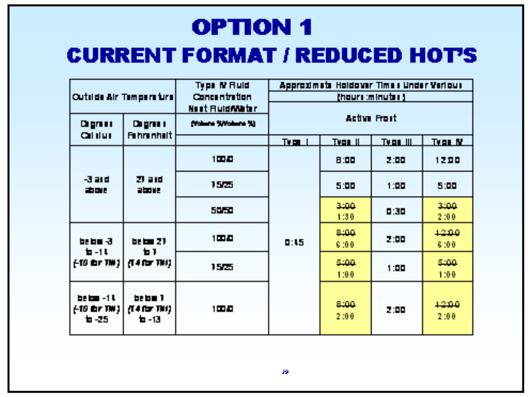
FLUID FREEZE POINT FAILURE

- The HOT table provides operational ranges specifying limits based on OAT
- In frost conditions, the skin temperature of an aircraft may be several degrees lower than the OAT
- If operating with a fluid close to the LOUT during frost conditions, the skin temperature of the aircraft could reach the fluid freeze point potentially causing ice to form in the fluid
- **FROST HOT'S NEED TO REFLECT SKIN TEMPERATURE**

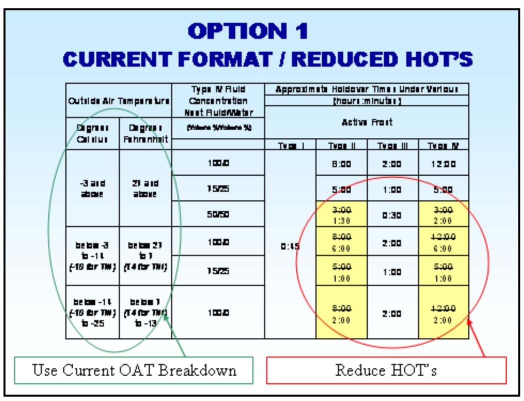




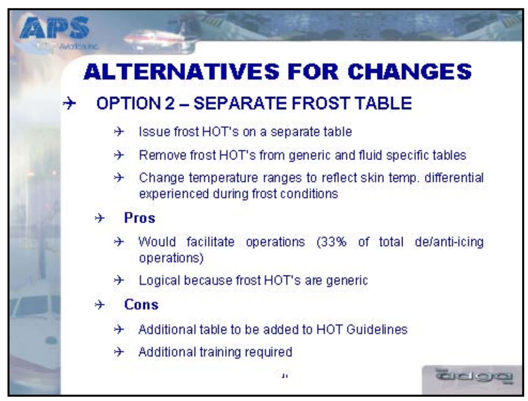


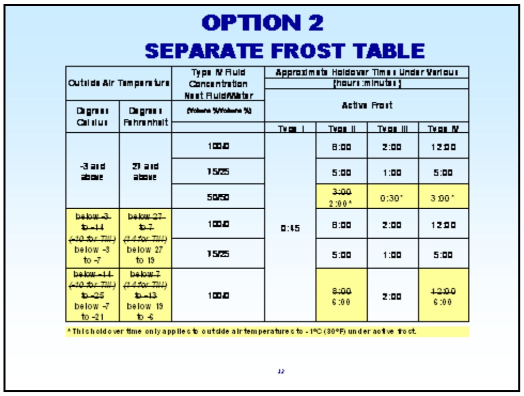


Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water	Approximate Holdover Times Under Various (hours:minutes)			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Active Frost			
			Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 1:30	0:30	~~3:00~~ 2:00
below -3 to -14 (-10 for TIV)	below 27 to 7 (14 for TIV)	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00
below -14 (-10 for TIV) to -25	below 7 (14 for TIV) to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 2:00

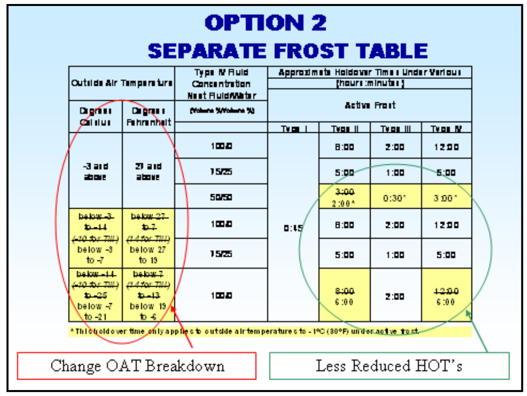


Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water	Approximate Holdover Times Under Various (hours:minutes)			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Active Frost			
			Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 1:30	0:30	~~3:00~~ 2:00
below -3 to -14 (-10 for TIV)	below 27 to 7 (14 for TIV)	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00
below -14 (-10 for TIV) to -25	below 7 (14 for TIV) to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 2:00

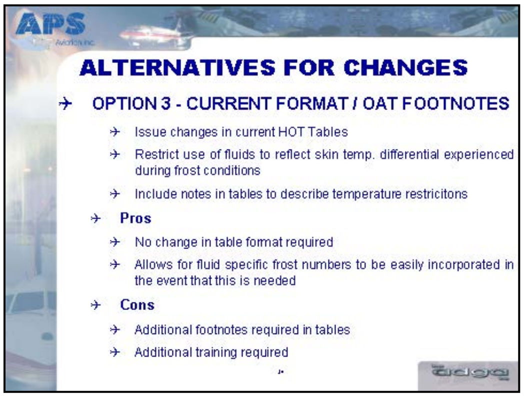


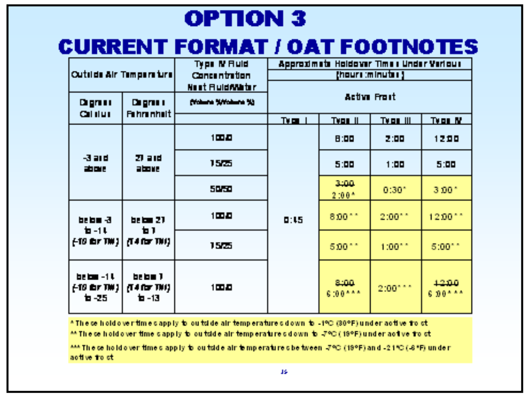


Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water	Approximate Holdover Times Under Various (hours:minutes) Active Frost			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 2:00*	0:30*	3:00*
~~below -3 to -14 (-10 for TIII)~~ below -3 to -7	~~below 27 to 7 (14 for TIII)~~ below 27 to 19	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
~~below -14 (-10 for TIII) to -25~~ below -7 to -21	~~below 7 (14 for TIII) to -13~~ below 19 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00

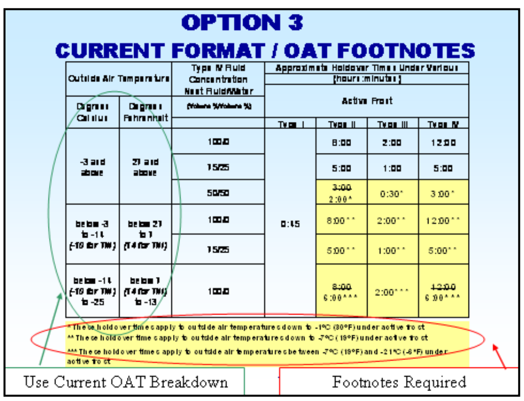


Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water	Approximate Holdover Times Under Various (hours:minutes) Active Frost			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 2:00*	0:30*	3:00*
~~below -3 to -14 (-10 for TIII)~~ below -3 to -7	~~below 27 to 7 (14 for TIII)~~ below 27 to 19	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
~~below -14 (-10 for TIII) to -25~~ below -7 to -21	~~below 7 (14 for TIII) to -13~~ below 19 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00

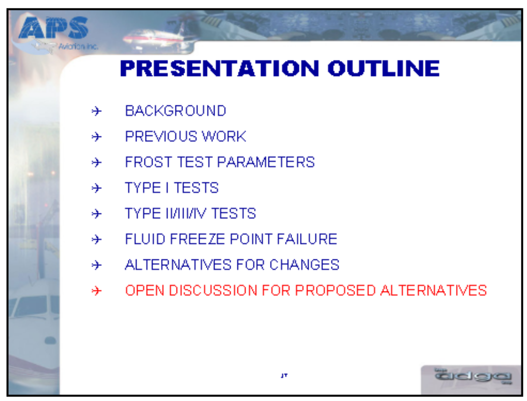


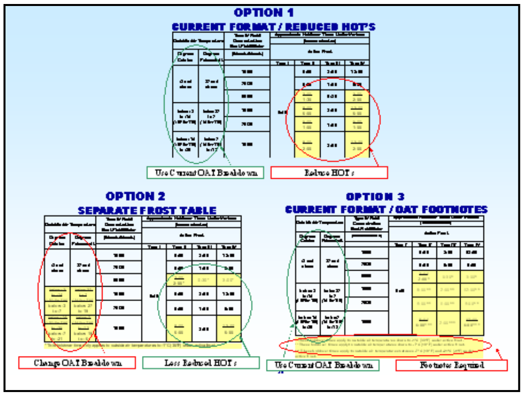


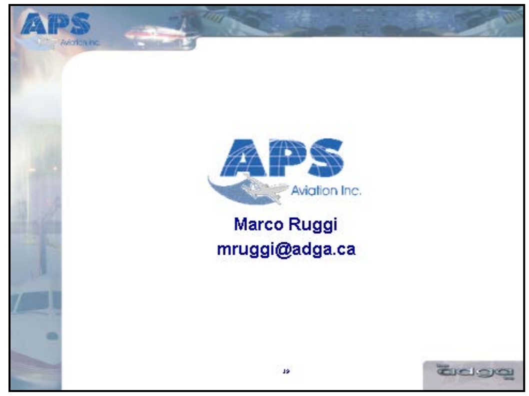
Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water	Approximate Holdover Times Under Various (hours:minutes) Active Frost			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 2:00*	0:30*	3:00*
below -3 to -14 (-10 for TIII)	below 27 to 7 (14 for TIII)	100/0		8:00**	2:00**	12:00**
		75/25		5:00**	1:00**	5:00**
below -14 (-10 for TIII) to -25	below 7 (14 for TIII) to -13	100/0		~~8:00~~ 6:00***	2:00***	~~12:00~~ 6:00***



Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water	Approximate Holdover Times Under Various (hours:minutes) Active Frost			
Degrees Celsius	Degrees Fahrenheit	(Volume %/Volume %)	Type I	Type II	Type III	Type IV
-3 and above	27 and above	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 2:00*	0:30*	3:00*
below -3 to -14 (-10 for TIII)	below 27 to 7 (14 for TIII)	100/0		8:00**	2:00**	12:00**
		75/25		5:00**	1:00**	5:00**
below -14 (-10 for TIII) to -25	below 7 (14 for TIII) to -13	100/0		~~8:00~~ 6:00***	2:00***	~~12:00~~ 6:00***




OPTION 1
CURRENT FORMAT / REDUCED HOT'S
Use Current OAT Breakdown
Reduce HOTs
OPTION 2
SEPARATE FROST TABLE
Change OAT Breakdown
Less Reduced HOTs
OPTION 3
CURRENT FORMAT / OAT FOOTNOTES
Use Current OAT Breakdown
Footnotes Required


APS
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APPENDIX G

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES
VERSION 5.0

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

Prepared for

Transportation Development Centre
Transport Canada

and the

Federal Aviation Administration

Prepared by:
Marco Ruggi

APS Aviation Inc.

October 2008
Version 5.0

ACTION ITEMS

1. Preliminary discussion with Transport Canada and Federal Aviation Administration
   - January 15, 2008 at 2pm
2. Discussion with Kilfrost, British Airways and KLM
   - March 12, 2008 at 14:00 GMT
3. Discussion with Transport Canada and Federal Aviation Administration to review changes based on March 12, 2008 discussion
   - March 26, 2008 at 2 pm
4. Discussion with Transport Canada and Federal Aviation Administration to review **proposal to adopt option 4**.
   - April 17, 2008 at 2 pm
5. Present proposed changes in Warsaw in May 2008
   - **Based on recent discussions, regulators will likely proceed with Option 4 and further work will be conducted.**
6. Discussion with TC, FAA, APS, Kilfrost, British Airways and KLM to continue discussions regarding proposed options and to address AEA questions and answers.
   - October 2, 2008 at 14:00 GMT
7. Present proposed changes in Warsaw in May 2008
   - **Based on recent discussions, regulators will likely proceed with Option 4 and further work will be conducted.**

SUMMARY OF PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

OPTION 1
CURRENT FORMAT / REDUCED HOT'S
- → Use current temperature breakdowns for Frost HOT's
- → Issue reduced HOT changes in current HOT table format

OPTION 2
CURRENT FORMAT / OAT FOOTNOTES FOR DILUTED FLUIDS
- → Issue changes in current HOT Tables
- → Restrict use of DILUTED fluids to reflect skin temp. differential experienced during frost conditions
- → Include notes in tables to describe temperature restrictions
- → Issue reduced HOT changes for Neat below -14ºC

OPTION 3
SEPARATE FROST TABLE
- → Issue frost HOT's on a separate table
- → Remove frost HOT's from generic and fluid specific tables
- → Change temperature ranges to reflect skin temp. differential experienced during frost conditions

OPTION 4
(SHORT-TERM SOLUTION)
STATUS QUO WITH CAUTION
- → No changes are issued to HOT's in short term
- → Cautionary note added to advise that radiational cooling during active frost conditions may reduce HOT when operating close to the lower end of the OAT range.

OPTION 1
CURRENT FORMAT / REDUCED HOT'S

- Use current temperature breakdowns for Frost HOT's
- Issue reduced HOT changes in current HOT table format

Pros

- No change in table format required
- Allows for fluid specific frost numbers to be easily incorporated in the event that this is needed

Cons

- Reduction in HOT in frost conditions for Type II and Type IV fluids

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 1

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

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

OPTION 1

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	**Degrees Fahrenheit**	**Active Frost**	**Freezing Fog**	**Snow or Snow Grains[1]**			**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
				Very Light	**Light**	**Moderate**				
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m^2 (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

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PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

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

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

Outside Air Temperature		**Type II Fluid Concentration**	**Approximate Holdover Times Under Various Weather Conditions (hours:minutes)**						
Degrees Celsius	**Degrees Fahrenheit**	**Neat Fluid/Water (Volume %/Volume %)**	**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	~~3:00~~ **1:30**	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	~~8:00~~ **6:00**	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	~~5:00~~ **1:00**	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	~~8:00~~[5] **2:00**[5]	0:15 – 0:20[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

OPTION 1

NOTES

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

CAUTIONS

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

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PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

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

NOTES

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

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-Generic

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

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

Outside Air Temperature		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	**Degrees Fahrenheit**	**Neat Fluid/Water (Volume %/Volume %)**	**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:35 – 1:15	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	
		75/25	5:00	1:05 – 1:45	0:20 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:35	
		50/50	3:00	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	~~12:00~~ **6:00**	0:20 – 1:20	0:20 – 0:40	0:20 – 0:45[3]	0:10 – 0:25[3]	CAUTION: No holdover time guidelines exist	
		75/25	~~5:00~~ **1:00**	0:25 – 0:50	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	~~12:00[5]~~ **4:00[5]**	0:15 – 0:40[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-D-ULTRA+

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
UCAR™ ADF/AAF ULTRA+

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

OPTION 1

Outside Air Temperature		**Type IV Fluid Concentration Neat Fluid/Water** (Volume %/Volume %)	**Approximate Holdover Times Under Various Weather Conditions (hours:minutes)**						
Degrees Celsius	**Degrees Fahrenheit**		**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	12:00	1:35 – 3:35	0:35 – 1:15	0:45 – 1:35	0:25 – 0:40	0:10 – 1:20	
		75/25						CAUTION: No holdover time guidelines exist	
		50/50							
below -3 to -14	below 27 to 7	100/0	~~12:00~~ 6:00	1:25 – 3:00	0:25 – 0:55	0:45 – 1:25[3]	0:30 – 0:45[3]		
		75/25							
below -14 to -25	below 7 to -13	100/0	~~12:00[5]~~ 4:00[5]	0:40 – 2:10[5]	0:20 – 0:45[5]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met.[5] Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1. These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3. These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5. These holdover times only apply to outside air temperatures to -24°C (-11°F).

CAUTIONS

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

OPTION 2
CURRENT FORMAT / OAT FOOTNOTES FOR DILUTED FLUIDS

- Issue changes in current HOT Tables
- Restrict use of DILUTED fluids to reflect skin temp. differential experienced during frost conditions
- Include notes in tables to describe temperature restrictions
- Issue reduced HOT changes for Neat below -14ºC

- **Pros**
- No change in table format required
- Allows for fluid specific frost numbers to be easily incorporated in the event that this is needed

- **Cons**
- Additional footnotes required in tables
- Additional training required

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 1

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

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

OPTION 2

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Snow or Snow Grains[1] Very Light	Snow or Snow Grains[1] Light	Snow or Snow Grains[1] Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m^2 (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

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

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

OPTION 2

Outside Air Temperature		Type II Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	**Degrees Fahrenheit**	**Neat Fluid/Water** (Volume %/Volume %)	**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	**3:00[6]**	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	~~8:00~~ **6:00**	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	~~5:00~~ **5:00[7]**	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	~~8:00[5]~~ **2:00[5]**	0:15 – 0:20[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES

1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
6 These holdover times only apply to outside air temperatures to -1°C (30°F) under active frost.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under active frost.

CAUTIONS

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

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TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

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

NOTES

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

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-Generic

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

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

Outside Air Temperature		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	**Degrees Fahrenheit**	**Neat Fluid/Water** (Volume %/Volume %)	**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:35 – 1:15	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	
		75/25	5:00	1:05 – 1:45	0:20 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:35	
		50/50	3:00	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	~~12:00~~ **6:00**	0:20 – 1:20	0:20 – 0:40	0:20 – 0:45[3]	0:10 – 0:25[3]		
		75/25	~~5:00~~ **5:00[6]**	0:25 – 0:50	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	~~12:00[6]~~ **4:00[5]**	0:15 – 0:40[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

OPTION 2

NOTES

1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
6 **These holdover times only apply to outside air temperatures to -10°C (14°F) under active frost.**

CAUTIONS

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

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PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-D-ULTRA+

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
UCAR™ ADF/AAF ULTRA+

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

OPTION 2

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	**Degrees Fahrenheit**		**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	12:00	1:35 – 3:35	0:35 – 1:15	0:45 – 1:35	0:25 – 0:40	0:10 – 1:20	
		75/25						CAUTION: No holdover time guidelines exist	
		50/50							
below -3 to -14	below 27 to 7	100/0	~~12:00~~ **6:00**	1:25 – 3:00	0:25 – 0:55	0:45 – 1:25[3]	0:30 – 0:45[3]		
		75/25							
below -14 to -25	below 7 to -13	100/0	~~12:00~~[5] **4:00**[5]	0:40 – 2:10[5]	0:20 – 0:45[5]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met.[5] Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 These holdover times only apply to outside air temperatures to -24°C (-11°F).

