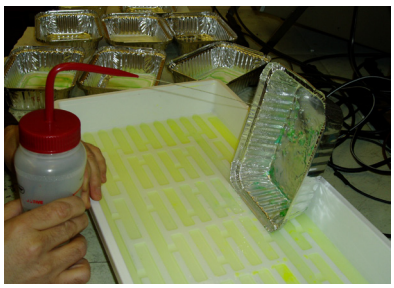
TP 14451E

Aircraft Ground Icing General Research Activities During the 2004-05 Winter



Prepared for
Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Center

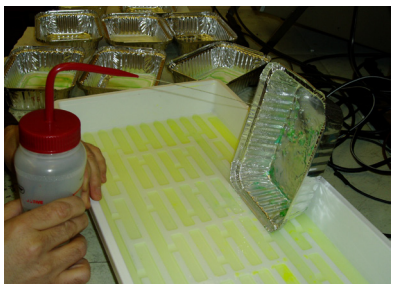
Prepared by

APS Aviation Inc.

October 2005
Final Version 1.0

TP 14451E

Aircraft Ground Icing General Research Activities During the 2004-05 Winter



by

APS Aviation Inc.

October 2005
Final Version 1.0

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

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

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by: APS Aviation Inc.

Reviewed by:



July 28, 2025

John D'Avirro, Eng., PBDM — Date
Program Manager

Approved by: **

Jean Valiquette — Date
President, APS Aviation Inc.

Un sommaire français se trouve avant la table des matières.

This report was first provided to Transport Canada as Final Draft 1.0 in October 2005.
It has been published as Final Version 1.0 in July 2025.

***Final Draft 1.0 of this report was signed and provided to Transport Canada in October 2005. A Transport Canada technical and editorial review was subsequently completed, and the report was finalized in July 2025; Jean Valiquette was not available to participate in the final review or to sign the current version of the report.*

PREFACE

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

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To conduct endurance time tests in frost on various test surfaces;
- To assist with the operational evaluation of Type III fluids;
- To finalize the laboratory snow test protocol with Type II, III, and IV fluids;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To assist the SAE G-12 Ground Equipment Subcommittee in evaluating forced air-assist systems;
- To evaluate the possibility of using a fluid failure sensor in holdover time testing;
- To conduct endurance time tests on non-aluminum plates;
- To examine the effect of heat on Type II, III, and IV fluid endurance times;
- To provide support for human factor tactile tests; and
- To conduct general and exploratory de/anti-icing research.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2004-05 are documented in nine reports. The titles of the reports are as follows:

- TP 14443E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2004-05 Winter;
- TP 14444E Winter Weather Impact on Holdover Time Table Format (1995-2005);
- TP 14445E Evaluation of Type IV Fluids Applied Using Forced Air Assist Equipment;
- TP 14446E A Sensor for Detecting Anti-Icing Fluid Failure: Phase II;
- TP 14447E Effect of Heat on Endurance Times of Anti-Icing Fluids;
- TP 14448E Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces;
- TP 14449E Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests;
- TP 14450E Development of Ice Samples for Comparison Study of Human and Sensor Capability to Detect Ice on Aircraft; and
- TP 14451E Aircraft Ground Icing General Research Activities During the 2004-05 Winter.

In addition, the following interim report is being prepared:

- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions.*

This report, TP 14451E, has the following objective:

- To document the exploratory research and general activities carried out for the Transportation Development Centre during the winter of 2004-05.

This research project 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.

PROGRAM ACKNOWLEDGEMENTS

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

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Stephanie Bendickson, Nicolas Blais, Michael Chaput, Sami Chebil, John D'Avirro, Peter Dawson, Stéphane Gosselin, Mark Mayodon, Chris McCormack, Nicoara Moc, Filomeno Pepe, Marco Ruggi, Joey Tiano, Kim Vepsa, and David Youssef.

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

REPORT ACKNOWLEDGEMENTS

APS Aviation Inc. would like to recognize the significant contributions of Stephanie Bendickson, Sami Chebil, John D'Avirro, and Kim Vepsa for their support in preparing this report.

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.	2. Project No.	3. Recipient's Catalogue No.
TP 14451E	5498-5501 (a-d)	

4. Title and Subtitle	5. Publication Date
Aircraft Ground Icing General Research Activities During the 2004-05 Winter	October 2005
	6. Performing Organization Document No.: CM1892.001
7. Author(s): APS Aviation Inc.	8. Transport Canada File No.: 2450-BP-14
9. Performing Organization Name and Address: APS Aviation Inc. 634 Saint-Jacques St., 4th Floor Montreal, Quebec, H3C 1C7	10. PWGSC File No.: MTB-3-01379
	11. PWGSC or Transport Canada Contract No.: T8200-033534
12. Sponsoring Agency Name and Address: Transportation Development Centre Transport Canada 800 René-Lévesque Blvd West, Suite 600 Montreal, Quebec, H3B 1X9	13. Type of Publication and Period Covered: Final
	14. Project Officer: Antoine Lacroix for Barry Myers

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada (TC). These are available from the Transportation Development Centre. Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface. This research project has been funded by the Civil Aviation Group of TC with support from the Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ.

16. Abstract

This report documents the exploratory research and general activities completed by APS Aviation Inc. (APS) related to aircraft ground deicing research in the winter of 2004-05. The activities documented in this report were carried out in addition to the main research projects completed in the winter of 2004-05, which are documented in separate reports. The eleven activities included in this report are described below.

1. Validity of 75/25 Endurance Time Test Protocol: Research was conducted to assess the accuracy of the current protocol for endurance time testing for fluid dilutions. Results were inconclusive, and further research was recommended.
2. Removal of Type III Fluid Residues: Research was conducted to investigate the tendency of Type III fluid to dry out relative to Type II and Type IV fluids commonly used in the industry.
3. Field Anti-Icing Fluid Viscosity Estimation: Research was conducted to determine the feasibility of using a simplified device to estimate anti-icing fluid viscosity in field operations.
4. Snow Testing at -14ºC to -25ºC: Testing to obtain fluid-specific holdover times (HOTs) in snow at -14ºC to -25ºC was not recommended, as these cells are rarely used, the values are similar, and testing would be expensive. Instead, maintaining the current generic values in these cells was recommended.
5. Video Documentation of Snowfall Intensities: APS undertook a project to document the four snowfall intensity categories — very light snow, light snow, moderate snow, and heavy snow — on video.
6. Holdover Time Guidelines Website: APS developed and implemented a website for the official Transport Canada 2005-06 HOT table guidelines.
7. Procedures, Presentations, and Fluid Manufacturer Reports: An account of the test procedures, presentations, and fluid manufacturer reports that were produced for the 2004-05 program of activities is included in this report.

Four other activities were carried out: demonstration flight to examine the removal of the neat Type III fluid from aircraft wings during takeoff, review of the negative 3ºC buffer on the first step application of deicing fluid on aircraft, development of Aerospace Recommended Practice (ARP) 5945 for the testing of Type I fluids, and indoor laboratory snow protocol for the endurance time testing.

17. Key Words	18. Distribution Statement
Deicing, Snowfall Intensity, Video, Visibility, Holdover Time, Dry-out	Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
Unclassified	Unclassified	—	xx, 42 apps	—

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. No de la publication de Transports Canada	2. No de l'étude	3. No de catalogue du destinataire
TP 14451E	5498-5501 (a-d)	

4. Titre et sous-titre	5. Date de la publication
Aircraft Ground Icing General Research Activities During the 2004-05 Winter	Octobre 2005
	6. No de document de l'organisme exécutant CM1892.001
7. Auteur(s) APS Aviation Inc.	8. No de dossier - Transports Canada 2450-BP-14
9. Nom et adresse de l'organisme exécutant APS Aviation Inc. 634, rue Saint-Jacques, 4ième étage Montréal (Québec) H3C 1C7	10. No de dossier - TPSGC MTB-3-01379
	11. No de contrat - TPSGC ou Transports Canada T8200-033534
12. Nom et adresse de l'organisme parrain Centre de développement des transports Transports Canada 800, Boul. René-Lévesque Ouest, Bureau 600 Montréal (Québec) H3B 1X9	13. Genre de publication et période visée Final
	14. Agent de projet Antoine Lacroix pour Barry Myers

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Plusieurs rapports de recherche ont été produits au nom de Transports Canada (TC) sur les essais réalisés au cours des hivers antérieurs. Ceux-ci sont disponibles auprès du Centre de développement des transports. Neuf rapports (dont celui-ci) ont été produits dans le cadre du programme de recherche de cet hiver. On trouvera dans la préface l'objet de ces rapports. Ce projet de recherche a été financé par le Groupe de l'Aviation civile de TC avec l'appui du William J. Hughes Technical Center de la Federal Aviation Administration, à Atlantic City, au New Jersey.

16. Résumé

Ce rapport fait état de la recherche exploratoire et des activités générales menées par APS Aviation Inc. (APS) en matière de recherche sur le dégivrage d'aéronefs au sol au cours de l'hiver 2004-2005. Les activités dont fait état ce rapport ont été effectuées en plus des projets de recherche principale menés pendant l'hiver 2004-2005, qui sont documentés dans des rapports distincts. Les onze activités qui font l'objet du présent rapport sont énumérées ci-dessous.

1. Validité du protocole d'essai sur les durées d'endurance à une dilution de 75/25 : Des recherches ont été menées pour évaluer la précision du protocole actuel pour les essais de durées d'endurance des dilutions de liquides. Les résultats n'ont pas été concluants et des recherches supplémentaires ont été recommandées.
2. Élimination des résidus de liquides de type III : Des recherches ont été menées pour étudier la tendance à sécher des liquides de type III par rapport aux liquides de type II et de type IV couramment utilisés dans le secteur.
3. Estimation de la viscosité du liquide antigivrage sur le terrain : Des recherches ont été menées pour déterminer la faisabilité d'utiliser un dispositif simplifié pour estimer la viscosité des liquides antigivrants dans les opérations sur le terrain.
4. Essais dans des conditions de neige de -14 °C à -25 °C : Il n'a pas été recommandé d'effectuer des essais pour obtenir des durées d'efficacité spécifiques aux liquides dans la neige de -14 °C à -25 °C, car ces cellules sont rarement utilisées, les valeurs sont semblables et les essais seraient coûteux. Il a plutôt été recommandé de conserver les valeurs génériques actuelles dans ces cellules.
5. Documentation vidéo des intensités de chute de neige : APS a entrepris un projet visant à documenter quatre catégories d'intensités de chute de neige sur bandes vidéo : neige très légère, neige légère, neige modérée et neige forte.
6. Site Web des lignes directrices sur les durées d'efficacité : APS a conçu et mis en place un site Web présentant les lignes directrices officielles de TC sur les durées d'efficacité pour 2005-2006.
7. Procédures, présentations et rapports des fabricants de fluides : Un certain nombre de procédures d'essais, de présentations et de rapports des fabricants de liquides ont été produits dans le cadre du programme d'activités de 2004-2005. Ceux-ci sont inclus dans le présent rapport.

Quatre autres activités ont été menées: vol de démonstration pour examiner l'élimination d'un liquide de type III pur des ailes d'un aéronef pendant le décollage, examen du tampon négatif de 3 °C lors de l'application initiale de liquide de dégivrage sur l'aéronef, élaboration du document de pratique recommandée en aérospatiale (ARP) 5945 pour la mise à l'essai des liquides de type I, et conception d'un protocole pour des essais de durées d'endurance dans des conditions de neige en laboratoire.

17. Mots clés	18. Diffusion
Dégivrage, intensité des chutes de neige, vidéo, visibilité, durée d'efficacité, assèchement	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xx, 42 ann.	—

CDT/TDC 79-005
Rev. 96

Canada

EXECUTIVE SUMMARY

On behalf of the Transportation Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) undertook a research program to further advance aircraft ground de/anti-icing technology.

This report documents the exploratory research and general activities completed by APS related to aircraft ground deicing research in the winter of 2004-05. The activities documented in this report were carried out in addition to the main research projects completed in the winter of 2004-05, which are documented in separate reports.

The eleven activities included in this report are described below.

Validity of 75/25 Endurance Time Test Protocol (Section 2)

Concerns have arisen that the protocol used to measure endurance times of diluted anti-icing fluids may not produce values consistent with those experienced during actual operations. These concerns have brought into question the accuracy of the current diluted fluid values in the Holdover Time (HOT) Guidelines and the current test protocol.

Research was conducted to assess the accuracy of the current protocol for endurance time testing for fluid dilutions. Results of testing with one fluid showed that this was not a problem; however, the results could not be extrapolated to all fluids, and further research was recommended.

Removal of Type III Fluid Residues (Section 3)

There have been incidents reported of restricted movement of flight control surfaces, which have been attributed to fluid dry-out. Fluid deposits have been known to rehydrate, freeze, and expand under certain atmospheric conditions, causing difficulties for aircraft without powered controls.

At the request of the FAA, APS undertook an exploratory research project to develop a simplified experimental procedure to investigate whether Type III fluid residues are easier to remove with the application of a heated fluid than commonly used Type II and Type IV fluid residues.

Based on the results drawn from ten tests, Type III fluid showed dry-out behaviour comparable to Type II and Type IV fluids commonly used in industry.

Field Anti-Icing Fluid Viscosity Estimation (Section 4)

In the winter of 1999-2000, APS conducted research to establish the feasibility of using a simplified viscosity measurement device to estimate the viscosity of anti-icing fluids during field operations. The simple viscometer device proved effective for the fluids that were tested. Further research work was conducted in 2004-05 in order to refine the viscosity device and to test it with other fluids. The research continued to show that the simple viscometer device was a viable alternative; however, further work is required.

Snow Testing at -14°C to -25°C (Section 5)

Currently, the HOTs in snow at -14°C to -25°C are 15 to 30 minutes for all Type II/IV propylene glycol (PG) fluids. An analysis of two possible options was completed. The first option was the status quo (maintain current generic values), and the second option was to develop fluid-specific values.

It was recommended that the current (generic) values in the -14°C to -25°C snow cells be maintained instead of developing fluid-specific values, because a large amount of resources would be required to conduct the tests; the number of deicing operations in the -14°C to -25°C cells is relatively insignificant, and intensive testing by APS and the Anti-Icing Materials Icing Laboratory (AMIL) has demonstrated that endurance times of most PG fluids are similar in this temperature range.

Video Documentation of Snowfall Intensities (Section 6)

At the request of the FAA, APS undertook a project in the winter of 2003-04 to document the four snowfall intensity categories — very light snow, light snow, moderate snow, and heavy snow — on video. APS created a procedure to make the video and retained the services of a professional videographer to collect the footage and edit the video. Initial footage was collected in the winter of 2003-04, and additional footage was collected in the winter of 2004-05. The final edit was completed and presented to TC and the FAA in September 2005.

Holdover Time Guidelines Website (Section 7)

APS developed and implemented a website for the official TC HOT Guidelines in 2003 to eliminate the safety risks associated with discrepancies occurring as a result of HOT information being published in multiple locations. In July 2005, APS updated this website with the 2005-06 HOT Guidelines.

Procedures, Presentations, and Fluid Manufacturer Reports (Section 8)

A number of test procedures, presentations and fluid manufacturer reports were produced for the 2004-05 program of activities. An account of these is included in this report.

Secondary General Activities

Four other activities were carried out and are described in this report:

- Demonstration flight to examine the removal of neat Type III fluid from aircraft wings during takeoff;
- Review of the negative 3ºC buffer on the first step application of deicing fluid on aircraft;
- Development of Aerospace Recommended Practice (ARP) 5945 for the testing of Type I fluids; and
- Indoor laboratory snow protocol for the endurance time testing.

This page intentionally left blank.

SOMMAIRE

Pour le compte du Centre de développement des transports (CDT) de Transports Canada (TC) et de la Federal Aviation Administration (FAA), APS Aviation Inc. (APS) a entrepris un programme de recherche visant à faire progresser les technologies associées au dégivrage et à l'antigivrage d'aéronefs au sol.

Ce rapport fait état de la recherche exploratoire et des activités générales menées par APS en matière de recherche sur le dégivrage d'aéronefs au sol au cours de l'hiver 2004-2005. Les activités dont fait état ce rapport ont été effectuées en plus des projets de recherche principale menés pendant l'hiver 2004-2005, qui sont documentés dans des rapports distincts.

Les onze activités qui font l'objet du présent rapport sont énumérées ci-dessous.

Validité du protocole d'essai sur les durées d'endurance à une dilution de 75/25 (Section 2)

Des préoccupations ont été soulevées quant au fait que le protocole utilisé pour mesurer les durées d'endurance des liquides antigivrants dilués peut ne pas produire de valeurs conformes à celles obtenues lors des opérations réelles. Ces préoccupations ont remis en question la précision des valeurs actuelles pour les liquides dilués dans les lignes directrices sur les durées d'efficacité et le protocole d'essai actuel.

Des recherches ont été menées pour évaluer la précision du protocole actuel pour les essais de durées d'endurance des dilutions de liquides. Les résultats des essais menés avec un liquide ont montré que ce n'était pas un problème; cependant, les résultats ne pouvaient pas être extrapolés à tous les liquides et des recherches supplémentaires ont été recommandées.

Élimination des résidus de liquides de type III (Section 3)

On a signalé des incidents de déplacement limité des surfaces de contrôle de vol, qui ont été attribués à l'assèchement des liquides. On sait que les dépôts de liquides se réhydratent, gèlent et se dilatent dans certaines conditions atmosphériques, ce qui pose des difficultés pour les aéronefs sans commandes électriques.

À la demande de la FAA, APS a entrepris un projet de recherche exploratoire visant à élaborer une procédure expérimentale simplifiée afin de déterminer si les résidus de liquides de type III sont plus faciles à éliminer avec l'application d'un liquide chauffé que les résidus de liquides de type II et de type IV couramment utilisés.

Selon les résultats obtenus lors de dix essais, les liquides de type III ont montré une tendance à l'assèchement comparable à celle des liquides de type II et de type IV couramment utilisés dans le secteur.

Estimation de la viscosité du liquide antigivrage sur le terrain (Section 4)

Au cours de l'hiver 1999-2000, APS a mené des recherches pour déterminer la faisabilité d'utiliser un dispositif simplifié de mesure de la viscosité pour estimer la viscosité des liquides antigivrants dans les opérations sur le terrain. Le viscosimètre simple s'est avéré efficace pour les liquides mis à l'essai. D'autres travaux de recherche ont été réalisés en 2004-2005 afin d'affiner le viscosimètre et de le mettre à l'essai avec d'autres liquides. La recherche a continué de montrer que le viscosimètre simple était une solution de rechange viable; toutefois, d'autres travaux sont nécessaires.

Essais dans des conditions de neige de -14 °C à -25 °C (Section 5)

Actuellement, les durées d'efficacité dans des conditions de neige de -14 °C à -25 °C sont de 15 à 30 minutes pour tous les liquides à base de propylène glycol (PG) de type II et de type IV. Une analyse de deux options possibles a été effectuée. La première option était le statu quo (maintenir les valeurs génériques actuelles) et la deuxième option était de définir des valeurs spécifiques aux liquides.

Il a été recommandé de maintenir les valeurs actuelles (génériques) dans les cellules « neige » de -14 °C à -25 °C au lieu de définir des valeurs spécifiques aux liquides, car : une grande quantité de ressources serait nécessaire pour mener les essais ; le nombre d'opérations de dégivrage dans les cellules de -14 °C à -25 °C est relativement négligeable ; et les essais intensifs réalisés par APS et le Laboratoire international des matériaux antigivre (LIMA) ont démontré que les durées d'endurance de la plupart des liquides à base de PG sont semblables dans cette plage de températures.

Documentation vidéo des intensités de chute de neige (Section 6)

À la demande de la FAA, APS a entrepris, au cours de l'hiver 2003-2004, un projet visant à documenter quatre catégories d'intensités de chute de neige sur bandes vidéo : neige très légère, neige légère, neige modérée et neige forte. APS a créé une procédure à cet effet et a retenu les services d'un vidéaste professionnel pour recueillir la vidéo et la monter. Le premier enregistrement sur bande vidéo a été capté au cours de l'hiver 2003-2004, et des enregistrements supplémentaires ont été captés au cours de l'hiver 2004-2005. Le montage définitif a été achevé et présenté à TC et à la FAA au cours du mois de septembre 2005.

Site Web des lignes directrices sur les durées d'efficacité (Section 7)

En 2003, APS a conçu et mis en place un site Web présentant les lignes directrices officielles de TC sur les durées d'efficacité, afin d'éliminer les risques pour la sécurité associés à la possibilité de divergences lorsque l'information sur les durées d'efficacité est publiée à plusieurs endroits. En juillet 2005, APS a mis à jour ce site Web avec les lignes directrices sur les durées d'efficacité de 2005-2006.

Procédures, présentations et rapports des fabricants de fluides (Section 8)

Un certain nombre de procédures d'essais, de présentations et de rapports des fabricants de liquides ont été produites dans le cadre du programme d'activités de 2004-2005. Le présent rapport contient une description de ces dernières.

Activités générales secondaires

Quatre autres activités ont été menées et sont décrites dans ce rapport :

- Vol de démonstration pour examiner l'élimination d'un liquide de type III pur des ailes d'un aéronef pendant le décollage;
- Examen du tampon négatif de 3 °C lors de l'application initiale de liquide de dégivrage sur l'aéronef;
- Élaboration du document de pratique recommandée en aérospatiale pratique recommandée en aérospatiale (ARP) 5945 pour la mise à l'essai des liquides de type I; et
- Conception d'un protocole pour des essais de durées d'endurance dans des conditions de neige en laboratoire.

This page intentionally left blank.

CONTENTS

Page

1. INTRODUCTION 1

1.1 Exploratory Research 1
1.1.1 Validity of 75/25 Endurance Time Test Protocol 1
1.1.2 Removal of Type III Fluid Residues 2
1.1.3 Field Anti-Icing Fluid Viscosity Estimation 2
1.2 Primary General Activities 2
1.2.1 Snow Testing at -14°C to -25°C 2
1.2.2 Video Documentation of Snowfall Intensities 3
1.2.3 Holdover Time Guidelines Website 3
1.2.4 Test Procedures, Presentations, and Fluid Manufacturer Reports for 2004-05 3
1.3 Secondary General Activities 3
1.3.1 Demonstration Flight to Examine Removal of Neat Type III Fluid from Aircraft Wings during Takeoff 3
1.3.2 Review of Negative 3°C Buffer on First Step Application of Deicing Fluid on Aircraft 3
1.3.3 Development of Aerospace Recommended Practice 5945 for Testing of Type I Fluids 4
1.3.4 Indoor Laboratory Snow Protocol for Endurance Time Testing 4

2. VALIDITY OF 75/25 ENDURANCE TIME TEST PROTOCOL 5

2.1 Background 5
2.2 Objective 5
2.3 Procedure 6
2.4 Data 7
2.5 Analysis 7
2.6 Conclusions 8
2.7 Recommendations 9

3. REMOVAL OF TYPE III FLUID RESIDUES 13

3.1 Background and Objective 13
3.2 Methodology 13
3.3 Results and Observations 14
3.4 Conclusion 15

4. FIELD ANTI-ICING FLUID VISCOSITY ESTIMATION 19

4.1 Background 19
4.2 Methodology 19
4.3 Processing of Data, Results and Analysis 20
4.4 General Conclusions 20
4.5 Recommendations 20

5. SNOW TESTING AT -14°C TO -25°C 23

5.1 Options Analysis 23
5.1.1 Option 1: Status Quo 23
5.1.2 Option 2: Fluid-Specific Values 23
5.2 Conclusions and Recommendations 26

6. VIDEO DOCUMENTATION OF SNOWFALL INTENSITIES 27

6.1 Objectives 27
6.2 Scenes 27
6.3 Videographer 28

6.4 Procedure 28
6.5 Data 28
6.6 Preliminary Edit 31
6.7 Final Edit 31

7. HOLDOVER TIME GUIDELINES WEBSITE 33

7.1 Background 33
7.2 Changes to the Website 33
7.3 Future Responsibilities 34

8. PROCEDURES, PRESENTATIONS, AND FLUID MANUFACTURER REPORTS 37

8.1 Procedures 37
8.2 Presentations 37
8.2.1 Standing Committee Meetings, Ottawa, Canada, September, 2004 37
8.2.2 SAE G-12 Work Group Meetings, Montreal, Canada, October, 2004 38
8.2.3 Federal Aviation Administration (FAA) Meetings, Atlantic City, U.S.A, November 2004 and January 2005 38
8.2.4 SAE G-12 Subcommittee Meetings, Pittsburgh, U.S.A, May 2005 38
8.3 Fluid Manufacturer Reports 39

REFERENCES 41

LIST OF APPENDICES

A Transportation Development Centre Work Statement Excerpt Aircraft & Anti-Icing Fluid Winter Testing 2003-05

B Trip Report: Demonstration Flight to Examine Removal of Neat Type III Fluid from Aircraft Wings During Takeoff

C Review of Negative 3ºC Buffer on First Step Application of Deicing Fluid on Aircraft, July 2005

D Aerospace Recommended Practice 5945, June 2025 – 2nd Ballot, Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type I

E Indoor Laboratory Snow Protocol for Endurance Time Testing

F Experimental Procedure: Comparison of Viscosities of Diluted Fluids (75/25) Before and After Spraying

G Preliminary R & D Field Anti-Icing Fluid Viscosity Estimation (Draining Time Method)

H Procedure: Video Documentation of Snowfall Intensities

I Transport Canada Holdover Time (HOT) Guidelines Winter 2005-2006

J Presentations: SAE G-12 Standing Committee Meetings, SAE G-12 Work Group Meetings, FAA Meetings, and SAE G-12 Subcommittee Aircraft Ground Deicing Meetings

LIST OF TABLES

Page

Table 2.1: Test Results 7
Table 3.1: Residue Removal Test Results 14
Table 5.1: APS Log of Tests at -25°C 24
Table 5.2: AMIL Log of Tests at -25°C 25
Table 5.3: HOT and Endurance Time Results 25
Table 6.1: TC Visibility Table 27
Table 6.2: Log of Video Footage 29
Table 6.3: Selected Clips 31
Table 8.1: List of Procedures for Winter 2004-05 40

LIST OF FIGURES

Page

Figure 2.1: Flowchart for Testing 6
Figure 2.2: Test Results – Research Fluid 8
Figure 2.3: Test Results – Commercial Fluid 8
Figure 7.1: HOT Guidelines Change Form 35

LIST OF PHOTOS

Page

Photo 2.1: Mobile Sprayer 11
Photo 2.2: Mobile Sprayer Nozzle 11
Photo 2.3: Applying Fluid to Airfoil Using Mobile Sprayer 12
Photo 2.4: Collecting Sample from Airfoil 12
Photo 3.1: Dry-Out Deposits on the Aluminum Foil Pans 17
Photo 3.2: Setup for Rinsing the Dry-Out Deposit 17

This page intentionally left blank.

GLOSSARY

AMIL	Anti-Icing Materials International Laboratory
APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CBAAC	Commercial and Business Aviation Advisory Circular
DVD	Digital Versatile Disc
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
LOUT	Lowest Operational Use Temperature
MSC	Meteorological Service Canada
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
OAT	Outside Air Temperature
PG	Propylene Glycol
SAE	Society of Automotive Engineers
TC	Transport Canada
TCCA	Transport Canada Civil Aviation
TDC	Transportation Development Centre
VHS	Video Home System
YUL	Montréal–Pierre Elliott Trudeau International Airport

This page intentionally left blank.

1. INTRODUCTION

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

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

Under the contract to TDC, APS Aviation Inc. (APS) undertook a research program co-sponsored by the FAA to further advance aircraft ground de/anti-icing technology.

The research program consisted of a number of major research projects, several exploratory research, and general activities. Each of the major research projects is documented in a separate individual report. The exploratory research and general activities are documented in this report.

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

1.1 Exploratory Research

1.1.1 Validity of 75/25 Endurance Time Test Protocol

Concerns have arisen that the protocol used to measure endurance times of diluted anti-icing fluids may not produce values consistent with those experienced during actual operations. These concerns have brought into question the accuracy of the current diluted fluid values in the Holdover Time (HOT) Guidelines and the current test protocol. Preliminary tests were conducted to examine this possibility. This topic is discussed in Section 2.

1.1.2 Removal of Type III Fluid Residues

There have been incidents reported of restricted movement of flight control surfaces that have been attributed to fluid dry-out. Fluid deposits have been known to rehydrate, freeze, and expand under certain atmospheric conditions, causing difficulties for aircraft with unpowered controls.

At the request of the FAA, APS undertook an exploratory project to develop a simplified experimental procedure to investigate whether Type III fluid residues are easier to remove with the application of a heated fluid than the residues of commonly used Type II and Type IV fluids. This topic is discussed in Section 3.

1.1.3 Field Anti-Icing Fluid Viscosity Estimation

In the winter of 1999-2000, APS conducted research to establish the feasibility of using a simplified viscosity measurement device to estimate the viscosity of anti-icing fluids during field operations. The device used was a plastic cylindrical 1 L bottle with a drain hole. The simple viscometer device proved to be effective for the fluids that were tested. Further research work was required in order to refine the viscosity device and to test it with other fluids. This topic is discussed in Section 4.

1.2 Primary General Activities

1.2.1 Snow Testing at -14°C to -25°C

At the May 2004 Society of Automotive Engineers (SAE) G-12 meeting in Frankfurt, Germany, it was recommended that HOT values for Type II/IV propylene glycol (PG) fluids in the -14°C to -25°C snow cells be changed to generic values. This followed an analysis of data that was collected indoors and outdoors in natural and artificial snow. TC and the FAA accepted the recommendation, and the HOTs for all Type II/IV PG fluids were changed to 15 to 30 minutes. The values for the only ethylene glycol (EG) fluid remained unchanged.

The group also recommended that artificial snow machines be used to determine fluid-specific HOTs in the -14°C to -25°C snow cells after the artificial snow methods had been approved for use in Aerospace Recommended Practice (ARP) 5485. The advantages and disadvantages of continuing with the above approach are discussed in Section 5.

1.2.2 Video Documentation of Snowfall Intensities

At the request of the FAA, APS undertook a project to document the four snowfall intensity categories — very light snow, light snow, moderate snow, and heavy snow — on video. APS developed a procedure to make the video and retained the services of a professional videographer to collect the necessary footage and edit the video. A preliminary version was prepared in July 2004; however, due to unfavourable weather conditions in the winter of 2003-04, additional footage was required and was collected in the winter of 2004-05. This topic is discussed in Section 6.

1.2.3 Holdover Time Guidelines Website

In July 2003, APS developed and implemented a website for the official TC HOT Guidelines. This was done in order to eliminate the discrepancies and potential safety risks associated with publishing the information in several locations, including websites and documents. This single source of HOT information was published in English and French, primarily for Canadian operators. In July 2005, APS updated the website with the new 2005-06 HOT Guidelines. This topic is discussed in Section 7.

1.2.4 Test Procedures, Presentations, and Fluid Manufacturer Reports for 2004-05

Section 8 contains an account of the test procedures, presentations, and fluid manufacturer reports that were prepared by APS in 2004-05.

1.3 Secondary General Activities

1.3.1 Demonstration Flight to Examine Removal of Neat Type III Fluid from Aircraft Wings During Takeoff

Tests were carried out in St. Louis, Missouri, to examine the removal of Type III fluid from aircraft wings during takeoff. A full description of the testing can be found in the related trip report, which is included in Appendix B.

1.3.2 Review of Negative 3°C Buffer on First Step Application of Deicing Fluid on Aircraft

According to the SAE ARP4737, heated fluids diluted to a freezing point 3°C above ambient temperature (-3°C buffer) may be used to deice as long as the anti-icing fluid is applied not more than 3 minutes after the start of deicing. However, there have been reports (Braathens, SAE G-12, Frankfurt, Germany, 2004) of deicing fluids freezing at very low ambient temperatures.

The objective of this activity was to review previous work related to the use of a -3°C buffer fluid as the deicer in a two-step de/anti-icing process. This was required to establish the hazard involved and to recommend procedural changes if necessary.

A preliminary report describing pertinent findings of previous research was prepared and is included in Appendix C. While the findings indicate that changing the buffer is not supported by previous research, some experts in the industry suggested (May 2005 SAE meetings) that such a reduction would reduce any risks associated with improper application procedures. The subject was debated extensively at the SAE general meetings in Pittsburgh, Pennsylvania, and it was recommended that further research on the subject was required.

1.3.3 Development of Aerospace Recommended Practice 5945 for Testing of Type I Fluids

The purpose of this document is to provide the sample selection and endurance time test procedures for SAE Type I aircraft deicing fluids recommended for the generation of endurance time data of acceptable quality for review by the SAE G-12 HOT Subcommittee.

The newly developed ARP5945 (see Appendix D) does not address endurance time testing under frost and artificial snow conditions. These conditions will be included in future versions of this document.

1.3.4 Indoor Laboratory Snow Protocol for Endurance Time Testing

HOTs that are used by pilots during winter precipitation have predominantly been developed under laboratory conditions. However, HOTs in snow have been developed by testing outdoors during snow events. A protocol for conducting snow tests indoors is currently in development. APS has worked with the National Center for Atmospheric Research (NCAR) and Anti-Icing Materials International Laboratory (AMIL) to develop a common procedure for inclusion in ARP5485, the document that describes the procedure for HOT testing. A copy of the latest draft version of the indoor snow protocol is included in Appendix E.

2. VALIDITY OF 75/25 ENDURANCE TIME TEST PROTOCOL

Concerns have arisen that the protocol used to measure endurance times of diluted anti-icing fluids may not produce values consistent with those experienced during actual operations. These concerns have brought into question the accuracy of the current diluted fluid values in the Holdover Time (HOT) Guidelines and the validity of the current test protocol.

2.1 Background

It has been found that, in general, endurance times increase with fluid viscosity. Therefore, anything that causes the viscosity of a fluid to decrease can also decrease the endurance time of the fluid.

One thing that reduces fluid viscosity is the shearing of the fluid by the application equipment. This shearing reduces the viscosity of the fluid, rendering the applied fluid less viscous than the original fluid; therefore, its endurance time can be shorter than that of the delivered fluid.

To account for the lower viscosity of the applied fluid relative to the fluid delivered to operators, endurance times are measured using fluid samples with lower viscosities. To create low-viscosity samples, fluid manufacturers mechanically shear fluid samples before submitting them for endurance time testing. The method of shearing varies from manufacturer to manufacturer, but all manufacturers shear a batch of neat fluid and then dilute portions of it to 75/25 and 50/50 dilutions.

This final step is where the test protocol for diluted fluids differs from actual operations. It has been theorized that because fluids submitted for endurance time testing are sheared prior to dilution and fluids that are used on aircraft are sheared after dilution, the viscosities (and therefore the endurance times) of the test fluids may be different from those of fluids used in operations. If the tested endurance times are longer than the actual endurance times, the test protocol for diluted fluids needs to be evaluated.

2.2 Objective

Several tests were conducted as an initial examination of shearing, dilution, and viscosity of 75/25 fluids. The objective of the tests was to determine if the fluids sheared before they are diluted have the same viscosity as the fluids sheared after they are diluted.

2.3 Procedure

To determine if the current test protocol produces fluid with the same viscosity as fluid applied in a deicing operation, a Type IV fluid was put through two processes: a simulated operational process and a simulated endurance time test process. The tests examined fluids diluted to 75/25 (glycol/hard water), as this dilution was of the most concern.

In the simulated operational process, neat fluid was diluted to 75/25 and then sprayed onto an airfoil using the Transport Canada (TC) mobile sprayer (see Photo 2.1 to Photo 2.3). The mobile sprayer was designed to replicate the spray equipment that is used by airlines in an operational environment. A sample was then collected from the airfoil using a scraper (see Photo 2.4). Care was taken not to shear the fluid during collection. The sample was returned to the APS Aviation Inc. (APS) laboratory for viscosity measurement.

In the simulated endurance time test process, neat fluid (from the same batch as the neat fluid used in the operational process) was sprayed onto the airfoil using the mobile sprayer. A sample was collected and returned to the APS laboratory. Once in the laboratory, part of the sample was diluted to 75/25, and its viscosity was measured. The two test processes are illustrated in Figure 2.1.

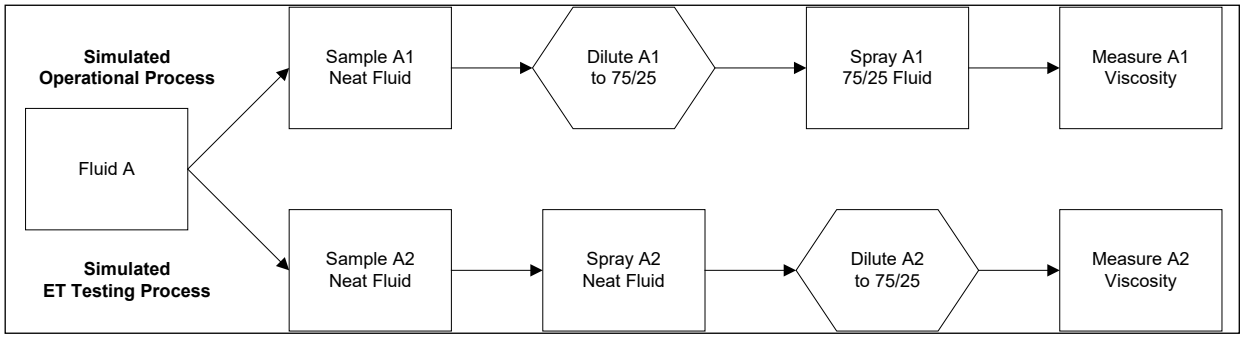


Figure 2.1: Flowchart for Testing

The standard viscosity measurement protocol was followed. The viscosity measurement parameters used for these tests were spindle 34, small sample adaptor (10 mL), 20°C, and 0.3 rpm.

The detailed test procedure is included in Appendix F.

2.4 Data

Tests were conducted outdoors at the APS test site located at Montréal–Pierre Elliott Trudeau International Airport (YUL). The tests took place the morning of March 23, 2005. The weather was clear, and the outside air temperature (OAT) was approximately -5°C.

One Type IV propylene glycol (PG) research fluid was tested as per the test procedure. A second Type IV PG commercial fluid was put through the simulated endurance time testing process; however, there was not enough fluid to complete the simulated operational process with the fluid.

The results are given in Table 2.1.

Table 2.1: Test Results

Test #	Fluid	Sample Description	Viscosity (mPa.s)	Brix (°)
1	Commercial Fluid	Neat	11,000	30.00
2	Commercial Fluid	75/25 Pre-spray	13,300	27.75
3	Commercial Fluid	75/25 Sprayed	1,700	27.75
4	Research Fluid	Neat	10,000	36.25
5	Research Fluid	75/25 Pre-spray	5,900	28.25
6	Research Fluid	75/25 Sprayed	1,600	28.25
7	Research Fluid	Neat sprayed	3,500	36.25
8	Research Fluid	Sprayed neat, diluted to 75/25	1,000	28.25

2.5 Analysis

The results of testing with the research fluid are shown graphically in Figure 2.2. The viscosity of the fluid put through the simulated operational process was 600 mPa.s greater than the fluid put through the simulated endurance time testing process.

No conclusions can be drawn from the commercial fluid, but the information may be useful in the future if more testing is done. The commercial fluid results are shown graphically in Figure 2.3.

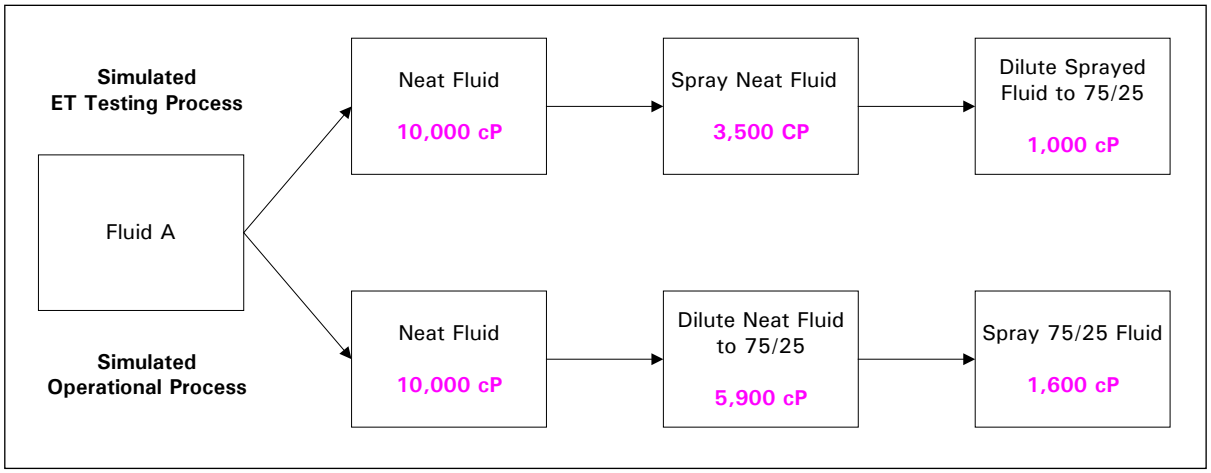


Figure 2.2: Test Results – Research Fluid

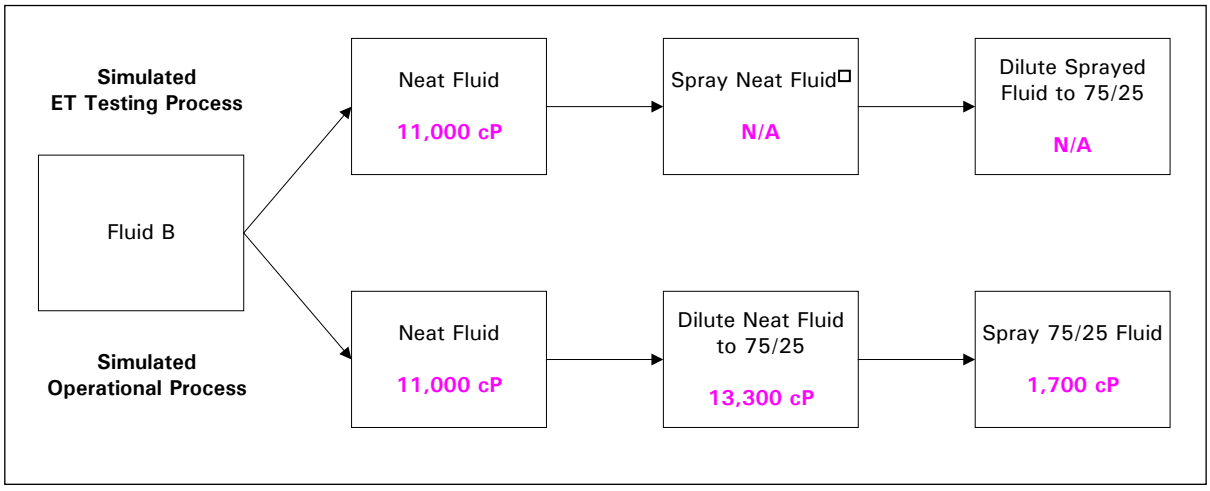


Figure 2.3: Test Results – Commercial Fluid

2.6 Conclusions

If the results seen in the research test could be extrapolated to all PG fluids, there would be no need to change the endurance time test protocol for diluted fluids. This is because the operational viscosities would be higher than the test viscosities; therefore, HOTs would likely be longer than given in the HOT Guidelines. However, these results are not conclusive because an important factor prevents the extrapolation of the results.

Previous research has shown that the more viscous a fluid is, the more susceptible it is to shearing. In other words, if two samples of the same fluid, one with a higher viscosity and one with a lower viscosity, are subjected to the same shearing, the higher viscosity fluid will experience a larger percentage decrease in viscosity. Many

fluids have higher viscosities in 75/25 dilutions than in neat dilutions. Therefore, if a fluid is sheared after it has been diluted to 75/25, it may experience a higher percentage decrease in viscosity than a fluid sheared in neat dilution and then diluted to 75/25.

The research fluid tested does not have a higher viscosity in 75/25 dilution than in neat dilution, and therefore it is not susceptible to this phenomenon.

2.7 Recommendations

It is recommended that further tests be carried out with several fluids of varying production range viscosities. At least one fluid should be more viscous in 75/25 dilution than in neat form.

If large differences are seen in initial testing with the mobile sprayer, conducting tests with actual deicing equipment may be required.

This page intentionally left blank.

Photo 2.1: Mobile Sprayer

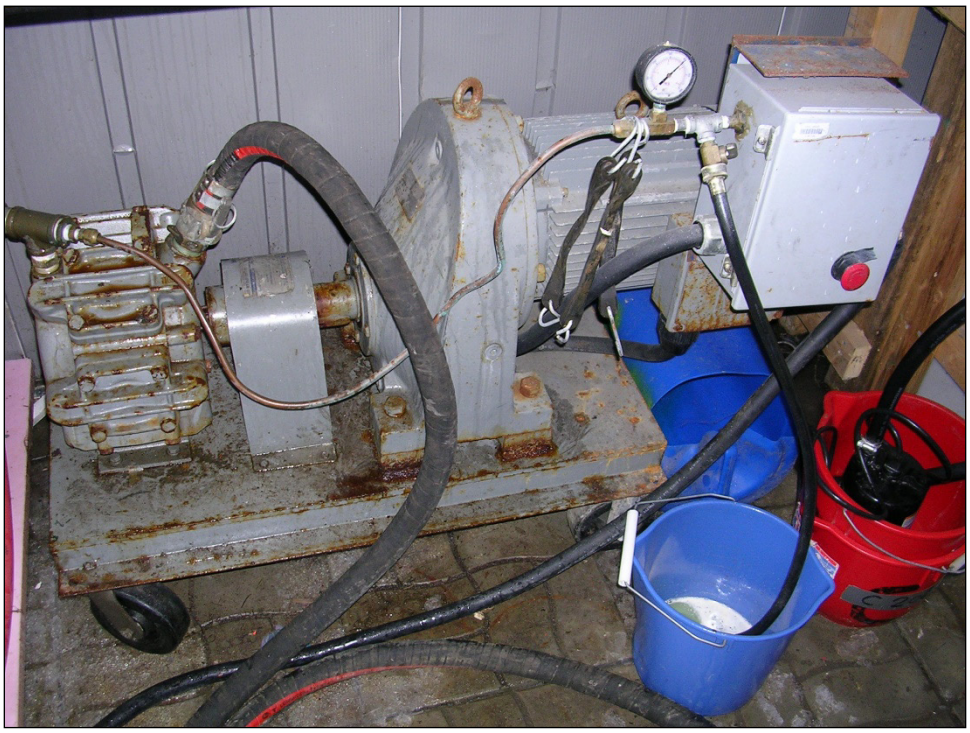


Photo 2.2: Mobile Sprayer Nozzle



Photo 2.3: Applying Fluid to Airfoil Using Mobile Sprayer



Photo 2.4: Collecting Sample from Airfoil



3. REMOVAL OF TYPE III FLUID RESIDUES

This section describes the research work conducted to examine whether the removal of Type III fluid residues is more difficult than the removal of Type II/IV fluid residues.

3.1 Background and Objective

There have been incidents reported of restricted movement of flight control surfaces, which have been attributed to fluid dry-out. This phenomenon may occur with repeated use of Type II and Type IV fluids without prior application of hot water or without a heated Type I fluid mixture. In this case, residue will be collected in aerodynamically quiet areas or crevices of the aircraft and will not flow out during normal takeoff conditions. These deposits have been known to rehydrate, freeze, and expand under certain atmospheric conditions and may cause difficulties for aircraft with unpowered controls.

At the request of the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) undertook an exploratory project to develop a simplified experimental procedure to investigate whether Type III fluid residues are easier to remove with the application of a heated fluid than the residues of commonly used Type II and Type IV fluids.

3.2 Methodology

Tests were conducted at the APS laboratory in Montreal. The experimental procedure developed was as follows:

- Aluminum foil pans, previously cleaned with isopropyl alcohol, were wetted with 20 mL of candidate Type II/III/IV fluids;
- The measured fluid thickness was about 2 mm;
- The fluid was dried out completely by keeping the wetted pan in an oven set at 60°C for three days;
- The weight of each pan was measured and recorded before and after the accelerated dry-out procedure;
- Residues were obtained by drying out the following fluids:
    - Type II: Clariant Safewing MP II 2025 ECO;
    - Type III: Clariant Safewing MP III 2031 ECO;
    - Type IV: Clariant Safewing MP IV 2001;
    - Type IV: Kilfrost ABC-S; and
    - Type IV: Dow Chemical UCAR ULTRA +.

- A squeeze bottle filled with fluid was used to rinse out the residue. Photo 3.1 shows the deposits on the aluminum foil pans;
- Before rinsing the residue, the distance between the foil and the squeeze bottle was set to 17 cm (Photo 3.2);
- Type I propylene glycol (PG) fluid mixed to 50/50 (glycol/hard water) was used to rinse the residue. Extra tests were conducted with 50/50 Type I ethylene glycol (EG) fluid and Type IV fluids;
- The rinsing fluids were applied at 60°C. Preliminary tests showed that the fluid volume needed to rinse the deposits is a function of its temperature;
- The aluminum pans were rinsed until no gel residue was visible; and
- The fluid volume required for rinsing was recorded.

To verify that the results were reproducible, the tests were run in duplicate.

3.3 Results and Observations

The average residue removal test results are summarized in Table 3.1.

Table 3.1: Residue Removal Test Results

Test #	Fluid Subjected to Dry-out (20 mL)	Rinsing Fluid (Applied at 60°C)	Rinsing Volume (mL)
1	Type II: Clariant Safewing MP II 2025 ECO	Propylene Type I (50/50)	500
2	Type III: Clariant Safewing MP III 2031 ECO	Propylene Type I (50/50)	378
3	Type III: Clariant Safewing MP III 2031 ECO	Type III: Clariant 2031	425
4	Type III: Clariant Safewing MP III 2031 ECO	Type III: Clariant 2031 (50/50)	390
5	Type IV: Clariant Safewing MP IV 2001	Propylene Type I (50/50)	473
6	Type IV: Clariant Safewing MP IV 2001	Type IV: Clariant 2001 (50/50)	471
7	Type IV: Kilfrost ABC-S	Propylene Type I (50/50)	363
8	Type IV: Kilfrost ABC-S	Type IV: Kilfrost ABC-S (50/50)	393
9	Type IV: Dow Chemical UCAR ULTRA +	Propylene Type I (50/50)	485
10	Type IV: Dow Chemical UCAR ULTRA +	Ethylene Type I (XL 54)	465

The following observations were made:

- Type III fluid dry-out results are comparable to those of the Type IV fluids tested;
- According to Test 3 and Test 4, the diluted Type III fluid removes the residue more easily than the concentrated fluid. Water may have a higher capacity for rinsing dry-out deposits than deicing and anti-icing fluids;
- The type of fluid (Type I versus Type IV) used for the rinsing process of Type IV fluid residues does not considerably affect the results (Test 5 vs. Test 6; Test 7 vs. Test 8);
- Rinsing Dow Chemical UCAR ULTRA + residue with EG or PG Type I fluids gave almost the same result;
- The Type II fluid residue was the hardest to remove. The last 10 percent of the deposit was the most difficult; and
- When using Type I PG fluid (50/50) for rinsing, Kilfrost ABC-S residue was the easiest to remove.

3.4 Conclusion

Based on the results from these tests, the ease of removal of Type III fluids is comparable to that of Type II and Type IV fluids commonly used in the industry.

This page intentionally left blank.

Photo 3.1: Dry-Out Deposits on the Aluminum Foil Pans



Photo 3.2: Setup for Rinsing the Dry-Out Deposit



This page intentionally left blank.

4. FIELD ANTI-ICING FLUID VISCOSITY ESTIMATION

This section describes the research work conducted to study the feasibility of using a simplified device to estimate anti-icing fluid viscosity in the field.

4.1 Background

In the winter of 1999-2000, APS Aviation Inc. (APS) conducted work to establish the feasibility of using a simple viscosity tester to estimate the viscosity of anti-icing fluids during field operations. The main component used to construct the viscosity tester was a plastic cylindrical 1 L bottle with a drain hole. Tests were performed with four different fluids. The draining time, which is a function of the viscosity, was measured and reported. The simple viscometer device proved effective for the fluids that were tested.

Further research work was conducted in 2004-05 to refine the viscosity device and to test it with other fluids; that work is described in this report.

4.2 Methodology

Two simplified viscosity devices were tested:

1. A 60 mL syringe (without the needle and the piston); and
2. A 1 L carboy container with a drain hole.

Further details on these simplified testers are provided in Appendix G.

The size of the opening of these two devices is standard. The testing procedure was set as follows:

1. A predefined fluid quantity (at room temperature) was poured in the viscosity device;
2. The draining time, which is a function of the fluid viscosity, was measured with a stopwatch; and
3. The viscosity of the fluid, sheared at different levels, was reported in a graph as a function of the corresponding draining time.

4.3 Processing of Data, Results, and Analysis

The processing of data, results, and analysis for tests conducted with both viscosity devices are summarized in Appendix G.

4.4 General Conclusions

Based on the results drawn from these tests, the following conclusions were made:

1. The results provided with the syringe and the carboy viscosity tester devices proved that the measured draining time could be an efficient method to estimate the viscosity of fluids exposed to shearing and to compare it to the minimum holdover time (HOT) viscosity;
2. This type of test could easily be conducted in a field operation since it requires only a standard container and the "draining time versus viscosity" graph. This graph should be provided for each fluid;
3. A critical draining time corresponding to the minimum HOT viscosity could be set for each fluid and used as a field indicator;
4. Comparing the syringe and the carboy devices, the results are more accurate with the carboy viscosity device, as it provides longer draining time, which reduces experimental error;
5. Since fluid viscosity is temperature dependent, the draining tests should be conducted at the same temperature indicated in the graph;
6. The shearing process usually causes bubbles to form in the fluid. Based on two samples, bubbles increase the draining time by 8 percent; and
7. Since experimental errors can be expected by using this simplified method, the critical draining time should be overstated by at least 10 percent. In all cases, if a failing result is found, the viscosity of the fluid should be measured following the manufacturer's recommended method to confirm the result.

4.5 Recommendations

The Society of Automotive Engineers (SAE) G-12 Fluids Subcommittee formed a working group to find a viscometer that is suitable, easy to use, and inexpensive for field measurements. The working group has completed a round-robin series of tests on a field viscometer made by Stony Brook Scientific, using three Type IV fluids with different viscosities. The results were presented at the 2005 SAE G-12 Fluid meeting in Pittsburgh, Pennsylvania, and refinements to this instrument were recommended.

It is recommended that further work on the field viscometer developed by APS be put on hold until the results of Stony Brook Scientific viscometer are finalized.

If the results with the Stony Brook Scientific device are not satisfactory, it is recommended that APS continue refining its viscosity estimation technique. Since the preliminary work was based on only two anti-icing fluids (Clariant 2025 ECO and Kilfrost ABC-S), further work should be carried out with other fluid brands. In order to refine this field viscosity estimation technique, it is recommended that additional viscosity and draining time measurements on samples collected from full-scale standard spray tests be carried out and be compared to laboratory results.

This page intentionally left blank.

5. SNOW TESTING AT -14ºC TO -25ºC

At the May 2004 Society of Automotive Engineers (SAE) G-12 meeting in Frankfurt, Germany, it was recommended that holdover time (HOT) values for Type II/IV propylene glycol (PG) fluids in the -14ºC to -25ºC snow cells be changed to generic values. This followed an analysis of data collected indoors and outdoors in natural and artificial snow. Transport Canada (TC) and the Federal Aviation Administration (FAA) accepted the recommendation, and the HOTs for all Type II/IV PG fluids were changed to 15 to 30 minutes. The values for the only ethylene glycol (EG) fluid remained unchanged.

The group also recommended that artificial snow machines be used to determine fluid-specific HOTs in the -14ºC to -25ºC snow cells after artificial snow methods were approved for use in Aerospace Recommended Practice (ARP) 5485. The advantages and disadvantages of continuing with this approach are discussed in this section.

5.1 Options Analysis

There are two possible options. The first option is the status quo, and the second option is to develop fluid-specific values.

5.1.1 Option 1: Status Quo

This is the least costly option, as no additional testing is required. The values in the HOT tables would remain as they are presently: all values for Type II/IV PG fluids would remain at 15 to 30 minutes, and the values for Dow Chemical UCAR Ultra+ (EG fluid) would remain at 20 to 45 minutes.

5.1.2 Option 2: Fluid-Specific Values

This is the more expensive and complex option, in that each fluid would have its own HOTs in the -14ºC to -25ºC cells. The values for each fluid measured by APS Aviation Inc. (APS) and by Anti-Icing Materials International Laboratory (AMIL) are shown in Table 5.1 and Table 5.2, respectively. Based on the current analytical protocols, endurance time data from APS and AMIL would result in the values that are shown in Table 5.3. The values tabulated in Table 5.3 were rounded.

Table 5.1: APS Log of Tests at -25ºC

Test No.	Test Date	Fluid Name	Fluid Type	Endurance Time (min)	Icing Intensity ± stdev (g/dm²/h)
25C 1	24-Mar-04	Kilfrost ABC-S	IV	28.1	10.3 ± 0.11
25C 3	24-Mar-04	Kilfrost ABC-S	IV	15.3	26.0 ± 0.78
25C 5	12-Mar-04	Dow Chemical UCAR ULTRA +	IV	85.5	10.2 ± 0.1
25C 7	12-Mar-04	Dow Chemical UCAR ULTRA +	IV	31.3	25.9 ± 0.26
25C 8	23-Mar-04	Dow Chemical UCAR ULTRA +	IV	32.0	25.9 ± 0.28
25C 9	12-Mar-04	Octagon Max-Flight	IV	29.8	10.5 ± 0.17
25C 10	15-Mar-04	Octagon Max-Flight	IV	31.1	10.4 ± 0.16
25C 11	12-Mar-04	Octagon Max-Flight	IV	12.4	26.1 ± 0.18
25C 12	15-Mar-04	Octagon Max-Flight	IV	13.5	26.4 ± 0.18
25C 13	12-Mar-04	SPCA AD-480	IV	27.8	10.4 ± 0.06
25C 14	23-Mar-04	SPCA AD-480	IV	32.7	10.1 ± 0.13
25C 15	12-Mar-04	SPCA AD-480	IV	12.2	26.2 ± 0.26
25C 16	23-Mar-04	SPCA AD-480	IV	11.3	26.0 ± 0.23
25C 17	12-Mar-04	Clariant Safewing MP IV 2001	IV	26.8	10.3 ± 0.2
25C 18	23-Mar-04	Clariant Safewing MP IV 2001	IV	27.7	10.3 ± 0.1
25C 19	12-Mar-04	Clariant Safewing MP IV 2001	IV	13.7	25.9 ± 0.93
25C 20	24-Mar-04	Clariant Safewing MP IV 2001	IV	14.2	26.0 ± 0.6
25C 21	24-Mar-04	Kilfrost ABC-II PLUS	II	22.7	10.9 ± 0.15
25C 23	24-Mar-04	Kilfrost ABC-II PLUS	II	12.2	25.8 ± 0.31
25C 25	15-Mar-04	Clariant Safewing MP IV 2012 Protect	IV	19.9	10.4 ± 0.22
25C 27	12-Mar-04	Clariant Safewing MP IV 2012 Protect	IV	11.2	26.0 ± 0.17
25C 29	15-Mar-04	SPCA Ecowing 26	II	23.8	10.4 ± 0.09
25C 30	23-Mar-04	SPCA Ecowing 26	II	28.0	10.1 ± 0.17
25C 31	15-Mar-04	SPCA Ecowing 26	II	10.2	26.2 ± 0.17
25C 32	24-Mar-04	SPCA Ecowing 26	II	14.3	26.2 ± 0.78
25C 37	24-Mar-04	Kilfrost ABC 2000	II	25.2	12.1 ± 0.33
25C 39	24-Mar-04	Kilfrost ABC 2000	II	16.7	26.0 ± 0.15
25C 41	15-Mar-04	Clariant Safewing MP II 2025 ECO	II	25.6	10.4 ± 0.09
25C 42	23-Mar-04	Clariant Safewing MP II 2025 ECO	II	28.8	10.3 ± 0.26
25C 43	15-Mar-04	Clariant Safewing MP II 2025 ECO	II	10.6	26.5 ± 0.17
25C 45	15-Mar-04	Clariant Safewing MP IV 2030 ECO	IV	24.3	10.5 ± 0.11
25C 46	23-Mar-04	Clariant Safewing MP IV 2030 ECO	IV	25.4	10.3 ± 0.27
25C 47	15-Mar-04	Clariant Safewing MP IV 2030 ECO	IV	11.5	26.3 ± 0.17

Table 5.2: AMIL Log of Tests at -25°C

Fluid	Fluid Type	Snow Machine Results at -25°C (min)
ABC-S	Type IV PG	13 – 26
Max-Flight	Type IV PG	13 – 27
AD 480	Type IV PG	10 – 18
Safewing 2001	Type IV PG	10 – 18
Safewing 2012	Type IV PG	11 – 20
Safewing 2030	Type IV PG	10 – 15
UCAR ULTRA +	Type IV EG	35 – 84
Safewing 2025	Type II PG	11 – 18
ABC 2000	Type II PG	14 – 20
ABC II Plus	Type II PG	14 – 22
Ecowing 26	Type II PG	12 – 22

Table 5.3: HOT and Endurance Time Results

Fluid	Fluid Type	Current HOT Values (min)	Snow Machine Results at -25°C (min)	
			APS	APS + AMIL
ABC-S	Type IV PG	15 – 30	15 (1) – 30 (1)	15 – 25
Max-Flight	Type IV PG	15 – 30	15 (2) – 30 (2)	15 – 30
AD 480	Type IV PG	15 – 30	10 (2) – 30 (2)	10 – 25
Safewing 2001	Type IV PG	15 – 30	15 (2) – 25 (2)	15 – 25
Safewing 2012	Type IV PG	15 – 30	10 (1) – 20 (1)	10 – 20
Safewing 2030	Type IV PG	15 – 30	10 (1) – 25 (2)	10 – 20
UCAR ULTRA +	Type IV EG	20 – 45	30 (2) – 85 (1)	35 – 85
Safewing 2025	Type II PG	15 – 30	10 (1) – 25 (2)	10 – 25
ABC 2000	Type II PG	15 – 30	15 (1) – 25 (1)	15 – 20
ABC II Plus	Type II PG	15 – 30	10 (1) – 25 (1)	10 – 20
Ecowing 26	Type II PG	15 – 30	10 (2) – 25 (2)	10 – 25
Generic	Type IV	15 – 30	10 – 20	10 – 20
Generic	Type II	15 – 30	10 – 20	10 – 20

Note: Values in parentheses ( ) designate # of tests conducted. For AMIL, one test was conducted in each condition.

5.2 Conclusions and Recommendations

Because the number of deicing operations in the -14°C to -25°C cells is insignificant, and because the HOTs in these cells are similar, carrying out testing to provide fluid-specific values would not be appropriate. In addition, the intensive testing by APS and AMIL at these temperatures has demonstrated that most of the endurance times of the PG fluids in this temperature range are similar.

It is therefore recommended to maintain the current (generic) values as HOTs in the -14°C to -25°C snow cells for PG fluids.

6. VIDEO DOCUMENTATION OF SNOWFALL INTENSITIES

At the request of the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) undertook a project in the winter of 2003-04 to document the four snowfall intensity categories — very light snow, light snow, moderate snow, and heavy snow — on video. The objective of the project was to create a training tool for individuals and organizations involved in aircraft ground deicing, including airlines, pilots, ground crews, and deicing operators.

This project was started in the winter of 2003-04; however, due to a lack of snow events in Montreal that winter, it was not completed, and the work was carried forward to the winter of 2004-05.

6.1 Objectives

Based on the current Transport Canada (TC) visibility table (see Table 6.1), there are 16 visual snowfall intensity categories based on lighting, temperature, and visibility. As there are many variables influencing nighttime visibility in the airport context, such as airport and aircraft lighting, it was decided the video would focus on daytime visibility. The primary objective was therefore to capture the eight daytime conditions. A baseline condition would also be collected in overcast conditions with no precipitation.

Table 6.1: TC Visibility Table

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤1/2	>1/2 to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

6.2 Scenes

Three scenes, all located at or near the APS test site at Montréal–Pierre Elliott Trudeau International Airport (YUL), were chosen to capture different aspects of snowfall intensity. The three scenes are described on the next page.

1. Airfoil: Footage was taken of an airfoil to show snowflakes falling on an aircraft wing.
2. Airport Building: Footage of an aircraft maintenance hangar was collected in order to document typical pilot views from aircraft. This building was also selected because snowflakes were highly visible in front of its dark exterior.
3. Road: Footage was collected from the end of a long straight road with a clear view of more than 3 km (2 statute miles) across the airport. The purpose of collecting footage from this location was to obtain the long-distance visual perspective of snowfall intensity.

A fourth scene, located at a different airport building, was recorded during the winter of 2003-04. This scene and the hangar scene were similar; therefore, it was decided that the footage of this building would not be used. Footage was not collected at this location in 2004-05.

6.3 Videographer

A professional videographer was retained for this project. In addition to collecting footage, he provided professional equipment, editing services, technical support, and guidance.

6.4 Procedure

In anticipation of snow events, the videographer was called to the APS test site. While an APS technician measured snowfall intensity rates using the standard plate pan measurement method, the videographer captured footage of the three scenes. The cycle was repeated if the snowfall intensity changed or appeared to be changing. Five-minute rate measurements were taken and later matched to individual video clips to ascertain the snowfall intensity seen in each clip.

The detailed procedure is included in Appendix H.

6.5 Data

A log of each video clip collected over the two winters is presented in Table 6.2. The table provides the date, location, precipitation rate, visibility, and outside air temperature (OAT) for each clip.

Table 6.2: Log of Video Footage

Date	Time	Rate ($g/dm^2/h$)	Snow Type	Temp. (°C)	Visibility* (km)	Location	Comments
20-Feb-04	17:29	0	N/A	-2	24.0	Road	Not enough daylight
20-Feb-04	17:40	0	N/A	-2	24.0	Road	Not enough daylight
21-Feb-04	9:30	0	N/A	0	2.2	Road	
21-Feb-04	9:38	0	N/A	0	2.4	Road	
21-Feb-04	9:42	0	N/A	0	2.6	Road	
21-Feb-04	9:57	11	Moderate	0	2.8	Airfoil	
21-Feb-04	10:39	11	Moderate	1	2.8	Road	
21-Feb-04	10:47	7	Light	1	2.8	Road	
21-Feb-04	10:53	5	Light	1	2.8	Road	
21-Feb-04	11:29	<1	Very Light	1	4.0	Airfoil	
21-Feb-04	14:51	0	N/A	1	4.8	Road	
20-Mar-04	15:38	19	Moderate	-1	0.8	Airfoil	
20-Mar-04	15:42	19	Moderate	-1	0.8	Road	
20-Mar-04	15:46	19	Moderate	-1	0.8	Airfoil	
20-Mar-04	16:24	37	Heavy	-1	0.8	Airfoil	
20-Mar-04	16:28	37	Heavy	-1	0.8	Road	
20-Mar-04	16:32	37	Heavy	-1	0.8	Airfoil	
20-Mar-04	17:25	6	Light	-1	1.0	Airfoil	
20-Mar-04	17:29	6	Light	-1	1.0	Road	
20-Mar-04	17:33	6	Light	-1	1.0	Airfoil	
23-Mar-04	7:42	<1	Very Light	-8	4.4	Building	Scene not used
23-Mar-04	7:46	<1	Very Light	-8	4.4	Road	
23-Mar-04	8:14	<1	Very Light	-7	6.4	Hangar	
23-Mar-04	8:18	<1	Very Light	-7	6.4	Airfoil	
23-Mar-04	8:45	0	N/A	-5	6.4	Airfoil	
23-Mar-04	8:49	0	N/A	-5	6.4	Hangar	
23-Mar-04	9:00	0	N/A	-5	24.1	Road	
23-Mar-04	9:02	0	N/A	-5	24.1	Building	Scene not used
23-Mar-04	16:19	6	Light	-1	12.9	Hangar	
23-Mar-04	16:22	28	Heavy	-1	4.0	Hangar	
23-Mar-04	16:24	28	Heavy	-1	4.0	Hangar	
23-Mar-04	16:45	114	Heavy	-1	4.0	Airfoil	
23-Mar-04	16:50	114	Heavy	-1	4.0	Road	
23-Mar-04	16:55	11	Moderate	-1	4.0	Building	Scene not used
4-Apr-04	18:35	17	Moderate	-1	2.4	Airfoil	Tar paper missing
4-Apr-04	18:38	13	Moderate	-1	2.4	Hangar	
4-Apr-04	18:51	12	Moderate	-1	2.4	Road	
4-Apr-04	18:58	12	Moderate	-1	2.4	Building	Scene not used
4-Apr-04	19:10	12	Moderate	-1	2.4	Hangar	
4-Apr-04	19:18	12	Moderate	-1	2.4	Airfoil	Tar paper removed
4-Apr-04	19:21	12	Moderate	-1	2.4	Road	
4-Apr-04	19:27	12	Moderate	-1	2.4	Building	Scene not used
6-Jan-05	13:16	4	Light	-13	19.3	Airfoil	Perfect
6-Jan-05	13:29	13	Moderate	-13	0.4 and 19.3	Hangar	Snow increased quickly, trucks, dark
6-Jan-05	13:49	17	Moderate	-13	0.4	Road	Okay, road looks strange

Table 6.2: Log of Video Footage (cont'd)

Date	Time	Rate ($g/dm^2/h$)	Snow Type	Temp. (°C)	Visibility* (km)	Location	Comments
6-Jan-05	14:13	12	Moderate	-13	0.4	Airfoil	Perfect
6-Jan-05	14:24	17	Moderate	-13	0.7	Hangar	Good, a bit dark
6-Jan-05	14:46	18	Moderate	-13	1.0	Road	Not usable b/c camera froze
10-Feb-05	8:55	6	Light	-6	1.6	Airfoil	Windy, do not use
10-Feb-05	9:10	7	Light	-6	1.6	Hangar	Windy, blowing snow
10-Feb-05	9:30	6	Light	-6	1.6	Road	Windy, blowing snow
10-Feb-05	9:47	6	Light	-6	1.6	Airfoil	Okay
10-Feb-05	9:58	7	Light	-6	1.6	Hangar	Good (best clip from Feb 10)
10-Feb-05	10:16	8	Light	-6	1.6	Road	Windy, blowing snow
10-Feb-05	10:30	6	Light	-6	1.4	Airfoil	Okay
10-Feb-05	10:45	6	Light	-6	1.2	Hangar	Good
10-Feb-05	10:57	8	Light	-6	1.2	Road	Windy, blowing snow
10-Feb-05	12:01	10	Light	-6	1.2	Airfoil	Good, some wind, building bright
10-Feb-05	12:15	9	Light	-6	1.2	Hangar	Good, some blowing snow
10-Feb-05	12:33	6	Light	-6	1.1	Road	Windy, blowing snow
10-Feb-05	12:40	5	Light	-6	1.0	Airfoil	Windy, do not use
10-Feb-05	12:49	6	Light	-6	1.0	Hangar	Windy, blowing snow, do not use
10-Feb-05	13:05	10	Light	-6	1.0	Road	Windy, blowing snow
16-Feb-05	13:15	17	Moderate	0	1.0	Airfoil	Good
16-Feb-05	13:22	17	Moderate	0	1.0	Hangar	Good
16-Feb-05	13:32	19	Moderate	0	1.3	Road	Good
16-Feb-05	13:54	12	Moderate	0	1.6	Airfoil	Good, looks light
16-Feb-05	14:01	11	Moderate	0	1.6	Hangar	Good
16-Feb-05	14:18	8	Light	0	1.6	Road	Good
16-Feb-05	14:38	6	Light	0	4.8	Airfoil	Good
16-Feb-05	14:43	5	Light	1	8.0	Hangar	Good, bright
16-Feb-05	15:12	3	Very Light	1	8.0	Road	Good, looks like no snow
16-Feb-05	15:22	3	Very Light	1	8.0	Airfoil	Good, very light
16-Feb-05	15:27	4	Light	1	7.2	Hangar	Looks very light
16-Feb-05	16:05	2	Very Light	1	6.4	Road	Good, looks like no snow
7-Mar-05	13:15	19	Moderate	-13	2.4	Road	Windy, blowing snow
7-Mar-05	13:32	12	Moderate	-12	4.4	Airfoil	Good, looks moderate
7-Mar-05	13:46	5	Light	-12	6.4	Hangar	Okay
7-Mar-05	13:59	5	Light	-12	6.4	Road	Okay, road looks strange
7-Mar-05	15:08	6	Light	-11	4.8	Airfoil	Wind, ice pellets, do not use
7-Mar-05	15:16	5	Light	-11	4.8	Hangar	Good, some wind
7-Mar-05	15:31	1	Very Light	-10	2.8	Road	Some snow visible, blowing
7-Mar-05	15:44	<1	Very Light	-10	0.8	Airfoil	Windy
7-Mar-05	15:51	2	Very Light	-10	0.8	Hangar	Good, tractor driving
7-Mar-05	16:01	5 and 13	Light/Mod	-10	0.8	Road	Rates are light/moderate, looks heavy
7-Mar-05	16:11	5	Light	-10	0.8	Airfoil	Some wind
7-Mar-05	16:17	7	Light	-10	0.8	Hangar	Not good

*Based on Meteorological Service Canada (MSC) hourly data — may not be representative of visibility at the specified time.

6.6 Preliminary Edit

APS provided a preliminary version of the video to TC and the FAA in July 2004. The preliminary version disregarded temperature and included footage from the four snowfall intensities (some above -1°C and some below -1°C). Based on subsequent discussions with TC and the FAA, it was decided that additional footage would be collected in the winter of 2004-05 before the video was finalized.

6.7 Final Edit

Additional footage was collected in the winter of 2004-05 and amalgamated with the footage from 2003-04. The best clips from each snowfall intensity category were selected and edited together. The clips included in the final edit are shown in Table 6.3.

Table 6.3: Selected Clips

Snowfall Intensity	Airfoil		Airport Building		Road	
No Snow	23-Mar-04	08:45	23-Mar-04	08:49	23-Mar-04	09:00
Very Light	16-Feb-05	15:22	7-Mar-05	15:51	16-Feb-05	15:12
Light	6-Jan-05	13:16	10-Feb-05	09:58	16-Feb-05	14:18
Moderate	6-Jan-05	14:13	16-Feb-05	13:22	16-Feb-05	13:32
Heavy Snow	23-Mar-04	16:45	23-Mar-04	16:22	23-Mar-04	16:50

As in the preliminary edit, temperature was disregarded. The reason for this was that the variables of natural lighting, wind speed, wind direction, and snowfall rate varied largely, making it difficult to obtain two clips that were virtually the same except for temperature. Instead, the difference between wet and dry snow was shown using one scene in one snowfall intensity as an example. The airfoil scene in light snow was selected for the wet versus dry comparison. The clips used were as follows:

- Dry: January 6, 2005, 13:16; and
- Wet: February 16, 2005, 14:38.

The video was finalized in September 2005 and provided to TC and the FAA on video home system (VHS) and digital versatile disc (DVD).

This page intentionally left blank.

7. HOLDOVER TIME GUIDELINES WEBSITE

7.1 Background

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

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

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

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

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

7.2 Changes to the Website

Since July 2004, several changes have been made to the website. In December 2004, a revised version of the 2004-05 HOT Guideline tables (entitled Revision 1.0) was posted. Minor editorial changes such as the following were included:

- Adding a note regarding the lowest operational use temperature (LOUT) to the Type I table;
- Note 3 reworded for clarification;

- Table 2-S-E26, the upper HOT value changed under "Rain on a Cold Soaked Wing";
- Change made to Table 5; and
- Removal of Clariant Safewing Four.

These changes are documented on Page 3 of the guidelines. In order for the changes to be approved, APS is required to obtain approval from both TC and the TDC. Figure 7.1 is used for this purpose.

In July 2005, the 2005-06 HOT Guidelines were published on the website and replaced the 2004-05 HOT Guidelines, which were archived on the site. Appendix I contains the 2005-06 HOT Guidelines as they appear in English on the website. As has been done in previous years, the changes from the previous year's guidelines are summarized on Page 3 of the document and explained in detail in the TC report, TP 14443E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2004-05 Winter* (1). In addition to content changes, several minor format improvements were also made to the 2004-05 HOT Guidelines, notably the following:

- Removal of the "above °C" temperature band;
- Removal of viscosity information from the fluid-specific tables to a separate table of viscosities;
- Replacing abbreviations with full spellings, i.e., "OAT" is "now outside air temperature";
- Addition of the word "active" to the frost column;
- Addition of the words "snow grains" to the snow column;
- Changes to the cautions section;
- Addition of one new Type IV fluid, Octagon MaxFlo;
- Removal of the Type IV fluid, Clariant Safewing MP IV 1957; and
- Minor editorial changes.

7.3 Future Responsibilities

APS has undertaken the responsibility to ensure that the website is operational, in terms of Internet availability, for a one-year period. In the summer of 2006, APS intends to update the website with new data from 2005-06 testing and post the 2006-07 HOT Guidelines.