CAUTIONS

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

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OPTION 3
SEPARATE FROST TABLE

- Issue frost HOT's on a separate table
- Remove frost HOT's from generic and fluid specific tables
- Change temperature ranges to reflect skin temp. differential experienced during frost conditions

- **Pros**
- Would facilitate operations (33% of total de/anti-icing operations)
- Logical because frost HOT's are generic

- **Cons**
- Additional table to be added to HOT Guidelines
- Additional training required
- Neat is penalized below -14

TABLE 1 - FROST

SAE TYPE I[1], II, III, IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes) Active Frost			
Degrees Celsius	Degrees Fahrenheit		Type I[2]	Type II	Type III	Type IV
above -1	above 30	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 1:30	0:30	3:00
below -3 to -10	below 27 to 14	100/0		8:00	2:00	~~12:00~~ 10:00
		75/25		5:00	1:00	5:00
below -10 to -14	below 14 to 7	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00
below -14 to -21	below 7 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
below -21 to -25	below -6 to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 4:00

NOTES (TO BE DEVELOPPED FURTHER)

1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.

2 May be used below -25°C (-13°F) provided the LOUT of the fluid is respected.

CAUTIONS (TO BE DEVELOPPED FURTHER)

- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2

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

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

Outside Air Temperature[5]		**Approximate Holdover Times Under Various Weather Conditions (minutes)**							
Degrees Celsius	**Degrees Fahrenheit**	**Freezing Fog**	**Snow or Snow Grains[1]**			**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
			Very Light	**Light**	**Moderate**				
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

OPTION 3

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m^2 (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.

2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.

3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.

4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

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

CAUTIONS

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

TABLE 3-Generic

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

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

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

NOTES

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

CAUTIONS

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

TABLE 4

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

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

NOTES

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

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 5-Generic

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

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

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

NOTES

1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 5-D-ULTRA+

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
UCAR™ ADF/AAF ULTRA+

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

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

NOTES
1. These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3. These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5. These holdover times only apply to outside air temperatures to -24°C (-11°F).

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

OPTION 4
(SHORT-TERM SOLUTION)
STATUS QUO WITH CAUTION

- No changes are issued to HOT's in short term
- Cautionary note added to advise that radiational cooling during active frost conditions may reduce HOT when operating close to the lower end of the OAT range.

- **Pros**
- No immediate change required
- Allows additional research to be conducted to substantiate change

- **Cons**
- Extra cautionary notes may lead to added confusion to operators

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 1

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

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

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
				Snow or Snow Grains[1]						
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Very Light	Light	Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

OPTION 4

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

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PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

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

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

Outside Air Temperature		Type II Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	**Degrees Fahrenheit**	**Neat Fluid/Water** (Volume %/Volume %)	**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	CAUTION: No holdover time guidelines exist
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	3:00[5]	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00[5]	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	5:00[5]	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	8:00[5,6]	0:15 – 0:20[6]	0:15 – 0:30[6]	CAUTION: No holdover time guidelines exist			
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

OPTION 4

NOTES

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

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

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

NOTES

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

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-Generic

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

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

Outside Air Temperature		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	**Degrees Fahrenheit**	**Neat Fluid/Water (Volume %/Volume %)**	**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:35 – 1:15	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	CAUTION: No holdover time guidelines exist
		75/25	5:00	1:05 – 1:45	0:20 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:35	
		50/50	3:00[5]	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	12:00[5]	0:20 – 1:20	0:20 – 0:40	0:20 – 0:45[3]	0:10 – 0:25[3]		
		75/25	5:00[5]	0:25 – 0:50	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	12:00[5,6]	0:15 – 0:40[6]	0:15 – 0:30[6]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce holdover times when operating close to the lower end of the outside air temperature range.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-D-ULTRA+

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
UCAR™ ADF/AAF ULTRA+

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

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	**Degrees Fahrenheit**		**Active Frost**	**Freezing Fog**	**Snow or Snow Grains**	**Freezing Drizzle[4]**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other[2]**
-3 and above	27 and above	100/0	12:00	1:35 – 3:35	0:35 – 1:15	0:45 – 1:35	0:25 – 0:40	0:10 – 1:20	CAUTION: No holdover time guidelines exist
		75/25							
		50/50							
below -3 to -14	below 27 to 7	100/0	12:00[5]	1:25 – 3:00	0:25 – 0:55	0:45 – 1:25[3]	0:30 – 0:45[3]		
		75/25							
below -14 to -25	below 7 to -13	100/0	12:00[5,6]	0:40 – 2:10[6]	0:20 – 0:45[6]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met.[5] Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce holdover times when operating close to the lower end of the outside air temperature range.
6 These holdover times only apply to outside air temperatures to -24°C (-11°F).

CAUTIONS

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

APPENDIX H

PRESENTATION: ANSWERS TO AEA DE/ANTI-ICING WORKING GROUP QUESTIONS - WARSAW, MAY 2008

ANSWERS TO AEA DE/ANTI-ICING WORKING GROUP QUESTIONS

MAY 5, 2008 EMAIL

By

Marco Ruggi

APS Aviation Inc.

For

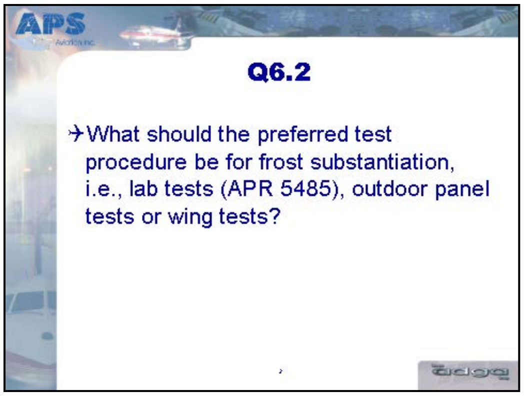
Transportation Development Centre
Transport Canada

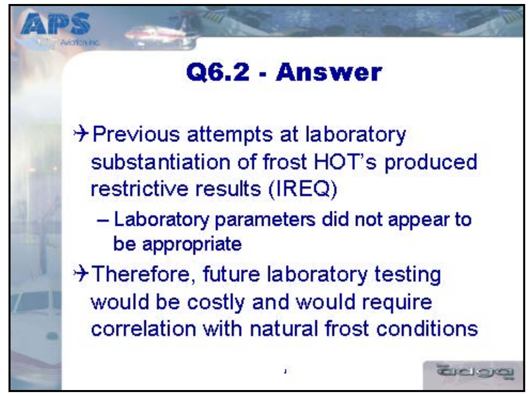
and the

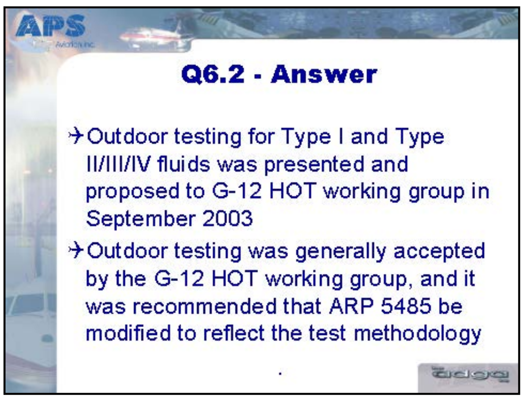
Federal Aviation Administration

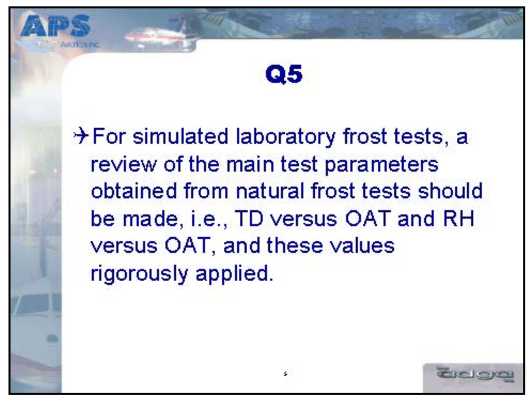
ISO 9001:2000

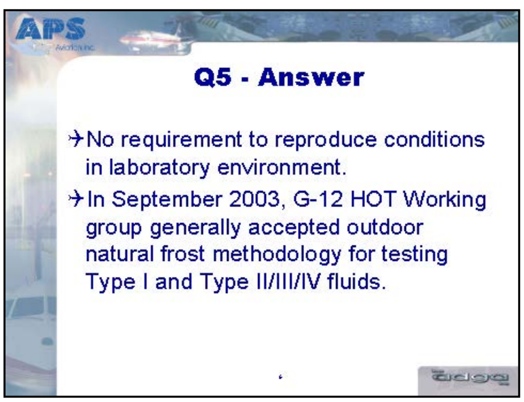
SAE G-12 HOT SUBCOMMITTEE
WARSAW – MAY 13, 2008

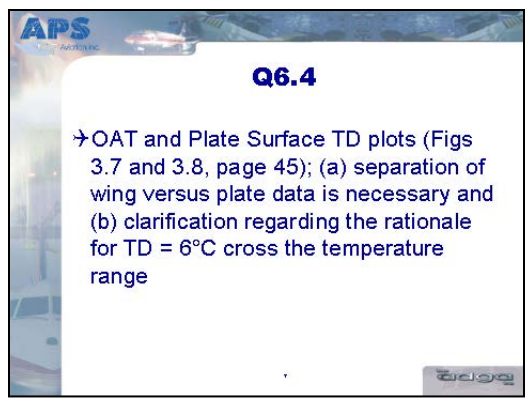

APS
Q6.2
What should the preferred test procedure be for frost substantiation, i.e., lab tests (APR 5485), outdoor panel tests or wing tests?

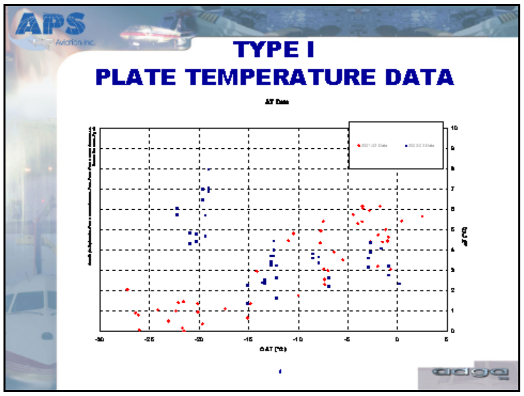

APS
Q6.2 - Answer
Previous attempts at laboratory substantiation of frost HOT's produced restrictive results (IREQ)
– Laboratory parameters did not appear to be appropriate
Therefore, future laboratory testing would be costly and would require correlation with natural frost conditions

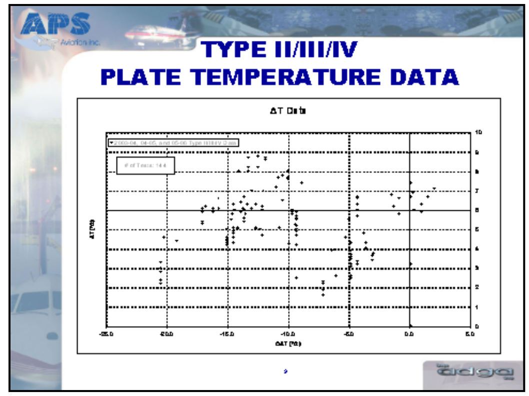

APS
Q6.2 - Answer
Outdoor testing for Type I and Type II/III/IV fluids was presented and proposed to G-12 HOT working group in September 2003
Outdoor testing was generally accepted by the G-12 HOT working group, and it was recommended that ARP 5485 be modified to reflect the test methodology

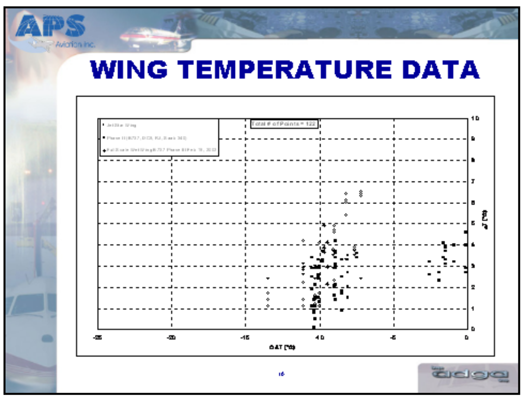

APS
Q5
For simulated laboratory frost tests, a review of the main test parameters obtained from natural frost tests should be made, i.e., TD versus OAT and RH versus OAT, and these values rigorously applied.

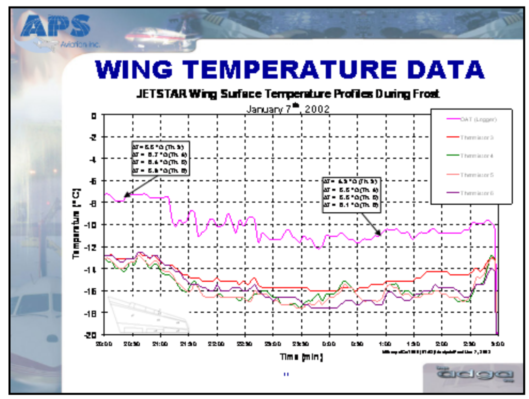

APS
Q5 - Answer
No requirement to reproduce conditions in laboratory environment.
In September 2003, G-12 HOT Working group generally accepted outdoor natural frost methodology for testing Type I and Type II/III/IV fluids.


APS
Q6.4
OAT and Plate Surface TD plots (Figs 3.7 and 3.8, page 45); (a) separation of wing versus plate data is necessary and (b) clarification regarding the rationale for TD = 6°C cross the temperature range







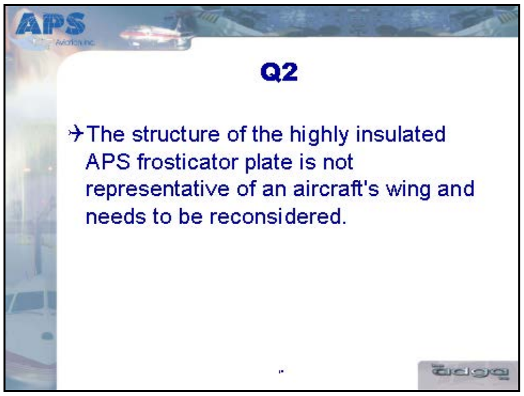


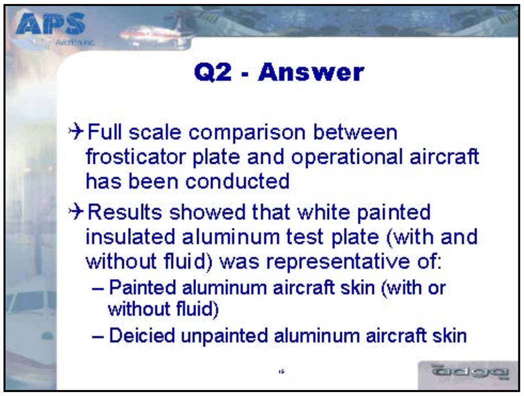
Q1

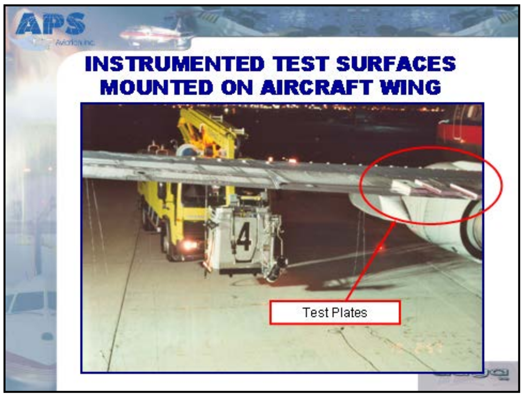
- The choice of TD is confused and should be clarified, i.e., APS proposed TD = 9.5°C in San Diego and subsequently TD = 6°C APS in Montréal, whereas TD = 5°C has been the undisputed basis for frost tests during the previous 25 years.
- General agreement regarding a realistic TD for frost substantiation tests is essential.

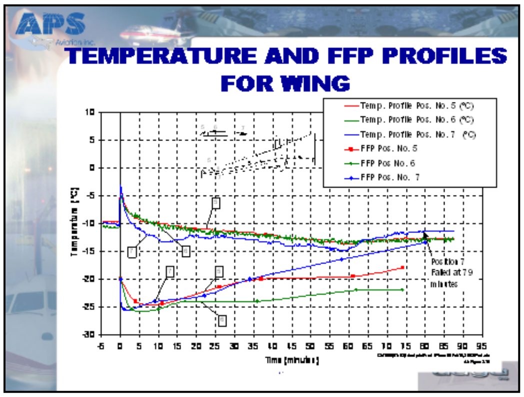
Q1- Answer

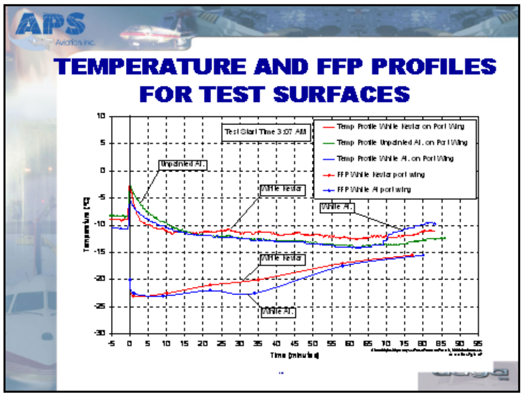
- 9ºC ΔT was observed on test plates
- 6.5ºC ΔT was observed during aircraft wing tests
- G-12 HOT working group recommended the use of 7ºC (max observed on aircraft) as 9ºC may be too restrictive

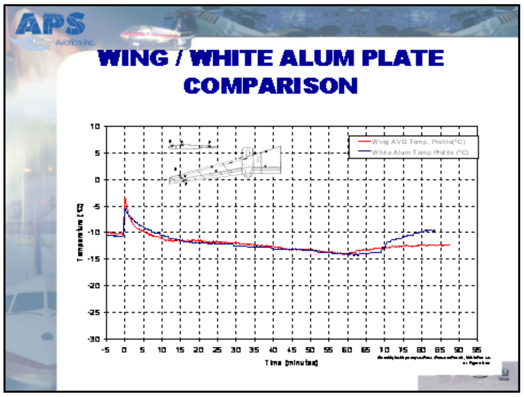

APS
Aviation Inc.
Q2
✈The structure of the highly insulated APS frosticator plate is not representative of an aircraft's wing and needs to be reconsidered.