Request for Change to Holdover Time Guidelines Website

Date: _____

Description of Change: _____

_____

_____

Affected Pages: _____

Requested By: _____

Reason for Change: _____

_____

_____

Confirmed by:

_____
Barry Myers
Senior Development Officer
Transportation Development Centre

Confirmed by:

_____
Douglas Ingold
Specialist Flight Technical
Transport Canada Civil Aviation

Procedure for making changes to the holdover time guidelines website:

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

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

Figure 7.1: HOT Guidelines Change Form

This page intentionally left blank.

8. PROCEDURES, PRESENTATIONS, AND FLUID MANUFACTURER REPORTS

This section contains an account of the test procedures, presentations, and fluid manufacturer reports that were prepared in 2004-05.

8.1 Procedures

Several procedures were developed to guide and support the research team in the methodology for conducting tests. Table 8.1 provides a list of the procedures developed for each major project. Each major project has been documented in a separate report, and the complete procedures have been included in these reports.

8.2 Presentations

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

In 2004-05, meetings were held in the following locations:

1. Ottawa, Canada, from September 29-30, 2004;
2. Montreal, Canada, from October 20-22, 2004;
3. Atlantic City, U.S.A, on November 16, 2004, and January 18, 2005; and
4. Pittsburgh, U.S.A, from May 23-26, 2005.

The presentations given by APS at each of these meetings are listed in the following subsections. A copy of the presentations is contained in Appendix J.

8.2.1 Standing Committee Meetings, Ottawa, Canada, September 2004

Two presentations were prepared for the Standing Committee for Operations Under Icing Conditions meetings held in Ottawa from September 29-30, 2004:

1. Aircraft De/Anti-Icing Fluid HOT Guideline Developments, 2004-05 Winter Operations; and
2. Aircraft Anti-Icing Fluid Lowest On-Wing Viscosity.

8.2.2 SAE G-12 Working Group Meetings, Montreal, Canada, October 2004

One presentation was prepared for the SAE G-12 Working Group and holdover time (HOT) meetings held in Montreal from October 20-22, 2004:

1. Revisions to HOT Table Format, Notes, and Cautions for Future Years.

8.2.3 Federal Aviation Administration (FAA) Meetings, Atlantic City, U.S.A, November 2004 and January 2005

Two presentations were prepared for FAA meetings held in Atlantic City on November 16, 2004, and January 18, 2005:

1. Test History Air-Assisted Application of Type II/IV Fluid; and
2. Ice-Making Feasibility Study for Ice Detection Threshold Tests.

8.2.4 SAE G-12 Subcommittee Meetings, Pittsburgh, U.S.A, May 2005

Seven presentations were prepared for the SAE G-12 meetings held in Pittsburgh from May 23-26, 2005:

1. Proposed ARP5945 Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type I;
2. Exploratory Endurance Time Tests;
3. Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2004-05 Winter Test Season – Type I;
4. Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2004-05 Winter Test Season – Type II/IV;
5. Type III Aircraft Ground De/Anti-Icing Fluid Endurance Time Test Results and HOT Table Developments;
6. Type III De/Anti-Icing Fluid Developments 2004-05 Winter; and
7. Type IV Fluid Application with Forced Air.

8.3 Fluid Manufacturer Reports

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

During the 2004-05 winter, four fluids were tested. Reports for each of the four fluids were provided directly to the fluid manufacturers. The reports for Clariant Safewing MP III 2031 ECO (Type III) and Octagon MaxFlo (Type IV) have also been included in Appendix C of TP 14443E (1).

Table 8.1: List of Procedures for Winter 2004-05

Program Element #	ID#	Contract Program Element	Name of Procedure	Date of Latest Version	Version #	Report
1.0	1.1	Holdover Time Testing and Evaluation of De/Anti-Icing Fluids	Test Requirements for Simulated Freezing Precipitation Flat Plate Testing	See TP 14374E – Appendix B		HOT
1.0	1.2	Holdover Time Testing and Evaluation of De/Anti-Icing Fluids	Test Requirements for Natural Precipitation Flat Plate Testing	23-Dec-2004	1.0	HOT
1.0	1.3	Holdover Time Testing and Evaluation of De/Anti-Icing Fluids	Overall Program of Tests at NRC, April 2005	31-Mar-2005	1.0	HOT
2.0/17.0	2.1	Endurance Time Testing in Frost – Type I/II/III/IV Fluid	Exp. Program – Endurance Time Testing in Frost with Type I, II, III and IV Fluids	See TP 14383E – Appendix B		FROST
3.0	3.1	Operational Evaluation of Type III Fluids	Experimental Program: Field Trials to Examine Removal of Neat Type III Fluid from Aircraft Wings During Takeoff (Dallas)	13-Oct-2004	1.0	EXPLORATORY
3.0	3.2	Operational Evaluation of Type III Fluids	Demonstration Flight to Examine Removal of Neat Type III Fluid from Aircraft Wings During Takeoff (St. Louis)	28-Oct-2004	1.2	EXPLORATORY
3.0	3.4	Operational Evaluation of Type III Fluids	Effect of Heat on Type III Endurance Time of Anti-Icing Fluids	23-Dec-2004	1.0	HEAT
8.0	8.1	Forced Air System Evaluation	Test Program Forced Air Systems – Type II/III/IV Fluid Applied over the Forced Air Stream	21-Jan-2005	1.0	FORCED AIR
8.0	8.2	Forced Air System Evaluation	Test Program – Viscosity Tests of Fluids Applied with FedEx Forced Air Systems (Pittsburgh)	21-Jan-2005	1.0	FORCED AIR
14.0	14.1	Sensor Technology to Minimize Variance in HOT Failure	Experimental Procedure: Comparison of Endurance Times Measured by Sensor and by Trained Personnel	12-Jan-2005	1.0	SENSOR
15.0	15.1	Video Documentation of Snowfall Intensities	Procedure Video Documentation of Snowfall Intensities	10-Nov-2004	1.0	EXPLORATORY
16.0	16.1	Photographic Documentation of Frost Formations	Photographic Documentation of Frost Formations	9-Feb-2005	1.0	FROST
18.0	18.1	Validity of 75/25 HOT Test Protocol (Spraying vs. Pouring)	Experimental Procedure: Comparison of Viscosities of Diluted Fluids (75/25) Before and After Spraying	21-Mar-2005	1.0	EXPLORATORY
19.0	19.1	Effect of Heat on Neat and Diluted Type II/IV Endurance Times	Effect of Heat on Type III Endurance Time of Anti-Icing Fluids	23-Dec-2004	1.0	HEAT/COMPOSITE
21.0	21.1	Endurance Time Testing of Non-Aluminum Plates				
22.0	22.2	Support for Human Factor Tactile Tests	Experimental Procedure: Human Factor Visual and Tactile Tests on Wing at PMG - Phase II	11-Jul-2005	1.0	TACTILE

REFERENCES

1. Bendickson, S., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2004-05 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, October 2005, TP 14443E, 68.

This page intentionally left blank.

APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2003-05

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2003-05

6.3 Operational Evaluation of Type III Fluids (Priority 1)

a) **St. Louis Demonstration Flight**: prepare procedure for demonstration flight test that will be conducted by AEA and Embraer. Monitor and support the test including the observation of fluid on Radome. Collect samples and report on test; and

b) **Dryout investigation**: compare the effectiveness of removing residues with treated Type III and heated Type I fluid. Conduct tests initially on small panels and subsequently on the Jetstar wing in the control surfaces.

6.5 Development of Indoor Snow Test Protocol (Priority 1)

a) In accordance with the recommendations of the SAE G-12 HOT Committee, finalize the development of the protocol for Type II/III/IV fluids for inclusion in ARP5485; and

b) Consider and evaluate the inclusion of a protocol for Type I fluids in ARP5945. While it may be logical to include a protocol in ARP5945 that is based on laboratory snow, it may not be economical at this time to do so.

6.6 Provision of Support Services and Other Activities

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

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

c) Provide support to address other issues that may emerge as having greater priority during the course of the winter season, which could be pursued on direction from TDC. Potential issues are as follows:

   i) Review of the usage of infrared heat with Type I and Type II/IV fluids;

   ii) Acquisition of Canadair RJ wing for use as a test bed;

   iii) Dispersion of fluids on airport surfaces;

   iv) Volume of fluid blown away by jet blast;

v) Volume of deicer fluid tracked by tires;

vi) Hot water deicing;

vii) Infrared system development for northern climates;

viii) Ice phobic materials (effect on Type IVs);

ix) Support development of SAE Standards for Electronic Message Boards (EMB); and

x) Participate at the workgroup meetings for the development of the EMB standards.

6.7 SAE Standards for Measuring Holdover Times (Priority 1)

6.7.1 Provide support to modifying and updating ARP5485 (the SAE Aerospace Council has asked that this standard be renamed). Further develop, finalize and ballot the new SAE Aerospace Standard for Type I fluids proposed ARP5945.

6.7.5 Support to Development of Field Viscometer

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

b) Conduct preliminary trials to evaluate simple field viscometer;

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

d) Develop standards for all fluids.

6.9 Study of Negative 3C Buffer on the First Step Application (Priority 2)

a) Review previous research and discuss problem with Braathens;

b) Prepare a test procedure;

c) Coordinate and conduct tests;

d) Analyze data;

e) Present findings at the next SAE G-12 Annual meeting; and

f) Prepare a report.

6.13 Web Site for HOT Guideline Tables

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

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

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

d) Implement changes to the website and post the new HOT Guidelines in summer of 2005 for use in winter of 2005-06.

6.15 Video Documentation of Snowfall Intensities

a) Revise 2003-04 test procedure as required;

b) Retain services of professional videographer;

c) Prepare test site for permanent aerofoil setup;

d) Collect data in wet and dry snow in all snowfall intensities;

e) Analyse data and select most appropriate footage; and

f) Edit and finalize video.

6.18 Validity of 75/25 HOT Test Protocol (Spraying vs. Pouring)

a) Design tests to evaluate the validity of the 75/25 fluid HOTs;

b) Prepare a procedure for testing outdoors with the TC fluid sprayer;

c) Conduct preliminary tests at the Dorval test site; and

d) Report findings to TC/FAA.

6.20 Holdover Times for Snow at -14 to -25°C (Priority 3)

a) Review previous work and testing that was completed at -14°C to -25°C;

b) Evaluate the possible alternatives for proceeding forward (i.e., use of generic values or fluid specific values); and

c) For each of the following fluids, carry out special endurance tests at -25°C:

   i) Clariant Safewing Protect 2012;

   ii) Clariant MP IV 2001;

   iii) Kilfrost ABC-II Plus;

iv) Kilfrost ABC-S;

v) Kilfrost ABC 2000;

vi) Octagon Maxflight;

vii) Octagon E MAX II;

viii) SPCA Ecowing 26;

ix) SPCA AD-480;

x) UCAR Ultra+;

xi) Clariant Safewing 2025;

xii) Clariant Safewing 2030;

xiii) Octagon Maxflight 04; and

xiv) Clariant 2031 Type III.

These tests shall only be conducted as they form part of a "piggy-back" on other test programs; and

d) Present findings to TC, FAA and industry.

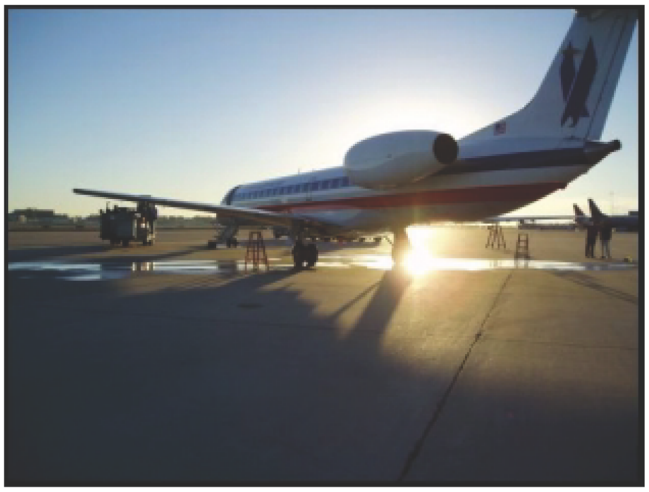
APPENDIX B

TRIP REPORT
DEMONSTRATION FLIGHT TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

CM1892.001 (04-05)

TRIP REPORT

Demonstration Flight to Examine Removal of Neat Type III Fluid from Aircraft Wings During Takeoff



Prepared by

John D'Avirro

Prepared for

Transportation Development Centre
In cooperation with
Civil Aviation
Transport Canada

November 2004
Final Version 1.0

CONTENTS

PAGE

1. GENERAL 1
1.1 Attendees 1
1.2 Acknowledgements 1
1.3 Objectives 1

2. METHODOLOGY 2
2.1 Procedure 2
2.2 Timeline 2

3. DATA COLLECTED 2
3.1 Fluid Viscosity 3
3.2 General Information 3
3.3 Fluid Thickness 3
3.4 Fluid Temperature 3
3.5 Deicing Vehicle and Nozzle 4
3.6 Flight Information 4
3.7 Photos of Tests and Videography 4

4. OBSERVATIONS 4
4.1 Flow Properties During Takeoff 4
4.2 Static Windshield Test 5
4.3 Radome Test During Takeoff 5
4.4 Pilot Commentary 5
4.5 Inspection of "Quiet Areas" 5
4.6 Fluid Appearance 6

5. CONCLUSION 6

6. RECOMMENDATIONS 6

ANNEXES

A Procedure: Demonstration Flight to Examine Removal of Neat Type III Fluid from Aircraft Wings during Takeoff

B Timeline for Type III Spray Demonstration Trials in St. Louis on October 30, 2004

C Clariant Fluid Inspection Certificate

D Data Forms

E Embraer Type III Demonstration Flight Fact Sheet

F Photos

1. GENERAL

In 2003-04, a new Type III fluid, Clariant Safewing MP III 2031 ECO, was certified to AMS1428 and tested for endurance times. Transport Canada and the Federal Aviation Administration have published a new Type III fluid holdover time table for use in Winter 2004-05, based on the test results of this new fluid.

Prior to allowing operators to use this new fluid, Embraer indicated a requirement for a demonstration flight with the Type III fluid on an Embraer Regional Jet aircraft. The demonstration flight was conducted at Lambert Field at St. Louis International Airport (STL) on October 30, 2004. The aircraft was operated by Trans States Airlines (TSA).

1.1 Attendees

- John D'Avirro, APS Aviation Inc.
- David J. Finchamp, Trans States Airlines
- Dan Patterson, Clariant Corporation
- Alexandre Pinheiro Goulart, Embraer
- Brad Seaman, Embraer
- Ed Shive, ExpressJet Airlines, Inc.
- Kurt Waggmer, Trans States Airlines
- Ron Whipple, American Eagle Airlines
- Mike White, Chief Pilot Trans States Airlines
- TSA Deicing Operator

Tests conducted at St. Louis on October 30, 2004 starting at 06:00 am.

1.2 Acknowledgements

APS would like to provide special thanks to the many participants and to the Federal Aviation Administration (FAA) and the Transportation Development Centre (TDC) for their support for this demonstration flight. In particular, a special thank you must go to Trans States Airlines for their participation and support that they provided for the tests, and also to American Eagle who were instrumental in initiating this demonstration flight.

1.3 Objectives

This project addressed the following objectives:

- To observe the flow properties of the Type III fluid when shearing off the wings during takeoff roll, rotation and climb-out;
- To examine the amount and location of fluid remaining on the aircraft surfaces upon return to the ground;
- To spray the windshield on the ground and observe whether the windshield wipers are capable of removing the Type III fluid and restoring adequate windshield visibility; and
- To spray the radome and observe whether the Type III fluid reaches the windshield during takeoff and whether the windshield wipers are capable of removing the fluid and restoring adequate windshield visibility while the airplane is flying.

2. METHODOLOGY

2.1 Procedure

A procedure was developed and was used to carry out the demonstration flight and to address the project objectives. A copy of this procedure is included as Annex A.

2.2 Timeline

A tentative timeline was prepared for the spray test (included as Annex B). Since there was a requirement from Trans States Airlines to finish testing by 11:00 am so that the aircraft could be used for a revenue flight, it was decided to move up the schedule by 1 hour on Saturday.

The revised schedule timing went as planned.

At 07:38 am the wings were sprayed for measurement of thickness and observation of the uniformity. At 08:18 am the wings were re-sprayed, and fluid was also applied to the tail and radome. The aircraft took-off at 08:33 am.

3. DATA COLLECTED

The demonstration flight was conducted on October 30, 2004 at St. Louis Airport. An Embraer 145 operated by Trans States Airlines was used for application of the Neat Type III fluid.

3.1 Fluid Viscosity

The certificate provided by Clariant (see Annex C) indicated that the Type III had a viscosity of 318 mPa.s (20ºC, 0.3 rpm, spindle 0, ASTM D 2196).

Samples were collected as follows:

- Two 1 litre samples from tote
- Two 1 litre samples from the tank of the truck
- Two 1 litre samples from wing after spray

The samples were shipped to the APS laboratory where their viscosities were measured. A different measurement method (0ºC, 0.3 rpm, spindle LV1, 500 mL) was used, as spindle 0 was not available. The results are as follows:

- Tote sample: 2600 cP
- Tank sample: 1960 cP
- On-wing sample: 1210 cP

Samples have also been sent to Clariant in Germany for additional verification, and measurement using the spindle 0 method.

3.2 General Information

A general form was completed for the test and contains general information such as weather conditions and fluid application times (see Annex D).

3.3 Fluid Thickness

In general, the fluid thickness was about 0.4 mm five minutes after fluid application, and 0.25 mm at twenty-two minutes after application. The fluid was found to be generally uniform over the entire wing surface.

3.4 Fluid Temperature

The temperature in the tank of the deicing vehicle 80ºC; when sprayed into a bucket the fluid temperature was measured to be 55ºC. Temperatures measured on the wing were found to be near the ambient air temperature (17ºC) about five minutes after spray.

3.5 Deicing Vehicle and Nozzle

The deicer was an FMC LA1000 built in 1972. A Type I Task Force Tips nozzle was used with the truck.

3.6 Flight Information

Annex E contains the Embraer Type III Demonstration Fact Sheet and scans of the original documents from which most of the data was extracted.

3.7 Photos of Tests and Videography

Photos (Annex F) and videos of tests were taken by:

- APS Aviation Inc.
- American Eagle Airlines
- Embraer

The photos show the following:

- Setup
- Fluid on wing
- Equipment used (e.g. truck, nozzle)
- Quiet areas on the stablizer
- Procedural shots

The videos are available if required.

4. OBSERVATIONS

4.1 Flow Properties During Takeoff

Two observers were seated in seats over the wing area. The Embraer representative sat in Row 15A to observe and video record the flow-off at the port wing, while the APS observer sat in Row 14C to observe and video record the flow-off on the starboard wing.

Review of the video record of the starboard wing indicates that the fluid came off the wing in a normal fashion prior to rotation.

After the takeoff run and return to the Trans States hangar, the wings were inspected for any remaining fluid. The wings were mostly dry; a very thin film could be seen in some areas on the trailing edge and spoiler area, not enough to collect into a sample bottle.

4.2 Static Windshield Test

Type III fluid was sprayed onto the windshield. The pilot was asked to remove the fluid with the windshield wipers and provide comments. The pilot indicated that the wipers were able to remove the fluid and restored adequate windshield visibility. Photo records are included in Annex F. Video records are available upon request.

4.3 Radome Test During Takeoff

Type III fluid was sprayed onto the radome just prior to takeoff to observe whether the Type III reaches the windshield during takeoff and whether the windshield wipers were able to remove the fluid adequately. During the takeoff run and while the aircraft was climbing, the Type III fluid from the radome flowed upwards onto two small strips on the main windshields. The small strips were about 2 to 5 cm wide and located on the inner edges of the two main windshield panes. In the pilot's view, these two strips did not hinder visibility and the pilot indicated that the fluid was easily removed wit the wipers during climb.

Photo records are included in Annex F. Video records are available as the representative form AEA was seated in the jump seat during the flight and recorded the windshield visibility.

4.4 Pilot Commentary

The pilot that operated the aircraft (Chief pilot with Trans States Airlines) indicated that the aircraft controls were normal; there were no abnormal characteristics and the aircraft operated normally. Regarding the windshield the pilot commented "Very comparable to Type I. Type III does tend to leave a slightly higher residue on surface. On windshield, visibility good".

4.5 Inspection of "Quiet Areas"

The Embraer representative indicated the areas that could be susceptible to gel formation after re-hydration. The quiet areas on the tail were inspected prior to spray and takeoff: those areas were clean. After application of the fluid and

takeoff, the quiet areas were inspected once again: the inside areas were found to be clean (no fluid), and two or three small droplets were found on the outside area of the quiet area hinges. Photos and video records of the quiet areas on the tail were taken.

4.6 Fluid Appearance

The fluid application resulted in a uniform glossy coating over both wings.

5. CONCLUSION

It was expected that the Type III fluid was going to flow off the wing much easier than Type II and Type IV fluids. The Embraer Type III demonstration flight was successful and confirmed what was expected of the fluid. On ground and in flight, the windshield wipers removed the Type III fluid that was sprayed on the windshield, as effectively as a Type I fluid.

6. RECOMMENDATIONS

It is recommended that that a standardized fluid flight test protocol be developed with industry so that all airframe manufacturers carry out a common test. A starting point for the protocol would be the one that was prepared for this test. In addition, a protocol to observe the quality of forced air assist fluid applications was developed in the last four years for the SAE G-12 Equipment Subcommittee. Some of the procedures from that protocol could be included. The industry has indicated that there is interest in observing characteristics such as foam, “fish eyes”, surface wetting, residues, ability of fluid to evaporate, flow-off the wing, etc.

ANNEX A

PROCEDURE: DEMONSTRATION FLIGHT TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

CM1892.001 (04-05)

DEMONSTRATION FLIGHT
TO EXAMINE REMOVAL OF NEAT TYPE III
FLUID FROM AIRCRAFT WINGS
DURING TAKEOFF

Winter 2004-05

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Michael Chaput p.p

Reviewed by: John D'Avirro



October 28, 2004
Version 1.2

ANNEX A

DEMONSTRATION FLIGHT TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

Winter 2004-05

In 2003-04, a new Type III fluid, Clariant Safewing MP III 2031 ECO, was certified to AMS1428 and tested for endurance times. Transport Canada and the Federal Aviation Administration have published a new Type III fluid holdover time table for use in Winter 2004-05, based on the test results of this new fluid.

Prior to allowing operators to use this new fluid, several airframe manufacturers have indicated a requirement for a demonstration flight with the Type III fluid on operational aircraft. This document provides the procedures and equipment required to support a demonstration flight with the Clariant Safewing MP III 2031 ECO fluid on an Embraer Regional Jet aircraft. The demonstration flight will be conducted at Lambert - St. Louis International Airport (STL) on October 30, 2004. The aircraft will be operated by Trans States Airlines.

1. OBJECTIVES

This project addresses the following objectives:

- To observe the flow properties of the Type III fluid when shearing off the wings during takeoff roll, rotation and climb-out;
- To examine the amount and location of fluid remaining on the aircraft surfaces upon return to the ground;
- To spray the windshield on the ground and observe whether the windshield wipers are capable of removing the Type III fluid and restoring adequate windshield visibility; and
- To spray the radome and observe whether the Type III fluid reaches the windshield during takeoff and whether the windshield wipers are capable of removing the fluid and restoring adequate windshield visibility while the airplane is flying.

2. PLAN

One demonstration flight will be performed with an Embraer Regional Jet.

3. PROCEDURES

3.1 Pre-Flight Setup

- Coordinate with Clariant for delivery of fluid to STL (RW);
- Coordinate with American Eagle/Trans States Airlines ground support for loading of Type III fluid into Type I de-icing vehicle (RW);
- Provide de-icing crew with spray procedures for the Type III fluid (RW);
- Provide pre-flight briefing to Trans States Airlines' flight crew (RW);
- Coordinate with airport authority for required permissions and access to de-icing pad (RW);
- Arrange for rolling stairs, step ladders and/or bucket trucks to allow for access to wing surfaces for data collection (RW);
- Arrange for security escorts and passes, if required (RW);
- Determine appropriate over-wing location for recording of video documentation (MC);
- Arrange for digital video camera for flight deck video documentation of the test flight (RW);
- Obtain one-litre sample containers for collecting fluid viscosity samples (RW); and
- Transport required equipment to STL (MC).

3.2 Conduct Flight

3.2.1 Prior to Application of Type III

- Record meteorological information: outside air temperature, wind speed and direction, relative humidity and sky condition on Form 1: General Data Form;
- Record fluid temperature out of spray nozzle;
- Collect two one-litre truck and fluid tote samples for viscosity verification; and
- Photograph and videotape the entire set-up.

3.2.2 Spray Application

- Fluid shall be sprayed onto the wings, tail and radome of the aircraft, using standard Type I fluid application procedures;
- A small amount of fluid shall be sprayed onto the windshield of the aircraft for a static test of the wipers ability to clear the fluid without smearing and restore adequate windshield visibility; and
- When spraying fluid on the aircraft, de-icing operators must avoid splashing the fuselage with fluid; this will prevent fluid from running back across cabin windows during the takeoff roll, obstructing view of the fluid shearing off the wings.

3.2.3 After Application of Type III

- Record fluid application quantities from de-icing crew;
- Within five minutes of fluid application, measure fluid thickness at selected locations on the aircraft and record information on the Form 2: Fluid Thickness Data Form. Fluid thickness will be recorded along two chord lines on each wing. The chord lines have been identified on Form 2. Four thickness measurements will be recorded on each chord:
  - One on the leading control surface, halfway between the nose and the leading edge joint (thickness locations 1, 5, 9, 13);
  - One on the main wing section above the leading edge joint (thickness locations 2, 6, 10, 14);
  - One on the main wing section above the trailing edge joint (thickness locations 3, 7, 11, 15); and
  - One on the trailing edge surface, halfway between the nose of the trailing edge and the joint (thickness locations 4, 8, 12, 16).
- Collect two one-litre Type III fluid samples on each wing for viscosity verification;
- Record wing temperatures at selected locations on the aircraft and record information on Form 3: Wing Temperature Data Form. At least three wing temperatures will be recorded per wing, along with the time of measurement. The selected wing temperature locations should include leading edge, trailing edge and main wing sections;
- Perform a static test of the wipers ability to remove Type III fluid applied to the windshield (flight crew); and

- Photograph and videotape the appearance of the fluid on the wings, tail, radome, and windshield; this should be done right after fluid application.

3.2.4 Prior to Departure from the De-Icing Pad

- Prior to departure of the aircraft from the de-icing pad, measure fluid thickness at selected locations on the aircraft and record information on the Form 2: Fluid Thickness Data Form. Fluid thickness will be recorded along two chord lines on each wing;
- Photograph and videotape the appearance of the fluid on the wings, tail, radome, and windshield; and
- Ensure that cockpit windshield and all over-wing cabin windows and are clean and clear of fluid; use squeegees, Windex and paper towels as required.

3.2.5 During Takeoff

- Prior to takeoff, update meteorological information, if required;
- Videotape and photograph the behaviour of the fluid on the wing during the takeoff run and climb, capturing any movement of fluid; and
- Videotape and photograph the behaviour of the fluid on the front of aircraft and windshield during the takeoff run and climb using a video camera located in the flight deck (RW).

3.2.6 Upon Return to the De-icing Pad

- Measure thickness of any fluid remaining on the aircraft and record information on Form 2: Fluid Thickness Data Form;
- Record wing skin temperatures on Form 3: Wing Temperature Data Form;
- Collect residual Type III fluid samples (if possible) for viscosity verification;
- Inspect aerodynamic quiet areas for accumulation of fluid;
- Videotape and photograph any accumulation of fluid in aerodynamic quiet areas;
- Videotape and photograph the appearance of fluid on the radome and windscreen; and
- Provide Form 4: Flight Crew Data Form to the flight crew and ensure that it is thoroughly completed by the flight crew.

4. EQUIPMENT AND FLUIDS

4.1 Equipment

The equipment required for the conduct of the Type III fluid demonstration flight has been included in Table 4.1.

4.2 Fluids

Propylene glycol-based Clariant Safewing MP III 2031 Type III fluid will be used in October 2004 demonstration flight.

Table 4.1: Equipment

EQUIPMENT LIST
CAMERA EQUIPMENT
Digital video camera for over-wing position (MC)
Digital video camera for cockpit (RW)
Digital still camera (MC)
GENERAL SUPPORT EQUIPMENT
Step ladders, rolling stairs, bucket trucks for wing access (RW)
TEST EQUIPMENT
Test procedures, data forms (MC)
Fluid thickness gauges (MC)
Temperature probe x 2 with batteries (MC)
Spatulas to lift fluid samples from wing (MC)
Sample bottles for viscosity measurement (RW)
Windex and paper towels to clean windshield (RW)
Squeegees (MC)

5. PERSONNEL

One APS personnel will be required for the demonstration flight at STL. The task assignments of this individual are the following:

- Ensure that all required equipment is available and functional;
- Provide direction as required during the demonstration flight;
- Ensure all data are collected and recorded on the appropriate data forms;
- Collect fluid samples for viscosity verification;
- Record meteorological information;
- Record thickness measurements;
- Record wing temperature information;
- Ensure time stamp operating and accurately set on video camera; and
- Photograph and videotape flight: set-up, outside and onboard the aircraft, fluid appearance on wings "before and after" each run and during climb, ensuring constant viewing angles are used, to facilitate comparisons.

Fluid application will be conducted by American Eagle/Trans States Airlines' personnel at a designated fluid spray area at STL.

American Eagle personnel will be responsible for providing video documentation of the flight from the flight deck.

Trans States Airlines' flight crews will operate the Embraer aircraft.

6. DATA FORMS

The following data forms are required for the October 2004 Embraer Regional Jet demonstration flight.

Form 1 General Data Form

Form 2 Fluid Thickness Data Form

Form 3 Wing Temperature Data Form

Form 4 Flight Crew Data Form

ANNEX A

FORM 1: GENERAL FORM

GENERAL DATA FORM: FIELD TRIALS TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

GENERAL INFORMATION

DATE: _____ AIRPORT: _____

AIRCRAFT TYPE: _____ AIRCRAFT FIN#: _____

FUEL LOAD: _____ LB/KG RUN#: _____

METEOROLOGICAL INFORMATION (PRIOR TO THE ONSET OF TESTING)

OAT: _____ °C WIND SPEED: _____ knots

WIND DIRECTION: _____ ° RH: _____

SKY CONDITION: _____

COMMENTS: _____

METEOROLOGICAL INFORMATION (PRIOR TO TAKEOFF, IF CHANGED)

OAT: _____ °C WIND SPEED: _____ knots

WIND DIRECTION: _____ ° RH: _____

SKY CONDITION: _____

COMMENTS: _____

FLUID APPLICATION INFORMATION

DE-ICING VEHICLE: _____ TRUCK #: _____

NOZZLE TYPE: _____ TYPE III FLUID TEMP.: _____ °C

START TIME: _____ END TIME: _____

AMOUNT OF FLUID APPLIED: _____

FLIGHT INFORMATION

DEPARTURE TIME FROM DE-ICING BAY: _____ START OF TAKEOFF ROLL: _____

TIME OF LANDING: _____ RETURN TO DE-ICING BAY: _____

DEPARTURE RUNWAY: _____ LANDING RUNWAY: _____

COMMENTS: _____

_____

APS OBSERVER: _____

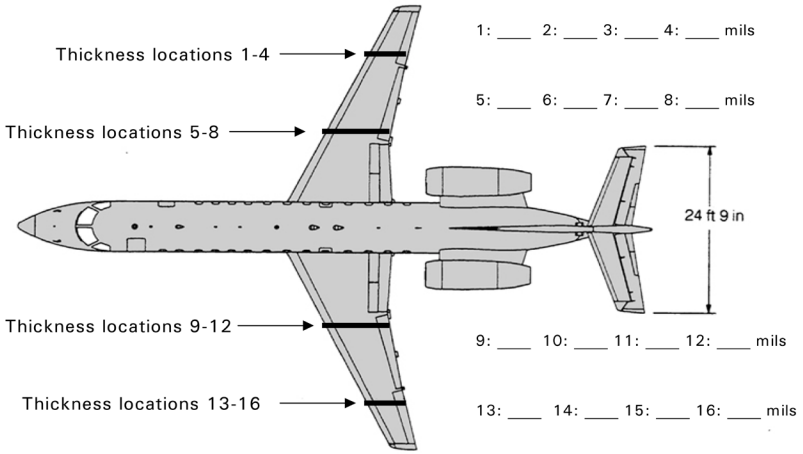
ANNEX A

FORM 2: FLUID THICKNESS DATA FORM

FLUID THICKNESS DATA FORM: FIELD TRIALS TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

DATE: _____ TIME: _____ RUN #: _____

TEST PHASE: AFTER FLUID APPLICATION: _____ AFTER 20 MINUTES: _____ AFTER LANDING: _____



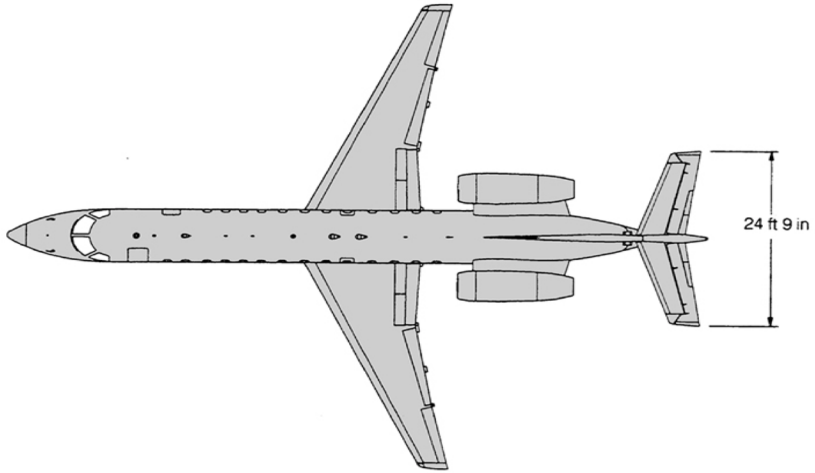
APS OBSERVER: _____

FORM 3: WING TEMPERATURE DATA FORM

WING TEMPERATURE DATA FORM: FIELD TRIALS TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

DATE: _____ TIME: _____ RUN #: _____

TEST PHASE: AFTER FLUID APPLICATION: _____ AFTER 20 MINUTES: _____ AFTER LANDING: _____



APS OBSERVER: _____

FORM 4: FLIGHT CREW DATA FORM

FLIGHT CREW DATA FORM: FIELD TRIALS TO EXAMINE THE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

DATE: _____ TIME: _____ AIRCRAFT TYPE: _____

FIN #: _____ CAPTAIN: _____ FIRST OFFICER: _____

ELEVATOR / AILERON HEAVINESS / SENSITIVITY: _____

_____

_____

ANY CONTROL VIBRATION / ABNORMAL CHARACTERISTICS / RESPONSIVENESS? _____

_____

_____

WERE WIPERS ABLE TO REMOVE THE FLUID ON GROUND AND RESTORE ADEQUATE WINDSHIELD VISIBILITY? _____

_____

IF FLUID FROM RADOME REACHED WINDSHIELD DURING TAKEOFF AND CLIMB, WERE WIPERS ABLE TO REMOVE FLUID IN FLIGHT AND RESTORE ADEQUATE WINDSHIELD VISIBILITY? _____

_____

OTHER COMMENTS: _____

_____

CAPTAIN SIGNATURE: _____

ANNEX B

TIMELINE FOR TYPE III SPRAY DEMONSTRATION TRIALS IN ST. LOUIS ON OCTOBER 30, 2004

ANNEX B

Timeline for Type III Spray Demonstration Trials in St. Louis on October 30, 2004

Friday at 2 pm	Meeting in Hotel (Marriott)
Friday 2 pm to 6 pm	- Pre-test setup at airport - Debrief of deicing personnel (RW)
Friday evening?	Debrief (RW)
Saturday 7 am	Meet at hotel to travel to airport
Saturday 7 am to 8 am	- Access airport - Setup at gate - Heat fluid - Debrief (RW)
Saturday 8 am to 9 am	- Windshield static test - Samples from wing - Samples from truck - Samples from tote - Photo setup, etc.
Saturday 9 am to 10 am	- Spray aircraft - Collect data - Conduct flight
Saturday 10 am to 11 am	- Collect data - Clean up - Debrief (RW)

ANNEX C

CLARIANT FLUID INSPECTION CERTIFICATE

ANNEX C

I n s p e c t i o n c e r t i f i c a t e Date: 10/26/2004
according to EN10204-2.2 Page: 1 / 1

Our consignment
Material : Safewing MP III 2031 ECO/950kg IBC PE SX
Material-no. : 20357319421
Batch No. : DEGE118525

During routine tests by the control on products from our production the following values were determined. They conform to the agreed product specification.

Inspection characteristic/-method	Specification	Result
pH value as is ASTM E 70	7.0 - 7.5	7.3 [-]
Refractive index at 20°C ASTM D 1747	1.389 - 1.392	1.390 [-]
Viscosity at 20°C / 0,3 rpm / spindle 0 ASTM D 2196	30 - 325	318 mPa·s
Water content Karl-Fischer ASTM E 203	47 - 50	50 %
Water Spray Endurance Time ISO 11078	>= 20	> 20 min

The above particulars do not release the customer from the obligation to carry out an inspection of goods received.

This report is not to be signed.

M:\Groups\CM1892 (TC-Deicing 04-05)\Reports\St. Louis Trip Report\Annexes\Annex C (Clariant).doc
Final Version 1.0, November 04

C-1

ANNEX D

DATA FORMS

FORM 1: GENERAL FORM

FORM 2: FLUID THICKNESS DATA FORM

FORM 3: WING TEMPERATURE DATA FORM

FORM 4: FLIGHT CREW DATA FORM

ANNEX D

FORM 1: GENERAL FORM

APS Aviation Inc.

GENERAL DATA FORM: FIELD TRIALS TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

GENERAL INFORMATION

DATE: Oct 30 2004 AIRPORT: ST Louis STL

AIRCRAFT TYPE: EMB 145 LR AIRCRAFT FIN#: N825HK

FUEL LOAD: 4000 lb LB/KG RUN#: 1 (Only RUN)

METEOROLOGICAL INFORMATION (PRIOR TO THE ONSET OF TESTING)

OAT: 17 °C WIND SPEED: 24.1 KPH

WIND DIRECTION: SW ° RH: 58%

SKY CONDITION: Sunny and clear

COMMENTS: Moderate winds with cold front coming thru

METEOROLOGICAL INFORMATION (PRIOR TO TAKEOFF, IF CHANGED)

OAT: 17.5 °C WIND SPEED: 28.7 KPH

WIND DIRECTION: SW ° RH: 52%

SKY CONDITION: Sunny and clear

COMMENTS: Winds gusting to 50kph.

Get this data from DAVID (TSA) OR Weight

FLUID APPLICATION INFORMATION

DE-ICING VEHICLE: LA1000 FMC TRUCK #: — Built in 1972

NOZZLE TYPE: Type 1 Task force Tips TYPE III FLUID TEMP.: 177°F in truck °C 55°C out of Nozzle in bucket (@1m dist

* ~~START~~ TIME: STBD 8:17:00 PORT ~~END~~ TIME: 8:19:45

AMOUNT OF FLUID APPLIED: Not possible to get this info

FLIGHT INFORMATION

DEPARTURE TIME FROM DE-ICING BAY: 8:26 START OF TAKEOFF ROLL: 8.33

TIME OF LANDING: 8:43 RETURN TO DE-ICING BAY:

DEPARTURE RUNWAY: RW 30L LANDING RUNWAY: RW 30L

COMMENTS: * for thickness measures see other form for spray times

APS OBSERVER: John D'Avirro, APS

OAT @ 7AM ≈ 20°C ; wing temp @ 7AM 17°C to 18°C

FORM 2: FLUID THICKNESS DATA FORM

APS Aviation Inc.

FLUID THICKNESS DATA FORM: FIELD TRIALS TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

STL

page 1 of 2

DATE: OCT 30 2004 TIME: 7AM RUN #: 1

TEST PHASE: AFTER FLUID APPLICATION: AFTER 20 MINUTES: AFTER LANDING:

Sequence was 1,2,5,6,9,10,13,14,15,16,11,12,7,8,3,

Measurement timing

START TIME 07:42:30

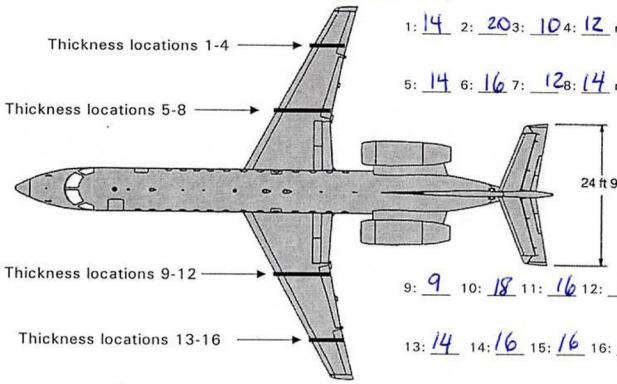
END TIME 07:47:15

RW (STBD)

Wind Direction

Thickness locations 1-4 → 1: 14 2: 20 3: 10 4: 12 mils

Thickness locations 5-8 → 5: 14 6: 16 7: 12 8: 14 mils



Thickness locations 9-12 → 9: 9 10: 18 11: 16 12: 16 mils

Thickness locations 13-16 → 13: 14 14: 16 15: 16 16: 16 mils

APS OBSERVER: John D'Agostino

LW (Port)

RW (STBD) WAS SPRAYED from 07:37:47 to 07:38:15

LW (Port) " " " 07 39 15 to 07 39 50

FORM 2: FLUID THICKNESS DATA FORM

APS Aviation Inc.

FLUID THICKNESS DATA FORM: FIELD TRIALS TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

STL

page 2/2

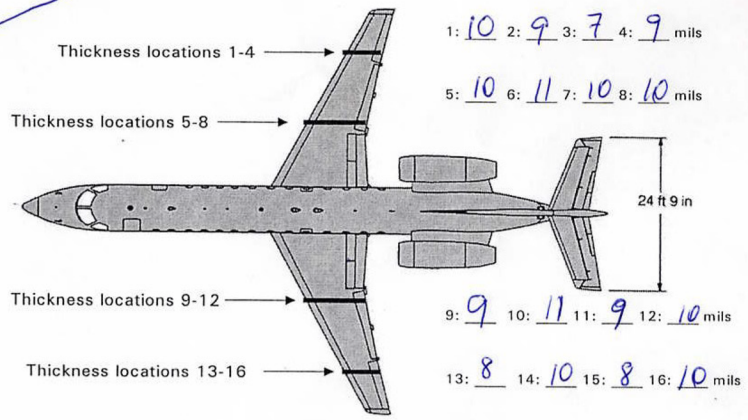
DATE: Oct 30 2004

START TIME: 07 57:00 End time 08 02 19

RUN #: 1

TEST PHASE: AFTER FLUID APPLICATION: _____ AFTER 20 MINUTES: _____ AFTER LANDING: _____

Sequence as per page 1/2



1: 10 2: 9 3: 7 4: 9 mils

5: 10 6: 11 7: 10 8: 10 mils

9: 9 10: 11 11: 9 12: 10 mils

13: 8 14: 10 15: 8 16: 10 mils

APS OBSERVER: JD

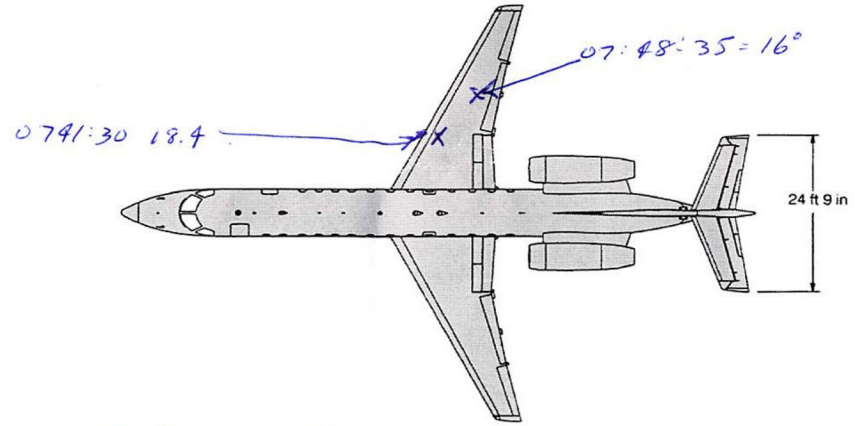
FORM 3: WING TEMPERATURE DATA FORM

APS Aviation Inc.

WING TEMPERATURE DATA FORM: FIELD TRIALS TO EXAMINE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

DATE: OCT 30 2004 TIME: _____ RUN #: 1

TEST PHASE: AFTER FLUID APPLICATION: _____ AFTER 20 MINUTES: _____ AFTER LANDING: _____



APS OBSERVER: JD

FORM 4: FLIGHT CREW DATA FORM

APS Aviation Inc.

FLIGHT CREW DATA FORM: FIELD TRIALS TO EXAMINE THE REMOVAL OF NEAT TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

DATE: 10/30/04 TIME: 13:55 UTC AIRCRAFT TYPE: EMB-145LR

FIN #: N875HS CAPTAIN: MIKE WHITE FIRST OFFICER: KURT WAGGNER

ELEVATOR / AILERON HEAVINESS / SENSITIVITY: NORMAL

ANY CONTROL VIBRATION / ABNORMAL CHARACTERISTICS / RESPONSIVENESS? NONE

WERE WIPERS ABLE TO REMOVE THE FLUID ON GROUND AND RESTORE ADEQUATE WINDSHIELD VISIBILITY? YES

IF FLUID FROM RADOME REACHED WINDSHIELD DURING TAKEOFF AND CLIMB, WERE WIPERS ABLE TO REMOVE FLUID IN FLIGHT AND RESTORE ADEQUATE WINDSHIELD VISIBILITY? YES

OTHER COMMENTS: VERY COMPARABLE TO TYPE I. TYPE III DOES TEND TO LEAVE A SLIGHTLY HIGHER RESIDUE ON SURFACE. ON WINDSHIELD, VISIBILITY GOOD.

CAPTAIN SIGNATURE: [signature]

ANNEX E

EMBRAER TYPE III DEMONSTRATION FLIGHT FACT SHEET

ANNEX E

EMBRAER TYPE III DEMONSTRATION FLIGHT
FACT SHEET
Trans States Airlines
October 30, 2004

Aircraft ID ……	Embraer 145 LR N825KH
Basic Operating Weight ……...	27,837 (Pounds)
Jumpseat Observer ……	170
Cabin Observers ……	990
Zero Fuel Weight ……..	28,997
Fuel ……	4,000
Ramp Weight ……	32,997
Taxi Burn ……..	200
Takeoff Weight …….	32,797
Enroute Burn …….	1,000
Landing Weight ……	31,797
Out Time ……..	0827 (Time Local)
Off Time ……..	0833
On Time ……...	0843
In Time …….	0850

METEOROGLOGICAL CONDITIONS

At final Type III anti-icing spray time (0825) and takeoff

Wind …….	230° at 15KTS
Temperature …….	17° (C)
Dew Point ……	9° (C)
Altimeter setting ……..	29.71

At landing

Wind …….	250° at 15KTS Gusting to 27
Temperature …….	18° (C)
Dew Point ……	6° (C)
Altimeter setting ……..	29.73

DESCRIPTION OF FLIGHT

Takeoff was on runway 30L, climbed to 2,000 feet (AGL), made right traffic in the pattern for a landing 10 minutes later on runway 30L. Maximum airspeed in pattern was a maximum of 200KTS.

Airspeeds

V1 ……	103 KTS
Vr (rotation) ……	106
V2 ……	121
V2 + 15 ……	136
Vfs ……..	147
Vref (landing over the fence) …….	115
Vapp (approach speed) ……	123

ANNEX E

TRANS STATES AIRLINES. **TAKE-OFF** **EMB**

FLT NO:	OUT: Z	OFF:	ACC HT
825 HK	13:17 0827	0833	1000'

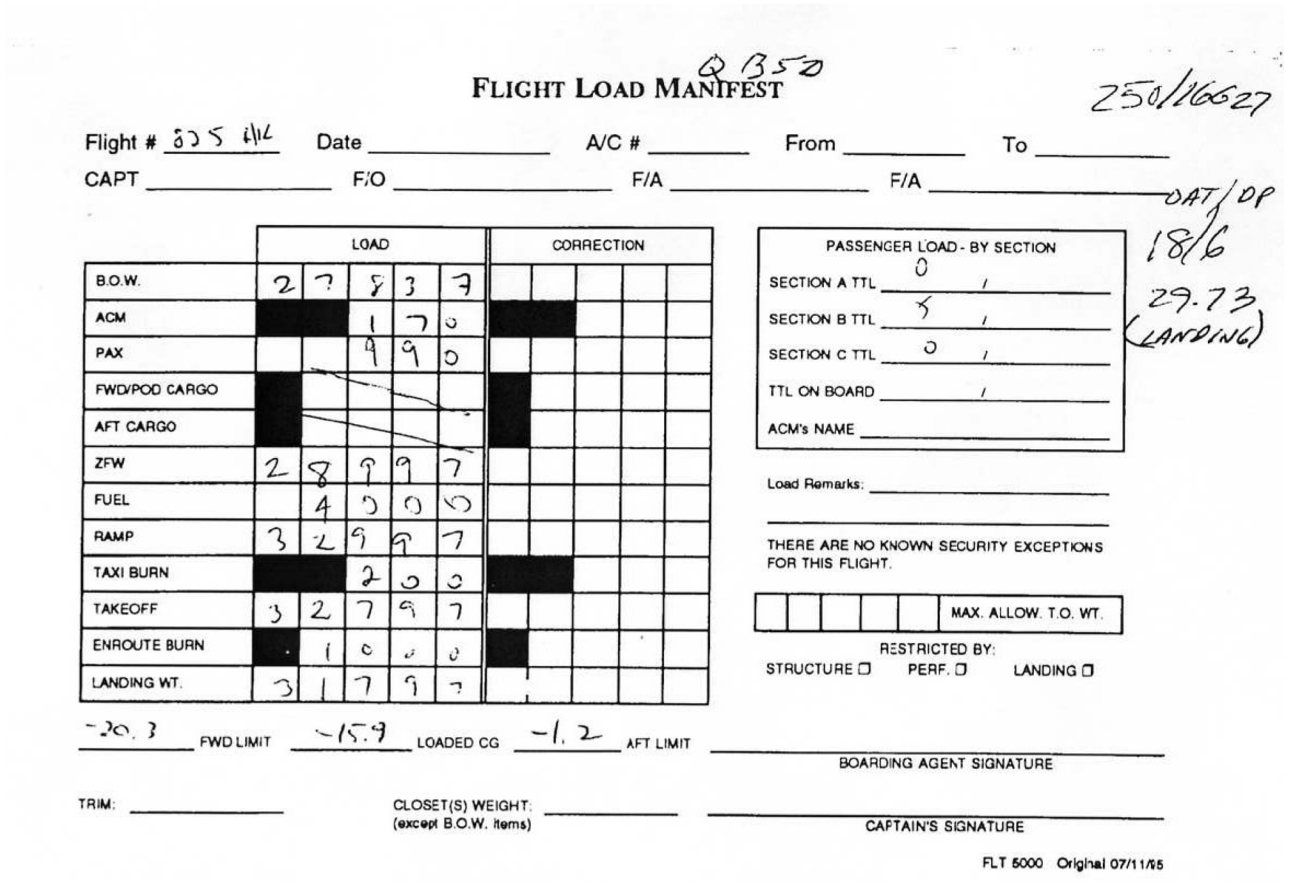
V_1 103	WEIGHT: 32.8
V_R 106	TRIM: 8 ½
V_2 121	ATIS: P TAKEOFF
$V_2 + 15$ 136	230 - 15 17/9 29.7 BIRDS MDW/EQUIP
V_{FS} 147	
RETURN	CLEARANCE: B OFF 0256
V_{REF} 115	
V_{APP} 123	

FLT E145 JAN 2004

ANNEX E

FLT NO: 825 AIK	TSA TRANS STATES AIRLINES. LANDING EMB	
V_{REF} 113		WEIGHT: 71.8
V_{APP} 125		ATIS: RWY 30L T.O. & LNDG.
V_{AC} 136		
V_{FS} 145		REMARKS:
ON: 0843 1343	IN: 0850 1350	BURN:

ANNEX E



Q 350

FLIGHT LOAD MANIFEST

250/16627

Flight # 825 4112 Date _____ A/C # _____ From _____ To _____

CAPT _____ F/O _____ F/A _____ F/A _____

OAT/DP 18/6

29.73 (LANDING)

	LOAD					CORRECTION				
B.O.W.	2	7	8	3	7					
ACM			1	7	0					
PAX			9	9	0					
FWD/POD CARGO										
AFT CARGO										
ZFW	2	8	9	9	7					
FUEL		4	0	0	5					
RAMP	3	2	9	9	7					
TAXI BURN			2	0	0					
TAKEOFF	3	2	7	9	7					
ENROUTE BURN		1	0	0	0					
LANDING WT.	3	1	7	9	7					

PASSENGER LOAD - BY SECTION

SECTION A TTL 0 /

SECTION B TTL 5 /

SECTION C TTL 0 /

TTL ON BOARD _____ /

ACM's NAME _____

Load Remarks: _____

THERE ARE NO KNOWN SECURITY EXCEPTIONS FOR THIS FLIGHT.

MAX. ALLOW. T.O. WT.

RESTRICTED BY:

STRUCTURE ☐ PERF. ☐ LANDING ☐

-20.3 FWD LIMIT -15.9 LOADED CG -1.2 AFT LIMIT

BOARDING AGENT SIGNATURE

TRIM: _____ CLOSET(S) WEIGHT: (except B.O.W. items) _____

CAPTAIN'S SIGNATURE

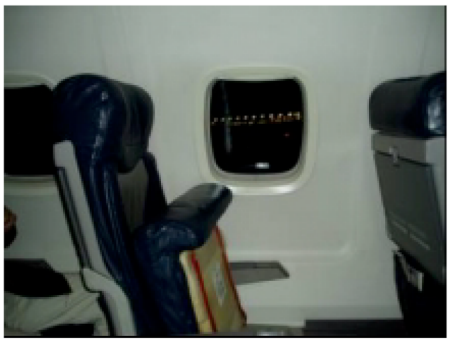
FLT 5000 Original 07/11/95

ANNEX F

PHOTOS

ANNEX F

APS PHOTOS













ANNEX F

APS PHOTOS (continued)







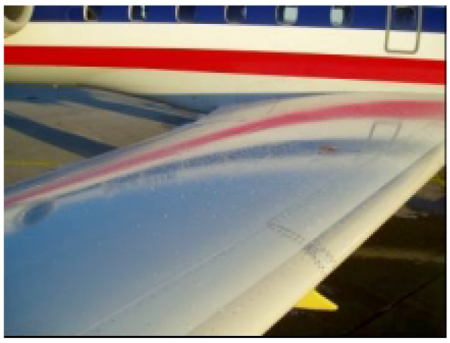




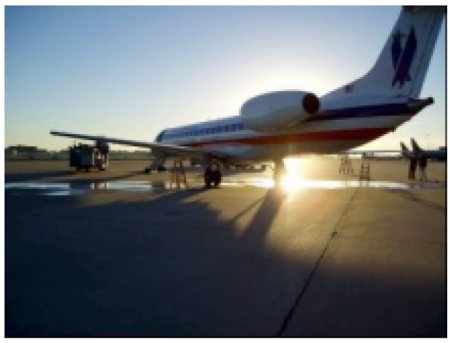


ANNEX F

APS PHOTOS (continued)





ANNEX F

APS PHOTOS (continued)







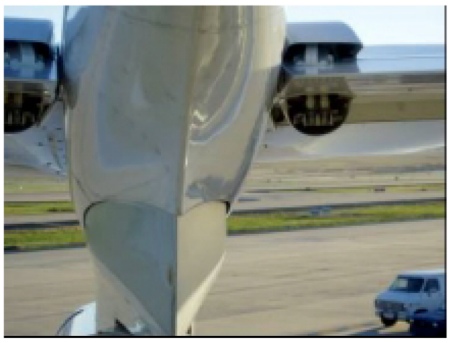






ANNEX F

APS PHOTOS (continued)

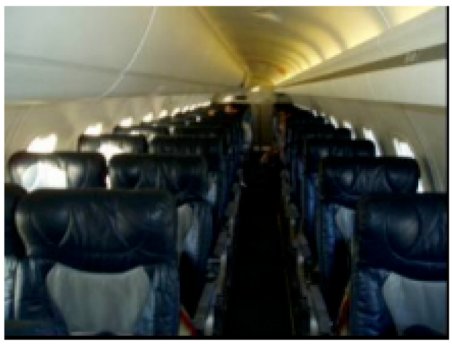












ANNEX F

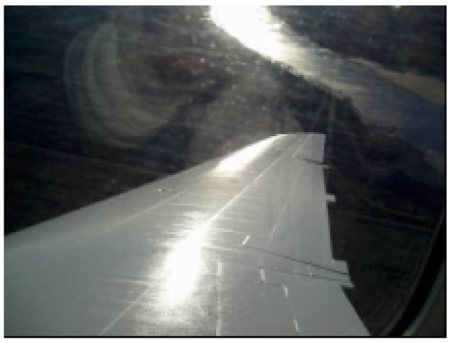
APS PHOTOS (continued)







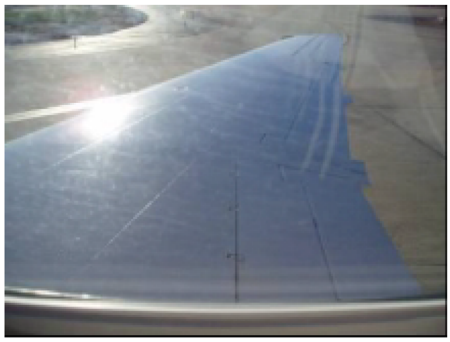


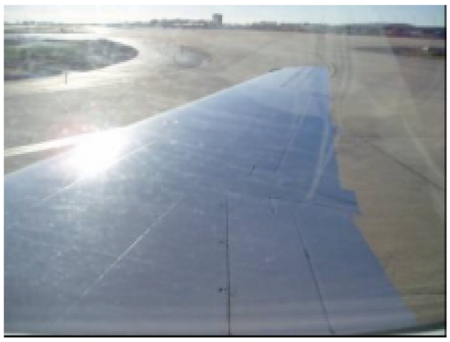


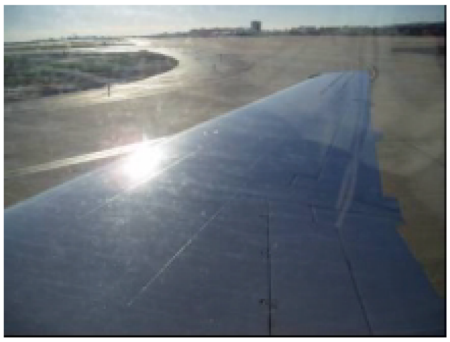


APS PHOTOS (continued)













APS PHOTOS (continued)











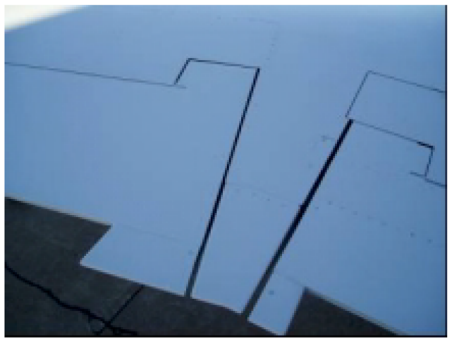


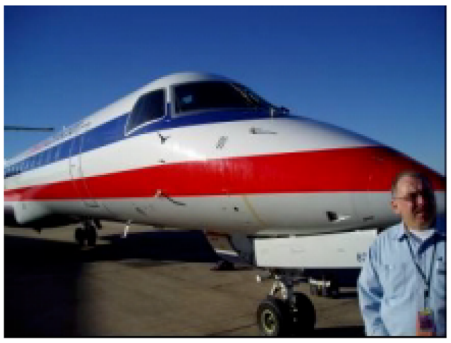
APS PHOTOS (continued)











ANNEX F

AEA PHOTOS













AEA PHOTOS (continued)



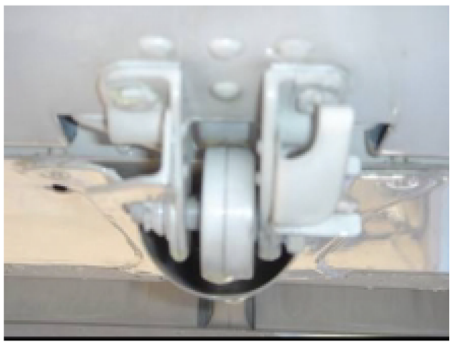






ANNEX F

EMBRAER PHOTOS













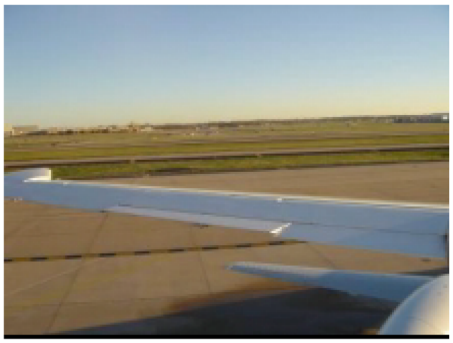
EMBRAER PHOTOS (continued)





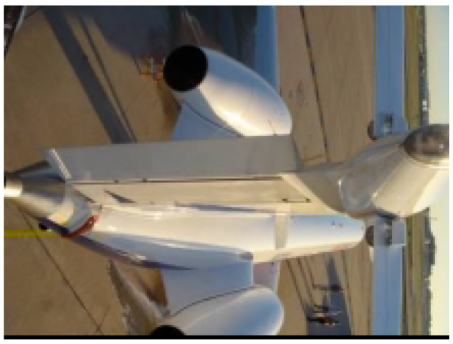








EMBRAER PHOTOS (continued)











APPENDIX C

REVIEW OF NEGATIVE 3°C BUFFER ON FIRST STEP APPLICATION OF DEICING FLUID ON AIRCRAFT
JULY 2005

REVIEW OF NEGATIVE 3°C BUFFER ON FIRST STEP APPLICATION OF DEICING FLUID ON AIRCRAFT JULY 2005

1. INTRODUCTION

This document has been prepared in partial response to an aircraft icing event reported by Braathens (Member of the SAS Group) and presented to the Society of Automotive Engineers (SAE) G-12 Fluid Subcommittee in 2004.

1.1 Background

The event occurred at 18:57 hrs (local time) on December 12, 2002, and involved a Boeing 737-500 flight from OSL (Oslo-Gardermoen) to BDU (Bardufoss).

The documented prevalent ambient conditions were the following:

- Darkness
- Thin Cloud Cover (200-300ft.)
- No Precipitation
- Freezing Fog
- Wind Calm
- OAT -16°C
- Dew Point -18°C

A pre-flight inspection revealed ice on rear side of the fan blades and engine deicing was activated. During a prolonged engine deicing procedure (interval > 1 hr), frost was observed to have deposited on wing surfaces, and the aircraft required ground-based fluid deicing prior to departure.

- The deicing sequence began with 1st Step fluid application at 1738Z using hot Type I ADF (38%) with a -13.5°C fluid freeze point (FFP) -2.5°C buffer, well within Aerospace Recommended Practice (ARP) 4737 guidelines.
- Fluid volume sprayed was 300 L, and the procedure began with fluid application to the starboard wing. Fuel temperature indicated -3 °C.
- An unspecified quantity of 100% Type II (FFP of -37°C) Aircraft Anti-icing Fluid (AAF), was applied at 1740Z. A time log of the overall deicing procedure indicates that it is possible the amount of Type II AAF applied may have been lower when compared to time guidelines from recommended wetting tables.

- A final inspection (visual, no tactile) was performed from the ground.
- Brakes were released at 1745Z.
- Engine run-up to 70% N1 (Nacelle 1?) for 45 seconds to shed ice.
- Wing anti-ice "on" during all ground operations until throttle-up for take-off.
- Take-off executed at 1757Z (12 minutes after brakes released post to completion of ground-based fluid deicing procedure).
- Upon clearing cloud/fog cover, ice was observed to have formed (or remained) on both wing leading edges and forward upper surfaces.
- More ice was observed to be present on the starboard wing (first to be deiced) than on the port wing.
- Use of wing anti-ice was ineffective at ice removal, and the aircraft was diverted to land at TRD (Vaernes) where upon approach, the ice melted and disappeared.
- Subsequent to landing, inspection of the aircraft revealed all systems checked out and were found to be in nominal condition.

Braathens questions whether the ambient conditions, the condition of the aircraft prior to ground deicing, and the deicing procedures (ground and in-flight) used combined to produce the reported aircraft icing event. Or is it possible that the event occurred simply a consequence of the meteorological conditions encountered in achieving flight altitude?

Furthermore, the Braathens Internal Investigation Group questioned the -3°C buffer practice (ARP4737G) for diluted Type I ADFs (1st Step fluids) in OATs lower than -5°C or -10°C.

The remainder of this document lists aircraft deicing fluid tests previously conducted by APS Aviation Inc. (APS) in conditions conducive to aircraft icing that are most closely related to the conditions reported in the Braathens presentation. This list has been compiled in order to consider whether there is any need to conduct further tests to verify either that ARP4737 guidelines are satisfactory in the document's present state, or whether the document is deemed to be in need of modification.

2. REVIEW OF APS TESTS

2.1 Documents from which this List was Compiled Include:

TP 13315E — Aircraft Deicing Fluid Freeze Point Buffer Requirements Deicing Only and First Step of Two-Step Deicing
APS Aviation Inc. December 1998

TP 13478E — Aircraft Deicing Fluid Freeze Point Buffer Requirements for Deicing Only Conditions
APS Aviation Inc. November 1999

TP 13483E — Hot Water Deicing of Aircraft
APS Aviation Inc. October 1999

TP13663E — Hot Water Deicing of Aircraft: Phase 2
APS Aviation Inc. November 2000

2.2 APS Report TP 13315E

2.2.1 Taken from TP13315E, Section 4.2 Aircraft Trials (pages 61 to 78)

Jan 21/22, 1998 - US Airways DC-9

Headwind = 9 km/hr; OAT = −12°C to −16°C

(Refer to Figures 4.2 to 4.4)

2.2.1.1 Run 1

Hot Water (0°C FFP) applied at 60°C

- Applied Volume = 158 L
- OAT = -13°C
- Buffer = -13°C

Results: Significant icing observed at 2 minutes post to fluid application. At 8 minutes, only top central portion of wing remained unfrozen.

2.2.1.2 Run 3

UCAR ADF (-3°C FFP) applied at 76°C

- Applied Volume = 155 L
- OAT = -15°C
- Buffer = -12°C

Results Icing of outer and trailing edge at 3 minutes post to fluid application.

2.2.1.3 Significant observations between Run 1 and Run 3 (Jan 21/22)

Essentially the same fluid quantity was applied in each run, but the dilute ADF in Run 3 was considerably hotter. By test end, icing was less than that of Run 1 at the 8-minute mark. Nonetheless, the dilute ADF exhibited ice formation within a three-minute interval post to fluid application, but icing did progress more slowly.

2.2.1.4 Run 5

UCAR ADF (-12°C FFP) applied at 75°C

- Applied Volume = 160 L
- OAT = -16°C
- Buffer = -4°C

Results: Icing of outer trailing edge at 20 minutes post to fluid application. Rear wing root exhibited icing (sparse fluid coverage in this area).

2.2.1.5 Significant Observations between Run 3 and Run 5 (Jan 21/22):

Applied fluid volumes and fluid temperatures were essentially identical. The buffer difference between Run 5 and Run 3 was 8°C. From the diagrams, onset of fluid freezing is not apparent. However, it is likely that no icing occurred before the three-minute interval post to fluid application.

2.2.2 Taken from TP 13315E, Section 4.2 Aircraft Trials (pages 61 to 78)

March 17/18, 1998 - US Airways DC-9

Winds Calm; OAT = -8°C

(Refer to Figures 4.5a and 4.5b)

2.2.2.1 Run 1

UCAR ADF (-4°C FFP) applied at 80°C

- Applied Volume = 71 L
- OAT = -8°C
- Buffer = -4°C

Results: Icing of outer trailing edge at 10 minutes post to fluid application. At test end, failure progression was minimal and consisted of discontinuous trailing edge areas including some spoiler surfaces.

2.2.2.2 Significant Observations Between Run 5 (Jan 21/22) and Run 1 (March 17/18):

Fluid quantity applied in the March Run 1 was less than half that of the January runs. At least two factors combined to compensate for the minimal icing observed in the March run. The first factor may be the higher outside air temperature (OAT), and the second would be the absence of any significant wind. A third possibility is the initial fluid temperature measured at the nozzle, which was 5°C greater than the January Run 5 fluid temperature. Note that in both tests, the applied fluids are temperature buffered to -4°C relative to the respective OATs. Note also that the -4°C fluid temperature buffer in either case approaches the ARP4737 recommended minimum buffer of -3°C.

The January Run 5 provides the closest conditions for comparison to the Braathens event in terms of the OAT/fluid buffer combination, but with no freezing fog and a 9 km/hr headwind.

The March Run 1 presents a milder OAT but with calm winds, which prevailed prior to the Braathens icing event.

2.2.3 Taken from TP 13315E, Section 4.3 Deicing Only Study (pgs 78 - 116)

In this section both wing and plate experimental results at test end (20 min) are presented for calm and windy conditions for a range of OATs (down to -40°C) and indicate that for very large negative buffers (-10°C), ice almost always formed for lower OATs, but this rarely occurred for -3°C and 0°C buffered fluids. Note that the deicing only testing was performed in no-precipitation conditions.

(Refer to Figures 4.12, 4.13, 4.15, 4.16, 4.18, 4.19, 4.21, and 4.22).

2.2.4 Taken from TP 13155E, Section 4.4 First Step Fluid Study (pgs 116 – 144)

The following sub-sections deal with temperature and fluid conditions similar to those encountered on the ground prior to the Braathens event (freezing fog), except that these experiments were carried out in active precipitation (light freezing rain at 25 g/dm^2/hr). Freezing fog poses a much lighter form and extent of contamination than does light freezing rain (Refer to Figures 4.32 to 4.37, especially Figures 4.36 and 4.37).

2.2.4.1 Taken from TP 13155E, Section 4.4.1 Duration of Safe Period Following Spray Application (pgs 117 to 124)

Figures 4.32 to 4.37 present the *interval to first appearance of freezing*, and also the *interval to plate failure*, for each of the ambient test conditions under calm winds and OATs of -3°C, -8°C, and -14°C in light freezing rain (25 g/dm^2/hr) for a number of fluids including water, Type I ADFs, *and* both Type II and Type IV AAFs, held to negative temperature FFP buffers.

In all fluid cases, including water, and regardless of OAT, no fluids exhibited freezing prior to a three-minute interval except for a fluid made exclusively from recycled spent aircraft deicing fluid, and this was not the interval to first freezing, but rather the time to plate failure. Furthermore, in the report, this value was deemed to be in error and is referred to as an *aberration* by the authors, meaning the failure call for this particular plate may have been questionable or premature.

Again, it is reiterated that the rate of precipitation was 25 g/dm^2/hr, which is the high rate limit for light freezing rain in the holdover time (HOT) table guidelines. Further to this, it is an anomalous situation to encounter freezing rain in naturally occurring conditions under such extreme temperature conditions (-14°C). So, the testing at -14°C pushes the extreme of what would naturally be encountered.

2.3 TP 13478E

This report presents results of tests carried out in *Deicing Only* conditions.

Laboratory tests were carried out at PMG Technologies Inc. (PMG) on flat plates and included various substrates different from aluminum as well as cold-soaked surfaces, under a variety of conditions.

Aircraft trials were also carried out at PET/Dorval (4 runs) in active frost forming conditions at OATs of -7°C to -9°C with UCAR ADF at initial FFP of -12°C. Wing temperature and FFP variations were monitored with time, and in no circumstances was failure indicated.

While these tests are instructive as to how the fluids behave under the various test conditions, no negative buffers were employed, so these results are not comparable to the first step fluid application parameters encountered in 2 Step fluid application procedures, as were employed prior to the Braathens event under scrutiny.

2.4 TP 13483E

2.4.1 Summary of Conditions

This report presents details of tests performed to explore hot water deicing wherein heated deicing fluids (water and dilute Type I ADF) were applied to contaminated test surfaces to observe the onset of freezing post to fluid application at various OATs and also at various wind speeds. Contamination consisted of freezing rain precipitation at the rate of 25g/dm^2/hr. In all experiments the temperature of the test surfaces were monitored, as was the fluid concentration as a function of time (for all runs except where only hot water was used as the deicing fluid).

The difference between these tests and previous testing to observe the same phenomenon is that in this study, the fluids were applied by spraying, and that the amount of fluid applied was not prescribed, except for the stipulation that spraying was to continue until all the contaminant was removed.

2.4.2 Intent

The net result of this exercise was to simulate the deicing process as it is implemented in the field. In other words, in actual aircraft deicing operations, operators do not apply a fixed quantity of fluid to an aircraft based on the surface area (type/size of aircraft) to be deiced. Rather, deicing fluid is applied to the extent that the resulting operation leaves the surface being de-iced in a "clean wing" state — which is meant to infer that no solid contamination remains on the surfaces post to the deicing procedure.

The important *general* observations that were made as a result of performing these tests are:

2.4.2.1 Effect of OAT (Calm Wind Conditions)

Regardless of fluid, the time interval post to fluid application to the onset of freezing was shortened as the ambient temperature of testing was lowered. Complementary to this observation is that the slope of the profile of the cooling curve of the test surface post to fluid application is steeper at lower OATs than for those closer to 0°C. Or, the lower the temperature, the quicker the cooling rate of the surface post to fluid application. This is most easily observed with use of hot water as the deicing fluid (Refer to Figures 5.1, 5.2, and 5.3).

In the case of diluted Type I ADFs (negative 3°C FFP buffer), the effect is less pronounced, but the time intervals are not significantly enhanced, and in some runs demonstrated shorter intervals than hot water. Note that these tests were not performed at the OAT of -3°C (Refer to Figures 5.5, 5.6, and 5.7).

When the ADF concentration was a standard full-strength deicing fluid (DOW/UCAR XL54), a significant enhancement in time interval to onset of freezing was observed (Refer to Figures 5.8 and 5.10). However, this fluid strength is very rapidly diluted to (essentially) the limiting concentration of pure water. Although this is not a large grace period, it is nonetheless significant.

2.4.2.2 Effect of Wind Speed (at any Fixed OAT)

Wind speed impacted the time to onset of freezing very significantly. At any OAT, the slope (negative) of the cooling curve became more pronounced with an increase in the wind speed (Refer to Figures 5.11, 5.12, and 5.13).

2.4.3 Most Significant Conclusions/Observations

1. The time interval to the onset of freezing was found to be most dependent on the quantity of fluid applied (and subsequently the amount of heat transferred from the fluid to the surface) in the ice removal/deicing process.
2. It is worthwhile to note that in all experiments (Run# or ID#) using diluted ADF, the intersection of plots of the test surface cooling curves and variation of fluid concentration (FFP inferred) do not accurately represent the onset of freezing. That is, it would be expected that when the FFP curve intersects the test surface cooling curve, one would observe freezing on the test surface. However, it was observed in these tests that the onset of freezing occurred significantly prior to the intersection of these two parameters. This may be partially explained by the positioning of the temperature- measuring device on the test surface (Refer to Figures 5.11.to 5.19).
3. By extension of the two above items, it does not seem unreasonable that an aircraft surface that has been 1st Step de-iced (as per ARP 4737) may exhibit freezing prior to the expected three-minute interval, especially if a sparing application of hot deicing fluid is performed. No matter what the situation, it is not justifiable to consider this a function of fluid concentration. It is rather an intrinsic function of the rate of surface cooling, which is dependent on OAT to some extent, to wind (whether the aircraft is stationary in active wind or taxiing in calm wind), and on the heat capacity of the flight surface or test surface under investigation.
4. A final note with respect to this report involves the reporting of the possibility that subsequent to hot water deicing (nozzle temperatures up to 70°C), it is possible that ice forms on the test surface prior to the possibility of application of ambient temperature anti-icing fluid (2 to 3 minutes) under least ideal conditions. This is reported in Appendix C of TP 13483E and is entitled “Hot Water Deicing Simulation Study in the Climatic Chamber for Air Canada”, by Y. Boluk (March 13, 1991) – Technology Department, Union Carbide Canada Limited, Montreal, Quebec, Canada. The application of ambient temperature AAF will not melt the ice once formed on the wing. Further to this end, an excerpt from Unconfirmed Minutes of the SAE Ground Deicing AD HOC Committee Meeting in Atlanta, Georgia (June 18, 1991) summarizes the salient points of this study in a 5-slide presentation.