APS
Aviation Inc.
Q2 - Answer
✈Full scale comparison between frosticator plate and operational aircraft has been conducted
✈Results showed that white painted insulated aluminum test plate (with and without fluid) was representative of:
– Painted aluminum aircraft skin (with or without fluid)
– Deiced unpainted aluminum aircraft skin


APS
Aviation Inc.
INSTRUMENTED TEST SURFACES MOUNTED ON AIRCRAFT WING
4
Test Plates


APS
Aviation Inc.
TEMPERATURE AND FFP PROFILES FOR WING
Temp. Profile Pos. No. 5 (°C)
Temp. Profile Pos. No. 6 (°C)
Temp. Profile Pos. No. 7 (°C)
FFP Pos. No. 5
FFP Pos No. 6
FFP Pos. No. 7
Temperature (°C)
Time (minutes)
Position 7 Failed at 79 minutes


APS
Aviation Inc.
TEMPERATURE AND FFP PROFILES FOR TEST SURFACES
Test Start Time 3:07 AM
Temp Profile White Kevlar on Port Wing
Temp Profile Unpainted Al. on Port Wing
Temp Profile White Al. on Port Wing
FFP White Kevlar port wing
FFP White Al port wing
Unpainted Al.
White Kevlar
White Al.
Temperature (°C)
Time (minutes)


APS
Aviation Inc.
WING / WHITE ALUM PLATE COMPARISON
Temperature (°C)
Time (minutes)

INFLUENCE OF TYPE I FLUID ON FROST GENERATION

	Surface Treatment		White Aluminum	Unpainted Aluminum	White Kevlar
Test 1 Average OAT = -6.3°C Average RH = 65%	Dry	ΔT (°C)	5.6	1.2	3.5
		Frost Rate ($g/dm^2/h$)			
	Type I fluid-covered	ΔT (°C)	5.3	5.0	4.4
		Endurance Time (min)	158	160	109
Test 2 Average OAT = -7.5°C Average RH = 70%	Dry	ΔT (°C)	5.4	1.5	3.8
		Frost Rate ($g/dm^2/h$)	0.09	0.01	0.07
	Type I fluid-covered	ΔT (°C)	5.3	5.3	4.7
		Endurance Time (min)	119	139	111

COMPARISON WING VERSUS TEST PLATES FROST GENERATION

RUN #	SURFACE	FIRST APPEARANCE OF FROST (min)	PLATE ENDURANCE TIME (min)
1	Port Wing	80	
	White aluminum plate on port wing	70	76

Q4

- Fluid application temperatures have not been used consistently i.e., 20°C to 60°C for Type I's.
- Also during normal winter operations Type II/IV 75/25 and 50/50 mixtures are typically applied hot, which has not been considered in current APS frost test methodology.

Q4 - Answer

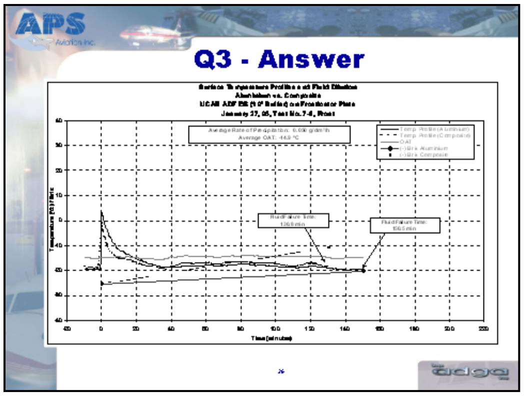
- Temperature profile on frosticator plate was found to be representative of aircraft wing
- Heated 20°C tests (conservative compared to 60°C) were conducted for Type I tests
  - Type I HOT was validated and no issues
- Heated thickened fluids have not been tested, however worst case (applied at OAT) provides conservative ET

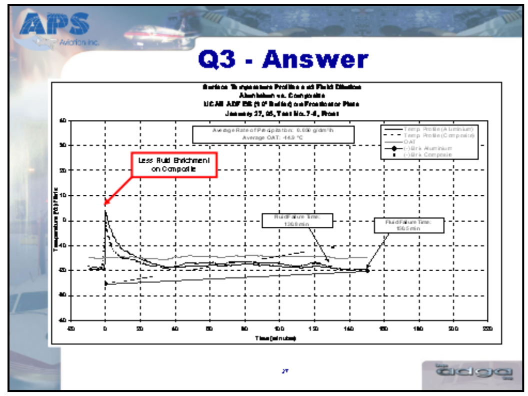
Q3

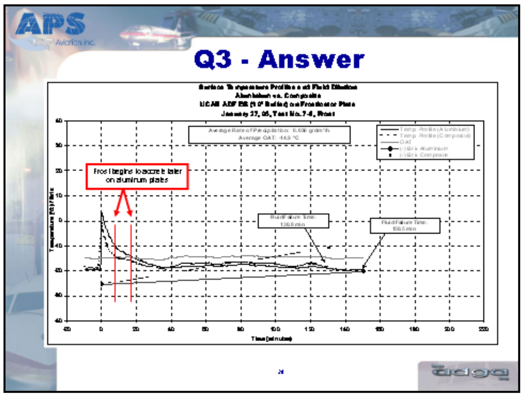
- The current APS study concentrates heavily on aluminum surfaces. It is believed that more consideration should be given to composites, in order to determine the most critical test surface for frost.

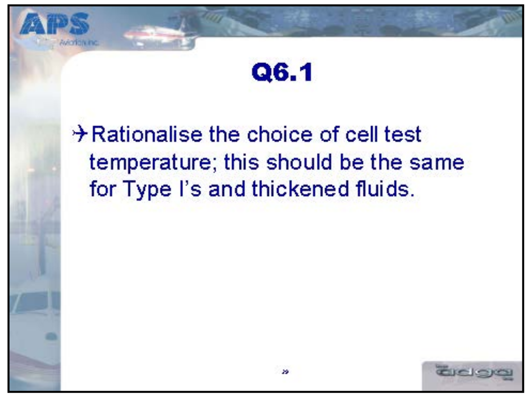
Q3 - Answer

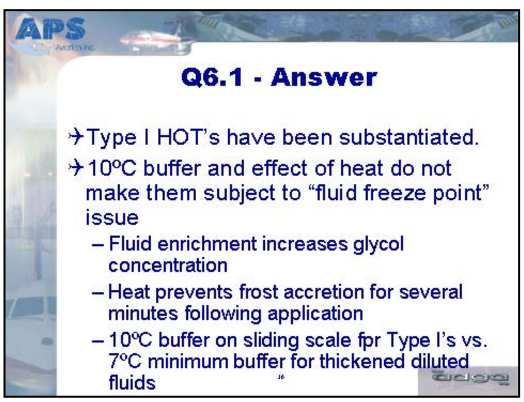
- Recent endurance time research using composite materials has shown:
  - Reduced ET for Type I
  - Similar ET for thickened fluids
- Using composite surfaces may generate more conservative results for Type I.

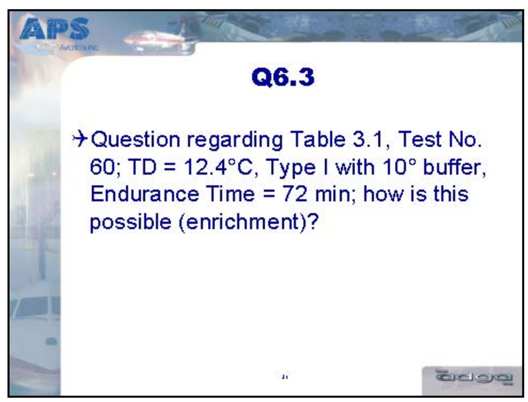

APS
Q3 - Answer


APS
Q3 - Answer
Less Fluid Enrichment on Composite


APS
Q3 - Answer
Frost begins to accrete later on aluminum plates


APS
Q6.1
Rationalise the choice of cell test temperature; this should be the same for Type I's and thickened fluids.


APS
Q6.1 - Answer
Type I HOT's have been substantiated.
10ºC buffer and effect of heat do not make them subject to "fluid freeze point" issue
– Fluid enrichment increases glycol concentration
– Heat prevents frost accretion for several minutes following application
– 10ºC buffer on sliding scale fpr Type I's vs. 7ºC minimum buffer for thickened diluted fluids


APS
Q6.3
Question regarding Table 3.1, Test No. 60; TD = 12.4°C, Type I with 10° buffer, Endurance Time = 72 min; how is this possible (enrichment)?

Q6.3 - Answer

- Heated Type I fluid experiences enrichment as water evaporates upon application
- ΔT reported is in error.
- Correction
  - Temperature data was only available from 23:18:01 to 23:50:00.
  - Avg Plate Temp = -10.4
  - ΔT = -3.7 – (-10.4) = 6.7ºC (similar to following tests)
  - Correction will be issued in next version

Q7

- One thing is not completely clear: is the APS data from outdoor panel tests or cold chamber tests?
- In particular how did they collect the data for the lower temperatures (did they test outside in true frost conditions at minus 25C, or did they just perform a test chamber WSET with the plate at minus 31/34/36C?)

Q7 - Answer

- All endurance time testing was conducted outdoors
- Outdoor testing was conducted using insulated frosticator plates
- Lowest OAT = -21ºC

Comments Regarding Working Group

- Possibly the best way forward would be to form a working group to discuss and resolve the concerns regarding the methodology.

Comments Regarding Working Group

- APS has had discussions with a working group consisting of industry operators and regulators
- It is anticipated that this working group approach will be continued during the coming winter

APS Aviation Inc.

Marco Ruggi
mruggi@adga.ca

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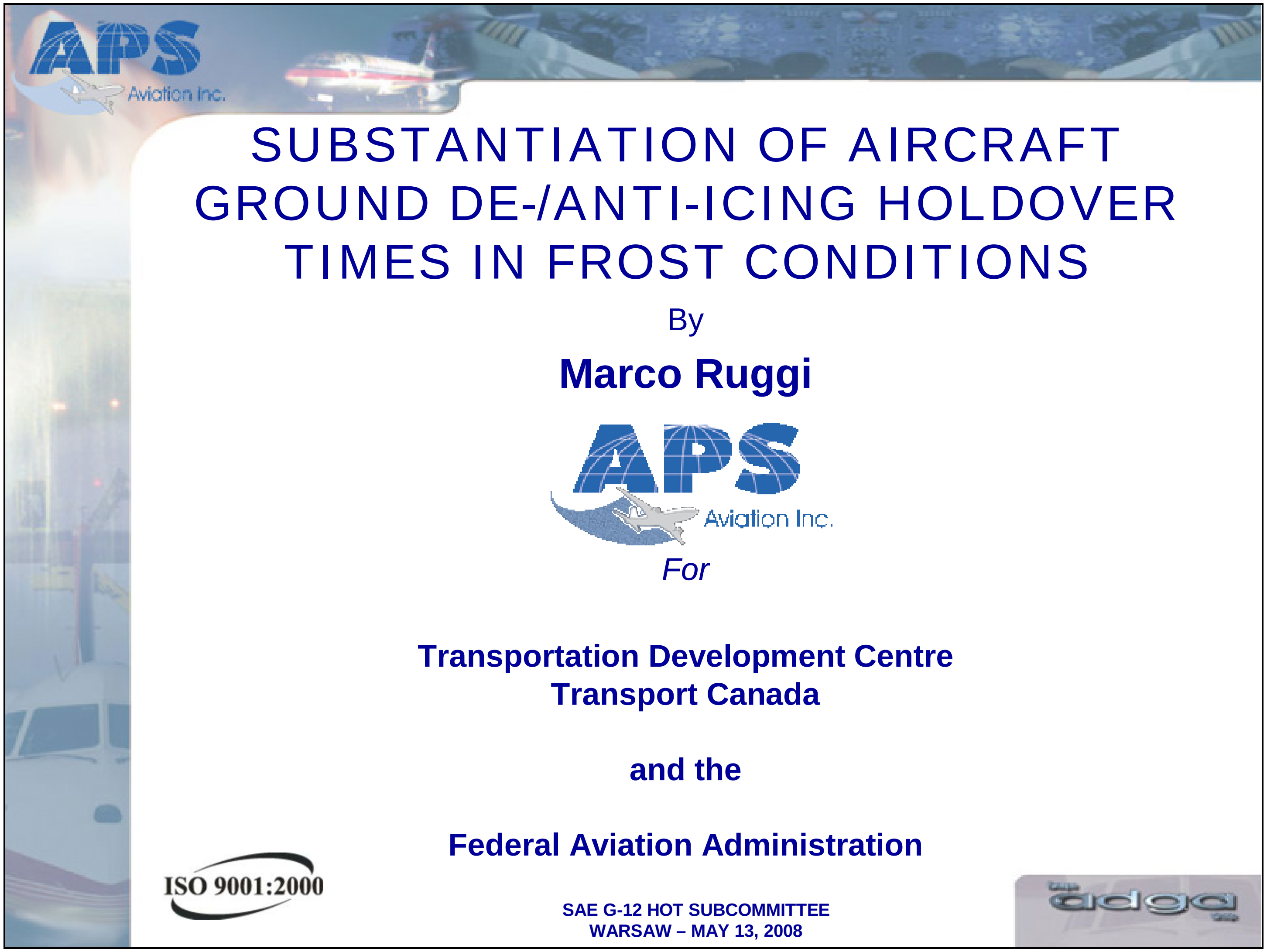
APPENDIX I

PRESENTATION: SUBSTANTIATION OF AIRCRAFT GROUND DE/ANTI-ICING HOLDOVER TIMES IN FROST CONDITIONS – WARSAW, MAY 2008



APS Aviation Inc.
SUBSTANTIATION OF AIRCRAFT GROUND DE-/ANTI-ICING HOLDOVER TIMES IN FROST CONDITIONS
By
Marco Ruggi
APS Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000
SAE G-12 HOT SUBCOMMITTEE
WARSAW – MAY 13, 2008
adga

PURPOSE

- Data collected by APS in natural frost conditions was presented at several meetings including the G-12 meeting in San Diego and in Montreal
- Attention was focused on:
  - **Reduced Endurance Times in Frost Conditions due to Fluid Freeze Point Issues**

PURPOSE

- Several working group meetings have been held between January and April 2008
- Attendees
  - Federal Aviation Administration
  - Transport Canada
  - APS
  - 2 Aircraft Operators
  - 1 Fluid Manufacturer
- Objective: Review current data available and scrutinize the proposed changes to the Frost HOT Guidelines

PURPOSE

- Purpose of this presentation is to briefly review test results and present the proposed **"Plan of Action"**

PRESENTATION OUTLINE

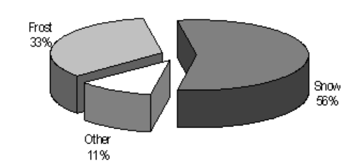
- BACKGROUND
- PREVIOUS WORK
- FROST ΔT PARAMETERS
- TYPE I TESTS
- TYPE II/III/IV TESTS
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
- PLAN OF ACTION

BACKGROUND

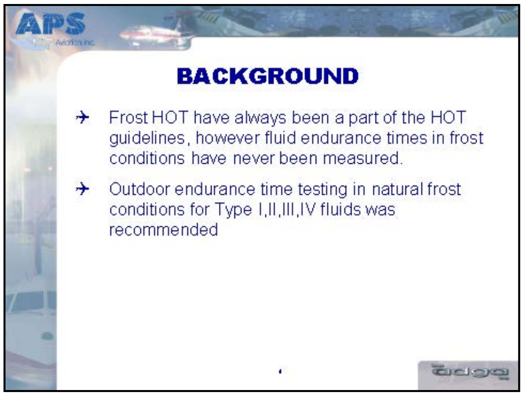
- A survey of deicing activities at airports was conducted by APS
- Data was collected from airports in North America, Europe and Asia
- Results showed removal of frost contamination represents a significant portion of deicing operations.
  - 90% of operations for airports with warmer climates
    - I.e. London and Paris
  - 25% of operations for airports with colder climates
    - I.e. Montreal

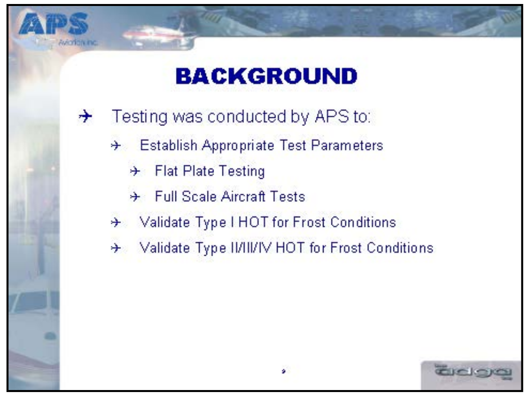
BACKGROUND

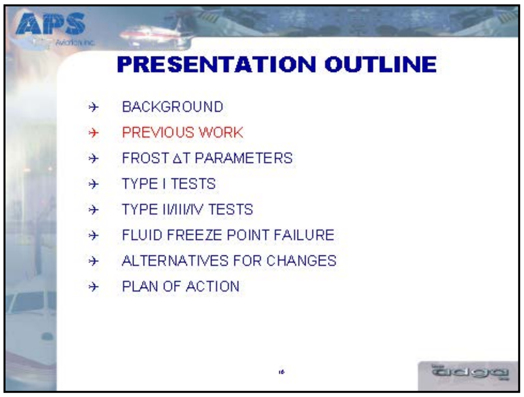
- Frequency of Deicing Operations Airport Survey 2000-03

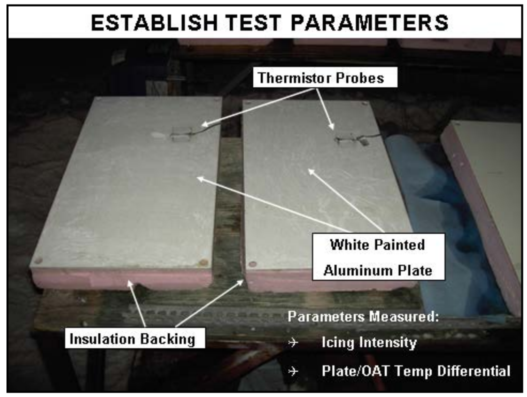


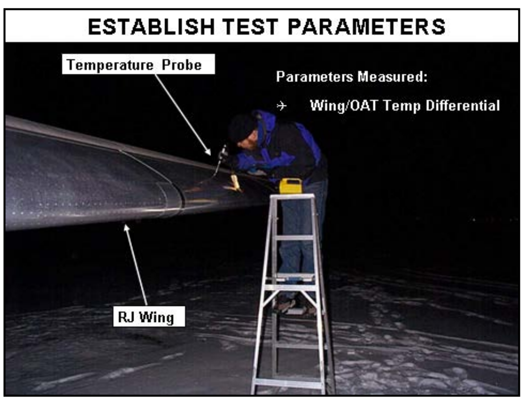
TC report TP 14375E

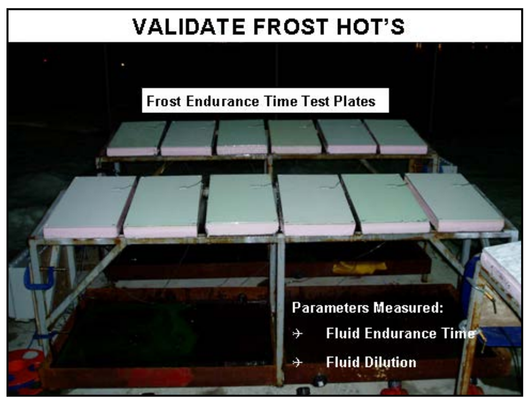

APS
BACKGROUND
Frost HOT have always been a part of the HOT guidelines, however fluid endurance times in frost conditions have never been measured.
Outdoor endurance time testing in natural frost conditions for Type I,II,III,IV fluids was recommended

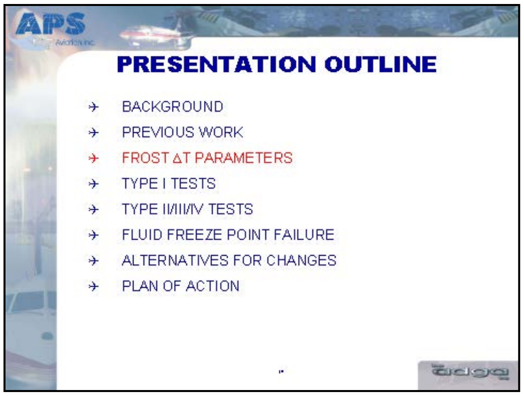

APS
BACKGROUND
Testing was conducted by APS to:
Establish Appropriate Test Parameters
Flat Plate Testing
Full Scale Aircraft Tests
Validate Type I HOT for Frost Conditions
Validate Type II/III/IV HOT for Frost Conditions

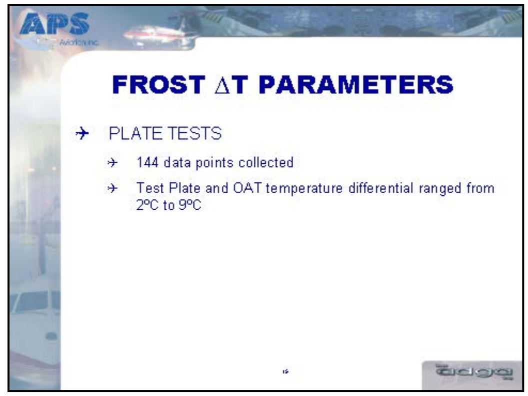

APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST ΔT PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
PLAN OF ACTION

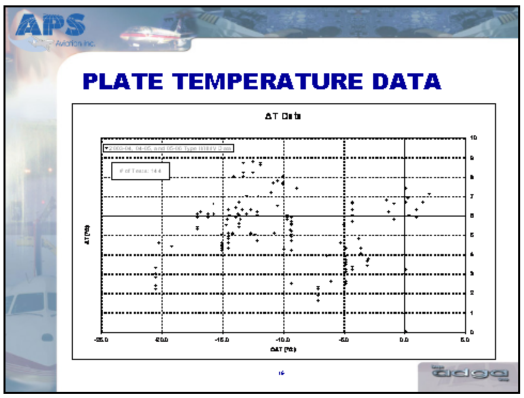

ESTABLISH TEST PARAMETERS
Thermistor Probes
White Painted Aluminum Plate
Insulation Backing
Parameters Measured:
Icing Intensity
Plate/OAT Temp Differential

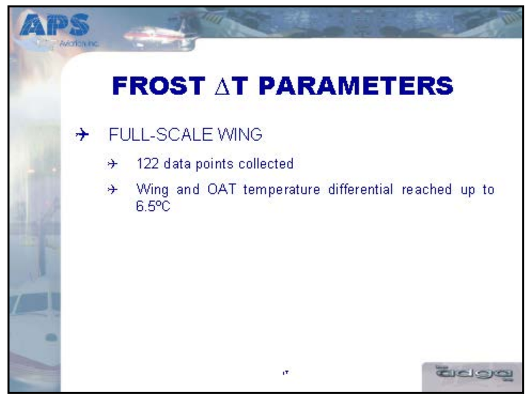

ESTABLISH TEST PARAMETERS
Temperature Probe
Parameters Measured:
Wing/OAT Temp Differential
RJ Wing

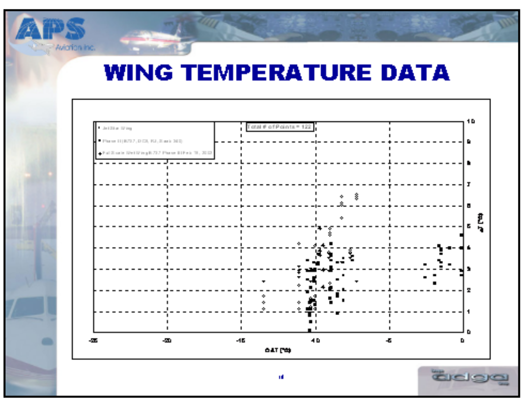

VALIDATE FROST HOT'S
Frost Endurance Time Test Plates
Parameters Measured:
Fluid Endurance Time
Fluid Dilution

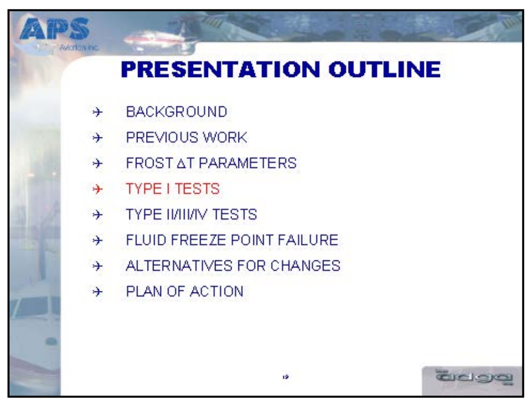

APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST ΔT PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
PLAN OF ACTION

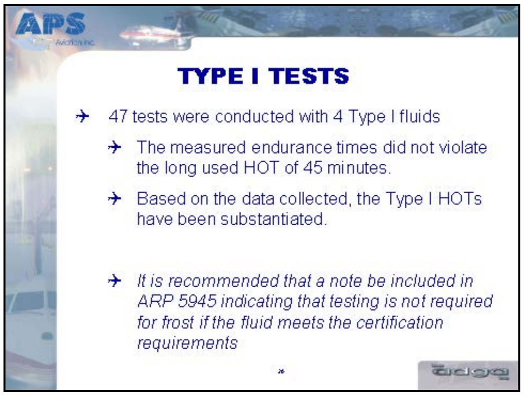

APS
FROST ΔT PARAMETERS
PLATE TESTS
144 data points collected
Test Plate and OAT temperature differential ranged from 2ºC to 9ºC

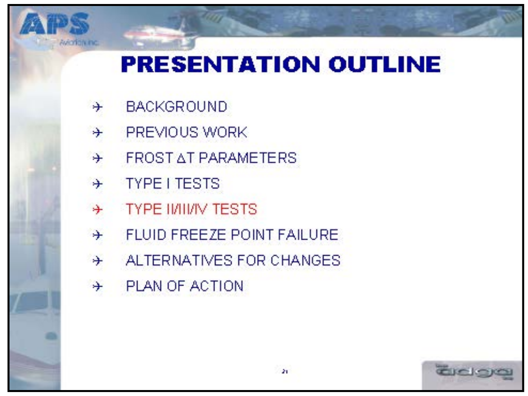

APS
PLATE TEMPERATURE DATA
ΔT Data
OAT (°C)

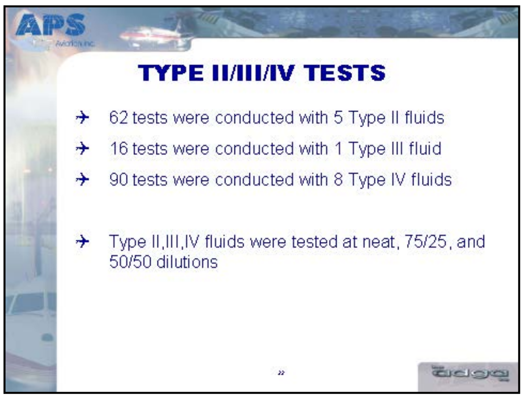

APS
FROST ΔT PARAMETERS
FULL-SCALE WING
122 data points collected
Wing and OAT temperature differential reached up to 6.5ºC

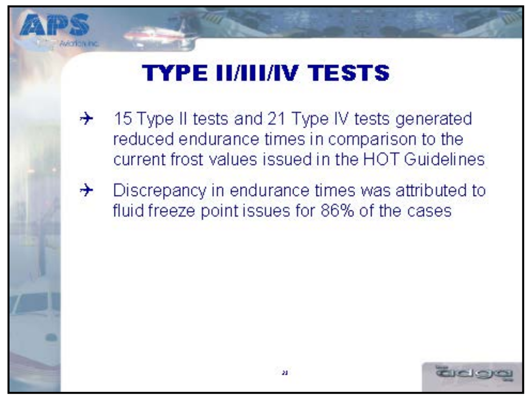

APS
WING TEMPERATURE DATA
OAT (°C)

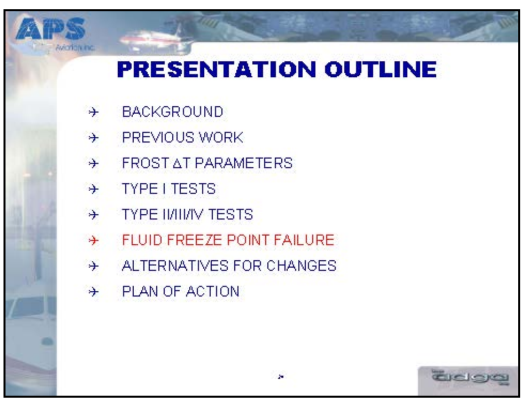

APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST ΔT PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
PLAN OF ACTION

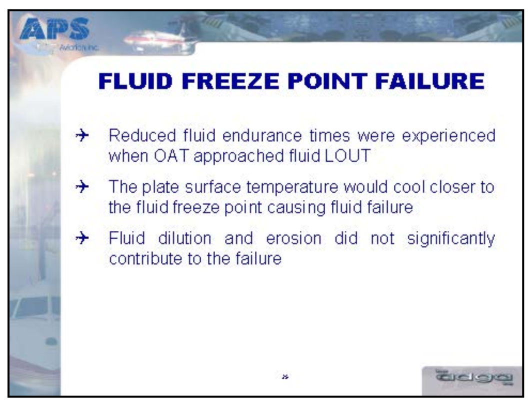

APS
TYPE I TESTS
47 tests were conducted with 4 Type I fluids
The measured endurance times did not violate the long used HOT of 45 minutes.
Based on the data collected, the Type I HOTs have been substantiated.
It is recommended that a note be included in ARP 5945 indicating that testing is not required for frost if the fluid meets the certification requirements


APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST ΔT PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
PLAN OF ACTION


APS
TYPE II/III/IV TESTS
62 tests were conducted with 5 Type II fluids
16 tests were conducted with 1 Type III fluid
90 tests were conducted with 8 Type IV fluids
Type II,III,IV fluids were tested at neat, 75/25, and 50/50 dilutions


APS
TYPE II/III/IV TESTS
15 Type II tests and 21 Type IV tests generated reduced endurance times in comparison to the current frost values issued in the HOT Guidelines
Discrepancy in endurance times was attributed to fluid freeze point issues for 86% of the cases


APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FROST ΔT PARAMETERS
TYPE I TESTS
TYPE II/III/IV TESTS
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
PLAN OF ACTION


APS
FLUID FREEZE POINT FAILURE
Reduced fluid endurance times were experienced when OAT approached fluid LOUT
The plate surface temperature would cool closer to the fluid freeze point causing fluid failure
Fluid dilution and erosion did not significantly contribute to the failure

FLUID FREEZE POINT FAILURE

- EXAMPLE
  - Type IV 75/25 Fluid
  - OAT = **-13.9°C** (within operational limit)
  - Plate Temperature = -13.9°C – (7°C) = **-20. 9°C**
  - Fluid Freeze Point = **-21°C**
    - Fluid would be designed with 7°C buffer based on LOUT of -14°C
  - **Plate temperature is cooled to LOUT**
  - **Fluid experiences contamination as ice crystals begin to form sporadically in fluid**

FLUID FREEZE POINT FAILURE

- Fluid freeze point failure can be experienced with dilutions when operating close to the LOUT
  - *Assuming ΔT=7ºC*

Type II/IV Dilution	LOUT	Approximate FFP	Possible Surface Temp. During Frost Conditions at LOUT
Neat	-25	-36	-32
75/25	-14	-21	-21
50/50	-3	-10	-10

FLUID FREEZE POINT FAILURE

- The HOT table provides operational ranges specifying limits based on OAT
- In frost conditions, the skin temperature of an aircraft may be several degrees lower than the OAT
- If operating with a fluid close to the LOUT during frost conditions, the skin temperature of the aircraft could reach the fluid freeze point potentially causing ice to form in the fluid
- **FROST HOT'S SHOULD CONSIDER THE EFFECT OF SKIN TEMPERATURE**

PRESENTATION OUTLINE

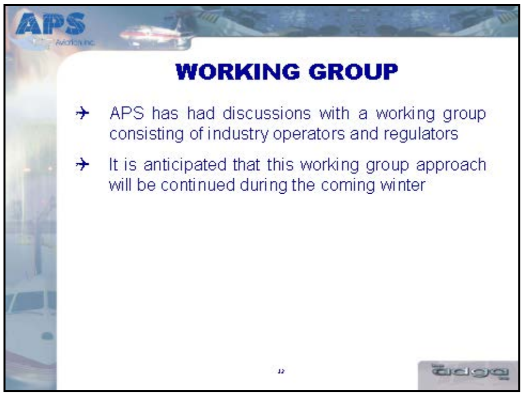
- BACKGROUND
- PREVIOUS WORK
- FROST ΔT PARAMETERS
- TYPE I TESTS
- TYPE II/III/IV TESTS
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
- PLAN OF ACTION

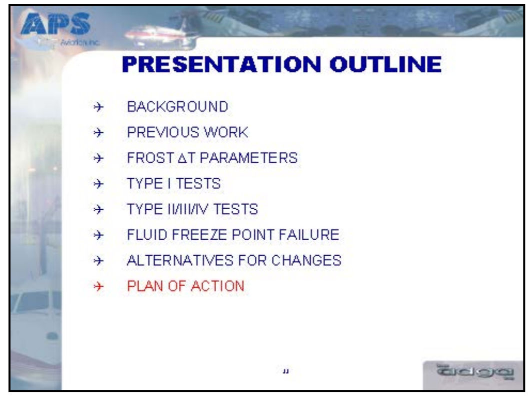
ALTERNATIVES FOR CHANGES

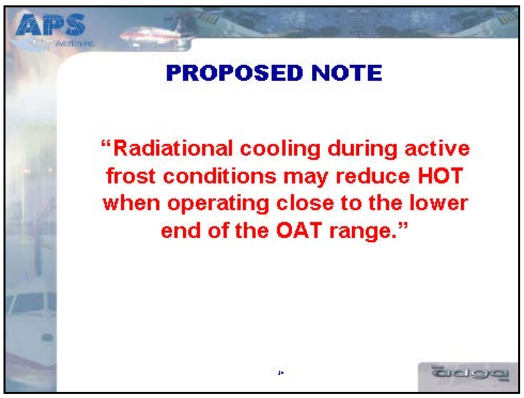
- Changes to the Frost HOT's are necessary to account for:
  - Endurance Time Data Collected
  - Fluid Freeze Point Failure
- 4 Options were developed and evaluated:
  - **CURRENT HOT FORMAT / REDUCED HOT'S**
  - **CURRENT HOT FORMAT / OAT FOOTNOTES**
  - **SEPARATE FROST HOT TABLE**
  - **NOTE IN HOT TABLE (INTERIM SOLUTION)**

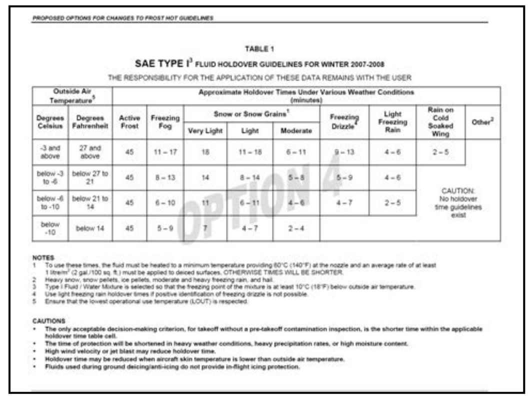
ALTERNATIVES FOR CHANGES

- Workgroup conclusions:
  - Reductions were apparent during natural frost ET testing, however;
  - Further work is required to substantiate current ET testing protocol for natural frost conditions
- Workgroup proposal:
  - HOT reductions will not be issued until further work is conducted, however;
  - A note will be included in the Type II and Type IV HOT tables to advise of possible reduced HOT's









PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 1

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

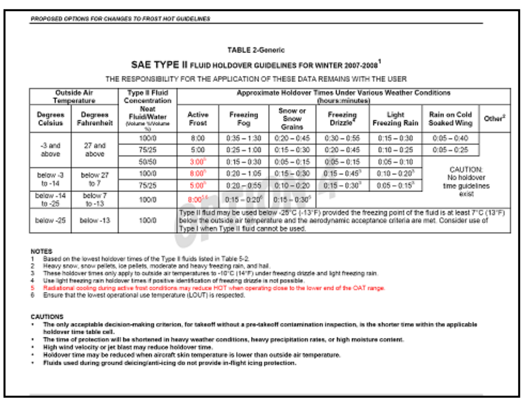
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Snow or Snow Grains[1] Very Light	Snow or Snow Grains[1] Light	Snow or Snow Grains[1] Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

OPTION 4

NOTES
1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces. OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

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



PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

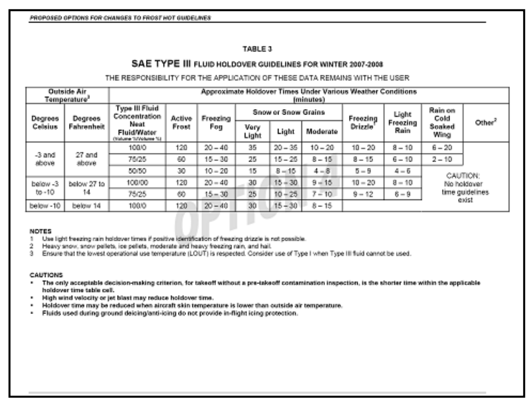
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