2.5 TP 13663E

This report presents details of aircraft deicing tests using hot water alone to de-ice the APS Lockheed Jetstar test wing. OATs of -4°C to -5°C prevailed. Three tests were carried out using artificially generated snow on March 11, 2000.

Again, these tests were not directly comparable to the Braathens event under scrutiny. So, no light could be shed on what might have occurred to possibly produce an icing condition while the Braathens aircraft was on the ground from comparison with these tests.

3. SCENARIOS SUPPORTING OR NEGATING THE POSSIBILITY OF FREEZING IN AMBIENT CONDITIONS RELEVANT TO THE BRAATHENS ICING EVENT

The following scenarios present possible situations that might be encountered in actual ground-based fluid deicing practice that could conceivably give rise to aircraft icing in a fashion similar to the particular event reported by Braathens. These cases present the possibility of reproducing the conditions encountered in the Braathens event for test purposes.

3.1 Case 1 – Poor or Inadequate Type I (1st Step Fluid) ADF application

In this scenario, either a sparingly light Type I ADF application, or a highly non-uniform Type I ADF application gives rise to two possible hazardous conditions:

1. The first condition, in which a sparse Type I ADF application is executed, results in a large surface that is pre-disposed to freezing either prior to Type II AAF application, or that might freeze upon being over-coated with the ambient temperature Type II fluid.

   The reason that freezing might occur in this situation would likely be due to insufficient heat transfer from the hot Type I ADF to the entire aircraft surface under consideration.

2. The second condition, in which an otherwise adequate quantity of Type I ADF is expended on application - but is not uniformly applied to the surface, results in surface elements that received inadequate direct hot fluid to be sufficiently heated to resist freezing. Again, either freezing of the negative temperature FFP buffered ADF prior to, or upon ambient temperature Type II AAF application may (conceivably) occur.

3. In either of the two situations, mitigating circumstances such as wind speed, OAT, and influence of potential contamination, will become part of the equation. It has already been shown that this is a concern with hot water deicing (Section 2.4.3, number 4.), and it should be possible to reproduce these two conditions while holding temperature, wind, and precipitation conditions to those encountered prior to Braathens discovery of wing icing while in flight.
4. Note that in the case of hot water deicing, there can be no enhancement of fluid freeze point, a phenomenon that has been observed and documented on numerous occasions by APS Aviation. Under these circumstances, fluid freeze points are depressed due to evaporation of water in the interim between 1st Step and 2nd Step fluid application. This would suggest an inherent suppression of the onset of freezing in non-precipitation conditions. This requires a certain minimum glycol concentration, which is probably sufficient at a FFP of -13.5°C, the FFP of the Type I ADF used to deice the aircraft prior to the cited icing event.

3.2 Case 2 – Mist of Type II (2nd Step Fluid) AAF application

In this scenario, only a mist of Type II AAF (2nd Step fluid) is applied to certain wing surface elements due to non-uniform AAF application. Even an adequate, uniform application of Type I ADF (wherein the required or expected heat transfer is effected) will become prone to freezing with time. The sparse Type II AAF application leads to unprotected surface elements, and expected HOTs will not be achieved. This also presents the opportunity for testing, and this situation could be replicated in a laboratory environment matching the OAT, wind, and precipitation conditions prevalent prior to take-off and subsequent discovery of the Baathens icing event.

4. CONCLUSIONS

The most applicable tests to compare to the Braathens icing incident are found in the report TP13315E report. The more severe conditions of the 1st Step fluid tests serve to underscore that the icing event was not likely related to the recommended practices outlined in ARP4737.

Especially note the extreme negative buffer values except for the last two tests cited in Section 2.2.4.1.

Although there is evidence to suggest that variations in OAT, wind, and both type and rate of precipitation can lead to or contribute to 1st Step fluid solid

contamination formation prior to anti-icing fluid application, these conditions were not prevalent in the ground deicing operations leading to the Braathens cited icing event.

It is always possible that the timeframe or fluid application coverage or the fluid concentration and fluid nozzle temperature were not actually the values stated.

Any combination of the above, coupled with the anti-icing procedures employed by Braathens prior to take-off may have contributed to the icing event.

It is quite possible that the icing event occurred as a result of the aircraft coming to altitude after clearing the cloud/fog cover. However, without doing any further tests, the cause of the cited icing event may never be known.

As ground deicing is essentially a procedure used to assure the provision of a "clean wing" condition (as the name suggests) and ultimately to assure safe take-off, the procedure cannot be held responsible for meteorological conditions encountered after the take-off roll is completed.

Of course, no test conditions cited actually identically reproduced the conditions leading up the icing event in question. However, laboratory and field-test evidence point to this event as having occurred in the air, rather than having been initiated on the ground.

Still, it would be too expedient to discount that any of the possible negative factors did not enter into the equation: Such as a minimal or spotty deicing fluid or anti-icing fluid application.

It would not be too difficult to simulate this event, if it did indeed occur on the ground. However, this would not be the case if it occurred once the aircraft executed its take-off roll.

Consideration ought to be given to the possibility that ambient Type II AAF (the 2nd Step fluid) may have been cold enough to freeze the remaining -3°C buffered ADF that was employed as per ARP4737, or that inadequate coverage of Type II AAF allowed freezing of the now-cooled wing during taxi to the take-off runway. Furthermore, flash freezing might occur under the right conditions during take-off. This is a test that has not been specifically performed and may be feasible to conduct in a laboratory environment so long as wind shear for the simulation of take-off conditions could be achieved.

APPENDIX D

AEROSPACE RECOMMENDED PRACTICE 5945
JUNE 2005 – 2ND BALLOT
ENDURANCE TIME TESTS FOR AIRCRAFT DEICING/ANTI-ICING FLUIDS
SAE TYPE I

[Insert SAE logo/letterhead here.]

Aerospace Recommended Practice 5945
June 2005 – 2nd Ballot

ENDURANCE TIME TESTS FOR AIRCRAFT DEICING/ANTI-ICING FLUIDS SAE TYPE I

FOREWORD

This document describes the procedures to be employed in the conduct of endurance time testing of aircraft deicing/anti-icing fluids certified under requirements of SAE Aerospace Material Specifications (AMS) 1424 “Aircraft Deicing/Anti-icing Fluids, Newtonian, Type I.”

Endurance time is defined as the time that a fluid can endure controlled and defined temperature and freezing precipitation conditions before attaining visual failure. These temperature and precipitation conditions were developed taking into consideration meteorological data. The resulting endurance time data are presented to the SAE G-12 Holdover Time Subcommittee for examination and validation. If found to be of acceptable quality, these data are used to update the holdover time (HOT) guidelines, which are used by many of the world’s airlines in assessing the time of effectiveness of aircraft anti-icing fluids. HOT guidelines are published in regulatory documents such as the US Federal Aviation Administration’s Flight Standards Information Bulletin for Air Transportation (FSAT) and Transport Canada HOT Guidelines. Other organizations, including the Association of European Airlines (AEA), publish HOT guidelines derived from endurance time data.

In prior years, fluids were tested in a laboratory environment that was similar to outdoor natural conditions in order to generate the data from which HOT guidelines were formulated. These laboratory methods evolved over several years and had been tacitly accepted. This Aerospace Recommended Practice (ARP) provides written documentation of the procedures to be employed for laboratory endurance time testing in freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing conditions.

Frost holdover times are currently based on the high humidity endurance test described in SAE Aerospace Standard (AS) 5901. A frost test is being developed and will be included in future versions of this document.

Prior to the year 2000, the Type I fluid HOT range used by operators worldwide in snow conditions was 6 to 15 minutes, based on early substantiation tests carried out by several organizations. During the 1999-2000 winter, a series of Type I fluid endurance time tests in natural snow were performed using a natural snow test protocol similar to that included within ARP 5485, which was developed for testing SAE Type II, Type III and Type IV fluids. These Type I fluid endurance time data suggested that the snow HOT range for Type I fluid was lower than the 6 to 15 minute HOT range. Subsequently, at the SAE G–12 Holdover Time Subcommittee meeting in Toulouse, France in May 2000, the SAE Type I HOT range for snow was reduced to values significantly shorter than 6 to 15 minutes. The reduction in fluid endurance times coincided with the general realization that the test protocol for Type I endurance times required further verification.

As a result, a new test protocol was developed for measuring endurance times for SAE Type I fluids that more closely reflects real field operations. The new protocol simulates the full nature

of actual deicing/anti–icing operations on real wings in the natural environment. This new protocol employs a new test surface that provides a thermal equivalent to an aircraft wing leading edge. This test surface produces a more accurate representation of the temperature decay rate demonstrated by wings following application of heated Type I fluids in natural outdoor conditions.

This ARP contains the natural snow endurance time test protocol that was developed for use in the time subsequent to the May 2000 Toulouse SAE G-12 meetings, as described in the above paragraph. A future version of this ARP will contain the laboratory snow test methods that have been developed and are being incorporated into ARP 5485.

TABLE OF CONTENTS

1. SCOPE 6

1.1 PURPOSE 6
1.2 EXAMINATION OF ENDURANCE TIME DATA 6
1.3 LIMITS 6
1.4 TESTING AGENT(S) 6
1.4.1 Independence of the Testing Agent 6
1.4.2 Role of the Testing Agent 6
1.4.3 Sending Samples 6
1.5 FACILITY/SITE 7
1.5.1 Independence of the Test Facility/Site 7
1.5.2 Role of the Facility/Site 7
1.6 UNITS 7
1.7 SAFETY 7

2. APPLICABLE DOCUMENTS 7

2.1 SAE PUBLICATIONS 7
2.2 ASTM PUBLICATIONS 8
2.3 ISO PUBLICATIONS 8
2.4 TRANSPORT CANADA PUBLICATIONS 8
2.5 US FEDERAL AVIATION ADMINISTRATION DOCUMENTS 8
2.6 OTHER DOCUMENTS 8

3. SAE TYPE I FLUID SAMPLES ELIGIBLE FOR ENDURANCE TIME TESTING 9

3.1 REQUIREMENTS 9
3.1.1 Normal Batch 9
3.1.2 Ready-to-Use Fluid 9
3.1.3 Fluid Concentrate 9
3.1.4 Composition of Hard Water 9
3.1.5 Manufacturer's Documentation 9
3.2 TESTING AGENT DUTIES 9
3.2.1 Conduct WSET and Report WSET Results for Ready-to-Use-Fluid 9
3.2.2 Conduct WSET and Report WSET Results on Fluid Concentrate 10
3.2.3 Check Documentation 10
3.2.4 Check WSET 10
3.3 AUTHORIZATION TO PROCEED WITH ENDURANCE TIME TESTING 10
3.3.1 Manufacturer's Authorization to Proceed 10
3.3.2 Final Check 10
3.4 CONDITION OF THE SAMPLE TO BE TESTED FOR ENDURANCE TIMES 10
3.4.1 Freezing Point 10
3.4.2 Lowest Test Temperature 10
3.4.3 Shear Level of Fluids Employed in Endurance Time Testing 11

4. ENDURANCE TIME TEST—GENERAL 11

4.1 PURPOSE 11
4.2 SUMMARY OF THE TESTS 11
4.3 GENERAL VERSUS SPECIFIC REQUIREMENTS 11
4.4 FACILITY/SITE QUALIFICATION 11
4.5 GENERAL ENVIRONMENTAL CHAMBER EQUIPMENT 11
4.5.1 Air Temperature Sensor 11
4.5.2 Lighting 11
4.5.3 Data Acquisition System 12
4.5.4 Temperature Control Equipment 12
4.5.5 Air Distribution System 12
4.5.6 Water Supply for Nozzles 12
4.6 CALIBRATION AND MEASUREMENT METHODS 12
4.6.1 Calibration of Standard Measuring Devices 12
4.6.2 Icing Intensity Measurement Methods 12
4.6.3 Measurement Methods for Icing Intensity Variability Across Test Plates 13
4.6.4 Horizontal Air Velocity Measurement 13
4.6.5 Water Droplet Size Measurement 14
4.7 GENERAL TEST PROCEDURES 14
4.7.1 Test Plate Cleanliness 14
4.7.2 Appearance of Frozen Contamination 15
4.7.3 Delayed Crystallization 15
4.7.4 Report 15

5. ENDURANCE TIME TEST—FROST 17

6. ENDURANCE TIME TEST — FREEZING FOG 18

6.1 FREEZING FOG TEST EQUIPMENT AND TEST PARAMETERS 18
6.1.1 Environmental Chamber Equipment and Plates 18
6.1.2 Test Plates 19
6.1.3 Spray Equipment 19
6.1.4 Example of Spray Equipment 19
6.2 FREEZING FOG MEASUREMENT METHODS 19
6.2.1 Icing Intensity Measurement Methods 19
6.2.2 Icing Intensity Variability Measurement Methods 21
6.3 FREEZING FOG TEST CONDITIONS 22
6.4 FREEZING FOG TEST PROCEDURE 22
6.4.1 Test Plate Cleanliness 22
6.4.2 Temperature Verification 22
6.4.3 Failure Time 22
6.4.4 Icing Intensity 23
6.4.5 Failure Criterion 23
6.4.6 Reproducibility/Precision 23
6.4.7 Report 23

7. ENDURANCE TIME TEST—LABORATORY SNOW 26

8. ENDURANCE TIME TEST—FREEZING DRIZZLE 27

8.1 FREEZING DRIZZLE TEST EQUIPMENT AND TEST PARAMETERS 27
8.1.1 Environmental Chamber Equipment and Plates 27
8.1.2 Test Plates 28
8.1.3 Ice-Catch Pans 28
8.1.4 Spray Equipment 28
8.1.5 Example of Spray Equipment 28
8.2 FREEZING DRIZZLE MEASUREMENT METHODS 28
8.2.1 Measurement Methods for Icing Intensity 28
8.2.2 Measurement Methods for Icing Intensity Variability Across Test Plate 29
8.3 FREEZING DRIZZLE TEST CONDITIONS 29
8.4 FREEZING DRIZZLE TEST PROCEDURE 29

8.4.1 Test Plate Cleanliness ... 29
8.4.2 Temperature Verification ... 29
8.4.3 Failure Time ... 29
8.4.4 Icing Intensity ... 29
8.4.5 Delayed Crystallization ... 30
8.4.6 Failure Criterion ... 30
8.4.7 Reproducibility/Precision ... 30
8.4.8 Report ... 30

9. ENDURANCE TIME TEST—LIGHT FREEZING RAIN ... 33

9.1 LIGHT FREEZING RAIN TEST EQUIPMENT AND TEST PARAMETERS ... 33
9.1.1 Environmental Chamber Equipment and Plates ... 33
9.1.2 Test Plates ... 34
9.1.3 Ice-catch Pans ... 34
9.1.4 Spray Equipment ... 34
9.1.5 Example of Spray Equipment ... 34
9.2 LIGHT FREEZING RAIN MEASUREMENT METHODS ... 34
9.2.1 Measurement Methods for Icing Intensity ... 34
9.2.2 Measurement Methods for Icing Intensity Variability Across Test Plates ... 34
9.3 LIGHT FREEZING RAIN TEST CONDITIONS ... 35
9.4 LIGHT FREEZING RAIN TEST PROCEDURE ... 35
9.4.1 Test Plate Cleanliness ... 35
9.4.2 Temperature Verification ... 35
9.4.3 Failure Time ... 35
9.4.4 Icing Intensity ... 35
9.4.5 Delayed Crystallization ... 36
9.4.6 Failure Criterion ... 36
9.4.7 Reproducibility/Precision ... 36
9.4.8 Report ... 36

10. ENDURANCE TIME TEST—RAIN ON A COLD-SOAKED WING ... 37

10.1 RAIN ON A COLD-SOAKED WING TEST EQUIPMENT AND TEST PARAMETERS ... 37
10.1.1 Environmental Chamber Equipment and Plates ... 37
10.1.2 Test Plates ... 38
10.1.3 Cold-Soak Box ... 38
10.1.4 Spray Equipment ... 38
10.1.5 Example of Spray Equipment ... 38
10.2 MEASUREMENT METHODS FOR RAIN ON A COLD-SOAKED WING ... 38
10.2.1 Measurement Methods for Icing Intensity ... 38
10.2.2 Measurement Methods for Icing Intensity Variability Across Test Plates ... 38
10.3 RAIN ON A COLD-SOAKED WING TEST CONDITIONS ... 38
10.4 RAIN ON A COLD-SOAKED WING TEST PROCEDURE ... 39
10.4.1 Test Plate Cleanliness ... 39
10.4.2 Temperature Verification ... 39
10.4.3 Failure Time ... 39
10.4.4 Icing Intensity ... 39
10.4.5 Delayed Crystallization ... 39
10.4.6 Failure Criterion ... 40
10.4.7 Reproducibility/Precision ... 40
10.4.8 Report ... 40

11. ENDURANCE TIME TEST—NATURAL SNOW ... 42

11.1 SNOW TEST EQUIPMENT AND TEST PARAMETERS ... 42
11.1.1 Conditions and Equipment ... 42
11.1.2 Outside Air Temperature Measurements ... 42
11.1.3 Lighting ... 42
11.1.4 Wind Speed ... 43
11.1.5 Calibration of Standard Measuring Devices ... 43
11.1.6 Test Plates ... 43

11.1.7 Empty Aluminum Boxes and Test Stand 43
11.1.8 Markings 43
11.1.9 Stand 43
11.1.10 Wind Orientation of the Test Stand 44
11.1.11 Plate Pan for Precipitation Rate Measurement 44
11.2 SNOW MEASUREMENT METHODS 45
11.2.1 Measurement Method for Snow Intensity 45
11.2.2 Rate Calculation 46
11.3 SNOW TEST PRECIPITATION RATE 47
11.4 SNOW TEST TEMPERATURE 47
11.5 SNOW TEST PROCEDURE 47
11.5.1 Test Plate Cleanliness 47
11.5.2 Fluid Application 47
11.5.3 Failure Time 48
11.5.4 Failure Criterion 48
11.5.5 Reproducibility/Precision 48
11.5.6 Type and Classification of Solid Precipitation 49
11.5.7 Report 49
12. NOTES 52
12.1 KEY WORDS 52

List of Tables

Table 1 - Examples of Water Droplet Size Measuring Methods 14
Table 2 - Requirements for Freezing Fog Test Equipment 18
Table 3 - Freezing Fog Test Conditions 22
Table 4 Requirements for Freezing Drizzle Test Equipment 27
Table 5 - Freezing Drizzle Test Conditions 29
Table 6 - Requirements for Light Freezing Rain Test Equipment 33
Table 7 - Light Freezing Rain Test Conditions 35
Table 8 - Requirements for Rain on a Cold-Soaked Wing Test Equipment 37
Table 9 - Rain on a Cold-Soaked Wing Test Condition 39
Table 10 - Requirements for Natural Snow Test Equipment 42

List of Figures

Figure 1 - Example of Spray Nozzle for Freezing Fog 24
Figure 2 - Arrangement of Ice-catch Plates and Reference Ice-catch Plates 25
Figure 3 - Ice-catch Pans 31
Figure 4 - Example of a Hydraulic Nozzle for Freezing Drizzle 32
Figure 5 – Cold-Soak Box 41
Figure 6 - Test Stand and Boxes 44
Figure 7 - Example of Schematic of Plate Pan 45
Figure 8 - Calculation of Outdoor Precipitation Rate 46
Figure 9 - Type of Frozen Precipitation 50

1. SCOPE

1.1 Purpose

The purpose of this ARP is to provide the sample selection criteria and test procedures for SAE Type I aircraft deicing/anti-icing fluids, required for the generation of endurance time data of acceptable quality for review by the SAE G-12 Holdover Time Subcommittee.

A significant body of previous research and testing has indicated that all Type I fluids formulated with glycol perform in a similar manner from an endurance time perspective. This applies to Type I deicing/anti-icing fluids formulated with propylene glycol, ethylene glycol, and diethylene glycol only. Type I deicing/anti-icing fluids containing these glycol bases no longer require testing for endurance times. The methods described in this ARP shall be employed, however, if endurance time testing of a glycol-based Type I deicing/anti-icing fluid is desired or requested by a fluid manufacturer, operator or other organization. Fluids formulated with glycol bases other than those listed herein, and all non-glycol Type I deicing/anti-icing fluids, must be tested for endurance times using the methods described in this ARP (as appropriate).

1.2 Examination of Endurance Time Data

Periodically, the SAE G-12 Holdover Time Subcommittee examines endurance time test data of SAE Type I aircraft deicing/anti-icing fluids and validates, based on the endurance time data, if such fluids can be used in conjunction with generic Type I HOT guidelines. As the SAE G-12 Holdover Time Subcommittee examines endurance time data, it will take into consideration the effects of natural variability of precipitation both in time and space to generate or adjust HOT guidelines.

1.3 Limits

This ARP provides criteria for the laboratory simulation of freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. It also describes test conditions for outdoor natural snow tests. Other forms of freezing/frozen precipitation are not addressed in this ARP.

1.4 Testing Agent(s)

1.4.1 Independence of the Testing Agent

The testing agent shall be independent of the fluid manufacturer or fluid vendor.

1.4.2 Role of the Testing Agent

The testing agent shall coordinate activities related to the sample selection procedures (see Section 3) and, as required, the testing agent may conduct endurance time testing at a suitable facility on the selected fluid.

1.4.3 Sending Samples

Fluid samples for testing shall be sent to a designated testing agent for verification under the sample selection procedures. In turn the testing agent, if the requirements of the applicable sample selection procedure are fulfilled, shall send the samples to the facility/site for endurance time testing.

1.5 Facility/Site

1.5.1 Independence of the Test Facility/Site

The test facility/site shall be independent of the fluid manufacturer or fluid vendor.

1.5.2 Role of the Facility/Site

The test facility/site shall be responsible for performing the endurance time tests (see Sections 4 to 11).

1.6 Units

The values stated in International System (SI) units are to be regarded as the standard.

1.7 Safety

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

2. APPLICABLE DOCUMENTS

The issues of the following documents in effect on the date of the purchase order form a part of this ARP to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been canceled and no superseding document has been specified, the last published issue of that document shall apply. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001:

AIR9968	Field Viscosity Test of Thickened Aircraft Deicing/Anti-icing Fluids
AMS 1424	Deicing/Anti-icing Fluid, Aircraft, SAE Type I
AMS 1428	Deicing/Anti-Icing Fluid, Aircraft, Non-Newtonian, Pseudoplastic, SAE Type II, III, IV
AMS 4037	Aluminum Alloy Sheet and Plate, 4.4 Cu - 1.5 Mg - 0.6 Mn (2024-T3 Flat Sheet, T351 Plate) Solution Heat Treated
AMS 4041	Aluminum Alloy, Alclad Sheet Plate, 4.4 Cu 0.60 Mn (Alclad 2024 and 1-½% T3 Flat sheet, 1-½% Alclad 2024 T351 Plate)
ARP4737	Aircraft Deicing/Anti-icing Methods with Fluids
ARP5485	Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Types II, III and IV

AS5900 Standard Test Method for Aerodynamic Acceptance of SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-Icing Fluids

AS5901 Water Spray and High Humidity Endurance Test Methods for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids

2.2 ASTM Publications

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959:

ASTM D 1193 Reagent Water

2.3 ISO Publications

Available from International Organization for Standardization, Case postale 56, rue Varembe, CH-1211, Switzerland:

ISO 10012 Quality Assurance Requirements for Measuring Equipment

2.4 Transport Canada Publications

Available from Transportation Development Center, Transport Canada, 800, boul. René-Lévesque Ouest, 6th Floor, Montréal QC, H3B 1X9, Canada:

TP 12899E Validation of Methodology for Simulating a Cold-Soaked Wing

TP 13827E SAE Type I Fluid Endurance Time Test Protocol

TP 13991E Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 2001–2002 Winter

TP 13994E Generation of Holdover Times Using the New Type I Fluid Test Protocol

2.5 US Federal Aviation Administration Documents

Flight Standards Information Bulletin for Air Transportation, FAA Approved Deicing Program Updates, Winter 2004-2005, FAA Bulletin number FSAT 04-05 (this document is updated in October of each year).

2.6 Other Documents

Godard, L. (1959), *Procédé pour déterminer les dimensions des gouttelettes de brouillard ou de nuages*, Bulletin de l'observation du Puy de Dôme, pp.11-13. (English translation: *Procedure for the Determination of Fog and Cloud Droplet Dimensions*).

Godard, S. (1960), *Mesure des gouttelettes de nuage avec un film de collargol.* Bulletin de l'observation du Puy de Dôme, pp. 41-46. (English translation: *Measurement of Cloud Droplets using a Colloidal Film*).

Mason, B.J. (1971), *Physics of Clouds,* 2nd edition. Oxford University Press, pp. 607.

Guide to Meteorological Instruments and Methods of Observation, World Meteorological Organization (1983).

3. SAE TYPE I FLUID SAMPLES ELIGIBLE FOR ENDURANCE TIME TESTING

3.1 Requirements

3.1.1 Normal Batch

The sample shall be fluid taken from a production batch in a form normally supplied by the vendor.

3.1.2 Ready-to-Use Fluid

If the fluid is intended for use undiluted (ready-to-use), the water spray endurance time (WSET) test results of the sheared sample must not be less than three minutes. (In the normal qualification process, the WSET is performed on fluids that have been sheared in accordance with the methods outlined in paragraph 3.3.4 of AMS 1424 for anti-icing performance tests. To ensure the candidate fluid fulfills the normal requirement of qualification, its WSET must be conducted on a sheared sample.)

3.1.3 Fluid Concentrate

If the fluid is intended for use as a dilution of a concentrate, the WSET result (as defined in AS 5901) of a sheared 50/50 volume ratio of fluid and hard water (see 3.1.4) must not be less than three minutes.

3.1.4 Composition of Hard Water

To make hard water, the following procedure shall be used: Dissolve 400 mg ± 5 calcium acetate dihydrate $Ca(C_2H_3O_2)_2.2H_2O$ and 280 mg ± 5 magnesium sulfate heptahydrate $MgSO_4.7H_2O$, both of analytical reagent quality, in 1 liter of ASTM D 1193 Type IV water. If calcium acetate dihydrate is not readily available, use calcium acetate monohydrate or anhydrous calcium acetate of analytical reagent quality and ensure the hard water has 82.6 mg/L Ca^{++} by atomic absorption (or equivalent method).

3.1.5 Manufacturer's Documentation

The fluid manufacturer shall send or make available the following documentation to the designated testing agent:

a. The SAE AMS 1424 certificates of conformance of the fluid (to ensure that the fluid is fully qualified).
b. The volume dilution versus freezing point data for the fluid (data needed to prepare the dilutions).
c. The freezing point versus refraction at 20°C data for the fluid (to check the correctness of dilutions).
d. A manufacturer's safety data sheet (MSDS) and/or other safety related documentation as deemed appropriate.

3.2 Testing Agent Duties

3.2.1 Conduct WSET and Report WSET Results for Ready-to-Use-Fluid

If the fluid is intended for use undiluted, the designated testing agent shall:

a. Perform a WSET on the sheared sample.

b. Report the results to the manufacturer prior to conducting any endurance time testing.

3.2.2 Conduct WSET and Report WSET Results on Fluid Concentrate

If the fluid is intended for use diluted, the designated testing agent shall:

a. Dilute the sample 50/50 by volume with hard water (see 3.1.4).

b. Conduct the WSET on the sheared, diluted fluid sample.

c. Report the results to the manufacturer prior to running any endurance time testing.

3.2.3 Check Documentation

The designated testing agent shall make sure that it has on hand the manufacturer's documentation described in 3.1.5.

3.2.4 Check WSET

The designated testing agent shall ensure that only fluids with WSET results no less than three minutes are passed on for endurance time testing.

3.3 Authorization to Proceed with Endurance Time Testing

3.3.1 Manufacturer's Authorization to Proceed

After reviewing the results of 3.2.1 or 3.2.2, the fluid manufacturer (if desirous of proceeding with endurance time tests) shall send to the designated testing agent authorization to proceed.

3.3.2 Final Check

The designated testing agent shall proceed with endurance time testing upon successful completion of 3.2.3 and 3.2.4 and 3.3.1 by sending the sample to the testing facility/site.

3.4 Condition of the Sample to be Tested for Endurance Times

3.4.1 Freezing Point

The sample shall be tested at dilutions where the freezing point is 10°C below the air temperature. The dilutions shall be prepared by the designated testing facility using hard water (see 3.1.4).

3.4.2 Lowest Test Temperature

The test temperature shall not be lower than the lowest temperature associated with acceptable aerodynamic performance in accordance with AS 5900, as reported in the certificate of conformance provided to the designated testing agent as part of the manufacturer's documentation. There is no reason to test below the lowest aerodynamic acceptance temperature of the fluid. Testing may be conducted below the lowest temperature with acceptable aerodynamic performance, but the fluid can’t be used below this temperature.

3.4.3 Shear Level of Fluids Employed in Endurance Time Testing

Fluids whose sheared samples have met the WSET requirements of 3.1.2 or 3.1.3 may be tested for endurance times. The fluid shall be sheared in accordance with the methods outlined in paragraph 3.3.4 of AMS 1424 for use in endurance time testing.

4. ENDURANCE TIME TEST—GENERAL

4.1 Purpose

This section of the ARP establishes the general minimum requirements for test equipment and test procedures used to carry out endurance time tests of aircraft deicing/anti-icing fluids under conditions of freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. The primary purpose for such a test method is to determine endurance time for these conditions under controlled laboratory conditions for SAE Type I fluids.

This section does not apply to natural snow testing (Section 11) except where noted otherwise.

4.2 Summary of the Tests

Fluids to be evaluated are applied to test plates exposed to freezing fog, snow, freezing drizzle, light freezing rain, and rain on a cold-soaked wing conditions. Endurance times are evaluated by measuring the minimum exposure time before a specified degree of freezing occurs.

4.3 General Versus Specific Requirements

This general section (Section 4) covers requirements that are common to many or all conditions (except where otherwise noted). Sections 5–10 establish the specific requirements for each precipitation condition.

4.4 Facility/Site Qualification

Substantiation that the facility and associated staff and resources satisfy the requirements of this endurance time test method, including calibration and measurement methods, shall be documented. Such documentation shall be kept for 3 years.

This requirement (paragraph 4.4) is applicable to Section 11.

4.5 General Environmental Chamber Equipment

4.5.1 Air Temperature Sensor

The air temperature sensor shall be in proximity to the test plate, typically within 1.5 meters of the side of the test plate, but outside the spray area (if any). The distance and position of the sensing device shall be reported.

4.5.2 Lighting

The test chamber shall be equipped with artificial lighting facilitating ice formation observation but positioned such that it does not interfere with air, fluid, and plate temperatures.

4.5.3 Data Acquisition System

The air temperature, plate temperature, and humidity sensors shall be linked to an electronic data acquisition system as a means of checking and recording the environmental characteristics of the test chamber and test plates throughout the course of a test run.

4.5.4 Temperature Control Equipment

The air temperature (for all conditions) and test plate temperature, if required by the test protocol, shall be maintained at the required level using heat exchangers connected to a temperature control system such as a solid state temperature sensor with a platinum resistance probe (100 ohms at 0 °C), coupled to a proportional temperature controller having a minimum resolution of 0.5 °C.

4.5.5 Air Distribution System

The air distribution system shall be comprised of a fan or fans to provide air recirculation through the main body of the test chamber and to the heat exchanger. Ducting for the passage of air at both the inlet and the outlet of the heat exchanger shall have entry and exit ports positioned to provide good air recirculation throughout the test chamber. The heat exchanger shall be capable of cooling the air and maintaining it at the specified temperature level. Airflow shall be measured using a suitable anemometer or velocity meter (see also 4.6.4).

4.5.6 Water Supply for Nozzles

Water supplied to nozzles shall conform to ASTM D1193 Type IV water or a hardness of less than 300 ppm reported as $CaCo_3$.

4.6 Calibration and Measurement Methods

4.6.1 Calibration of Standard Measuring Devices

All temperature sensors, humidity sensors, electronic balances, anemometers, velocity meters, and timing devices shall be maintained in a known state of calibration in accordance with recognized international standards, such as ISO 10012, by calibrating each instrument at least once every six months or whenever a piece of equipment is repaired, replaced, moved, or otherwise suspect. A written record of the calibrations shall be kept available.

4.6.2 Icing Intensity Measurement Methods

The following methods are intended to produce the same results.

4.6.2.1 Icing Intensity Measurement Methods Using Reference Ice-Catch Plates (Method A)

In most cases the icing intensity on a test plate with fluid cannot be measured directly as the fluid and some of the precipitation will flow off of the test plate preventing the weighing of the total precipitation for the duration of the test. Icing intensity is generally established by catching the precipitation with a specified number of so-called reference ice-catch plates placed adjacent to the test plate and weighing the amount of precipitation for the duration of the test period. At least one example of an appropriate icing intensity measurement method using reference ice-catch plates is given in this ARP for each of the conditions listed (Sections 6–11). This one example for each condition is called Method A to differentiate it from other icing intensity methods.

4.6.2.2 Icing Intensity Measurement Method Using Regression Analysis (Method B)

An alternative way of measuring icing intensity is to catch the precipitation a number of times at the very position of the test plate before and after the test and average the results. For this method, called Method B, at least two tests with fluid are performed and endurance times determined at each of the targeted rates. The results are analyzed using regression analysis to determine the endurance time at the targeted rates of precipitation. Examples of icing intensity using regression analysis are described in Sections 6, 8, 9 and 10.

4.6.2.3 Other Icing Intensity Measurement Methods

Icing intensity measurement methods may differ from methods described in 4.6.2.1 or 4.6.2.2 depending on the specific configuration of the equipment (e.g., number of ice-catch plates or their geometry) used to create the various precipitation conditions.

4.6.2.4 Documentation

Each facility/site performing endurance time tests shall develop and document appropriate icing intensity measurement methods for each precipitation condition to ensure that the test conditions are within the specified limits. Reports issued by the facility/site shall describe the icing intensity measurement methods and their results.

4.6.3 Measurement Methods for Icing Intensity Variability Across Test Plates

4.6.3.1 Measurement Method for Intensity Variability Across a Test Plate (used with Method A)

It is important to establish that icing intensity across each test plate is uniform and within specified limits. The icing intensity variability (uniformity or lack of) across each test plate can be established by periodically replacing the test plates with a specified number of pre-weighed ice-catch plates, weighing the precipitation, and calculating the range. The range is simply the highest value minus the lowest value and is a quantitative representation of the variability of precipitation data across each plate. This range must not exceed limits that are specified for each test condition. The measurement of the icing intensity variability across a test plate shall be run at least every six months or whenever a piece of equipment is repaired, replaced, moved or otherwise suspect.

4.6.3.2 Measurement Method for Intensity Variability Across all Test Plates (used with Method B)

This method is described in 6.2.2.3. The measurement of the icing intensity variability across the test plate support shall be run every time tests are performed.

4.6.3.3 Other Methods for Measuring Icing Intensity Variability Across Test Plates

A facility/site may have specific equipment that requires a method for estimating the icing intensity variability across test plates differently than in 4.6.3.1 or 4.6.3.2. Such other methods are acceptable if they are shown to be equivalent or more conservative.

4.6.4 Horizontal Air Velocity Measurement

Horizontal air velocity shall be measured 50 mm above the surface of the test plate using a velocity meter or anemometer.

4.6.5 Water Droplet Size Measurement

Several methods are available to determine the water droplet size (median volume diameter). Table 1 lists several acceptable methods as a function of droplet size. A description of the methods of Table 1 follows:

a) Slide Impact Method with Oil: A sample of the water droplets from the precipitation is collected on an oil coated microscope slide. An oil having a viscosity of 5000 mPa.s at 20 °C, spread to an appropriate thickness, will be suitable for certain droplet sizes (see Table 1 for appropriate thickness). The oil may be either a mineral oil or silicone oil. The droplet size is determined by direct observation under a microscope using an eyepiece with the appropriate graticule or from enlarged photographs of the slide.

b) Slide Impact Method with Colloidal Silver: A sample of the water droplets from the precipitation is collected on a microscope slide coated with a colloidal silver solution. A thin film of 95 percent water and 5 percent colloidal silver is brushed over a microscope slide. Once the film is dry (about 30 seconds) it is exposed to the water spray, where it becomes permanently marked with the droplet imprints. The droplet diameter is one third of the print diameter measured under a microscope using an eyepiece with the appropriate graticule or from enlarged photographs of the slide.

c) Laser Diffraction Method: Using a laser diffraction particle analyzer, incorporating a low power laser transmitter and photo detector, the size of the droplets can be measured as they fall towards the surface of the test plate. Analysis of the diffraction patterns gives the size and the distribution of the droplets. Some equipment is capable of achieving this in real time.

d) Dye Stain Method. Prepare discs by dusting filter paper discs with a water-activated very finely divided powder form of methylene blue dye. The prepared discs are manually positioned under precipitation for a fixed time in order to acquire a droplet size pattern. A calibration curve is then used to convert from the measured diameter of the droplets on the pattern to the experimental median volume diameter.

Table 1 - Examples of Water Droplet Size Measuring Methods

Droplet Size	Slide Impact with Oil (Required Oil Film Thickness)	Slide Impact with Colloidal Silver	Laser Diffraction	Dye Stain
5 μm		X		
20 μm	X (500 μm)	X	X	
200 μm	X (1000 μm)			X
1000 μm	X (2000 μm)			X

X denotes a recommended method

4.7 General Test Procedures

4.7.1 Test Plate Cleanliness

The test plates shall be free of all visible contamination, smears, or stains, except for markings used to estimate ice coverage. Between test runs, any contamination shall be removed by washing with hot water immediately followed by an ethanol rinse. If the same fluid is tested on the same plate for two or more consecutive tests, it is not necessary to clean the plates with ethanol before the second test; a hot water rinse is sufficient. Allow the plates to dry after rinse and ensure they are at the appropriate temperature before use.

4.7.2 Appearance of Frozen Contamination

Failure is called when 30 percent of the plate area is covered with frozen contamination. Appearance of this frozen contamination includes but is not limited to:

a. An ice front
b. An ice sheet
c. Slush, in clusters or as a front
d. Disseminated fine ice crystals
e. Frost on the treated surface
f. Clear ice pieces partially or totally imbedded in fluid
g. Snow bridges on top of the fluid

4.7.3 Delayed Crystallization

Delayed crystallization may occur during the course of a test run (for all precipitation conditions except for snow which is already crystalline) and is defined as a sudden (within 30 seconds) appearance of frozen contamination covering a large surface area of a test plate. If this sudden coverage exceeds the percentage of the test plate area that is considered to be a failure, the test is invalid and must be repeated. In the case of suspected delayed crystallization, if the test has been invalidated three times, the plate may be seeded at the center top edge of the plate with an ice crystal to initiate crystallization. Seeding consists of putting an ice crystal in contact with the fluid by means of a chilled metal rod (below 0 °C). If upon seeding, the frozen contamination area suddenly exceeds the percentage of the plate area that is considered to be a failure, the test is invalid.