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

Outside Air Temperature		Type II Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	3:00[5]	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00[5]	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	5:00[5]	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	8:00[5,6]	0:15 – 0:20[6]	0:15 – 0:30[6]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce HOT when operating close to the lower end of the OAT range.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

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



PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

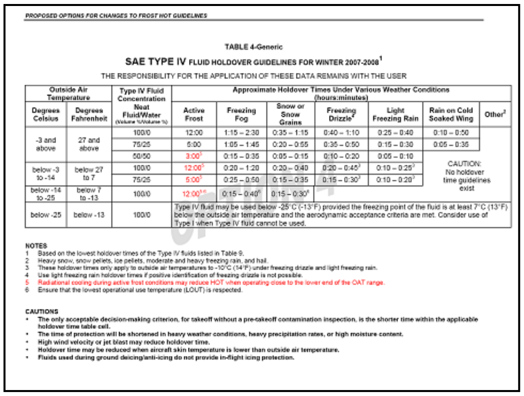
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

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

OPTION 4

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

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



PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-Generic

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

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

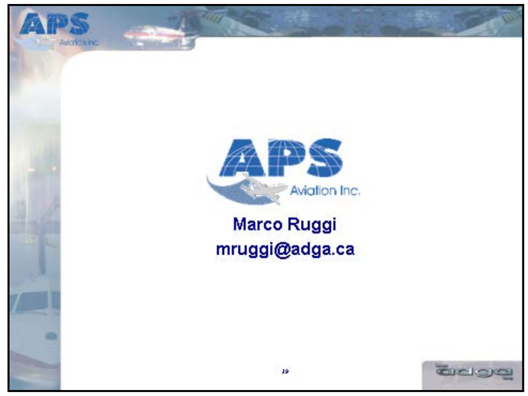
Outside Air Temperature		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:35 – 1:15	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	
		75/25	5:00	1:05 – 1:45	0:20 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:35	
		50/50	3:00[5]	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00[5]	0:20 – 1:20	0:20 – 0:40	0:20 – 0:45[3]	0:10 – 0:25[3]		
		75/25	5:00[5]	0:25 – 0:50	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	12:00[5,6]	0:15 – 0:40[6]	0:15 – 0:30[6]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce HOT when operating close to the lower end of the OAT range.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

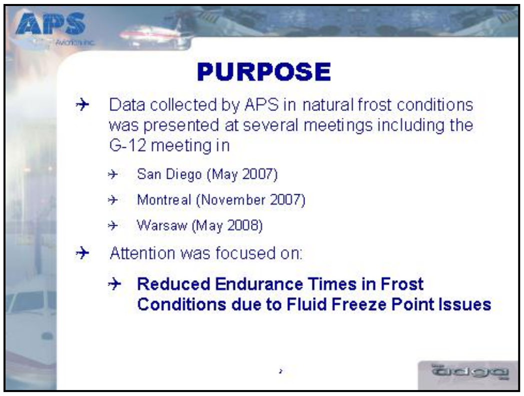
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**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

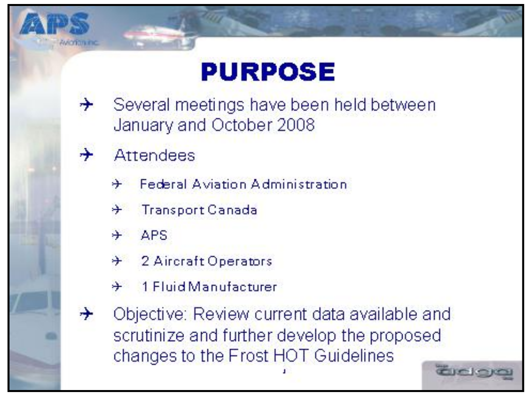


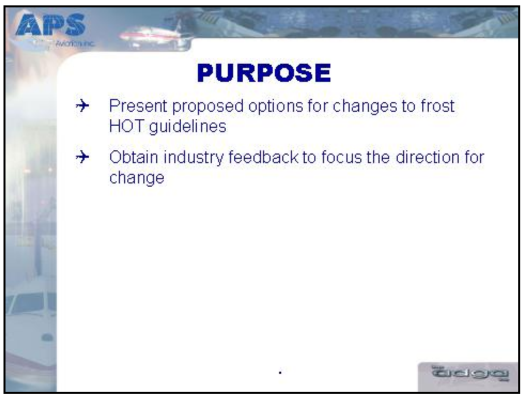
APPENDIX J

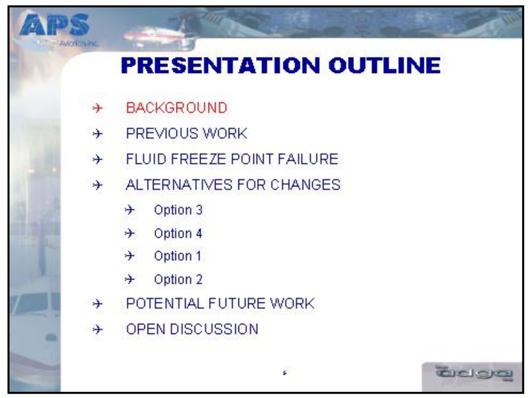
PRESENTATION: PROPOSED CHANGES TO FROST HOT GUIDELINES, NOVEMBER 2008

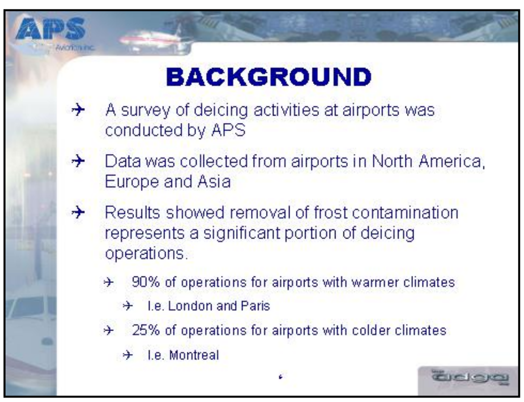

PROPOSED CHANGES TO
FROST HOT GUIDELINES
By
Marco Ruggi
APS
Aviation Inc
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
SAE G-12 HOT SUBCOMMITTEE
MONTREAL – NOVEMBER 5, 2008

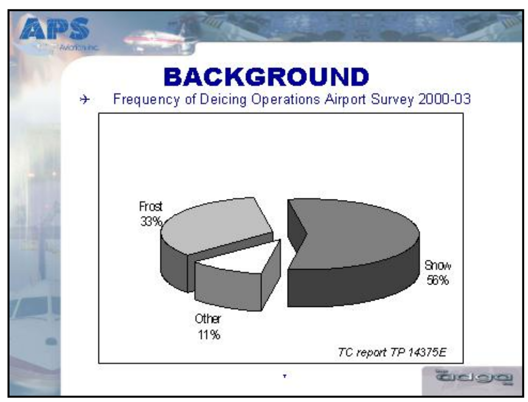

APS
PURPOSE
Data collected by APS in natural frost conditions was presented at several meetings including the G-12 meeting in
San Diego (May 2007)
Montreal (November 2007)
Warsaw (May 2008)
Attention was focused on:
Reduced Endurance Times in Frost Conditions due to Fluid Freeze Point Issues

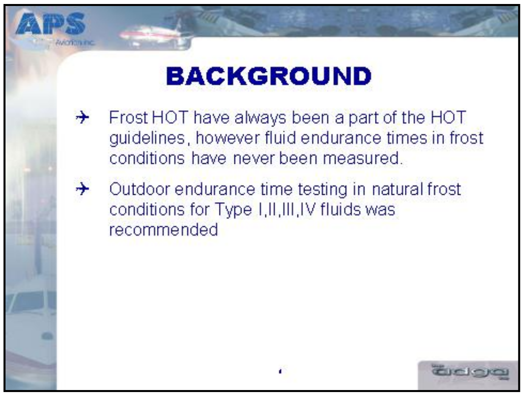

APS
PURPOSE
Several meetings have been held between January and October 2008
Attendees
Federal Aviation Administration
Transport Canada
APS
2 Aircraft Operators
1 Fluid Manufacturer
Objective: Review current data available and scrutinize and further develop the proposed changes to the Frost HOT Guidelines

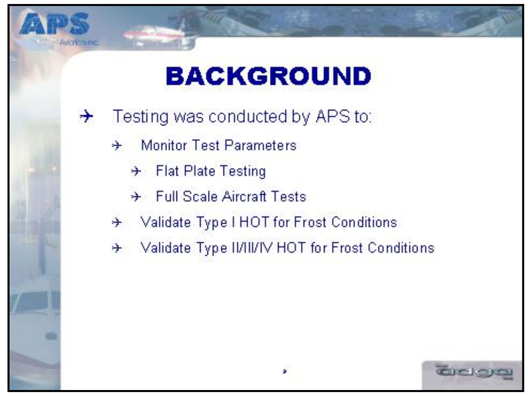

APS
PURPOSE
Present proposed options for changes to frost HOT guidelines
Obtain industry feedback to focus the direction for change

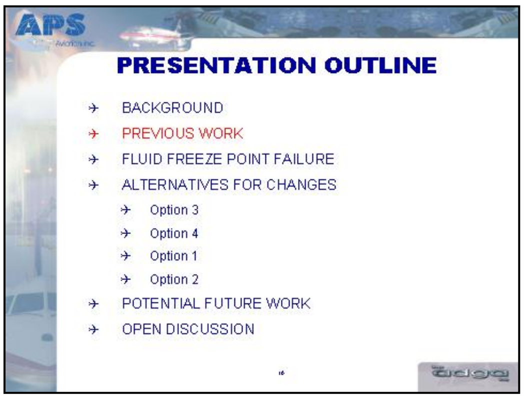

APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
Option 3
Option 4
Option 1
Option 2
POTENTIAL FUTURE WORK
OPEN DISCUSSION

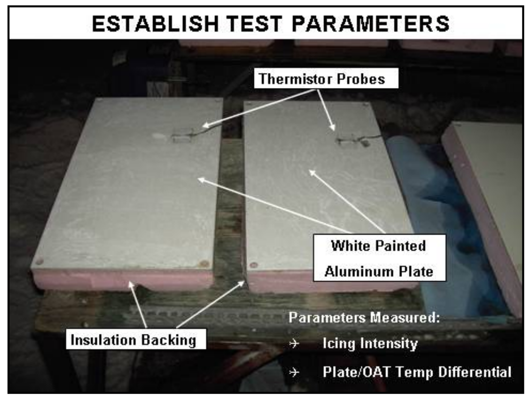

APS
BACKGROUND
A survey of deicing activities at airports was conducted by APS
Data was collected from airports in North America, Europe and Asia
Results showed removal of frost contamination represents a significant portion of deicing operations.
90% of operations for airports with warmer climates
I.e. London and Paris
25% of operations for airports with colder climates
I.e. Montreal

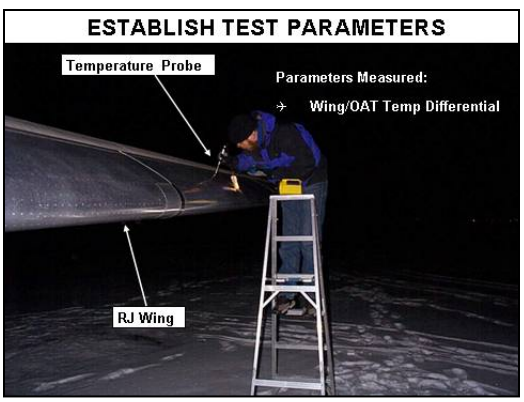

APS
BACKGROUND
Frequency of Deicing Operations Airport Survey 2000-03
Frost 33%
Snow 56%
Other 11%
TC report TP 14375E

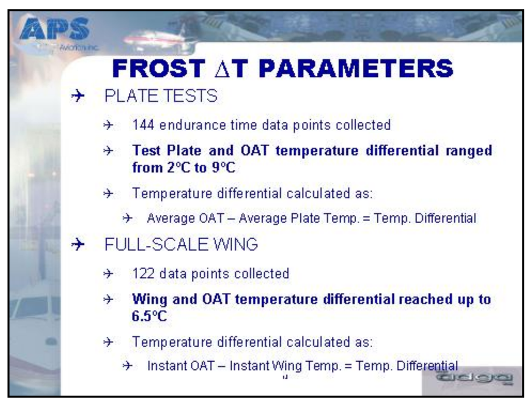

APS
BACKGROUND
Frost HOT have always been a part of the HOT guidelines, however fluid endurance times in frost conditions have never been measured.
Outdoor endurance time testing in natural frost conditions for Type I,II,III,IV fluids was recommended

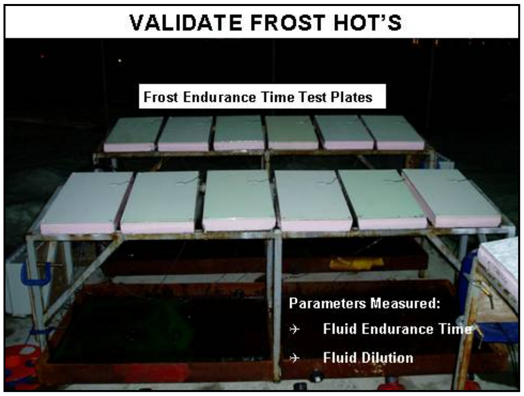

APS
BACKGROUND
Testing was conducted by APS to:
Monitor Test Parameters
Flat Plate Testing
Full Scale Aircraft Tests
Validate Type I HOT for Frost Conditions
Validate Type II/III/IV HOT for Frost Conditions

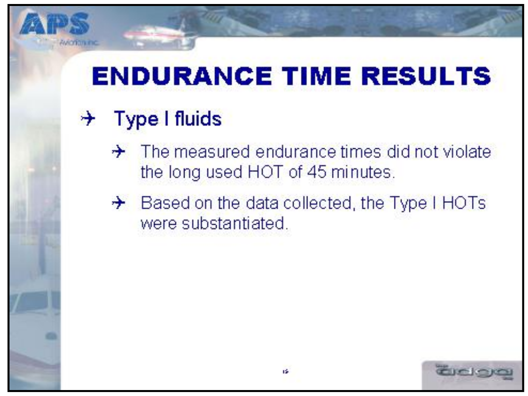

APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
Option 3
Option 4
Option 1
Option 2
POTENTIAL FUTURE WORK
OPEN DISCUSSION

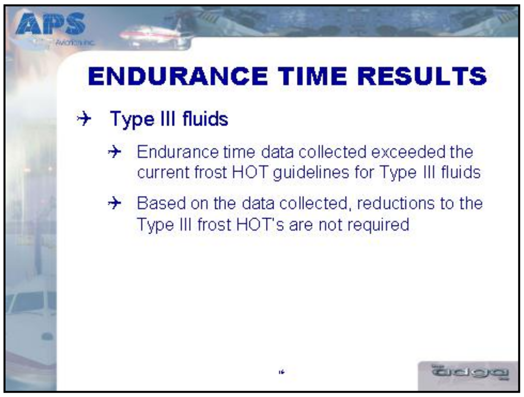

ESTABLISH TEST PARAMETERS
Thermistor Probes
White Painted
Aluminum Plate
Insulation Backing
Parameters Measured:
Icing Intensity
Plate/OAT Temp Differential

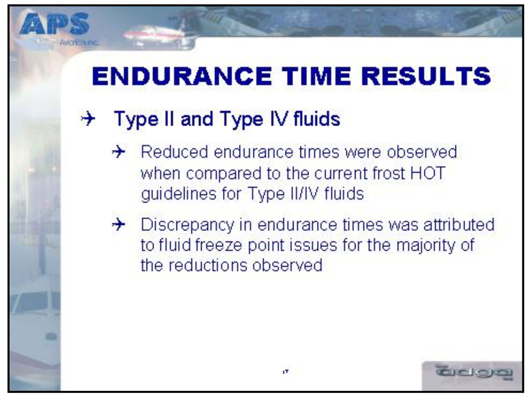

ESTABLISH TEST PARAMETERS
Temperature Probe
Parameters Measured:
Wing/OAT Temp Differential
RJ Wing

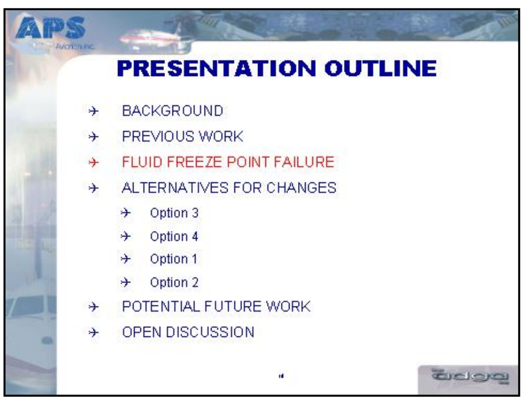

APS
FROST ΔT PARAMETERS
PLATE TESTS
144 endurance time data points collected
Test Plate and OAT temperature differential ranged from 2°C to 9°C
Temperature differential calculated as:
Average OAT – Average Plate Temp. = Temp. Differential
FULL-SCALE WING
122 data points collected
Wing and OAT temperature differential reached up to 6.5°C
Temperature differential calculated as:
Instant OAT – Instant Wing Temp. = Temp. Differential

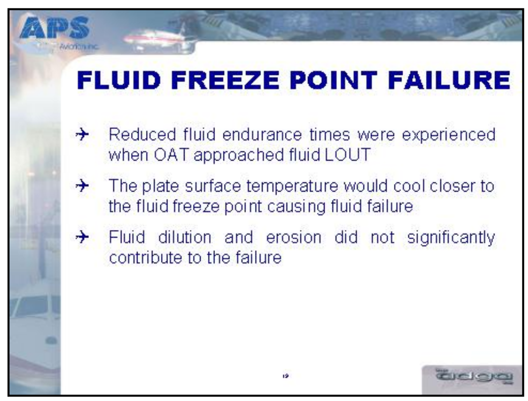

VALIDATE FROST HOT'S
Frost Endurance Time Test Plates
Parameters Measured:
Fluid Endurance Time
Fluid Dilution


APS
ENDURANCE TIME RESULTS
Type I fluids
The measured endurance times did not violate the long used HOT of 45 minutes.
Based on the data collected, the Type I HOTs were substantiated.


APS
ENDURANCE TIME RESULTS
Type III fluids
Endurance time data collected exceeded the current frost HOT guidelines for Type III fluids
Based on the data collected, reductions to the Type III frost HOT's are not required


APS
ENDURANCE TIME RESULTS
Type II and Type IV fluids
Reduced endurance times were observed when compared to the current frost HOT guidelines for Type II/IV fluids
Discrepancy in endurance times was attributed to fluid freeze point issues for the majority of the reductions observed


APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS WORK
FLUID FREEZE POINT FAILURE
ALTERNATIVES FOR CHANGES
Option 3
Option 4
Option 1
Option 2
POTENTIAL FUTURE WORK
OPEN DISCUSSION


APS
FLUID FREEZE POINT FAILURE
Reduced fluid endurance times were experienced when OAT approached fluid LOUT
The plate surface temperature would cool closer to the fluid freeze point causing fluid failure
Fluid dilution and erosion did not significantly contribute to the failure

FLUID FREEZE POINT FAILURE

- EXAMPLE
  - Type IV 75/25 Fluid
  - OAT = **-13.9°C** (within operational limit)
  - Plate Temperature = -13.9°C – (7°C) = **-20. 9°C**
  - Fluid Freeze Point (FFP) = **-21°C**
    - Fluid would be designed with 7°C buffer based on operational limit of -14°C
  - **Plate temperature is cooled to FFP**
  - **Fluid experiences contamination as ice crystals begin to form sporadically in fluid**

FLUID FREEZE POINT FAILURE

- Fluid freeze point failure can be experienced with dilutions when operating at the lower end of the temperature ranges
  - *Assuming ΔT=7°C*

Type II/IV Dilution	Lowest Possible Condition Temperature (°C)	Approximate FFP (°C)	Possible Surface Temp. During Frost Conditions (°C)
Neat	-25	-36	-32
75/25	-14	-21	-21
50/50	-3	-10	-10

FLUID FREEZE POINT FAILURE

- The HOT table provides operational ranges specifying limits based on OAT
- In frost conditions, the skin temperature of an aircraft may be several degrees lower than the OAT
- If operating with a fluid close to the lower end of the temperature range during frost conditions, the skin temperature of the aircraft could reach the fluid freeze point potentially causing ice to form in the fluid
- **FROST HOT'S SHOULD CONSIDER THE EFFECT OF SKIN TEMPERATURE**

PRESENTATION OUTLINE

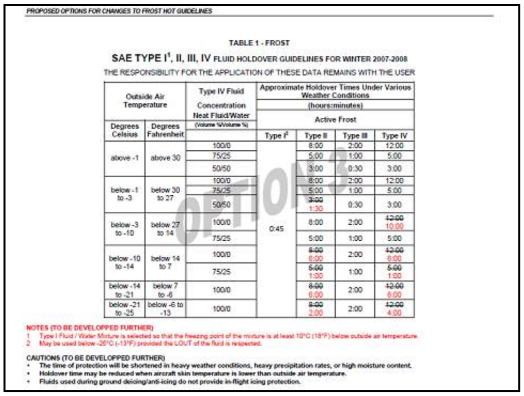
- BACKGROUND
- PREVIOUS WORK
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
  - Option 3
  - Option 4
  - Option 1
  - Option 2
- POTENTIAL FUTURE WORK
- OPEN DISCUSSION

ALTERNATIVES FOR CHANGES

- Changes to the Frost HOT's are necessary to account for:
  - Endurance Time Data Collected
  - Fluid Freeze Point Failure
- 4 Options were developed and evaluated:
  - **#3 - SEPARATE FROST HOT TABLE**
  - **#4 - NOTE IN HOT TABLE (INTERIM SOLUTION)**
  - **#1 - CURRENT HOT FORMAT / REDUCED HOT'S**
  - **#2 - CURRENT HOT FORMAT / OAT FOOTNOTES**

OPTION 3
SEPARATE FROST TABLE

- Issue frost HOT's on a separate table
- Remove frost HOT's from generic and fluid specific tables
- Change temperature ranges to reflect skin temp. differential experienced during frost conditions



PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 1 - FROST

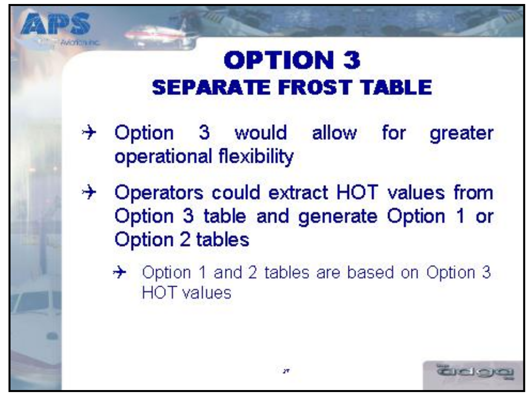
SAE TYPE I[1], II, III, IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

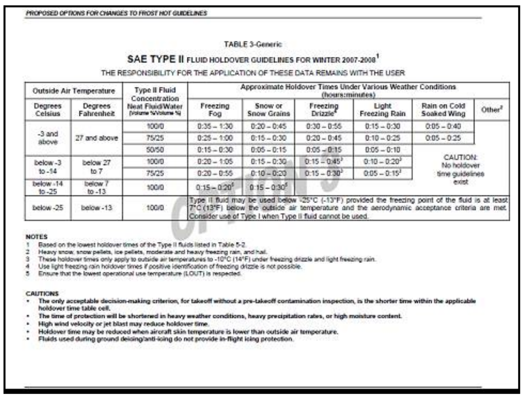
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature Degrees Celsius	Outside Air Temperature Degrees Fahrenheit	Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Active Frost Type I[2]	Active Frost Type II	Active Frost Type III	Active Frost Type IV
above -1	above 30	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 1:30	0:30	3:00
below -3 to -10	below 27 to 14	100/0		8:00	2:00	~~12:00~~ 10:00
		75/25		5:00	1:00	5:00
below -10 to -14	below 14 to 7	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00
below -14 to -21	below 7 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
below -21 to -25	below -6 to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 4:00

NOTES (TO BE DEVELOPPED FURTHER)
1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 May be used below -25°C (-13°F) provided the LOUT of the fluid is respected.

CAUTIONS (TO BE DEVELOPPED FURTHER)
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.
- Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.
- Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.





PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 3-Generic

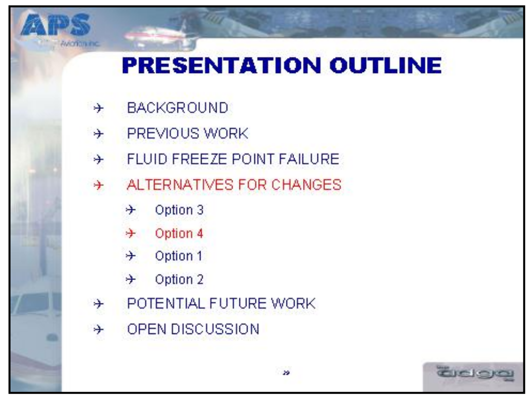
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

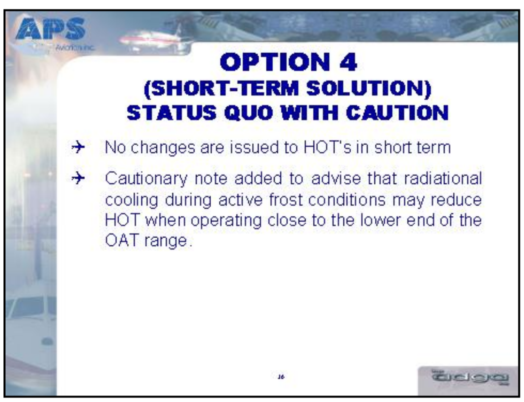
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

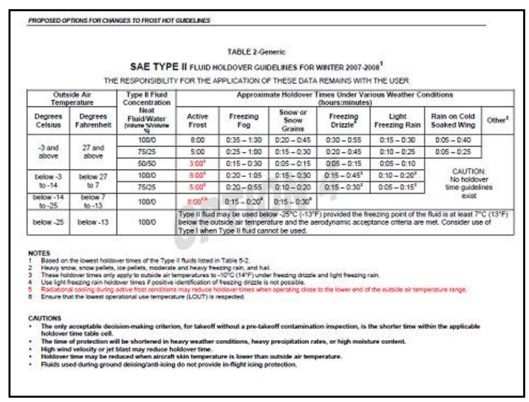
Outside Air Temperature Degrees Celsius	Outside Air Temperature Degrees Fahrenheit	Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	0:35 – 1:30	0:20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

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

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







PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

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

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

Outside Air Temperature Degrees Celsius	Outside Air Temperature Degrees Fahrenheit	Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	CAUTION: No holdover time guidelines exist
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	3:00[5]	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	8:00[5]	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	5:00[5]	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	8:00[5,6]	0:15 – 0:20[6]	0:15 – 0:30[6]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce holdover times when operating close to the lower end of the outside air temperature range.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

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

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-Generic

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

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

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:35 – 1:15	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	
		75/25	5:00	1:05 – 1:45	0:20 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:35	
		50/50	3:00[5]	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00[5]	0:20 – 1:20	0:20 – 0:40	0:20 – 0:45[3]	0:10 – 0:25[3]		
		75/25	5:00[5]	0:25 – 0:50	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	12:00[5,6]	0:15 – 0:40[6]	0:15 – 0:30[6]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES
1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce holdover times when operating close to the lower end of the outside air temperature range.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

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

APS Aviation Inc.

PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS WORK
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
  - Option 3
  - Option 4
  - Option 1
  - Option 2
- POTENTIAL FUTURE WORK
- OPEN DISCUSSION

APS Aviation Inc.

OPTION 1
CURRENT FORMAT / REDUCED HOT'S

- Use current temperature breakdowns for Frost HOT's
- Issue reduced HOT changes in current HOT table format

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

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

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

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	~~3:00~~ 1:30	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	~~8:00~~ 6:00	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	~~5:00~~ 1:00	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	~~8:00[5]~~ 2:00[5]	0:15 – 0:20[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

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

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

APS Aviation Inc.

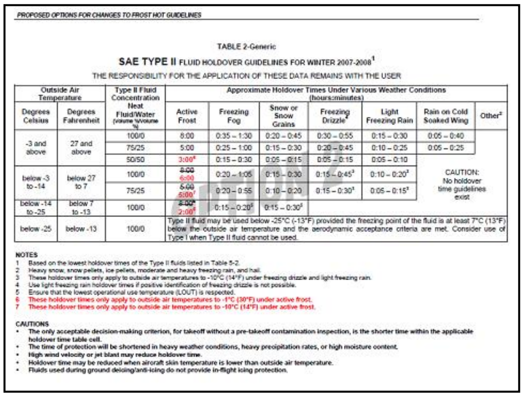
PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS WORK
- FLUID FREEZE POINT FAILURE
- ALTERNATIVES FOR CHANGES
  - Option 3
  - Option 4
  - Option 1
  - Option 2
- POTENTIAL FUTURE WORK
- OPEN DISCUSSION

APS Aviation Inc.

OPTION 2
CURRENT FORMAT / OAT FOOTNOTES FOR DILUTED FLUIDS

- Issue changes in the current HOT tables
- Restrict use of DILUTED fluids to reflect skin temp. differential experienced during frost conditions
- Include notes in tables to describe temperature restrictions



PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

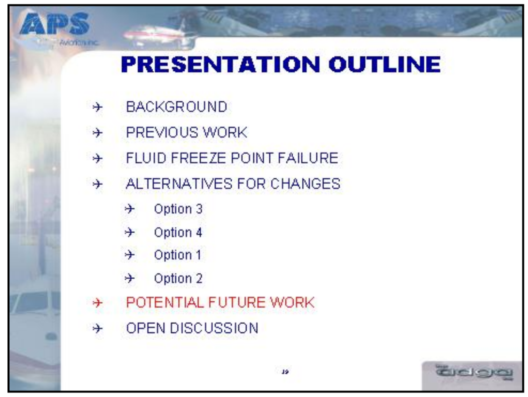
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

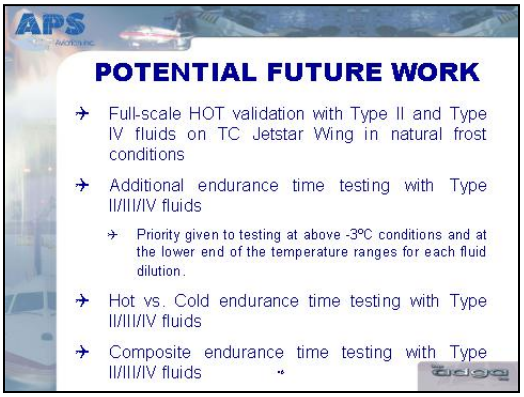
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

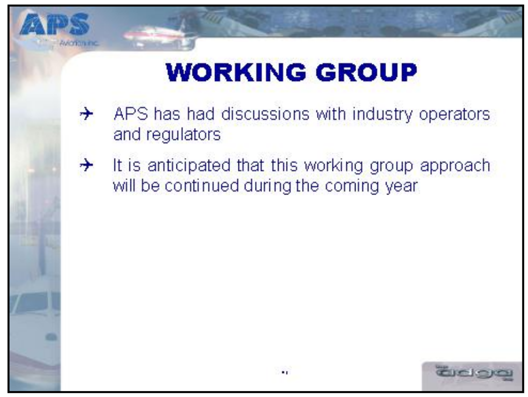
Outside Air Temperature		Type II Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (volume %/volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[2]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	3:00[6]	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	~~8:00~~ 6:00	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]	CAUTION: No holdover time guidelines exist	
		75/25	~~5:00~~ 5:00[7]	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	~~8:00~~[4] 2:00[6]	0:15 – 0:20[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

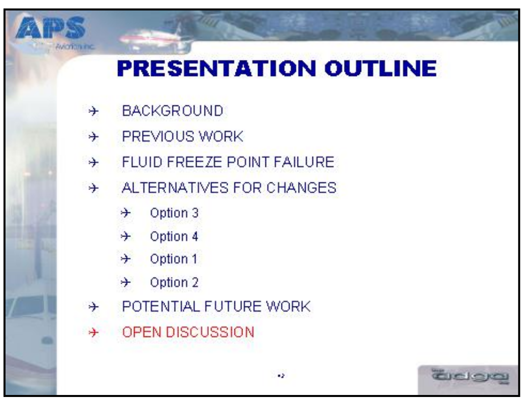
NOTES
1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
6 These holdover times only apply to outside air temperatures to -1°C (30°F) under active frost.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under active frost.

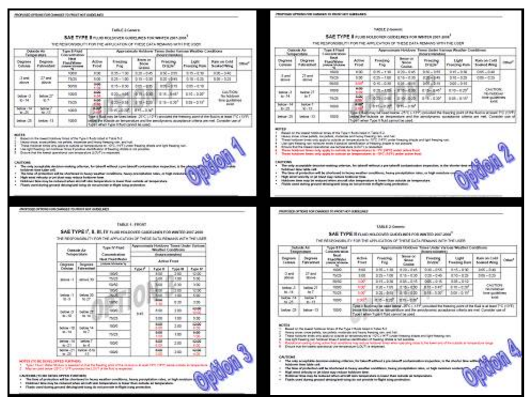
CAUTIONS
- The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture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







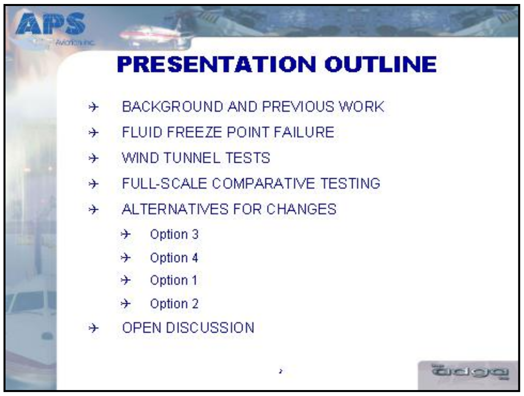


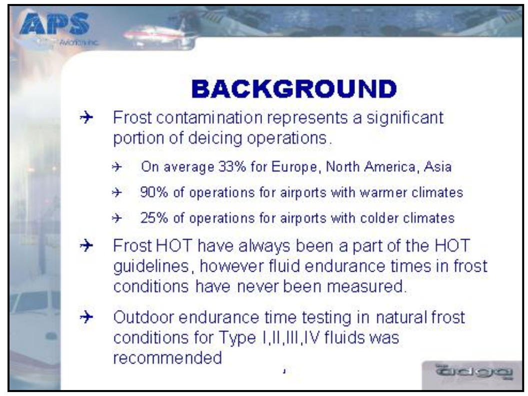


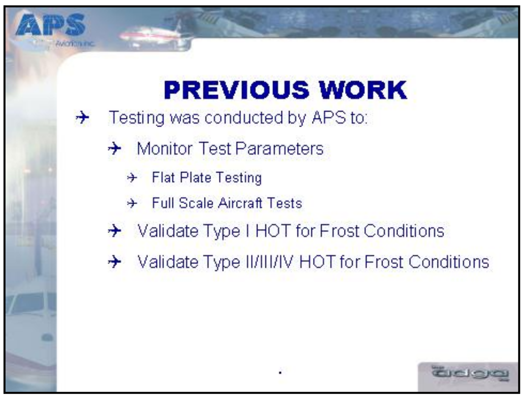
APPENDIX K

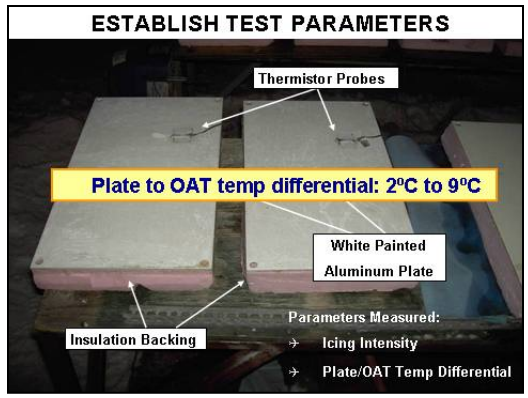
PRESENTATION: PROPOSED CHANGES TO FROST HOT GUIDELINES, CHARLESTON - MAY 2009

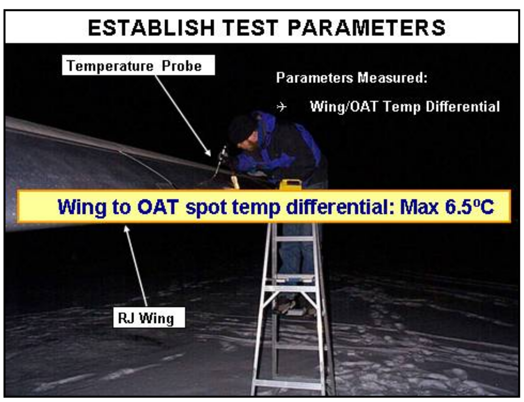

PROPOSED CHANGES TO FROST HOT GUIDELINES
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
SAE G-12 HOT SUBCOMMITTEE
CHARLESTON – MAY 12, 2009