4.7.4 Report

The report shall include:

a. Name and address of the facility conducting the tests.
b. Statement confirming that the test facility is autonomous of the manufacturer and vendor of the fluid.
c. Date(s) the tests were conducted.
d. Manufacturer's or vendor's name and address.
e. Name or reference number and lot number of the fluid tested.
f. Type of fluid (SAE Type I) and dilution tested (e.g., received SAE Type I concentrate; tested diluted 1:1 with hard water).
g. Quantity of fluid applied to test plates, if different from the norm.
h. Summary of test results and the icing intensity results for each test.
i. Icing intensity measurement method, including ice-catch raw data.
j. Method of estimation of failure area.
k. Description of appearance of frozen contamination. For natural snow, report the form of the snow according to Figure 9.

l. Measurement method for icing intensity variability across test plates, its results (range), and date performed.

m. Distance and location of air temperature sensor from test plates.

n. For natural snow tests, orientation of the test stand and direction of the wind.

5. ENDURANCE TIME TEST—FROST

This section is being developed for future versions of this ARP.

6. ENDURANCE TIME TEST — FREEZING FOG

6.1 Freezing Fog Test Equipment and Test Parameters

6.1.1 Environmental Chamber Equipment and Plates

In addition to the requirements given in 4.5, environmental chamber and associated equipment requirements for freezing fog endurance time testing are given in Table 2 and in the following paragraphs.

Table 2 - Requirements for Freezing Fog Test Equipment

Test Parameters	Requirements
Environmental Chamber	
Minimum volume	7 m³ for each 300 x 500 mm test plate
Air temperature range	0 °C to at least -25 °C
Minimum temperature sampling rate	1 datum per minute
Horizontal air velocity	≤ 0.4 m/s
Relative humidity	> 40 %
Test Plates	
Material	Aluminum alloy AMS 4037 or 4041
Test plate dimensions	500 mm long x 300 mm wide x 3.2 mm thick
Angle	10.0° ± 0.2
Surface finish	Average surface roughness: Ra ≤ 0.5 µm
Temperature at start of test	Within 0.5 °C of air temperature
Number of test plates	2 per fluid tested
Fluid application temperature	20 °C ± 5
† Ice-catch Plates	
Ice-catch plates	100 x 100 x 1.6 mm thick
Number of reference ice-catch plates	8 surrounding each test plate
Number of ice-catch plates for measuring icing intensity variability across test plates	12 per test plate
‡ Ice-catch Pans	
Ice-catch pans	277 x 540 mm
Number of ice-catch pans	1 per test location
Spray Equipment	
Water supply temperature	Adjusted to produce supercooled water droplets
Water droplet median volume diameter	22 µm ± 5

† Method A
‡ Method B

6.1.2 Test Plates

6.1.2.1 Each test plate is removable and placed on a support that is housed within the environmental chamber.

6.1.2.2 Each test plate shall be equipped with a temperature sensor located on the underside of or embedded within the plate. This sensor shall be capable of measuring to an accuracy of ± 0.5 °C and shall be linked to an electronic data acquisition system.

6.1.2.3 Method A. The test plate support is set up in such a way that it can accommodate eight ice-catch plates per test plate. The ice-catch plates shall be adjacent to, but not in contact with, each test plate. The test plate support face shall be inclined from the horizontal as specified in Table 2. The test plate shall be placed on the support such that the fluid can freely flow off all edges of the plate. The test stand should be designed as to minimize the contact between the test surface and the support.

6.1.2.4 Method B. The test plate support is set up in such a way that it can accommodate six test plates. The test plate support face shall be inclined from the horizontal as specified in Table 2. The test plate is placed on the support such that the fluid can freely flow off all edges of the plate. The test stand should be designed to minimize the contact between the test surface and the support.

6.1.3 Spray Equipment

6.1.3.1 It is a fundamental requirement of this test that the spray impinges onto the surface of the test plate as supercooled water droplets that freeze on impact. This is verified by observation of an ice-catch plate.

The equipment used to provide the water spray comprises a low flow nozzle supplied with water of quality and condition described in 4.5.6. This equipment is housed in the upper region of the test chamber above the test plate. The exact type and geometry of the spray system used to generate the water spray for the test is left to the discretion of the testing facility, provided the requirements of Table 2 and Table 3 are met.

6.1.4 Example of Spray Equipment

An example of a suitable spray system is as follows: the nozzle comprises two sections, outer and inner units for the respective passage of water and compressed air (Figure 1). The nozzle reciprocates to provide even and reproducible coverage of the test plate at the specified water spray intensity.

6.2 Freezing Fog Measurement Methods

6.2.1 Icing Intensity Measurement Methods

6.2.1.1 For general requirements see 4.6.2.

6.2.1.2 Method A: Each test plate is replaced with 12 ice-catch plates which in turn are surrounded by 8 additional reference ice-catch plates (examples, see Figure 2). All plates are weighed before and after a run made without fluid (so-called calibration run). The ice-catch is recorded for each plate. The average ice-catch of the 12 ice-catch plates replacing a test plate and the average ice-catch of the reference plates are calculated. The ratio of these 2 averages is calculated using Equation 1.

For a run without fluid (calibration run):

$$Ratio = I_{plate} / I_{ref} \qquad \text{Equation 1}$$

Where:

Ratio = ratio of the ice-catch over the plates replacing the test plate with respect to the ice-catch on the reference plates
I_{plate} = average ice-catch on the ice-catch plates replacing the test plate
I_{ref} = average ice-catch on the reference ice-catch plates surrounding the test plate

The ratio is used to estimate the ice-catch intensity during a test run with fluid when only the reference plates are available. The ice-catch is measured on the reference plates and averaged. This average is multiplied by the ratio calculated above based on the test performed without fluid. The resulting value is reported as the icing intensity over the test plate.

For a run with fluid:

$$I_{plate} = Ratio \times I_{ref} \qquad \text{Equation 2}$$

Where:

I_{plate} = reported intensity of that plate
I_{ref} = average ice-catch on the reference plate surrounding the test plate during the run with fluid
Ratio = see above

6.2.1.3 Method B: Icing Intensity Measurement: Initially, place ice-catch pans (27.7 cm x 54 cm) on the test plate support at each test location (typically 12 locations). Each pan is marked with a number identifying the collection location on the test plate support. The individual pans are weighed prior to exposure to precipitation and the weights are recorded. At the start of the ice-catch period, the exact time (hh:mm:ss) is recorded. The pans are then placed on the test plate support for a period of at least 10 minutes. The pans are re-weighed following this period and the ice-catch rate (R1) is calculated per Equation 3.

$$R\#=(W_{a1}-W_{b1})/\text{Area-of-pan}*(T_{a1}-T_{b1}) \qquad \text{Equation 3}$$

Where:

=numerical indicator for ice-catch rate collection period
W_{a1}=weight after of the 1st measurement
W_{b1}= weight before of the 1st measurement
T_{a1}= time at the end of the 1st measurement
T_{b1}=time at the beginning of the 1st measurement

The pans are then weighed and placed on the test plate support for a second collection period and the second ice-catch rate calculated (R2). A fluid test begins following the second ice-catch rate collection period. Following the failure of a test plate, an ice-catch pan placed at the plate location for at least 10 minutes and the third ice-catch rate is calculated (R3). Another ice-catch

is done to get a fourth ice-catch rate (R4). More ice-catch runs before or after a fluid test may be performed at the discretion of the testing agent.

The rate of precipitation (icing intensity) for any location on the stand is calculated by averaging at least two rates measured immediately prior to the test (more than 2 rates may be run) and at least two rates measured immediately following the test (more than 2 rates may be run). In order for the test to be valid, the average rate and the standard deviation must be within the limits shown in Table 3.

At a given temperature, two tests are conducted at the lower icing intensity (e.g., FOG –A) and two tests are conducted at the upper icing intensity (e.g., FOG-B). If the endurance time at one of the icing intensities lies outside ± 10 percent from the average, then two additional tests are run, for a total of 4 data points at that icing intensity. All of the data points are used for the regression analysis — no data points shall be rejected.

The endurance times are obtained by producing a best-fit regression curve using a power law transformation based on all of the data collected at the lower and upper rates. A minimum of four data points are required to generate the regression curve for any fluid, with at least two at each icing intensity.

The equation used to treat the data is as follows:

$$t = cR^a \qquad \text{Equation 4}$$

where
t = time (minutes)
R= rate of precipitation (g/dm^2/hr)
a, c= coefficients determined from the regression

The upper and lower fluid endurance time values are determined from the points at which the best-fit curve intersects the lower (e.g., at 2.0 g/dm^2/h for FOG-A) and upper icing intensity (e.g., at 5.0 g/dm^2/h for FOG-B).

Continuous Rate Monitoring: During a test, rates are continuously monitored to ensure that icing intensity remains within specification. One ice-catch pan is used for continuous rate monitoring when conducting 1 to 6 fluid tests, and two ice-catch pans are used for continuous rate monitoring continuous when conducting 7 to 12 tests. For this purpose, ice collection pans are weighed and placed on each designated location. The ice-catch pans are re-weighed at 15 minute intervals during the test and the icing intensity calculated using Equation 3 (but with the "R' replaced with "RC"; e.g., RC1 for the first 15 minute interval, RC2 for the second 15 minute interval, etc.). For any given test to be valid, the continuous rates of the selected monitoring position (including R1, R2, all the RCs, R3, and R4 at this position) must be within 1.5 times the standard deviation limits in Table 3.

6.2.2 Icing Intensity Variability Measurement Methods

6.2.2.1 For general requirements see 4.6.3.

6.2.2.2 Measurement Method for Variability Across a Test Plate (used with Method A): The icing intensity variability across a test plate shall be the range of the icing intensities measured for the 12 ice-catch plates in 6.2.1.2 and shall conform to the value of the "Icing intensity range across a test plate" in Table 3. It shall be done for all test plates.

6.2.2.3 Measurement Method for Variability Across All Test Plates (used with Method B): With method B the variability is not measured for a single (divided) plate as it is with method A; rather, it is measured across all of the (undivided) plates for a given period of time. The icing intensity variability across all test plates shall be the range of icing intensities for all R1s (R1 for position 1, R1 for position 2, etc., for all positions) defined in 6.2.1.3. The range of all R1s shall conform to the value of the "Icing intensity range across test plates" in Table 3. Furthermore, the range of R2s, R3s and R4s shall also conform to the value of the "Icing intensity range across test plates" in Table 3. Results from positions not fulfilling this requirement shall not be used.

6.3 Freezing Fog Test Conditions

Test conditions for freezing fog are in Table 3

Table 3 - Freezing Fog Test Conditions

Test Condition	FOG-A	FOG-B	FOG-S	FOG-T	FOG-C	FOG-D	FOG-E	FOG-F
Air temperature, °C	-3 ± 0.5	-3 ± 0.5	-6 ± 0.5	-6 ± 0.5	-10 ± 0.5	-10 ± 0.5	-25 ± 1	-25 ± 1
Air temperature standard deviation	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5
† Icing intensity, g/dm^2/h	2.0 ± 0.2	5.0 ± 0.2	2.0 ± 0.2	5.0 ± 0.2	2.0 ± 0.2	5.0 ± 0.2	2.0 ± 0.2	5.0 ± 0.2
‡ Average icing intensity, g/dm^2/h	2.0 ± 0.3	5.0 ± 0.4	2.0 ± 0.3	5.0 ± 0.4	2.0 ± 0.3	5.0 ± 0.4	2.0 ± 0.3	5.0 ± 0.4
‡ Icing intensity standard deviation	<0.3	<0.4	<0.3	<0.4	<0.3	<0.4	<0.3	<0.4
† Icing intensity range across a test plate, g/dm^2/h	≤ 0.4	≤ 0.6	≤ 0.4	≤ 0.6	≤ 0.4	≤ 0.6	≤ 0.4	≤ 0.6
‡ Icing intensity range across all test plates, g/dm^2/h	≤ 1.2	≤ 1.7	≤ 1.2	≤ 1.7	≤ 1.2	≤ 1.7	≤ 1.2	≤ 1.7

† Method A
‡ Method B

6.4 Freezing Fog Test Procedure

6.4.1 Test Plate Cleanliness

Clean test plates according to 4.7.1.

6.4.2 Temperature Verification

Ensure the test chamber, fluid, and test plates are at the required temperature.

6.4.3 Failure Time

Pour 1 L of fluid onto each test plate. As soon the fluid has spread over the plates (almost instantaneous for Type I fluids), expose to precipitation and start the timing device. Observe the plates and, when the failure occurs (defined in 6.4.5), record the time as the endurance time.

6.4.4 Icing Intensity

After all of the plates have failed, shield the ice-catch plates from precipitation, and weigh the ice-catch on each ice-catch plate; using a method such as described in 6.2.1, estimate the icing intensity for each test plate. If the icing intensity is not within the specified limits (Table 3) for the test being conducted, the time recorded is not valid.

Delayed Crystallization

See 4.7.3

6.4.5 Failure Criterion

Failure is called when 30 percent of the plate is covered with frozen contamination. Frozen contamination is described in 4.7.2. Pen marks on the plate can be used to estimate the area of failure. For instance, a line drawn across the plate at 150 mm from the top edge will delineate an area corresponding to 30 percent of the plate.

6.4.6 Reproducibility/Precision

6.4.6.1 Reproducibility/Precision for Method A: The test is dynamic by nature, and small variations can be expected. If the range (highest value minus lowest value) of the endurance time is less than 10 percent of the average anti-icing endurance time, report the average as the endurance time for that condition. If not, repeat testing on two additional plates, for a total of four data points. The highest and lowest points shall be discarded, and the average of the two remaining points shall be the endurance time for that condition.

6.4.6.2 Reproducibility/Precision for Method B: With this method, data is not rejected but incorporated using regression analysis. See 6.2.1.3.

6.4.7 Report

See 4.7.4.

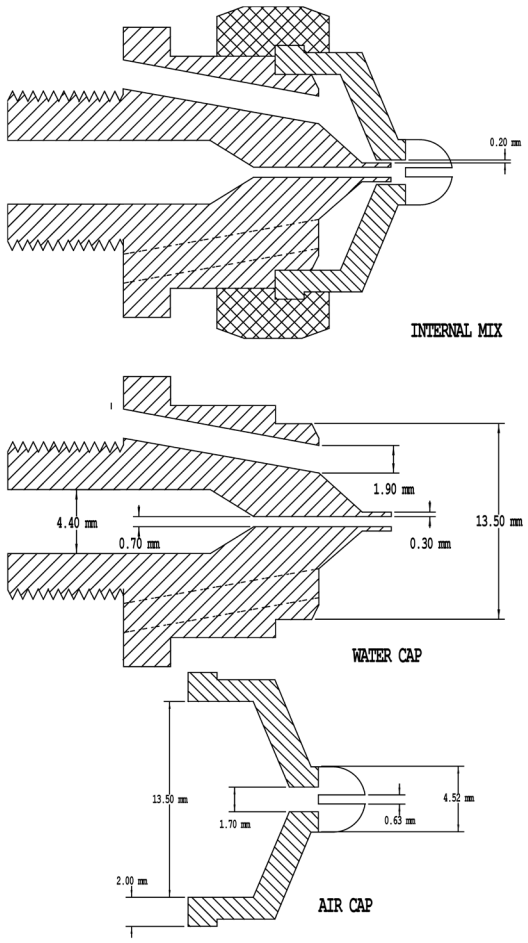


Figure 1 - Example of Spray Nozzle for Freezing Fog

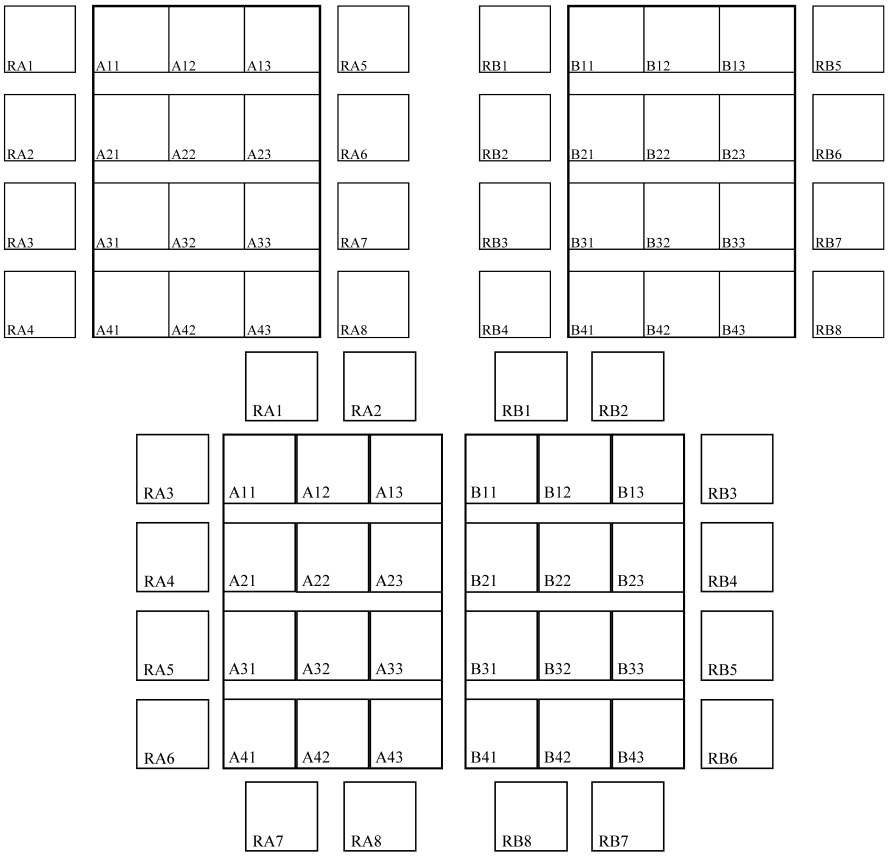


Figure 2 - Arrangement of Ice-catch Plates and Reference Ice-catch Plates

Two examples of dispositions of reference ice-catch plates (denoted RA1 to RA8 for plate A and RB1 to RB8 for plate B) each surrounding the 12 ice-catch plates replacing the test plates (A11 to A43 for test plate A and B11 to B43 for test plate B).

7. ENDURANCE TIME TEST—LABORATORY SNOW

This section is being developed for future versions of this ARP.

8. ENDURANCE TIME TEST—FREEZING DRIZZLE

8.1 Freezing Drizzle Test Equipment and Test Parameters

8.1.1 Environmental Chamber Equipment and Plates

In addition to the requirements given in 4.5, environmental chamber and associated equipment requirements for freezing drizzle endurance time testing are given in Table 4 and in the following paragraphs.

Table 4 Requirements for Freezing Drizzle Test Equipment

Test Parameters	Requirements
Environmental Chamber	
Air temperature range	0 °C to -10 °C
Minimum temperature sampling rate	1 datum per minute
Horizontal air velocity	≤ 1.0 m/s
Relative humidity	> 40 %
Test Plates	
Material	Aluminum alloy AMS 4037 or 4041
Test plate dimensions	500 mm long x 300 mm wide x 3.2 mm thick
Angle	10° ± 0.2
Surface finish	Average surface roughness: Ra ≤ 0.5 µm
Temperature at start of test	Within ± 0.5 °C of air temperature
Number of test plates	2 per fluid tested
Fluid application temperature	20 °C ± 5
† Ice-catch Pans	
Ice-catch pan dimensions	100 mm x 100 mm x 0.8 mm thick with all around rim 15 mm high
Number of reference ice-catch pans	8 surrounding each test plate
Number of ice-catch pans for measuring icing intensity variability across test plates	12 per test plate
‡ Ice-catch Pans	
Ice-catch pans	277 x 540 mm
Number of ice-catch pans	1 per test location
Spray Equipment	
Distance between nozzle and test plate	7 m ± 0.5
Water supply temperature	≤ 2 °C just before the nozzle
Water droplet median volume diameter	300 µm ± 100

† Method A
‡ Method B

8.1.2 Test Plates

8.1.2.1 Each test plate is removable and placed on a support that is housed within the environmental chamber.

8.1.2.2 Each test plate shall be equipped with a temperature sensor located on the underside of or embedded within the plate. This sensor shall be capable of measuring to an accuracy of ± 0.5 °C and shall be linked to an electronic data acquisition system.

8.1.2.3 Method A. The test plate support is set-up in such a way that it can accommodate eight 100 x 100 mm ice-catch pans surrounding, but not in contact with, each test plate. The test plate support face shall be inclined from the horizontal (see Table 4 for the angle). The test plates are placed on the support such that the fluid can freely flow off all edges of the plate. The test stand should be designed as to minimize the contact between the test surface and the support.

8.1.2.4 Method B. The test plate support is set up in such a way that it can accommodate six test plates. The test plate support face shall be inclined from the horizontal as specified in Table 4. The test plate is placed on the support such that the fluid can freely flow off all edges of the plate. The test stand should be designed to minimize the contact between the test surface and the support.

8.1.3 Ice-Catch Pans

The ice-catch pans for Method A are described in Figure 3.

8.1.4 Spray Equipment

8.1.4.1 It is a fundamental requirement of this test that the spray impinges onto the surface of the test plate as supercooled water droplets that freeze on impact. This is verified by observation of an ice-catch plate.

8.1.4.2 The equipment used to provide the water spray comprises a low-flow nozzle supplied with water of quality described in Table 5. This equipment is housed in the upper region of the test chamber above the test plate. The exact type and geometry of the spray system used to generate the water spray for the test is left to the discretion of the testing facility/site, provided the requirements of Table 4 and Table 5 are met.

8.1.5 Example of Spray Equipment

The hydraulic nozzle shown in Figure 4 comprises three sections: an outer unit holding two inner units. Water is stored in a pressurized tank and provides the flow to the nozzle. The water droplet size depends on the nozzle used and the settings on a pulse system which controls the flow of water to the nozzle. The icing intensity is controlled by selecting the opening and closing times (on/off) of the pulse system. An even distribution over the test plate is achieved by a controlled oscillation of the nozzle.

8.2 Freezing Drizzle Measurement Methods

8.2.1 Measurement Methods for Icing Intensity

The methods are the same as in 6.2.1 except that the ice-catch plates are replaced by ice-catch pans in 6.2.1.2 and that Table 3 is replaced by Table 5 throughout.

8.2.2 Measurement Methods for Icing Intensity Variability Across Test Plate

The methods are the same as in 6.2.2 except that: (a) the ice-catch plates are replaced by ice-catch pans in 6.2.2.2 and (b) Table 3 is replaced by Table 5 throughout.

8.3 Freezing Drizzle Test Conditions

Test conditions for freezing drizzle are in Table 5.

Table 5 - Freezing Drizzle Test Conditions

Test Condition	ZL-A	ZL-B	ZL-S	ZL-T	ZL-C	ZL-D
Air temperature, °C	-3 ± 0.5	-3 ± 0.5	-6 ± 0.5	-6 ± 0.5	-10 ± 0.5	-10 ± 0.5
Air temperature standard deviation, °C	0.3	0.3	0.3	0.3	0.3	0.3
† Icing intensity, g/dm^2/h	5 ± 0.2	13 ± 0.5	5 ± 0.2	13 ± 0.5	5 ± 0.2	13 ± 0.5
‡ Average icing intensity, g/dm^2/h	5 ± 0.4	13 ± 0.5	5 ± 0.4	13 ± 0.5	5 ± 0.4	13 ± 0.5
‡ Icing intensity standard deviation	< 0.4	< 0.7	< 0.4	< 0.7	< 0.4	< 0.7
† Icing intensity range across a test plate, g/dm^2/h	≤ 0.6	≤ 1.4	≤ 0.6	≤ 1.4	≤ 0.6	≤ 1.4
‡ Icing intensity range across all test plates, g/dm^2/h	≤ 1.4	≤ 2.2	≤ 1.4	≤ 2.2	≤ 1.4	≤ 2.2

† Method A
‡ Method B

8.4 **Freezing Drizzle Test Procedure**

8.4.1 Test Plate Cleanliness

Clean test plates according to 4.7.1.

8.4.2 Temperature Verification

Ensure the test chamber, fluid, and test plates are at the required temperature.

8.4.3 Failure Time

See 6.4.3 except that failure is defined in 8.4.6.

8.4.4 Icing Intensity

After all the plates have failed, turn off the water spray and weigh the ice-catch on each ice-catch plate; using a method such as described in 8.2.1, estimate the icing intensity for each test plate. If the icing intensity is not within the specified limits for the test being conducted, the time recorded is not valid.

8.4.5 Delayed Crystallization

See 4.7.3.

8.4.6 Failure Criterion

See 6.4.5.

8.4.7 Reproducibility/Precision

See 6.4.6.

8.4.8 Report

See 4.7.4.

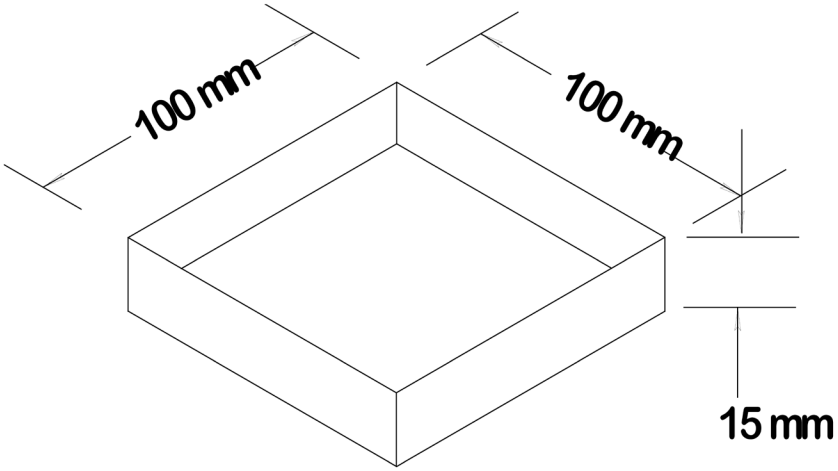


Figure 3 - Ice-catch Pans

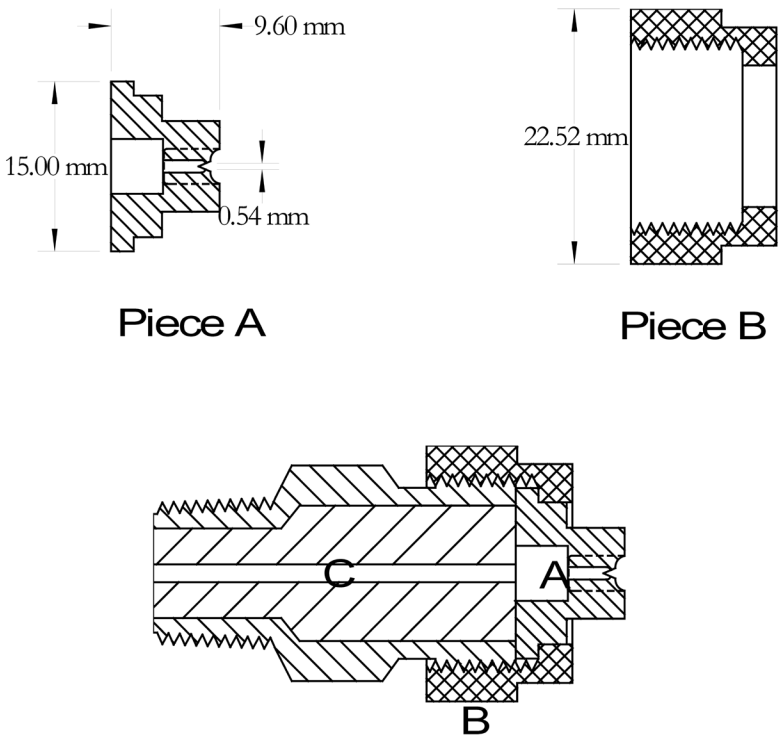


Figure 4 - Example of a Hydraulic Nozzle for Freezing Drizzle

9. ENDURANCE TIME TEST—LIGHT FREEZING RAIN

9.1 Light Freezing Rain Test Equipment and Test Parameters

9.1.1 Environmental Chamber Equipment and Plates

In addition to the requirements given in 4.5, environmental chamber and associated equipment requirements for light freezing rain endurance time testing are given in Table 6 and in the following paragraphs.

Table 6 - Requirements for Light Freezing Rain Test Equipment

Test Parameters	Requirements
Environmental Chamber	
Air temperature range	0 °C to -10 °C
Minimum temperature sampling rate	1 datum per minute
Horizontal air velocity	≤ 1.0 m/s
Relative humidity	> 40 %
Test Plates	
Material	Aluminum alloy AMS 4037 or 4041
Test plate dimensions	500 mm long x 300 mm wide x 3.2 mm thick
Angle	10° ± 0.2
Surface finish	Average surface roughness: Ra ≤ 0.5 μm
Temperature at start of test	Within ± 0.5 °C of air temperature
Number of test plates	2 per fluid tested
Fluid application temperature	20 °C ± 5
† Ice-catch Pans	
Ice-catch pan dimensions	100 mm x 100 mm x 0.8 mm thick with all around rim 15 mm high
Number of ice-catch pans	8 surrounding each test plate
Number of ice-catch pans for measuring icing intensity variability across test plates	12 per test plate
‡ Ice-catch Pans	
Ice-catch pans	277 x 540 mm
Number of ice-catch pans	1 per test location
Spray Equipment	
Distance between nozzle and test plate	7 m ± 0.5
Water supply temperature	≤ 2 °C just before the nozzle
Water droplet median volume diameter	1000 μm ± 100

† Method A
‡ Method B

9.1.2 Test Plates

9.1.2.1 Each test plate is removable and placed on a support that is housed within the environmental chamber.

9.1.2.2 Each test plate shall be equipped with a temperature sensor located on the underside of or embedded within the plate. This sensor shall be capable of measuring to an accuracy of ± 0.5 °C and shall be linked to an electronic data acquisition system.

9.1.2.3 The test plate support is set-up in such a way that it can accommodate eight 100 x 100 mm ice-catch pans surrounding, but not in contact with, each test plate. The test plate support face shall be inclined from the horizontal (see Table 6 for the angle). The test plates are placed on the support such that the fluid can freely flow off all edges of the plate. The test stand should be designed to minimize the contact between the test surface and the support.

9.1.3 Ice-catch Pans

The ice-catch pans, described in Table 6 and Figure 3, are used to evaluate the ice-catch.

9.1.4 Spray Equipment

9.1.4.1 It is a fundamental requirement of this test that the spray impinges onto the surface of the test plate as supercooled water droplets which freeze on impact. This is verified by observation of an ice-catch plate.

9.1.4.2 The equipment used to provide the water spray comprises a low flow nozzle supplied with water of quality described in 4.5.6. This equipment is housed in the upper region of the test chamber above the test plate. The exact type and geometry of the spray system used to generate the water spray for the test is left to the discretion of the testing facility/site, provided the requirements of Table 6 and Table 7 are met.

9.1.5 Example of Spray Equipment

See 8.1.5.

9.2 Light Freezing Rain Measurement Methods

9.2.1 Measurement Methods for Icing Intensity

The methods are the same as in 6.2.1 except that the ice-catch plates are replaced by ice-catch pans in 6.2.1.2 and that Table 3 is replaced by Table 7 throughout.

9.2.2 Measurement Methods for Icing Intensity Variability Across Test Plates

The method is the same as in 6.2.2 except that: (a) the ice-catch plates are replaced by ice-catch pans and (b) Table 3 in 6.2.2.2 is replaced by Table 7.

Table 7 - Light Freezing Rain Test Conditions

Test Condition	LZR-A	LZR-B	LZR-S	LZR-T	LZR-C	LZR-D
Air temperature, °C	-3 ± 0.5	-3 ± 0.5	-6 ± 0.5	-6 ± 0.5	-10 ± 0.5	-10 ± 0.5
Air temperature standard deviation, °C	*	*	0.3	0.3	0.3	0.3
† Icing intensity, g/dm^2/h	*	*	13 ± 0.5	25 ± 1.0	13 ± 0.5	25 ± 1.0
‡ Average icing intensity, g/dm^2/h	*	*	13 ± 0.5	25 ± 1.0	13 ± 0.5	25 ± 1.0
‡ Icing intensity standard deviation	*	*	< 0.7	< 1.5	< 0.7	<1.5
† Icing intensity range across a test plate, g/dm^2/h	*	*	≤ 1.4	≤ 3.0	≤ 1.4	≤ 3.0
‡ Icing intensity range across all test plates, g/dm^2/h	*	*	≤ 2.0	≤ 4.0	≤ 2.0	≤ 4.0

* Type I fluids are not tested in freezing rain at -3ºC because the latent heat of freezing in calm test conditions produces artificially long endurance times. Use results from testing at –6°C.
† Method A
‡ Method B

9.3 Light Freezing Rain Test Conditions

Test conditions for light freezing rain are in Table 7.

9.4 Light Freezing Rain Test Procedure

9.4.1 Test Plate Cleanliness

Clean test plates according to 4.7.1.

9.4.2 Temperature Verification

Ensure the test chamber, fluid, and test plates are at the required temperature.

9.4.3 Failure Time

See 6.4.3 except that failure is defined in 9.4.6.

9.4.4 Icing Intensity

After all the plates have failed, turn off the water spray and weigh the ice-catch on each ice-catch plate; using a method such as described in 8.2.1, estimate the icing intensity

for each test plate. If the icing intensity is not within the specified limits for the test being conducted, the time recorded is not valid.

9.4.5 Delayed Crystallization

See 4.7.3.

9.4.6 Failure Criterion

See 6.4.5.

9.4.7 Reproducibility/Precision

See 6.4.6.

9.4.8 Report

See 4.7.4.

10. ENDURANCE TIME TEST—RAIN ON A COLD-SOAKED WING

10.1 Rain on a Cold-Soaked Wing Test Equipment and Test Parameters

10.1.1 Environmental Chamber Equipment and Plates

In addition to the requirements given in 4.5, environmental chamber and associated equipment requirements for rain on a cold-soaked wing endurance time testing are given in Table 8 and in the following paragraphs.

Table 8 - Requirements for Rain on a Cold-Soaked Wing Test Equipment

Test Parameters	Requirements
Environmental Chamber	
Air temperature range	1 °C
Minimum temperature sampling rate	1 datum per minute
Horizontal air velocity	≤ 1.0 m/s
Relative humidity	> 40 %
Test Plates	
Material	Aluminum alloy AMS 4037 or 4041
Test plate dimensions	500 mm long x 300 mm wide x 3.2 mm thick
Angle	10° ± 0.2
Surface finish	Average surface roughness: Ra ≤ 0.5 µm
Number of test plates	2 per fluid tested
Fluid application temperature	20 °C ± 5
† Ice-catch Pans	
Ice-catch pan dimensions	100 mm x 100 mm x 0.8 mm thick with all around rim 15 mm high
Number of reference ice-catch pans	8 surrounding each test plate
‡ Ice-catch Pans	
Ice-catch pans	277 x 540 mm
Number of ice-catch pans	1 per test location
Cold Soak Box	
Material	Aluminum alloy AMS 4037 or 4041
Material Thickness	1.6 mm
Dimensions	430 mm x 300 mm x 75 mm
Coolant in box	65 % propylene glycol, 35 % water
Spray Equipment	
Distance between nozzle and test plate	7 m ± 0.5
Water supply temperature	≤ 2 °C just before the nozzle

† Method A, ‡ Method B

10.1.2 Test Plates

The test plate represents the upper surface of the cold-soak box (Figure 5).

10.1.3 Cold-Soak Box

Before starting the test, the cold-soak box (Figure 5) must be filled with coolant and both the box and its coolant must be at the pre-start temperature (see Table 9). It is acceptable to either refrigerate the box and its (static) coolant or circulate refrigerated coolant at an appropriate temperature to achieve the pre-start temperature. The cold-soak box shall be insulated (except for the test surface) with a 25 mm polystyrene jacket (RSI = 0.88). The box shall be equipped with a temperature sensing device capable of measuring the temperature of the test plate with an accuracy of ± 0.5 °C and situated within the test plate, 150 mm from the top and 150 mm from the side of the plate. This temperature sensor shall be linked to a data acquisition system to check and record the test plate temperature throughout the course of a test run. The cold-soak box face shall be inclined from horizontal (see Table 8 for the angle). The test plate is positioned on the box so that fluid can freely flow off all edges of the plate.

10.1.4 Spray Equipment

The equipment used to provide the water spray comprises a low-flow nozzle supplied with water of quality described in Table 8. This equipment is housed in the upper region of the test chamber above the test plate. The exact type and geometry of the spray system used to generate the water spray for the test is left to the discretion of the testing facility/site, provided the requirements of Table 8 and Table 9 are met.

10.1.5 Example of Spray Equipment

See 8.1.5.

10.2 Measurement Methods for Rain on a Cold-Soaked Wing

10.2.1 Measurement Methods for Icing Intensity

The methods are the same as in 6.2.1 except that the ice-catch plates are replaced by ice-catch pans in 6.2.1.2 and that Table 3 is replaced by Table 9 throughout.

10.2.2 Measurement Methods for Icing Intensity Variability Across Test Plates

The method is the same as in 6.2.2 except that: (a) the ice-catch plates are replaced by ice-catch pans and (b) Table 3 in 6.2.2.2 is replaced by Table 9.

10.3 Rain on a Cold-Soaked Wing Test Conditions

Test conditions for rain on a cold-soaked wing are in Table 9.

Table 9 - Rain on a Cold-Soaked Wing Test Condition

Test Condition	RCSW-A	RCSW-B
Air temperature, °C	1 ± 0.5	1 ± 0.5
Air temperature standard deviation, °C	0.3	0.3
Test plate temperature at start, °C	-10 ± 1	-10 ± 1
Pre-start coolant temperature, °C	-12 ± 1	-12 ± 1
Water droplet median volume diameter	300 μm ± 100	1400 μm ± 150
† Icing intensity, g/dm^2/h	5.0 ± 0.2	75.0 ± 3.0
‡ Average icing intensity, g/dm^2/h	5.0 ± 0.4	75.0 ± 3.0
‡ Icing intensity standard deviation	< 0.4	< 4.5
† Icing intensity range across a test plate, g/dm^2/h	≤ 0.6	≤ 9.0
‡ Icing intensity range across all test plates, g/dm^2/h	≤ 1.2	≤ 15

† Method A
‡ Method B

10.4 **Rain on a Cold-Soaked Wing Test Procedure**

10.4.1 Test Plate Cleanliness

Clean test plates according to 4.7.1.

10.4.2 Temperature Verification

Prior to the start of a test, ensure that the test chamber and fluid are at the required temperatures. Ensure that the cold-soak box and its coolant are at the pre-start temperature. Place both paper towels and a cover over the test plate and the ice-catch plates to prevent any accumulation of ice.

10.4.3 Failure Time

Wait for the temperature of the test plate (or, if no test plate is used, the upper surface of the cold-soak box) to be at the start temperature. When the start temperature is reached, remove the paper towels and cover. Continue as in 6.4.3 except that failure is defined in 10.4.6.

10.4.4 Icing Intensity

After all the plates have failed, turn off the water spray, and weigh the ice-catch on each ice-catch plate; using a method such as described in 8.2.1, estimate the icing intensity for each test plate. If the icing intensity is not within the specified limits for the test being conducted, the time recorded is not valid.

10.4.5 Delayed Crystallization

See 4.7.3.

10.4.6 Failure Criterion

See 6.4.5.

10.4.7 Reproducibility/Precision

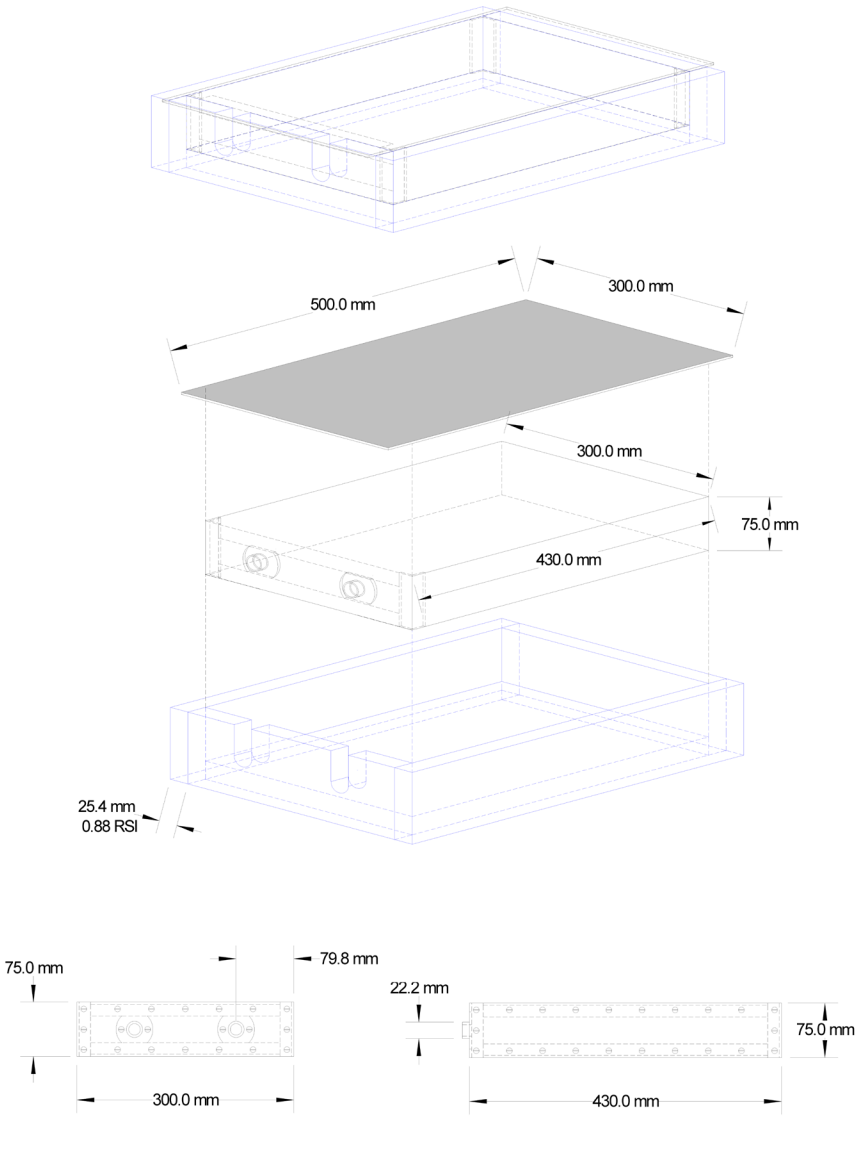
See 6.4.6.

10.4.8 Report

See 4.7.4.

Figure 5 – Cold-Soak Box

Profile view



2nd Ballot
June 2005

Page 41

11. ENDURANCE TIME TEST—NATURAL SNOW

The general requirements given in Section 4 are not applicable for the natural snow tests, except where otherwise specified.

11.1 Snow Test Equipment and Test Parameters

11.1.1 Conditions and Equipment

Test equipment and other requirements for natural snow endurance time testing are given in Table 10 and in the following paragraphs.

Table 10 - Requirements for Natural Snow Test Equipment

Test Plates	
Material	Aluminum alloy AMS 4037 or 4041
Test plates dimensions	500 mm long x 300 mm wide x 3.2 mm thick
Angle	10.0° ± 0.2
Surface finish	Average surface roughness: Ra ≤ 1.0 µm
Plate temperature at start of test	Typically within ± 0.5 °C of air temperature (See 11.5.2)
Number of tests	See 11.5.5
Fluid application temperature	See 11.5.2
Empty Aluminum Box	
Material	Aluminum alloy AMS 4037 or 4041
Material Thickness	1.6 mm
Dimensions	430 mm x 300 mm x 75 mm
Ice-catch Pans	
Ice-catch pan dimensions	Typically, 430 x 300 x 0.8 mm thick with all around rim 40 mm high and 35 mm flanges protruding from the shorter side.

11.1.2 Outside Air Temperature Measurements

The outside air temperature shall be measured using a thermometer that is shielded from radiation.

11.1.3 Lighting

The test site shall be equipped with artificial lighting facilitating observation of ice formation but positioned such that it does not interfere with air, fluid, and plate temperatures.

11.1.4 Wind Speed

Every time the precipitation rate (icing intensity) is measured, wind speed shall be measured using a suitable anemometer or velocity meter. Wind speed shall be measured at 2 meters above the ground in the proximity of the test stands.

11.1.5 Calibration of Standard Measuring Devices

All thermistors, electronic balances, and timing devices shall be maintained in a known state of calibration, in accordance with recognized international standards, by calibrating each instrument at least once every year or whenever a piece of equipment is repaired, replaced, moved, or otherwise suspect. A written record of the calibrations shall be kept available.

11.1.6 Test Plates

The test plate represents the upper surface of the empty aluminum box (Figure 5).

11.1.7 Empty Aluminum Boxes and Test Stand

The empty aluminum box provides a thermal equivalent to the wing leading edge. Each test box is removable and placed on a test stand.

The empty aluminum box shall be insulated (except for the test surface) with a 25 mm polystyrene jacket (RSI = 0.88). The box shall be equipped with a temperature sensing device capable of measuring the temperature of the test plate with an accuracy of ± 0.5 °C and situated within the test plate, 150 mm from the top and 150 mm from the side of the plate. This temperature sensor shall be linked to a data acquisition system to check and record the test plate temperature throughout the course of a test run. The empty aluminum box face shall be inclined from the horizontal (see Table 10 for the angle). The test plate is positioned on the box so that fluid can freely flow off all edges of the plate. The test stand should be designed to minimize the contact between the test surface and the support.

For materials of construction and dimensions, see Table 10 and Figure 6.

11.1.8 Markings

Test box surfaces can have pen markings to help estimate the percent coverage. For instance, each test box surface can be marked as shown in Figure 6 with lines at 2.5 and 15 cm (1 and 6 in.) from the panel top edge, with 15 crosshair points and with vertical lines 2.5 cm (1in.) from each side; this marks off a working area of 25x40 cm (10x18 in.) on each panel. All marks can be made using a 0.3 cm (1/8 in.) thick black marker or silk screen process, which does not come off with application of the test fluids or any of the cleaning agents.

11.1.9 Stand

A typical test stand is illustrated in Figure 6; it may be altered to suit the location and facilities, but the angle for the plates must conform to Table 10. There shall be no

flanges or obstructions close to the edges of the plates that could interfere with the airflow over the plates.

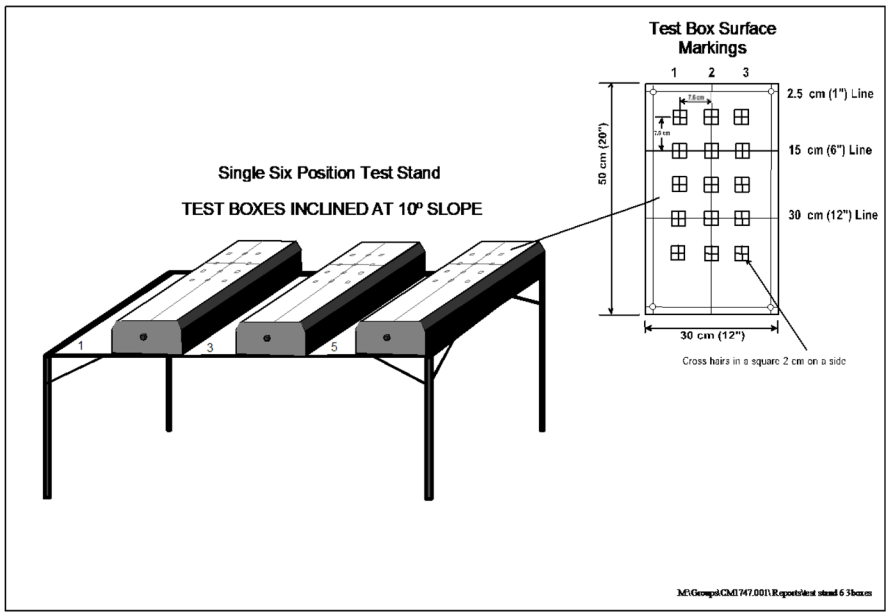


Figure 6 - Test Stand and Boxes

11.1.10 Wind Orientation of the Test Stand

The test stand shall be oriented facing into the predominant wind direction at the beginning of the test. A test stand is defined as facing into the wind when the long axes of the test panels are facing into the wind direction. The orientation of the test stand shall be recorded. The wind direction shall be recorded at least every 15 minutes. If the wind shifts during the test, do not move the stand.

11.1.11 Plate Pan for Precipitation Rate Measurement

A plate pan, placed at a 10º inclination on the test stand will be used to collect and weigh snow. The positioning of the plate pan on the test stand shall be such that the longer dimension axis of the pan is parallel with the longer dimension axis of the test plate. The procedure for the collection of precipitation rates using this method is described in 11.2. A schematic of the plate pan is provided in Figure 7.

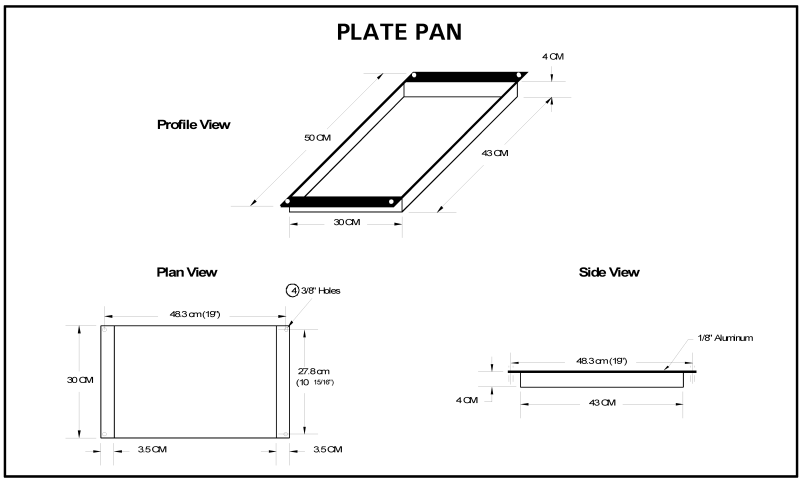


Figure 7 - Example of Schematic of Plate Pan

11.2 Snow Measurement Methods

11.2.1 Measurement Method for Snow Intensity

Ensure that the plate pans are identified with a marking when using more than one. Coat the bottom of each plate pan, as well as the inner sides of each pan, with at least 1 mm of neat anti-icing fluid. Weigh the wetted pans to the nearest 0.2 g. Record the start time (hr/min/sec) of the rate collection before leaving the rate station to place the pans on the test stand, taking into consideration the time delay necessary to proceed outside from the rate station.

The rate pans shall remain on the test stand collecting snow for a period no longer than 10 minutes. While positioned on the test stand, the plate pans should be carefully rotated every 5 minutes to prevent accumulating snow from blowing away. The time of rotation should be reduced to 2 minutes during heavy precipitation or periods of high winds.

Prior to the removal of the plate pans from the test stand for re-weighing, carefully wipe away any accumulated precipitation from the edges of the plate pans (ensure that the precipitation does not fall into the plate pan). Carefully remove the plate pans from the stand and proceed immediately to the rate station to re-weigh the pans. Care must be taken to ensure that snow or ice does not fall into the pans when transporting them into the weighing area. Do not rest the pans on top of one another while transporting. Once inside the protected weigh station area, record the rate collection end time (hr/min/sec). Carefully wipe the bottom, sides and lips of the pans prior to weighing. Weigh the plate pan, record the new weight, and bring the pans back outside. Continue the rate collection procedure until the final plate on the test stand has failed.

11.2.2 Rate Calculation

The rate for any holdover time test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of the particular test.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 8. The start and end times of the test are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t_1, t_2, and t_3 (minutes). The calculated rates for each collection period are indicated by R_1, R_2, and R_3 (g/dm^2/h). In order to calculate the average rate for this pan, the following formula (Equation 5) is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3} \qquad \text{Equation 5}$$

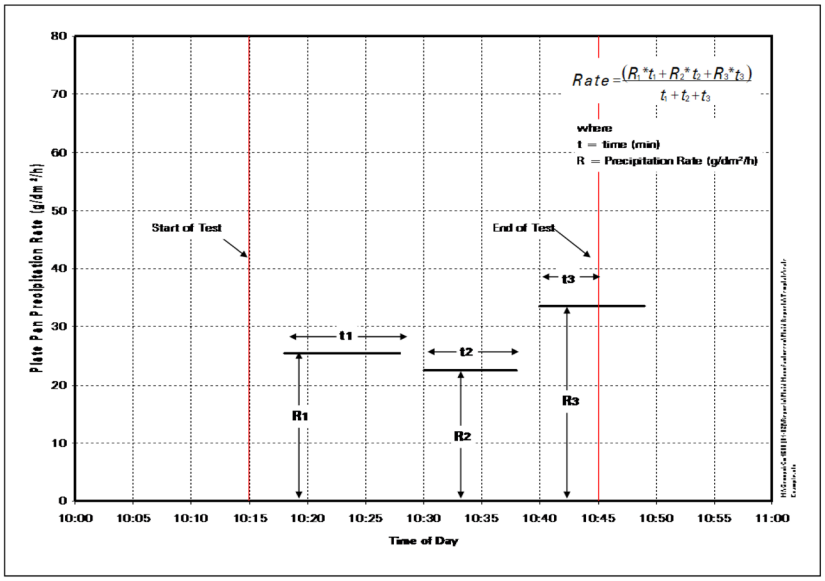


Figure 8 - Calculation of Outdoor Precipitation Rate

In the example shown in Figure 8, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

$$= 25.9 \text{ g/dm}^2\text{/h}$$

11.3 Snow Test Precipitation Rate

Since tests are conducted outside, the precipitation rate cannot be controlled. Tests may be conducted at any precipitation rate. It is recommended that tests be conducted under all snow precipitation rate ranges in the Type I HOT guidelines (very light snow, light snow, and moderate snow).

11.4 Snow Test Temperature

Since tests are conducted outside, the test temperature cannot be controlled. Tests may be conducted at any temperature. It is recommended that tests also be conducted at the lower end of temperature ranges in the Type I HOT guidelines.

11.5 Snow Test Procedure

11.5.1 Test Plate Cleanliness

The test plates shall be free of any visible contamination.

Before applying test fluid to a plate, use a squeegee to remove any precipitation or moisture from the surface of the test plate. Prior to the start of the test, rinse and clean the test plate with the fluid to be tested. Remove the fluid used to clean the plate with a squeegee and quickly begin the test. To avoid cross-contamination of fluids, one squeegee shall be used per deicing product. Alternatively clean according to 4.7.1.

11.5.2 Fluid Application

The fluid application procedure for Type I fluid endurance tests in natural snow conditions involves the following:

a) Use an empty aluminum box (see 11.1.7 for details) treated according to the procedure outlined below;
b) Clean all contamination from the test surface and wet the surface with a small amount of test fluid at ambient temperature prior to applying test fluid;
c) Apply 0.5 L of test fluid heated to 60ºC (+2ºC and 0ºC) using a fluid spreader positioned along the top edge of the test surface; and
d) Position a spreader horizontally at the top end of the test plate, supported at a fixed distance above the plate surface by wood forms at each end. The spreader is constructed from a length of PVC pipe, 30 cm long and with a 15 cm diameter. The upper side of the pipe has a large opening, which allows fluid to be poured quickly into the pipe. The underside of the pipe has 12 drain holes, 4.8 mm (3/16 in.) diameter, at equal intervals along the length.

Prior to the application of fluid, the plate temperature should be at equilibrium with the outside air temperature. The actual plate temperature may be different than the outside air temperature due to radiation effects, possibly as much as 2 °C.

11.5.3 Failure Time

Pour the test fluid onto each test surface. As soon the fluid has spread over the plates start the timing device. Observe the test surfaces and, when the failure occurs (defined in 11.5.4), record the time as the endurance time.

11.5.4 Failure Criterion

Failure is called when the accumulating snow fails to be absorbed at any five of the crosshair marks on the panels or when 30 percent of the test panel is covered with accumulating precipitation.

Fluid at a crosshair is considered failed when, as viewed from a shallow angle, snow (not slush, but white snow) on the fluid is no longer being absorbed by the fluid.

In general, there are two modes of failure in natural snow tests:

- Dilution failure: The fluid has eroded due to dilution and snow begins to accumulate on the plate surface; and
- Snow-bridging failure: The fluid no longer absorbs the snow and it begins to rest on top of the fluid.

An example of a typical dilution-style failure is shown in Photo 1. In this case, the fluid has been diluted due to ongoing precipitation and the fluid film has eroded substantially. Failures have reached just beyond the 7.6 cm (3 in.) line on the plate (white snow is visible in the failed area). Dilution failures normally occur from top to bottom on the test surface and are common at warm temperatures and low rates of precipitation.

An example of a snow-bridging failure is shown in Photo 2. In this case, the fluid resists dilution and a thick film of fluid remains on the entire plate surface. Plate failure has occurred in this test because snow, resting on top of the fluid, covers more than 1/3 of the plate surface. Snow-bridging failures do not always occur in top-to-bottom fashion and are common at cold temperatures and high rates of precipitation.

Type I fluid failures are typically dilution failures. The layer of Type I fluid that remains on the test surface after application is much thinner than that of a Type II or IV fluid. Type I fluid also dilutes faster than Type II or IV fluid, diminishing significantly the chance of having a snow-bridging type of failure.

11.5.5 Reproducibility/Precision

Outdoor snow precipitation is variable in nature. All of the data points collected are used for the regression analysis.

The endurance times are obtained by producing a best-fit regression curve using a power-law transformation based on all of the data collected. A minimum of 20 data

points is recommended to generate the regression curves for any fluid. A minimum test point distribution should contain data collected in all applicable temperature ranges and the widest range of snow rate conditions possible.

The equation used to treat the collected data for any fluid is as follows:

$t = cR^a(2-T)^b$ Equation 6

where
t = time (minutes)
R= rate of precipitation (g/dm^2/hr)
a, c= coefficients determined from the regression
T= temperature

The general form of the regression equation was modified for natural snow by substituting "2-T" for the variable "T" to prevent taking the log of a negative number, as natural snow can occur at temperatures approaching 2 °C.

11.5.6 Type and Classification of Solid Precipitation

The solid precipitation observed for each test in natural conditions will be classified and recorded. A black velvet-covered board should be used to facilitate the collection and identification of solid precipitation. Expose the black velvet-covered board to the natural precipitation for a period of 10 seconds. Using Figure 9, determine and record the form of the solid precipitation collected on the black velvet-covered board. If several forms of precipitation co-exist, record all of them. For example, if snow grains are mixed with snow, note that both forms of precipitation exist.

The World Meteorological Organization (WMO) defines snow grains as:

Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.

Only snow and snow grain data (F1 to F7) will be used to determine snow endurance times. Data obtained containing precipitation classifications other than those identified in F1 to F7 in Figure 9 will not be used to generate snow endurance times.

11.5.7 Report

See 4.7.4, except for item (l).

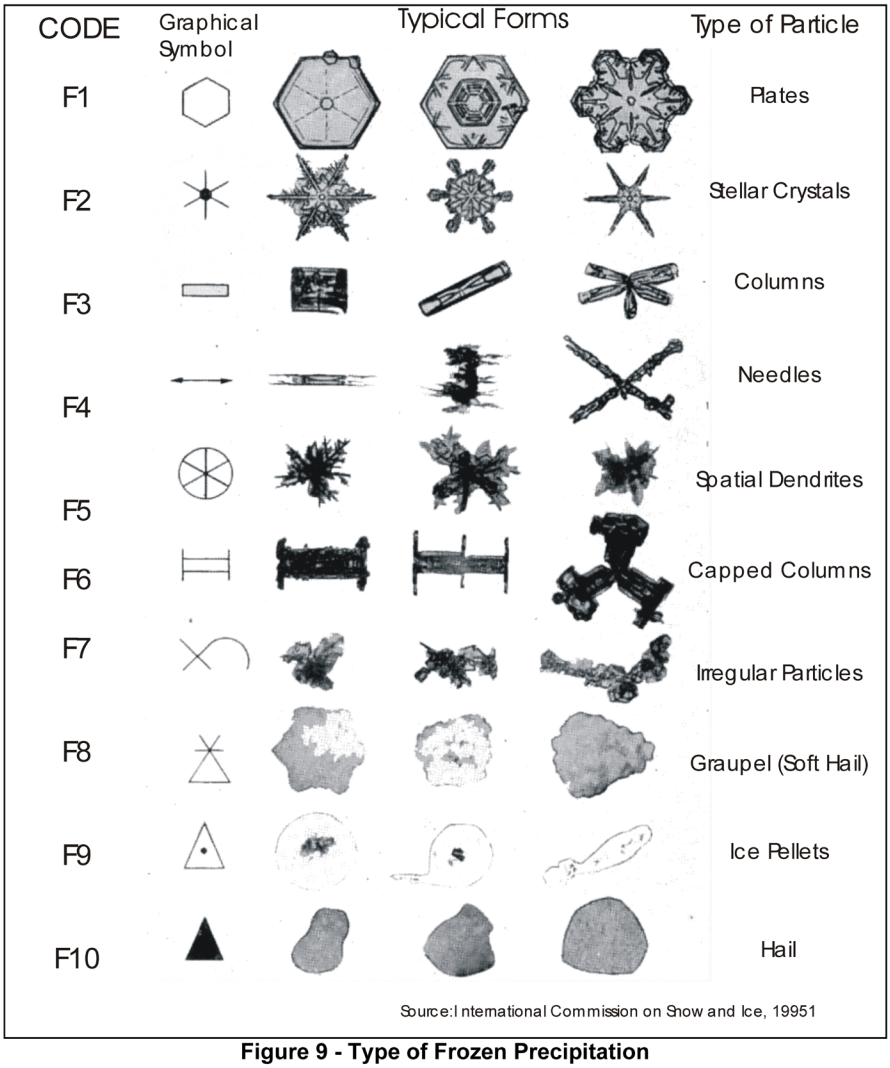


Figure 9 - Type of Frozen Precipitation

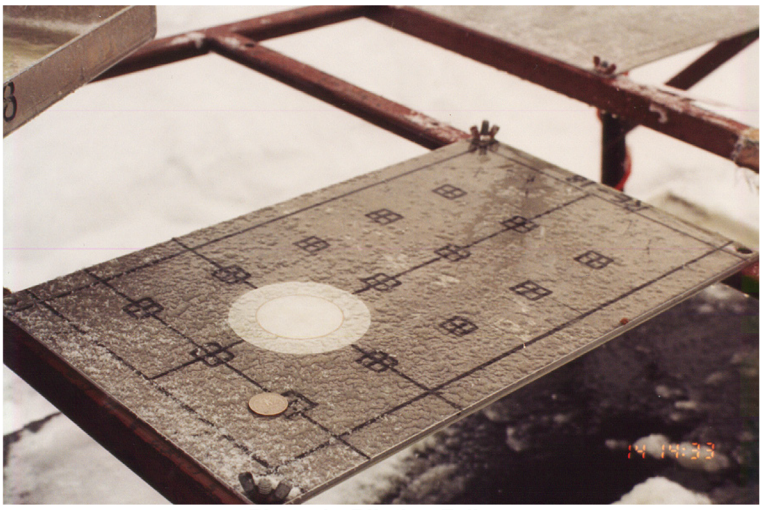


Photo 1 - Dilution Failure



Photo 2 - Snow Bridging Failure

12. NOTES

12.1 Key Words

Endurance, holdover time, holdover, HOT, Type I fluid, aircraft, exterior, surfaces, snow, frost, ice, freezing, rain, drizzle, frost, fog, cold, soaked, wing.

PREPARED BY SAE COMMITTEE G–12, AIRCRAFT GROUND DEICING

APPENDIX E

INDOOR LABORATORY SNOW PROTOCOL FOR ENDURANCE TIME TESTING

1. ENDURANCE TIME TEST— INDOOR LABORATORY SNOW

1.1 Inside Snow Test Equipment and Test Parameters

1.1.1 Environmental Chamber Equipment and Plates

In addition to the requirements given in 5.5, environmental chamber and associated equipment requirements for laboratory snow endurance time testing are given in Table 1 and in the following paragraphs.

Table 1: Requirements for Indoor Snow Test Equipment

Test Parameters	**Requirements**
Environmental Chamber	
Air temperature range	-25 to 0 ºC
Minimum temperature sampling rate	1 Datum per minute
Horizontal air velocity	≤ 1 m/s
Relative humidity	0 % < Rh < 75%
Test Plates	
Material	Aluminum alloy AMS 4037 or 4041
Test plate dimensions	500 mm long x 300 mm wide x 3.2 mm thick
Angle	10.0° ± 0.2
Surface finish	Average surface roughness: Ra ≤ 0.5 μm
Number of test plates	2 per fluid per test condition

1.1.2 Test Plates and Test Stand

1.1.2.1 Each test plate is removable and placed on a support that is housed within the environmental chamber.

1.1.2.2 Each test plate shall be equipped with a temperature embedded within the plate in the centre, 1/3 of the way down. This sensor shall be capable of measuring to an accuracy of ±0.5 °C and shall be linked to an electronic data acquisition system. Each test plate shall be equipped with temperature control equipment that prevents its temperature to descend below the values prescribed in Table 2. [At the start of the test (and maybe the end) the plate temperature is not within that range, it is the same as the air temperature and therefore it has to be a minimum] [If the plate temperature especially at the end of the test is not as per the values in Table 2, then the ET results will be different. This is one of the reasons we are cooling the room more than the test condition temperature].

1.1.2.3 The test plate support face shall be inclined from the horizontal (see Table 1 for the angle). The test plates are placed on the support such that the fluid can freely flow off all edges of the plate and be collected, along with the incoming precipitation, into a pan (Figure 1). The pan rests on a balance capable of recording the weight of the fluid and incoming snow throughout the test. The balance is then used to measure, and, along with a computer control program, control, the rate of snow falling, to meet the prescribed rates of Table 2.

1.1.3 Test Plate Temperature

1.1.3.1 Several years of testing have indicated that in order to get a reasonable correlation between indoor and outdoor endurance times, the temperature of the test plate needs to be controlled. Research has shown that the best correlation between indoor and outdoor results is achieved when the plate temperature is set according to the following equation:

PT = TT – 0.065 * II – 0.5, where:

PT – Plate Temperature in ºC

TT – Test Condition Temperature in ºC

II – Icing Intensity ($g/dm^2/hr$)

The test values indicated in Table 2 are calculated using the above equation.

1.1.4 [See note above, we are only heating the plates, not cooling] [as per my note above, this will need some discussion] Snow Sources:

1.1.4.1 The precipitation may be natural or laboratory-made simulated snow. Laboratory-made snow shall be made with deionized water. The snow shall be in the form of solid crystals and meet the snow density requirements described herein. It shall show no sign of sintering, agglomeration or recrystallization (if stored, sintering may occur within seven days depending on the form of the snow crystals and storage conditions). The snow density, after distribution on the plate, must remain within the requirements that are described herein.

1.1.4.2 The method of collecting natural snow or the method of making laboratory snow is left to the discretion of the facility/site as long as the requirements of 1.1.4.1 are met. Examples of such snowmaking (and of snow distribution systems) can be found below.

1.1.5 Snow Distribution System

1.1.5.1 Configuration Requirements: For tests on Types, II, III and IV, the configuration of the snow distribution system is left to the discretion of the facility/site as long as all the parameters shown in Table 2 are satisfied.

1.1.6 Example 1: Snow Making, Storage and Distribution System

1.1.6.1 General: In this example, the system can be divided into three parts: snow making, snow storage, and systematic distribution of the snow onto the test plates.

1.1.6.2 The artificial snow is made using a fine water spray which freezes in the air to produce an artificial soft rime. The exact type and geometry used to generate the water spray is left to the discretion of the testing facility/site, provided the artificial snow made has a density of less than 0.25 g/cm³ when measured according to section 1.2.1.

1.1.6.3 Example of an Artificial Snow Making Method: The artificial snow is made in a cold chamber by means of two pneumatic water spray nozzles supplied with water and compressed air. The nozzles produce a spray of very fine water droplets which become supercooled in cold air and freeze to form solid ice crystals on contact with a collection plate on the chamber floor.

1.1.6.4 Typical parameters are:

a) Air temperature: -20°C ± 5

b) Water droplet size: Median volumetric diameter, MVD = 22 μm ± 3

c) Water flow rate to nozzle: 70 ml/minute

d) Air pressure to nozzle: 260 kPa

1.1.6.5 Artificial Snow Storage: The laboratory-made snow shall be stored in an insulating container kept in a freezer at a temperature below -10°C for no longer than 2 weeks prior to testing. The snow quality shall be verified prior to each test by means of a density measurement of section 1.2.1. If the artificial snow shows any evidence of sintering, agglomeration or crystallization, it shall not be used.

1.1.6.6 Artificial Snow Distribution: Once the snow has been made and stored it must be evenly distributed over the test plates. The exact method used is up to the discretion of the test facility but it must meet the allowed variations presented in Table 2.

1.1.6.7 Example of an Artificial Snow Distribution System: For the snow tests, the snow is distributed as ice particles in the form of clusters to obtain the desired range. The snow is placed in a U-shaped aluminum box, 320 mm long, 253 mm high and 132 mm wide at the top, with a 65 mm high drawer a the top with a sliding base which allows the addition of snow in between and during tests (Figure 1). The box is suspended from a track around 336 mm above the bottom of the test plate. The track is attached to a motor which provides the lateral movement of the snow box. The lateral displacement speed depends on the desired snow intensity. The snow is continually stirred inside the box by a rotating system consisting of three blades disposed at 120° angles from each other (Figure 2). Each blade measures 50 x 300 mm and consists of a frame housing a wire mesh. The continued rotation of the blades prevents clumping of the snow prior to dispensing. The box contains an opening at the base, 10 mm wide along the length of the box. This opening houses a 32 mm diameter cylinder to transfer snow from the box to the test plate, which contains cavities arranged in 6 rows at 60° spacing (Figure 3). The cylinder turns after a given time interval thus dispensing snow clusters onto the test plate. The rotation speed of the cylinder is adjusted by the computer control to obtain the desired snow intensity.

1.1.6.8 Temperatures: The plate temperature at start of tests shall be within O.5ºC of air temperature. The fluid application temperature shall be within 3ºC of the air temperature. Temperature control shall be such that there is capability of providing heat to the test plate to maintain it within the limits prescribed in Table 3. For the -3ºC condition, the air temperature cannot rise above -5ºC in the cold room since the snow may melt and/or re-crystallize.

1.1.6.9 Balance: Each test plate shall be placed on an individual support such that the fluid can freely flow off all edges of the plate and be collected, along with the incoming precipitation, into a pan (Figure 1). The pan is then placed onto a balance capable of recording the weight of the fluid and incoming snow throughout the test. The balance is then used to measure, and, along with a computer control program, control, the rate of snow falling, to meet the prescribed rates of Table 2.

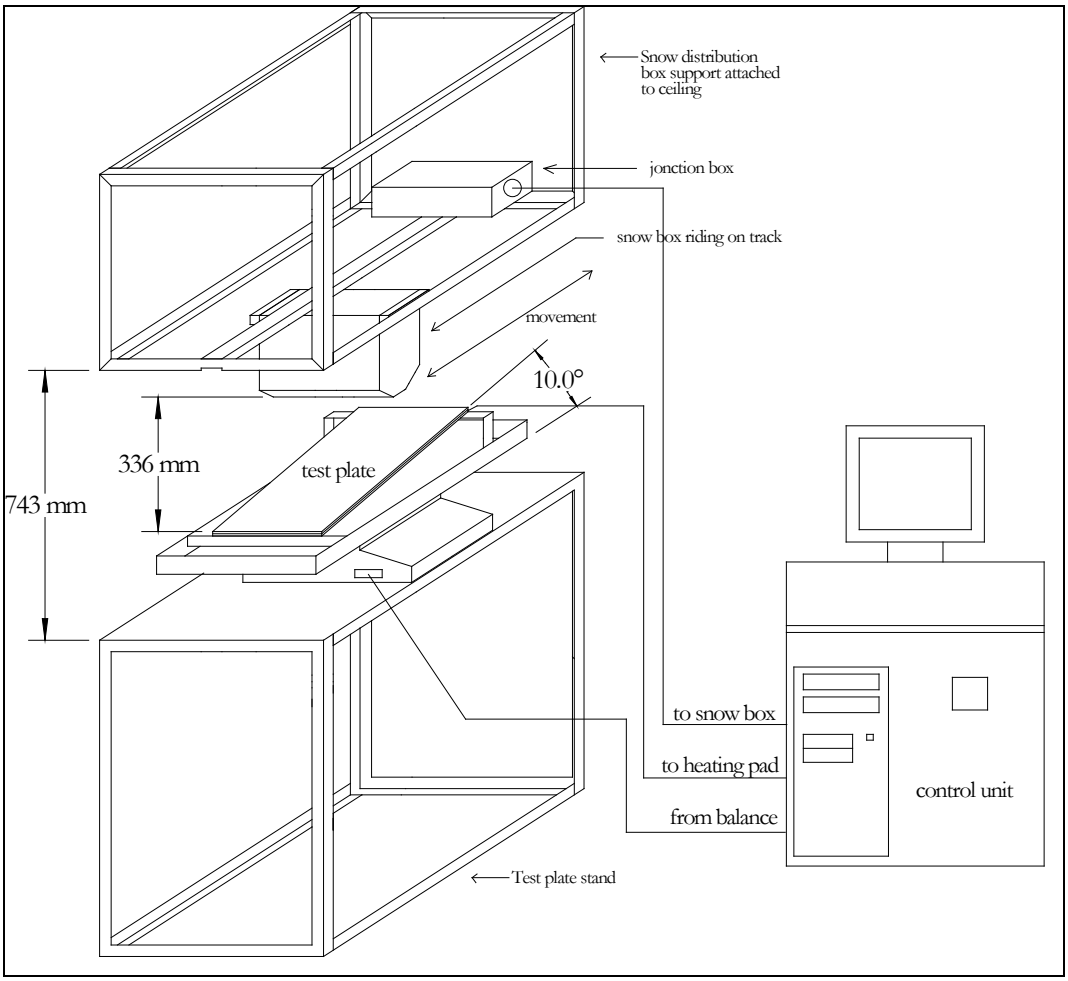


Figure 1: Snow Box Distribution System

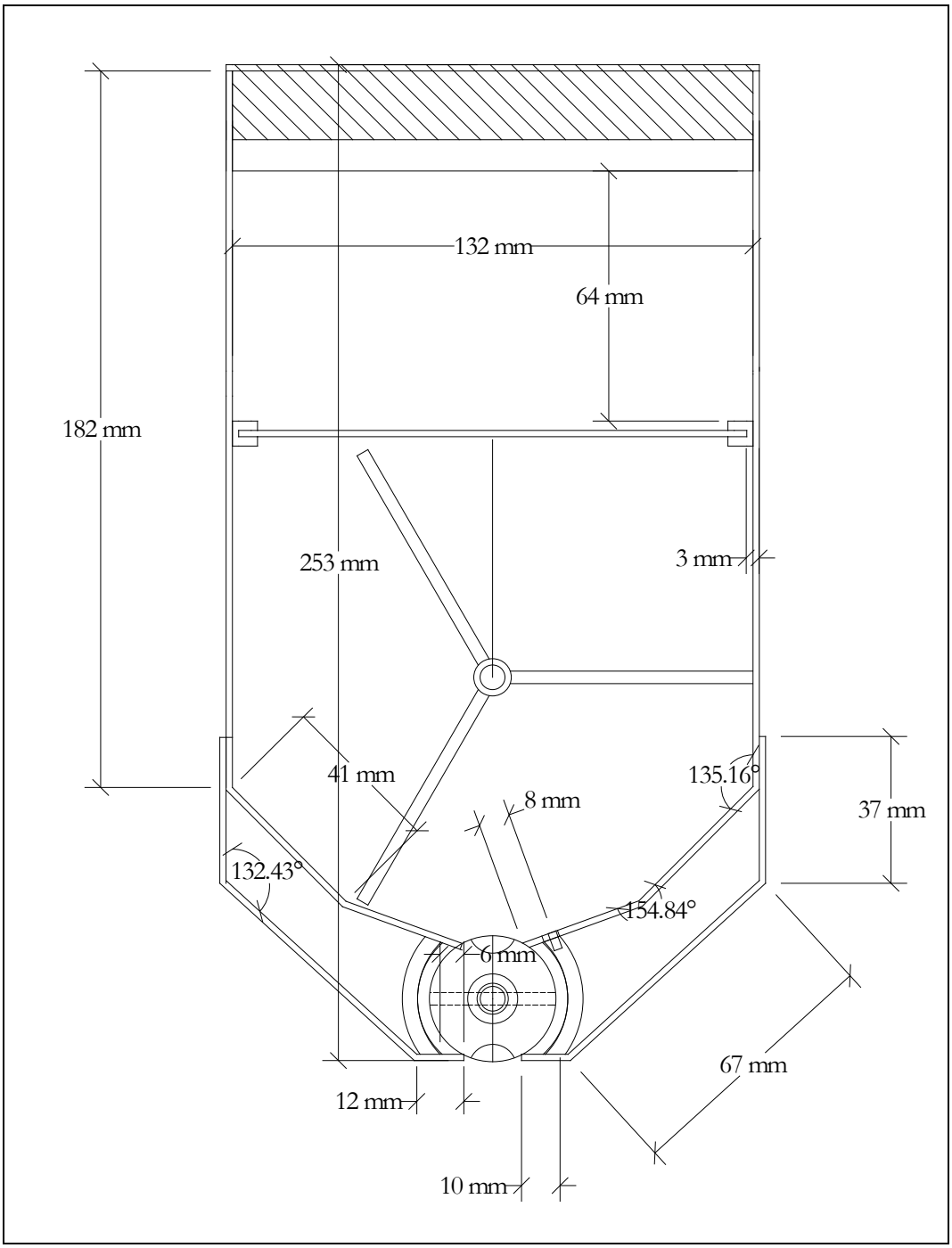


Figure 2: Cross-Section of Snow Box

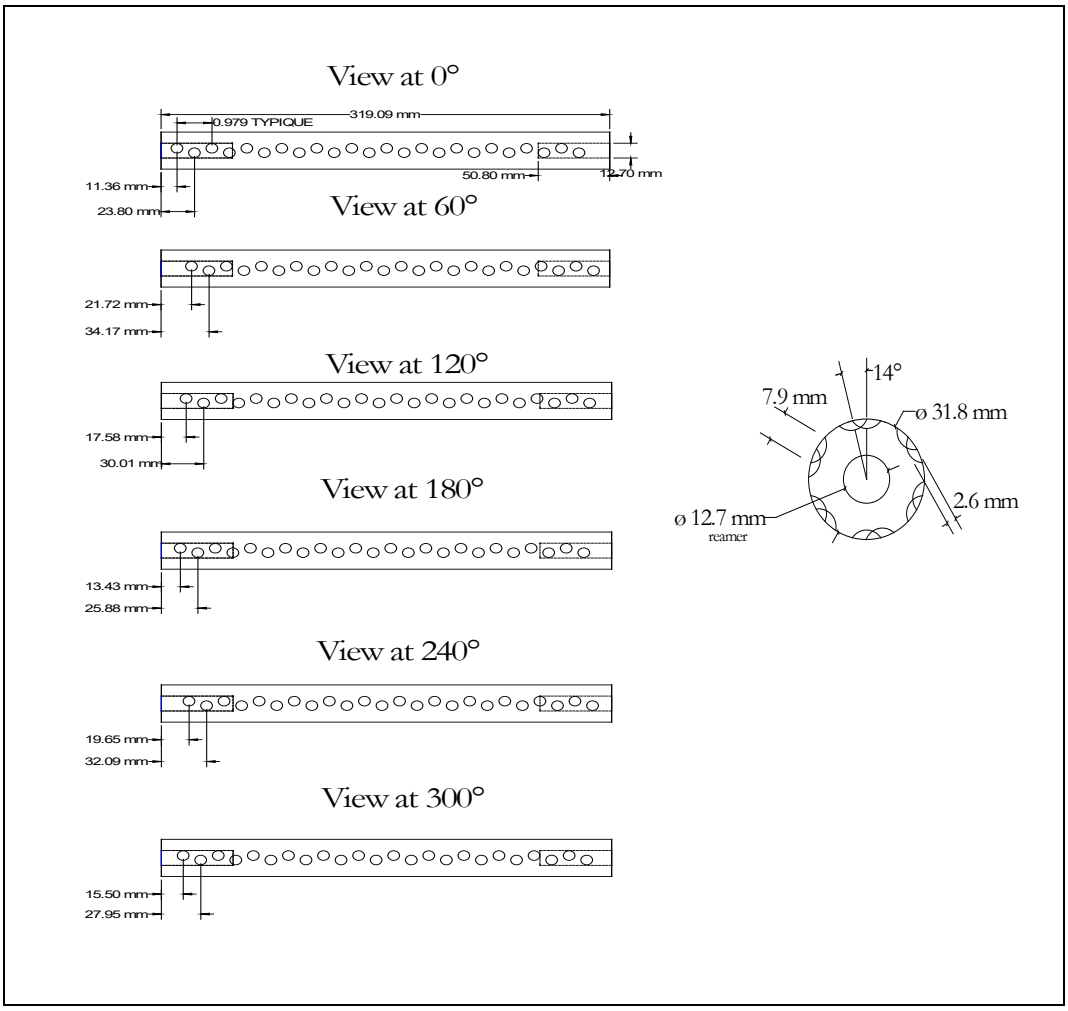


Figure 3: Side Views and Cross Section of Acetal Cylinder with 6 Rows of 24 Cavities which Transfer Snow from the Box to the Test Plate