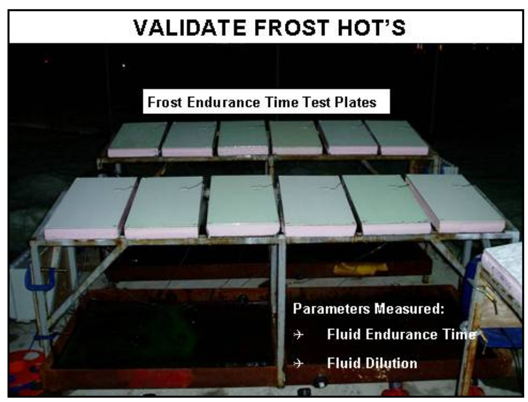

APS
PRESENTATION OUTLINE
BACKGROUND AND PREVIOUS WORK
FLUID FREEZE POINT FAILURE
WIND TUNNEL TESTS
FULL-SCALE COMPARATIVE TESTING
ALTERNATIVES FOR CHANGES
Option 3
Option 4
Option 1
Option 2
OPEN DISCUSSION

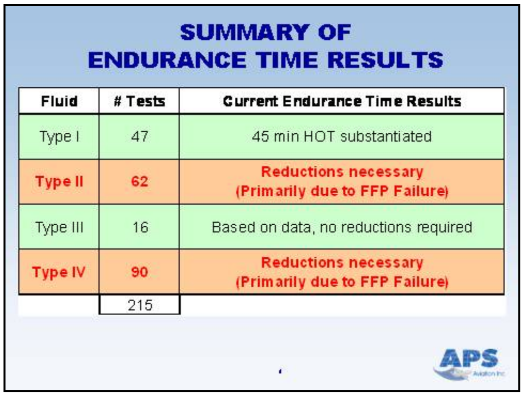

APS
BACKGROUND
Frost contamination represents a significant portion of deicing operations.
On average 33% for Europe, North America, Asia
90% of operations for airports with warmer climates
25% of operations for airports with colder climates
Frost HOT have always been a part of the HOT guidelines, however fluid endurance times in frost conditions have never been measured.
Outdoor endurance time testing in natural frost conditions for Type I,II,III,IV fluids was recommended

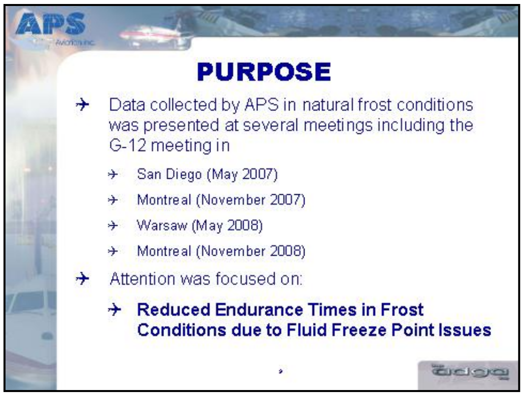

APS
PREVIOUS WORK
Testing was conducted by APS to:
Monitor Test Parameters
Flat Plate Testing
Full Scale Aircraft Tests
Validate Type I HOT for Frost Conditions
Validate Type II/III/IV HOT for Frost Conditions

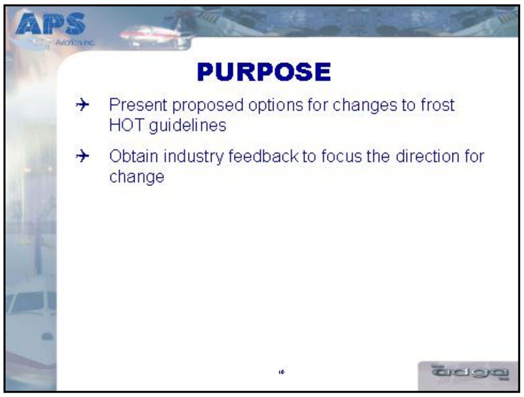

ESTABLISH TEST PARAMETERS
Thermistor Probes
Plate to OAT temp differential: 2ºC to 9ºC
White Painted Aluminum Plate
Insulation Backing
Parameters Measured:
Icing Intensity
Plate/OAT Temp Differential

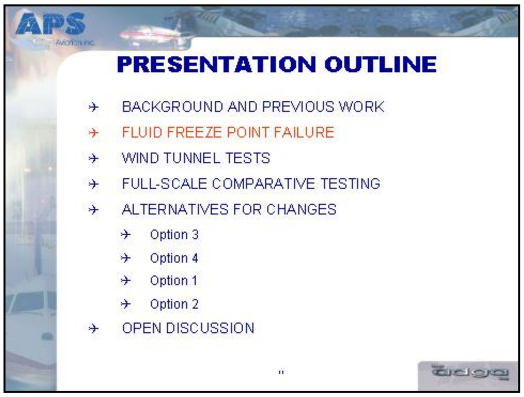

ESTABLISH TEST PARAMETERS
Temperature Probe
Parameters Measured:
Wing/OAT Temp Differential
Wing to OAT spot temp differential: Max 6.5ºC
RJ Wing


VALIDATE FROST HOT'S
Frost Endurance Time Test Plates
Parameters Measured:
Fluid Endurance Time
Fluid Dilution


SUMMARY OF
ENDURANCE TIME RESULTS
Fluid | # Tests | Current Endurance Time Results
Type I | 47 | 45 min HOT substantiated
Type II | 62 | Reductions necessary (Primarily due to FFP Failure)
Type III | 16 | Based on data, no reductions required
Type IV | 90 | Reductions necessary (Primarily due to FFP Failure)
215
APS


APS
PURPOSE
Data collected by APS in natural frost conditions was presented at several meetings including the G-12 meeting in
San Diego (May 2007)
Montreal (November 2007)
Warsaw (May 2008)
Montreal (November 2008)
Attention was focused on:
Reduced Endurance Times in Frost Conditions due to Fluid Freeze Point Issues


APS
PURPOSE
Present proposed options for changes to frost HOT guidelines
Obtain industry feedback to focus the direction for change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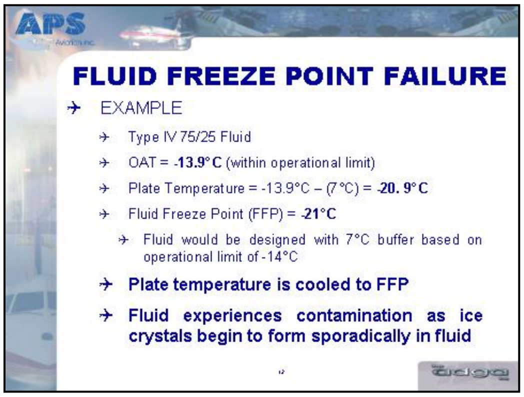
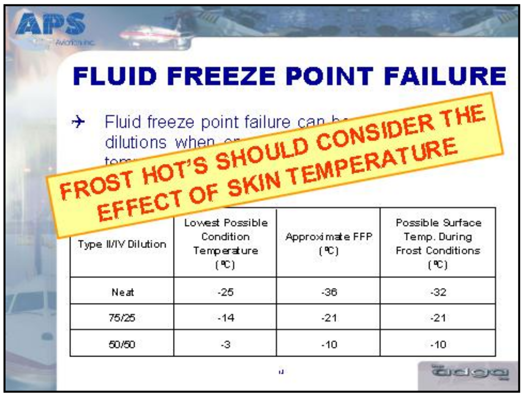
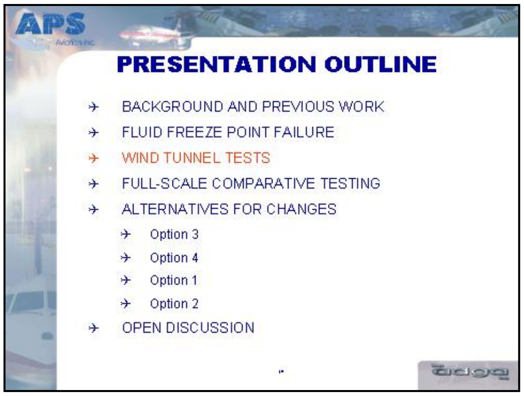

APS
FLUID FREEZE POINT FAILURE
EXAMPLE
Type IV 75/25 Fluid
OAT = -13.9°C (within operational limit)
Plate Temperature = -13.9°C – (7°C) = -20. 9°C
Fluid Freeze Point (FFP) = -21°C
Fluid would be designed with 7°C buffer based on operational limit of -14°C
Plate temperature is cooled to FFP
Fluid experiences contamination as ice crystals begin to form sporadically in fluid


APS
FLUID FREEZE POINT FAILURE
Fluid freeze point failure can b
dilutions when
FROST HOT'S SHOULD CONSIDER THE EFFECT OF SKIN TEMPERATURE
Type II/IV Dilution | Lowest Possible Condition Temperature (°C) | Approximate FFP (°C) | Possible Surface Temp. During Frost Conditions (°C)
Neat | -25 | -36 | -32
75/25 | -14 | -21 | -21
50/50 | -3 | -10 | -10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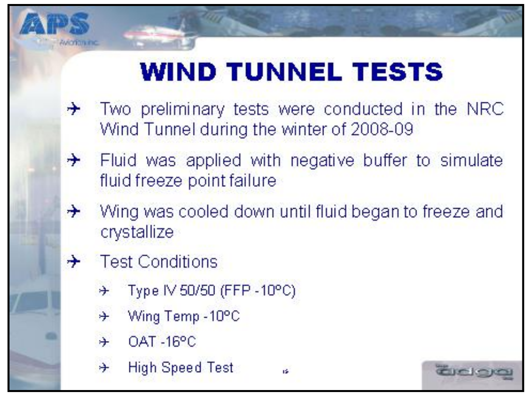
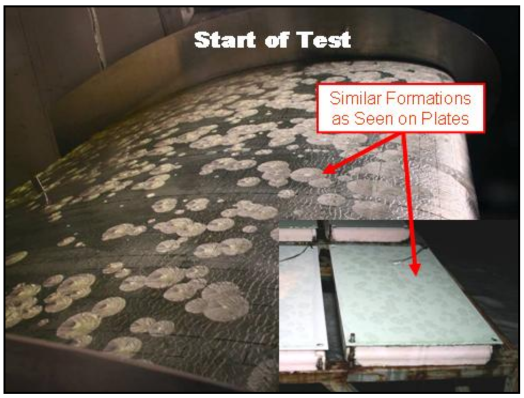
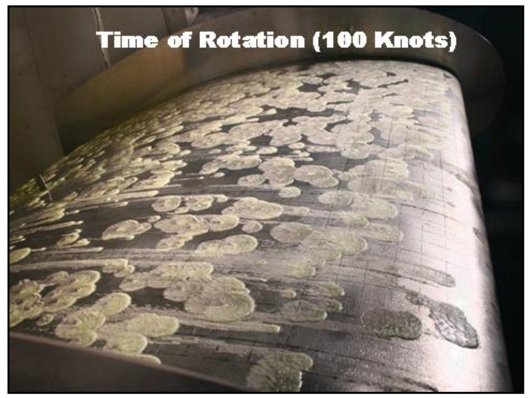
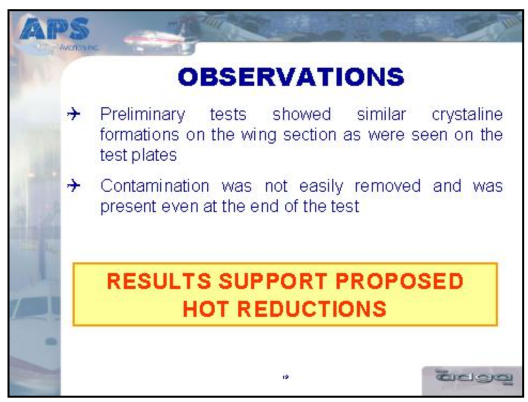
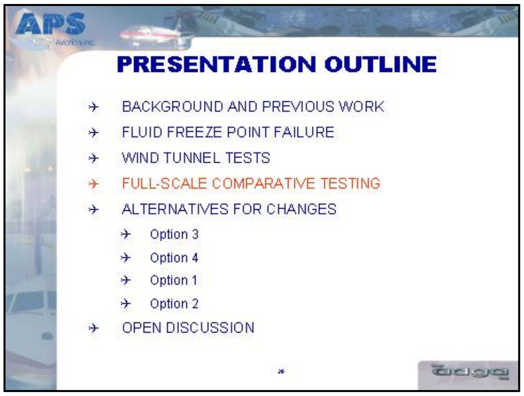

WIND TUNNEL TESTS
Two preliminary tests were conducted in the NRC Wind Tunnel during the winter of 2008-09
Fluid was applied with negative buffer to simulate fluid freeze point failure
Wing was cooled down until fluid began to freeze and crystallize
Test Conditions
Type IV 50/50 (FFP -10°C)
Wing Temp -10°C
OAT -16°C
High Speed Test


Start of Test
Similar Formations as Seen on Plates


Time of Rotation (100 Knots)


End of Test


OBSERVATIONS
Preliminary tests showed similar crystaline formations on the wing section as were seen on the test plates
Contamination was not easily removed and was present even at the end of the test
RESULTS SUPPORT PROPOSED HOT REDUCTIONS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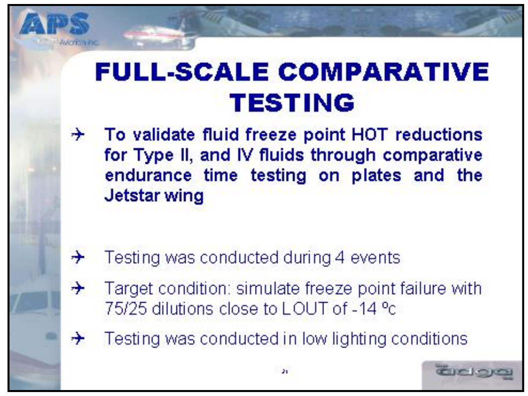
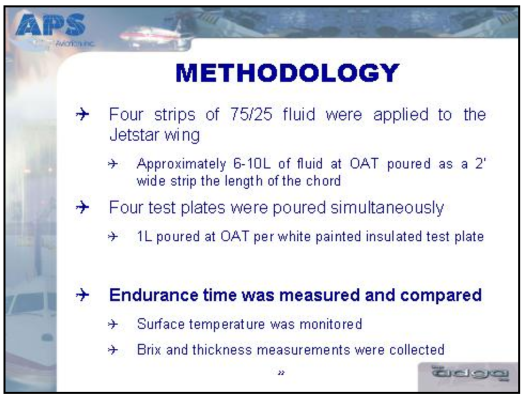
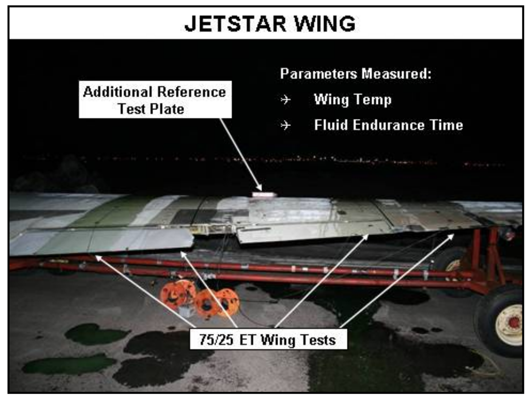

APS
FULL-SCALE COMPARATIVE TESTING
To validate fluid freeze point HOT reductions for Type II, and IV fluids through comparative endurance time testing on plates and the Jetstar wing
Testing was conducted during 4 events
Target condition: simulate freeze point failure with 75/25 dilutions close to LOUT of -14 ºC
Testing was conducted in low lighting conditions


APS
METHODOLOGY
Four strips of 75/25 fluid were applied to the Jetstar wing
Approximately 6-10L of fluid at OAT poured as a 2' wide strip the length of the chord
Four test plates were poured simultaneously
1L poured at OAT per white painted insulated test plate
Endurance time was measured and compared
Surface temperature was monitored
Brix and thickness measurements were collected


JETSTAR WING
Additional Reference Test Plate
Parameters Measured:
Wing Temp
Fluid Endurance Time
75/25 ET Wing Tests

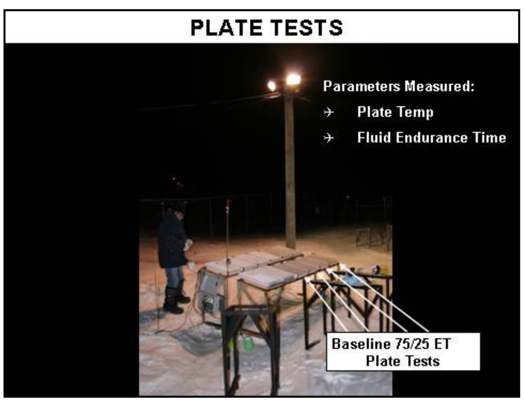
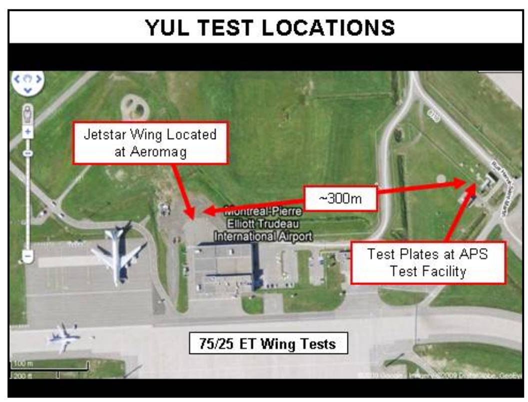
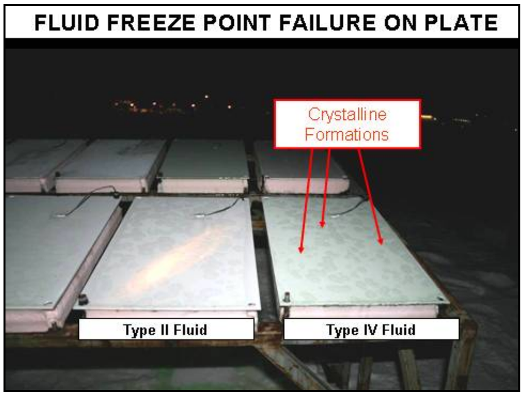
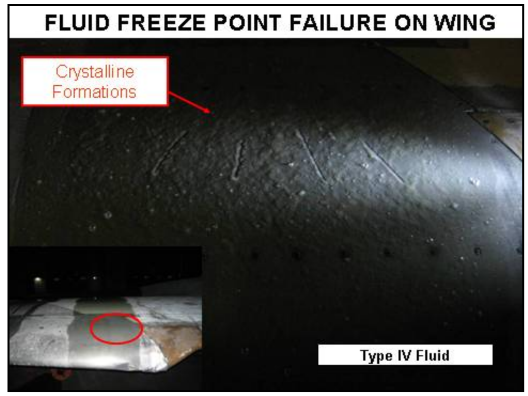
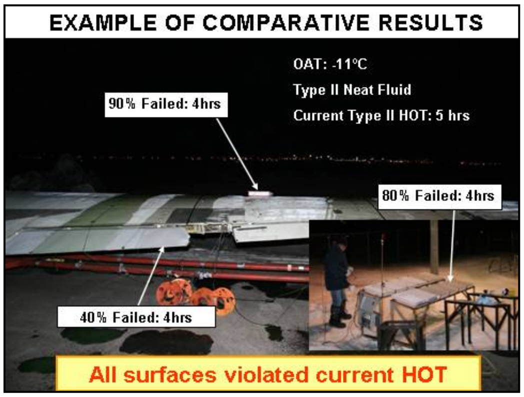


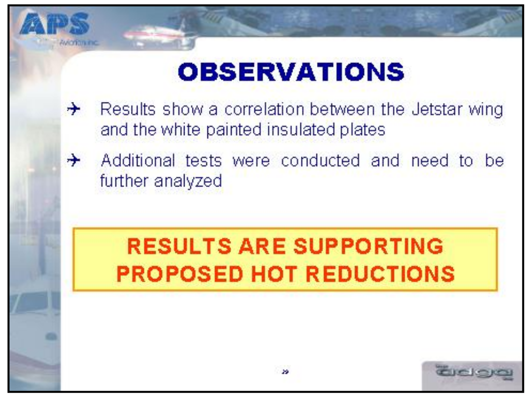
PLATE TESTS
Parameters Measured:
Plate Temp
Fluid Endurance Time
Baseline 75/25 ET Plate Tests

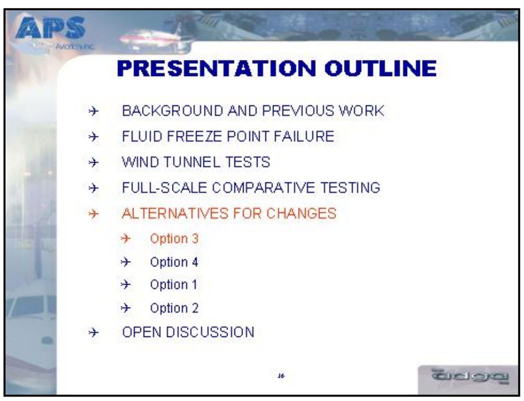

YUL TEST LOCATIONS
Jetstar Wing Located at Aeromag
~300m
Test Plates at APS Test Facility
75/25 ET Wing Tests


FLUID FREEZE POINT FAILURE ON PLATE
Crystalline Formations
Type II Fluid
Type IV Fluid


FLUID FREEZE POINT FAILURE ON WING
Crystalline Formations
Type IV Fluid


EXAMPLE OF COMPARATIVE RESULTS
OAT: -11°C
Type II Neat Fluid
Current Type II HOT: 5 hrs
90% Failed: 4hrs
80% Failed: 4hrs
40% Failed: 4hrs
All surfaces violated current HOT


APS
OBSERVATIONS
Results show a correlation between the Jetstar wing and the white painted insulated plates
Additional tests were conducted and need to be further analyzed
RESULTS ARE SUPPORTING PROPOSED HOT REDUCTIONS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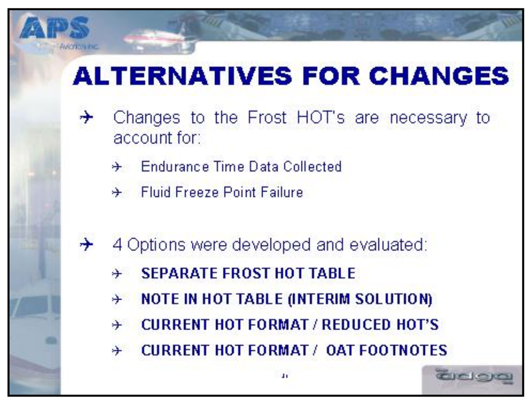
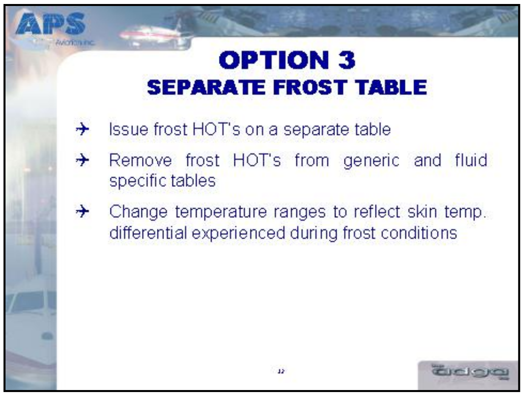

APS
ALTERNATIVES FOR CHANGES
Changes to the Frost HOT's are necessary to account for:
Endurance Time Data Collected
Fluid Freeze Point Failure
4 Options were developed and evaluated:
SEPARATE FROST HOT TABLE
NOTE IN HOT TABLE (INTERIM SOLUTION)
CURRENT HOT FORMAT / REDUCED HOT'S
CURRENT HOT FORMAT / OAT FOOTNOTES



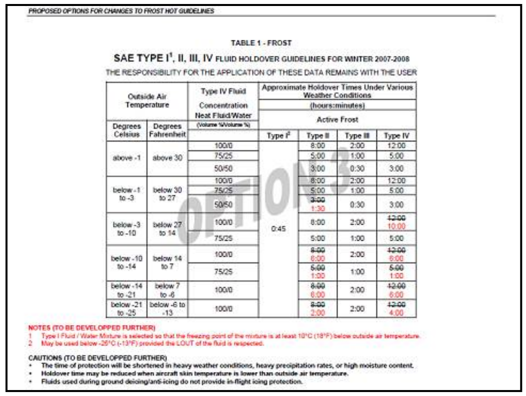

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 1 - FROST

SAE TYPE I[1], II, III, IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes) Active Frost			
Degrees Celsius	Degrees Fahrenheit		Type I[2]	Type II	Type III	Type IV
above -1	above 30	100/0	0:45	8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0		8:00	2:00	12:00
		75/25		5:00	1:00	5:00
		50/50		~~3:00~~ 1:30	0:30	3:00
below -3 to -10	below 27 to 14	100/0		8:00	2:00	~~12:00~~ 10:00
		75/25		5:00	1:00	5:00
below -10 to -14	below 14 to 7	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
		75/25		~~5:00~~ 1:00	1:00	~~5:00~~ 1:00
below -14 to -21	below 7 to -6	100/0		~~8:00~~ 6:00	2:00	~~12:00~~ 6:00
below -21 to -25	below -6 to -13	100/0		~~8:00~~ 2:00	2:00	~~12:00~~ 4:00

NOTES (TO BE DEVELOPPED FURTHER)
1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 May be used below -25°C (-13°F) provided the LOUT of the fluid is respected.

CAUTIONS (TO BE DEVELOPPED FURTHER)
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.
- Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.
- Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.

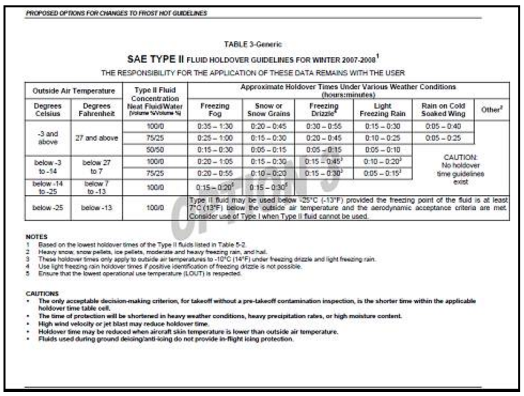

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 3-Generic

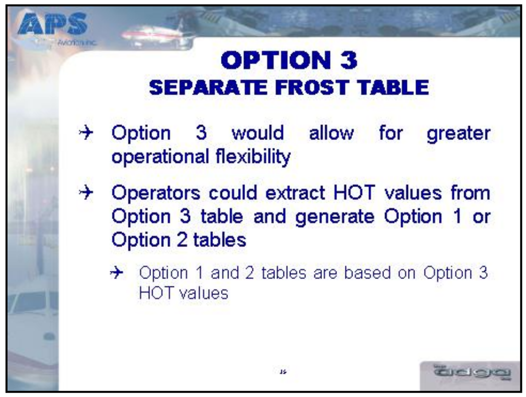
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

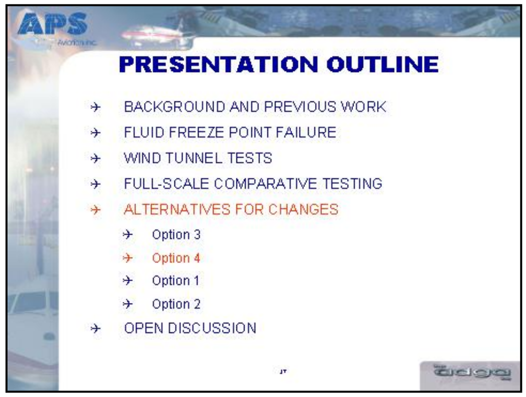
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

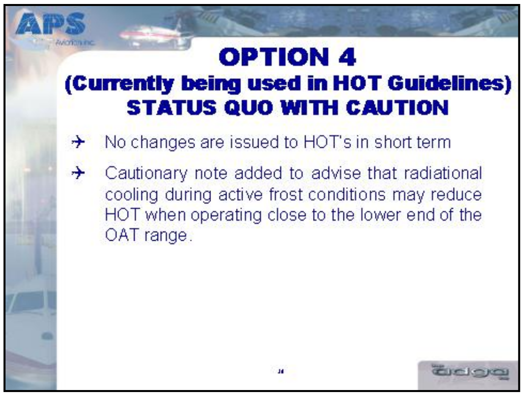
Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing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

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

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







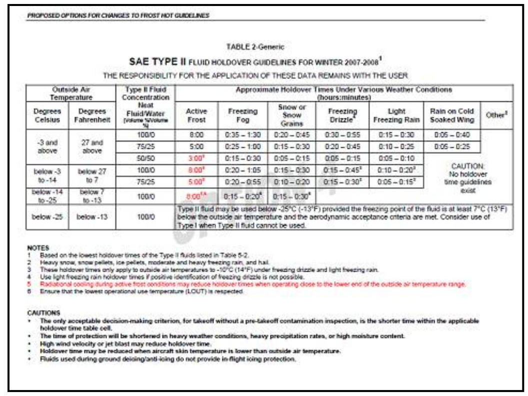

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

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

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

Outside Air Temperature		Type II Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	3:00[5]	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00[5]	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	5:00[5]	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	8:00[5,6]	0:15 – 0:20[6]	0:15 – 0:30[6]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce holdover times when operating close to the lower end of the outside air temperature range.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

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

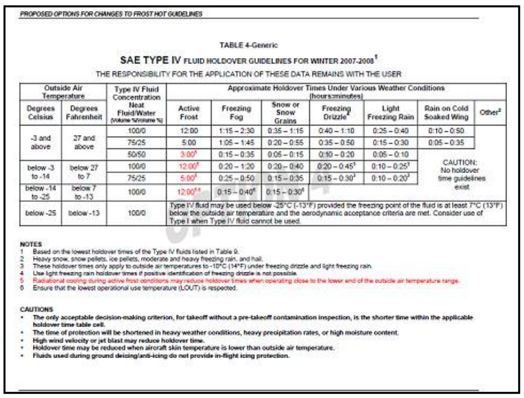

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 4-Generic

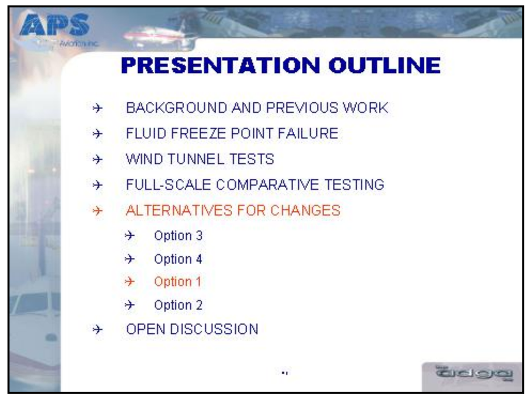
SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

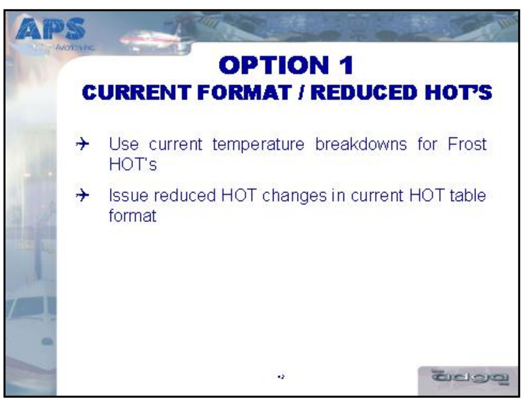
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:35 – 1:15	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	
		75/25	5:00	1:05 – 1:45	0:20 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:35	
		50/50	3:00[5]	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00[5]	0:20 – 1:20	0:20 – 0:40	0:20 – 0:45[3]	0:10 – 0:25[3]		
		75/25	5:00[5]	0:25 – 0:50	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	12:00[5,6]	0:15 – 0:40[6]	0:15 – 0:30[6]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES
1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Radiational cooling during active frost conditions may reduce holdover times when operating close to the lower end of the outside air temperature range.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

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





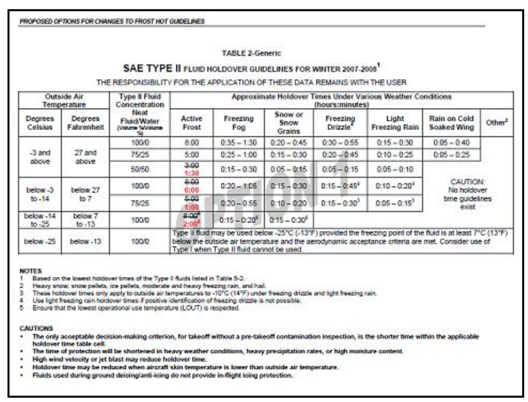

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

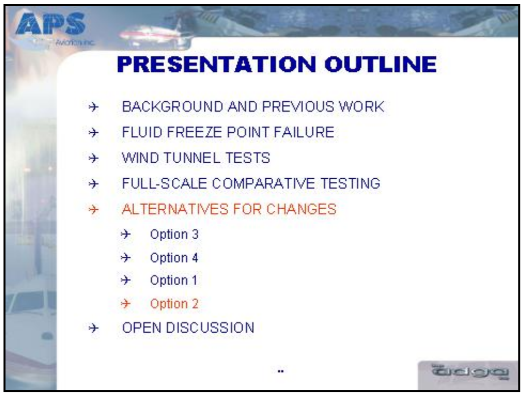
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

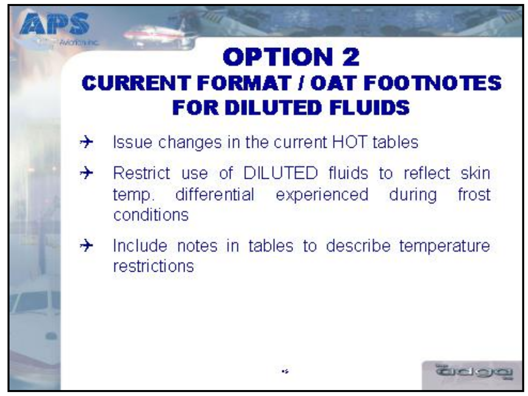
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature		Type II Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	~~3:00~~ 1:30	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	~~8:00~~ 6:00	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]		
		75/25	~~5:00~~ 1:00	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	~~8:00[5]~~ 2:00[5]	0:15 – 0:20[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

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

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





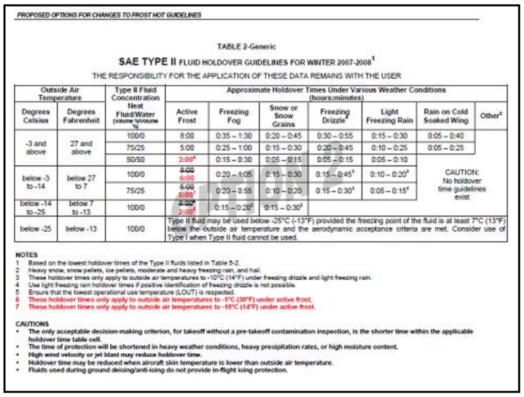

PROPOSED OPTIONS FOR CHANGES TO FROST HOT GUIDELINES

TABLE 2-Generic

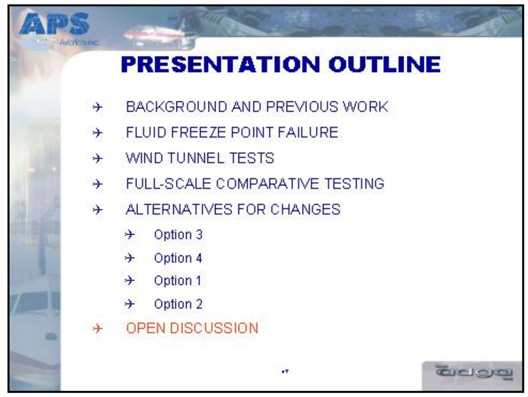
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

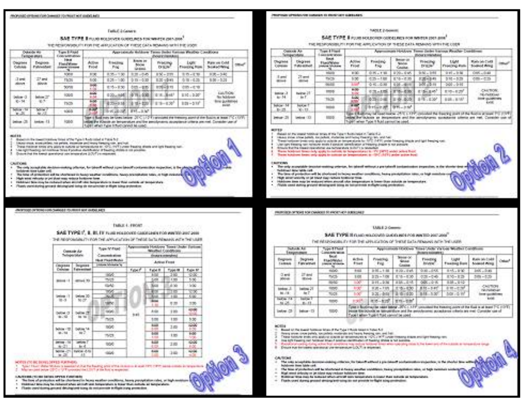
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (volume %/volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	3:00[6]	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	~~8:00~~ 6:00	0:20 – 1:05	0:15 – 0:30	0:15 – 0:45[3]	0:10 – 0:20[3]	CAUTION: No holdover time guidelines exist	
		75/25	~~5:00~~ 5:00[7]	0:20 – 0:55	0:10 – 0:20	0:15 – 0:30[3]	0:05 – 0:15[3]		
below -14 to -25	below 7 to -13	100/0	~~8:00~~ 2:00[6]	0:15 – 0:20[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
6 These holdover times only apply to outside air temperatures to -1°C (30°F) under active frost.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under active frost.

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





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