1.1.7 Example 2 Simultaneous Artificial Snow Making and Fluid Testing System

1.1.7.1 General: The artificial snow generating system described here generates artificial snow at the same time as the fluid test by mechanically shaving a deionized water ice core inside an enclosure measuring approximately 3 meters tall. The length and width are trapezoidal with the top of the machine being shorter in length and width than the bottom of the machine. The shaving is accomplished with a 7.5 cm diameter drill bit (or potentially larger) rotating between 620 and 3100 rpm which is wider than the typical 6 cm diameter ice core. The ice core is fed with a horizontally oriented constant speed translator into the rotating drill bit. Ice shavings are produced with a snow density less than 0.10 g/cm^3. The snow density is measured by allowing the snow to build up on the plate to about 1 cm and then measuring the depth at various locations and weighing the mass. The size of the ice shavings should be between 0.5 and 10 mm in order to simulate actual snow. The distance between the ice core and the test plate must be greater than 500 mm in order to achieve a more even snowfall distribution across the test plate. Icing intensity (snowfall rates) up to 50 g/dm^2/hr can be generated controlling the speed of the ice core translator with a digitally controlled stepper motor. Only one test plate can be tested at a time with this system due to the limited dispersion of the snow. Snow is concentrated onto the test plate by a semi-circular panel positioned above and perpendicular to the spread of ice core shavings produced by the drill bit. Typical horizontal distance of the deflector panels from the snow generation point is 10 cm. To aid in the production of a uniform snow distribution, the snow could be dispersed with air from air jets placed throughout the enclosure or other methods.

1.1.7.2 Generation of Ice Cores: Ice cores are produced with deionized water in 6 cm inner diameter cylindrical molds with an open top. The length of the ice core and molds should be at least 112 cm long in order to have sufficient ice for the duration of the snow test. The ice core molds should use a tapered insulation such that the lower part of the mold is half insulated and the upper part of the mold is fully insulated; this causes freezing to proceed from the lower to the upper part of the mold, eliminating cracks in the ice core which can cause the core to shatter upon removal from the mold or shaving in the machine. Ice cores should be defrosted slowly by exposing to room temperature air in order to prevent cracking of the ice. The bottom part of the mold should be kept out of thermal contact with the floor to prevent non-uniform thawing. Ice cores should be removed from the molds the day of the experiment in order to have a uniform size core unaffected by sublimation.

1.1.7.3 To ensure that the desired test plate temperature is achieved and maintained during the test, the cold room temperature shall be, typically, 2°C colder than the test plate temperature. The temperature of the applied fluid shall be between the cold room set temperature and the test condition temperature. The test condition temperature is defined according to the temperature breakdowns in the holdover time tables and is presented in Table 2.

1.2 Snow Measurement Methods

1.2.1 Snow Density

The snow density is:

$$\rho = \frac{M_{full} - M_{empty}}{Volume}(g/cm^3) \qquad \text{(Eq. 1)}$$

where:

M_{full} = Mass of the snow filled container (g)

M_{empty} = Mass of the empty container (g)

Volume = Volume of the container (cm^3)

Similarly, another method could be used to measure snow density. Allow snow to accumulate on a plate (50 cm x 30 cm) without fluid until approximately 1 cm of snow has accumulated. Measure the total mass of accumulated snow, and then the depth at various locations to get the density.

1.2.2 Snow Measurements for Use with Method in Example 1

1.2.2.1 Snow Density Measurement method: Note that all material used to make the density measurement must be at the cold room temperature. Weigh an empty plastic container. Sift snow over the plastic container using a standard domestic flour sifter until the container is full. Level the snow in the container using a plastic ruler, while taking care not to compact the snow. Weigh the container to 0.1 g.

1.2.2.2 Icing Intensity: An electronic balance is placed under the test plate support and records the weight of the snow falling on the test plate (Figure 1). This data is then acquired by the test program which controls the snow intensity throughout the duration of the test.

1.2.2.3 Snow Intensity Variability Across the Test Plate: The method is the same as 6.2.1 except that the ice-catch plates are replaced with snow-catch pans. The snow catch pans are used to evaluate the snow distribution during calibration tests. The snow-catch pans are 100 mm x 150 mm x 0.8 mm thick with all round rim 15 mm high. Ten snow-catch pans per test plate are used for measuring snow intensity variability across the test plates. The icing intensity range across a test plate shall be within 1.5 g/dm²/h and 4.0 g/dm²/h for icing intensities of 10 g/dm²/h and 25 g/dm²/h, respectively.

1.2.3 Snow Measurements for Use with Method in Example 2

1.2.3.1 Icing Intensity Method: The icing intensity shall be appropriately measured and fall within the requirements of Table 2.

1.2.3.2 Icing Intensity Standard Deviation: The icing intensity standard deviation shall be measured over the duration of the test, after stabilization (typically 5 minutes following the start of the test), and shall fall within the limits of the icing intensity in Table 2 for each test condition.

1.2.3.3 Icing Intensity Variability Across Test Plates: Range Measurement Method: To assess the icing intensity across a test plate, the test plate is replaced with six snow-catch pans. The snow-catch pans are used to evaluate the snow distribution during calibration tests. The ice-catch pan dimensions are 150 mm x 167 mm x 0.8 mm thick with all around rim 15 mm high. Two pans are placed on the top, middle, and bottom, respectively in order to ensure that the top to bottom and side to side snow distribution is sufficiently uniform. The evaluation of icing intensity variability involves exposing the pans to snow generated by the snow machine and then weighing the pans at specific time intervals. The difference in the pan weight before and after exposure to the snow period is the icing intensity (snow catch) for each pan. The average icing intensity of the pans shall fall within the limits of the icing intensity in Table 2 for each test condition. The icing intensity range of the pans shall be within 20% of the desired icing intensity for the test condition.

1.3 Snow Test Conditions

Test conditions for snow tests performed inside are in Table 2.

1.4 Snow Test Procedure

1.4.1 Test Plate Cleanliness

Clean test plates according to 4.7.1.

1.4.2 Temperature Verification: Ensure the test chamber, fluid and test plates are at the required temperature

1.4.3 Failure Time

See 11.4.3 except that failure is defined in 11.4.4.

1.4.4 Icing Intensity

After the plate has failed, estimate the icing intensity for the test. If the icing intensity is not within the specified limits (Table 2) for the test being conducted, the test is invalid.

1.4.5 Failure Criterion

See 6.4.6.

1.4.6 Reproducibility/Precision

See 6.4.7.

1.4.7 Report:

See 4.7.4.

Table 2: Snow Test Conditions

Test Condition	SNW-A	SNW-B	SNW-C	SNW-D	SNW-E	SNW-F	SNW-G	SNW-H
Types II and IV, neat	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Types II and IV, 75/25 (neat fluid/water)	Yes	Yes	No	No	Yes	Yes	No	No
Types II and IV, 50/50 (neat fluid/water)	Yes	Yes	No	No	No	No	No	No
Types III, neat	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Types III, 75/25 (neat fluid/water)	Yes	Yes	Yes	Yes	No	No	No	No
Types III, 50/50 (neat fluid/water)	Yes	Yes	No	No	No	No	No	No
Test Condition Temperature, °C	-3	-3	-10	-10	-14	-14	-25	-25
Snow intensity, g/dm^2/h	10 ± 0.6	25 ± 1.5	10 ± 0.6	25 ± 1.5	10 ± 0.6	25 ± 1.5	10 ± 0.6	25 ± 1.5
Snow intensity standard deviation	≤ 0.5	≤ 1.25	≤ 0.5	≤ 1.25	≤ 0.5	≤ 1.25	≤ 0.5	≤ 1.25
Plate temperature, °C	-4.2 ± 0.5	-5.1 ± 0.5	-11.2 ± 0.5	-12.1 ± 0.5	-15.2 ± 0.5	-16.1 ± 0.5	-26.2 ± 0.5	-27.1 ± 0.5
Plate temperature standard deviation	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5

APPENDIX F

EXPERIMENTAL PROCEDURE:
COMPARISON OF VISCOSITIES OF DILUTED FLUIDS (75/25)
BEFORE AND AFTER SPRAYING

CM1892.001 (04-05)

EXPERIMENTAL PROCEDURE
COMPARISON OF VISCOSITIES OF DILUTED FLUIDS (75/25) BEFORE AND AFTER SPRAYING

Winter 2004-05

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson

Reviewed by: John D'Avirro

APS Aviation Inc.

March 21, 2005
Version 1.0

EXPERIMENTAL PROCEDURE
COMPARISON OF VISCOSITIES OF DILUTED FLUIDS (75/25) AND AFTER SPRAYING

Winter 2004-05

1. BACKGROUND

Concerns have arisen that the protocol used to measure endurance times of diluted anti-icing fluids may not produce values consistent with those experienced during actual operations. These concerns have brought into question the accuracy of the current diluted fluid values in the holdover time guidelines and the current test protocol.

The goal of endurance time testing is to determine the length of time, after application, a fluid will remain uncontaminated in winter precipitation. In general, it has been found that the more viscous the fluid the longer the endurance time, especially in warmer temperatures. During the application process fluids are subjected to shearing by the application equipment. This shearing reduces the viscosity of the fluid, rendering the applied fluid less viscous than the original fluid.

To replicate the shearing of the fluid caused during application, fluid manufacturers mechanically shear fluid samples before they are sent to APS Aviation Inc. (APS) for endurance time testing. The method of shearing varies from manufacturer to manufacturer, but all manufacturers shear a batch of neat fluid and then dilute portions of it to 75/25 and 50/50 dilutions.

It has been shown that the more viscous a fluid is, the more susceptible it is to shearing. In other words, if two samples of the same fluid, one with a higher viscosity and one with a lower viscosity, are subjected to the same shearing, the higher viscosity fluid will experience a larger percentage decrease in viscosity.

It has been theorized that because fluids submitted for endurance time testing are sheared *prior* to dilution and fluids that are used on aircraft are sheared *after* dilution, the endurance times of fluids tested for endurance times are different from the endurance times of fluids used in operations.

2. OBJECTIVE

The objective of these tests is to determine if fluids sheared before they are diluted have the same viscosity as fluids sheared after they are diluted. The measurement of viscosities will be used as in indicator of endurance times.

If the viscosities are different, it will have implications for holdover time testing protocol. Currently, fluids are sheared and then mixed for holdover time testing, but in operations, fluids are provided mixed to users and then sheared when they are applied.

3. PROCEDURE

Samples of several Type IV fluids will be sprayed using the mobile sprayer. Samples of the sprayed fluid will be collected and returned to the APS laboratory where their viscosities will be measured.

These tests will examine fluids diluted to 75/25 (glycol/hard water). To replicate the operational type and timing of shearing, a sample of each neat fluid will be diluted to 75/25 prior to spraying. To replicate the endurance time testing type and timing of shearing, a sample of the same neat fluid will be sprayed and then diluted to 75/25. The two test processes are illustrated in Figure 3.1.

The viscosity of the fluids will be measured at each step in the process when possible. The key viscosity measurement will be the viscosity of the final samples.

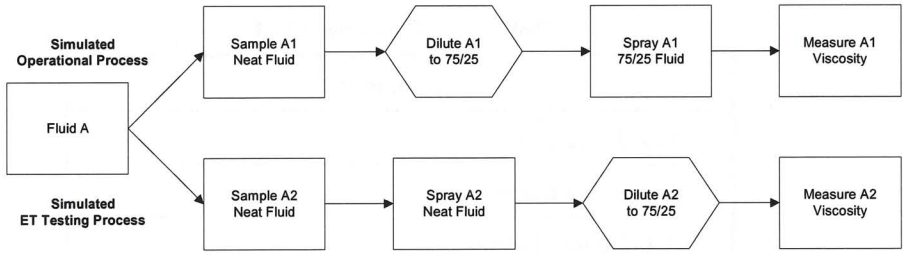


Figure 3.1: Flowchart for Testing

4. FLUIDS

Two fluids will be tested: Homeoil Type IV and Octagon Max-Flight. Each fluid will be sprayed in neat dilution and diluted to 75/25 and sprayed.

5. PERSONNEL

Two individuals are required for the spray tests. One individual is required to conduct the viscosity tests.

6. TEST PLAN

The test plan for spray tests is given in Table 6.1.

Table 6.1: Test Plan

Test #	Fluid	Dilution	Notes
1	Octagon Max-Flight	100/0	
2	Octagon Max-Flight	75/25	Dilute neat sample
3	Homeoil Type IV	100/0	
4	Homeoil Type IV	75/25	Dilute neat sample

7. EQUIPMENT

Table 7.1 lists the equipment required.

Table 7.1: Equipment List

Equipment
Mobile Sprayer
Collection Barrel
1 L Sample Bottles
Brookfield Viscometer and Temperature Bath

8. DATA FORMS

A data form has been created for the spray tests and is given in Figure 8.1. The APS viscosity log book will be used to record the results of the viscosity tests.

COMPARISON OF VISCOSITIES OF DILUTED FLUIDS (75/25) BEFORE AND AFTER SPRAYING

Date: _____ Temperature: _____

Weather: _____ Wind: _____

Test No.	Fluid	Dilution	Time of Application	Comments

Performed By: _____ Written By: _____

Figure 8.1: Spray Test Data Form

9. SAFETY PRECAUTIONS

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

- Appropriate footwear is to be worn by all personnel at the test site to prevent slipping;
- Warm clothing is to be worn by all personnel to prevent frostbite;
- Electrical appliances (including computers) are to be unplugged before any wires or connections are altered. If necessary, the affected breaker is to be turned off;
- If fluid comes into contact with skin, rinse hands under running water; and
- If fluid comes into contact with eyes, flush with the portable eye wash station located inside the main trailer.

APPENDIX G

PRELIMINARY R & D
FIELD ANTI-ICING FLUID VISCOSITY ESTIMATION
(DRAINING TIME METHOD)

PRELIMINARY R & D
FIELD ANTI-ICING FLUID VISCOSITY ESTIMATION
(DRAINING TIME METHOD)

1. SYRINGE VISCOSITY TESTER DEVICE

1.1 Methodology

A 60 mL syringe (without the needle and the piston) was used as a viscosity device (Figure 1). The size and the opening in these syringes are usually standard. The testing procedure was set as follows: 60 mL of the fluid (at 20°C) to test are poured in the syringe container (with a thumb blocking the syringe opening).

The draining time to be measured with a stopwatch is defined as the time that the fluid would take to drain between graduation 50 mL and 20 mL (Figure 1). An average of three tests is usually required.

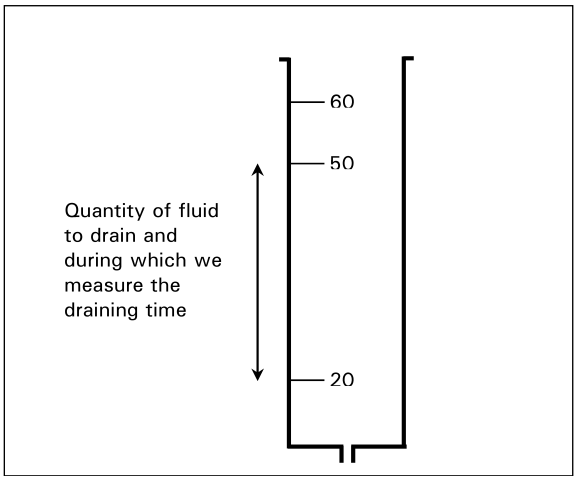


Figure 1: The Syringe Simplified Viscosity Tester

1.2 Processing of Data and Analysis

The syringe viscosity tester trials were performed on different Type IV Kilfrost ABC-S samples that were sheared in the lab with the mixer. The draining time was determined at 20°C, and the viscosity was measured according to the manufacturer method (at 20°C). The results are summarized in Table 1.

Table 1: Viscosity vs. Draining Time for Sheared Kilfrost ABC-S Samples (Syringe Tester)

Sample #	Shearing Method	Viscosity * (mPa.s)	Draining Time (s)
J1	Virgin	22,500	102
J2	0.75 L sheared with the mixer (Low speed/Stir) during 1 min	8,920	77
J3	0.75 L sheared with the mixer (Low speed/Stir) during 3.5 min	2,460	57
J4	0.75 L sheared with the mixer (Low speed/Stir) during 7 min	1,120	49

* Viscosity method: SC4-31/13R, 10 ml, at 20°C, 0.3 rpm, 10 min.

The shearing effect causes a significant reduction in fluid viscosity. The correspondent draining time for each sample is also reduced. Figure 2 shows the viscosity plotted against the draining time. The regression curve connecting the points and the correspondent equation shown in Figure 2 prove that the viscosity variation, function of the draining time, follows a quasi-predictable linear trend.

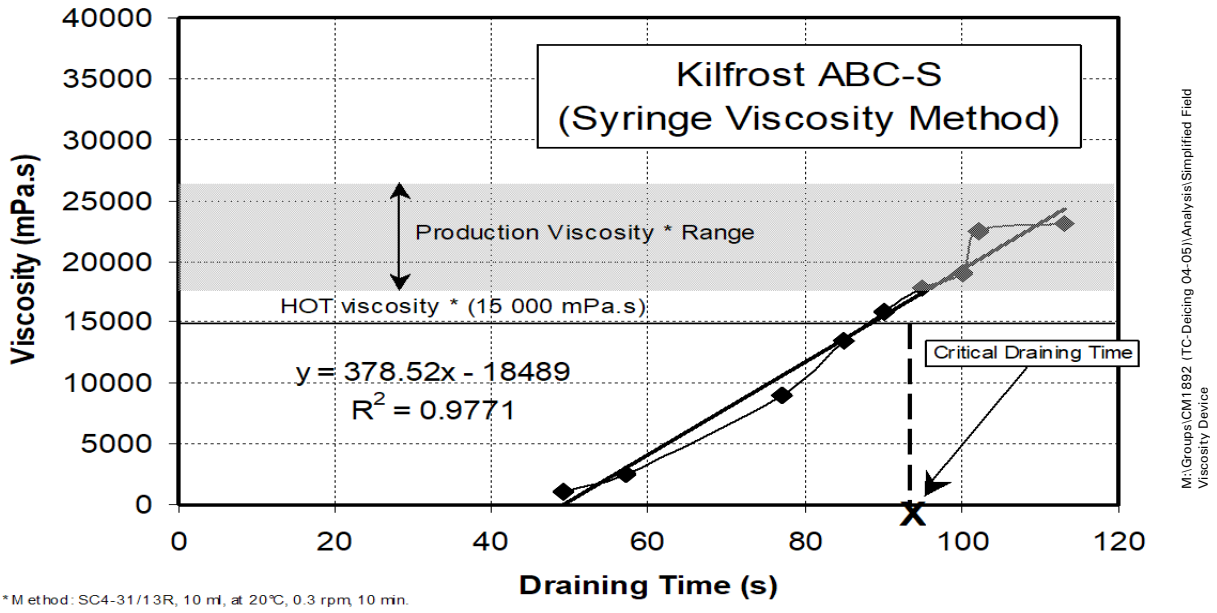


Figure 2: Viscosity vs. Draining Time for Different Kilfrost ABC-S Sheared Samples (Syringe Tester)

Tests were also performed with sheared Type II Clariant 2025 ECO samples. The shearing method, the viscosity and the correspondent draining time for each sample, are summarized in Table 2. The results presented in Figure 3 shows that the viscosity function of the draining time is relatively linear.

Table 2: Viscosity vs. Draining Time for Sheared Clariant MP II 2025 ECO Samples (Syringe Tester)

Sample #	Shearing Method	Viscosity * (mPa.s)	Draining Time (s)
C2025	Virgin	6,040	50
C2025 D1500	0.75 L sheared on March 2003 with the mixer (Low speed/Stir) during 1 min	1,740	40
C2025 D500	0.75 L sheared on March 2003 with the mixer (Low speed/Stir) during 5 min	680	37
C2025 D0	0.75 L sheared on March 2003 with the mixer (High/Liquefy speed) during 8 min	100	30

* Method: Brookfield Spindle LV1 with guard leg, 500 mL of neat fluid, at 20°C, 0.3 rpm, for 10 minutes

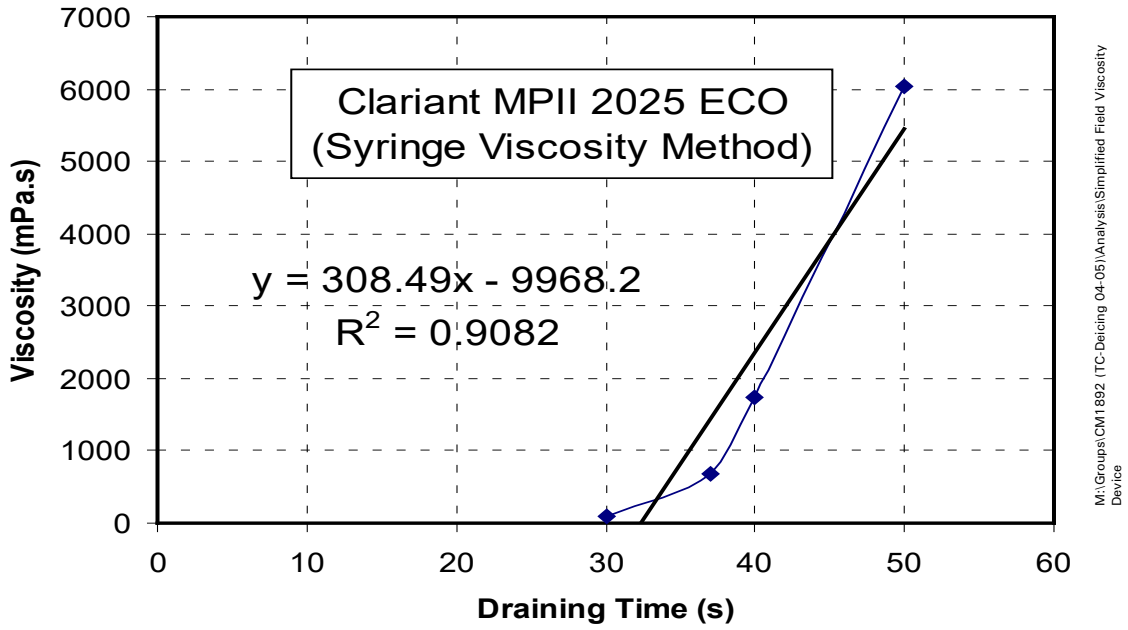


Figure 3: Viscosity vs. Draining Time for Different Clariant 2025 ECO Sheared Samples (Syringe Tester)

Figure 2 and Figure 3 prove that the draining time measured with the simplified viscosity tester could be an efficient and easy method to roughly predict the viscosity of fluids exposed to shearing.

This type of tests could be easily conducted in a field operation since it only requires a 60 mL syringe and the "draining time versus viscosity" graph.

As shown in Figure 2, a Critical Draining Time (CDT) corresponding to the minimum HOT viscosity could be set for each fluid and used as a field indicator.

Since experimental errors can be expected from this simplified method, the CDT should be overstated by at least 10 percent. In all cases, if a failing result is found, the viscosity measurement following the manufacturer's recommended method should be used to confirm the result.

Further trials were performed with the syringe viscosity tester using various fluids having different viscosities. The draining time tests were conducted on different samples at 20 ºC. The results are summarized in Table 3. For each fluid, the draining time is plotted against the viscosity value and presented in Figure 4.

Table 3: List of Samples Tested with the Simplified Syringe Viscosity Tester

Bottle #	Fluid Brand, Dilution	Viscosity (mPa.s)	Draining Time (s)
F	(Clariant MPII 2025 ECO, 50%)	2,750*	17
I	(Clariant MPIV 2030 ECO, 50%)	7,580*	20
E	(Clariant MPII 2025 ECO, 75%)	8,950*	34
H	(Clariant MPIV 2030 ECO, 75%)	14,300**	45
D	(Clariant MPII 2025 ECO, Neat)	5,840*	49
G	(Clariant MPIV 2030 ECO, Neat)	10,200**	75
J	(Kilfrost ABC-S, Neat)	22,500**	97

* Viscosity method: Spindle LV1 with guard leg, 500 mL of neat fluid, at 20°C, 0.3 rpm, for 10 min.

** Viscosity method: SC4-31/13R, 10 mL, at 20°C, 0.3 rpm, 10 min.

When the simplified viscosity test is applied on different fluid brands and dilutions, the results show that the viscosity and the draining time do not follow a linear predictable function similar to previous cases. The simplified method seems to be valid only for fluids exposed to different shearing rates.

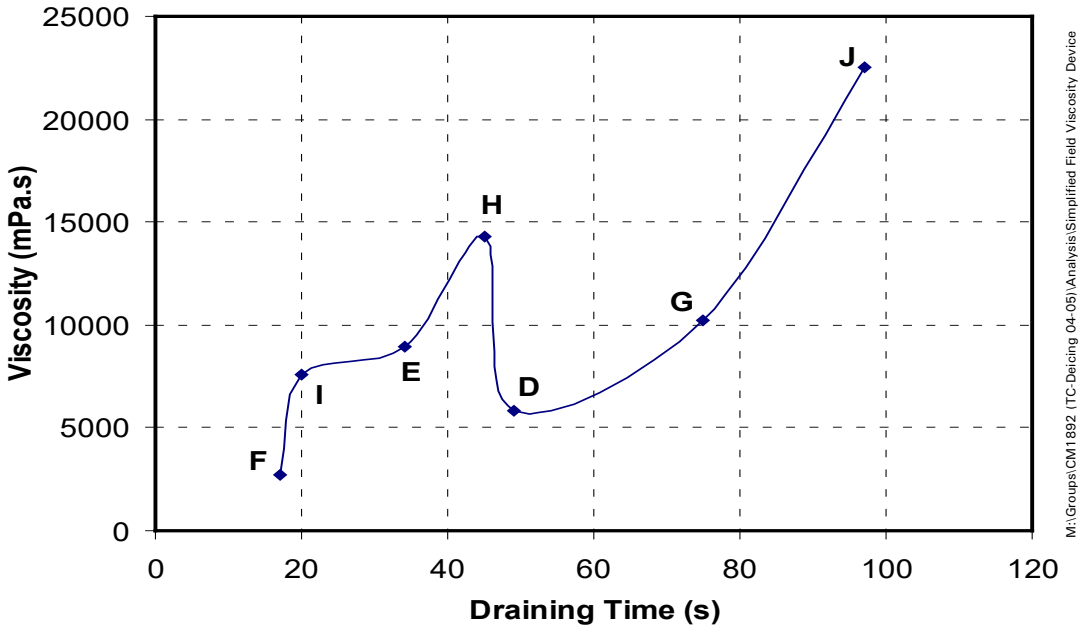


Figure 4: Viscosity vs. Draining Time for Different Fluid Brands (Syringe Tester)

1.3 Conclusions

The draining time measured with the simplified syringe viscosity tester could be an efficient method to predict the viscosity of fluids exposed to shearing, and to roughly compare it to the minimum holdover time (HOT) viscosity. This type of tests could easily be conducted in a field operation since it requires only a 60 mL syringe and the draining time-viscosity equivalence curve.

A CDT corresponding to the minimum HOT viscosity could be set for each fluid and used as a field indicator. Since this simplified method may involve experimental errors (due to temperature fluctuation, bubbles, etc.), the CDT should be overstated by at least 10 percent. In all cases, if a failing result is found, the viscosity measurement following the manufacturer's recommended method should be used to confirm the result.

The simplified viscosity tester is not a valid method to predict the viscosity when it is applied on different fluid brands and dilutions. In that case, the viscosity and the draining time do not follow a predictable function.

2. THE CARBOY VISCOSITY TESTER DEVICE

In order to prove that the method is valid with other devices and to reduce the error in the draining time reading, tests were also conducted using a one-liter carboy with tubulation (Low-Density Polyethylene, NALGENE), as shown in Figure 5.



Figure 5: Carboy Used as a Simplified Viscosity Tester

2.1 Methodology

One-liter carboy container was used as a viscosity device (Figure 6). The size and the opening in this carboy are usually standard. The item purchased from VWR Canlab is referenced 16333-673.

The testing procedure was set as follows: one liter of fluid (at room temperature) is poured (with a thumb blocking the tubulation) in the carboy. The draining time to be measured with a stopwatch is defined as the time that the fluid would take to drain between Graduation I and Graduation II (Figure 6). An average of three tests is usually required.

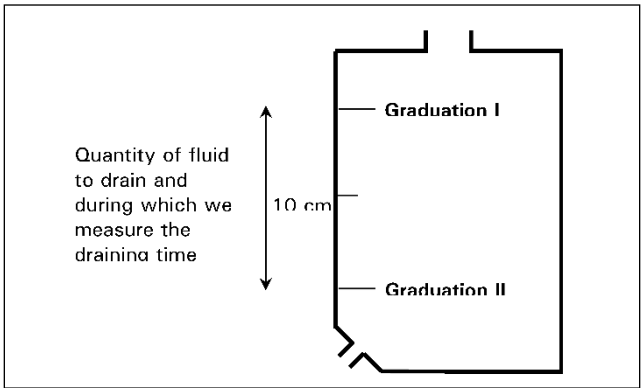


Figure 6: The Carboy Simplified Viscosity Tester

2.2 Processing of Data and Analysis

The bottle simplified viscosity tester trials were performed only with Type IV Kilfrost ABC-S samples that were sheared in the lab with the mixer. The draining time was determined at room temperature (~20ºC) and the viscosity was measured according to the following specified method: Brookfield Spindle SC4-31/13R, small sample adapter, 10 mL of fluid, at 20°C, 0.3 rpm, 10 minutes. The results are summarized in Table 4.

Table 4: Viscosity vs. Draining Time for Sheared Kilfrost ABC-S Samples (Carboy Tester)

Sample #	Shearing Method	Viscosity * (mPa.s)	Draining Time (s)
J5	Virgin	24,500	1400
J6	0.75 L sheared with the mixer (Low speed/Stir) during 10 sec	17,850	1255
J7	0.75 L sheared with the mixer (Low speed/Stir) during 20 sec	15,450	1127
J8	0.75 L sheared with the mixer (Low speed/Stir) during 30 sec	12,950	1040
J9	0.75 L sheared with the mixer (Low speed/Stir) during 1 min	9,150	825
J10	0.75 L sheared with the mixer (Low speed/Stir) during 2 min	5,150	681
J11	0.75 L sheared with the mixer (Low speed/Stir) during 4 min	2,000	548

* Method used: Brookfield Spindle SC4-31/13R, small sample adapter, 10 ml of fluid, at 20°C, 0.3 rpm, 10 minutes 0 seconds.

The shearing effect causes a significant reduction in fluid viscosity. The correspondent draining time for each sample is also reduced. Figure 7 shows the viscosity plotted against the draining time.

The best fitting for all these experimental data prove that the viscosity variation, function of the draining time, follows a predictable linear trend.

For checking purposes, one sample was collected during the forced air project (Pittsburgh, January 23-26, 2005) after being sprayed from an LMD 2000 truck (with no air sleeve). The sample was very bubbly. The results are summarized in Table 5.

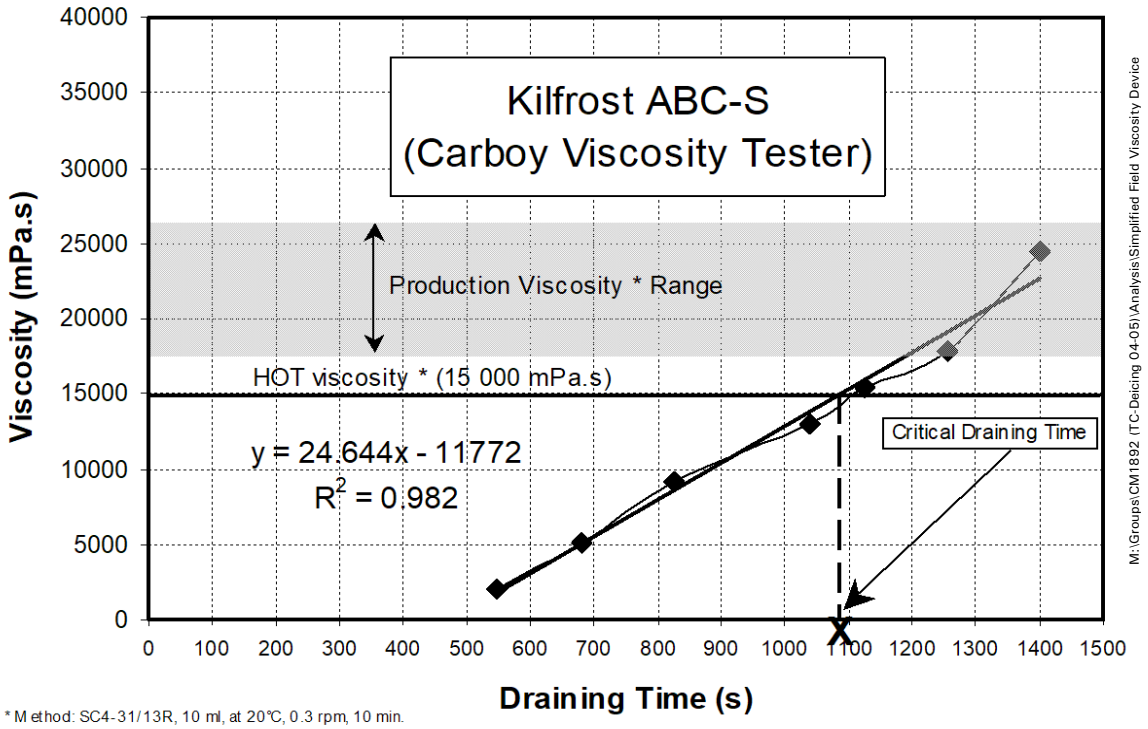


Figure 7: Viscosity vs. Draining Time for Different Kilfrost ABC-S Sheared Samples (Carboy Tester)

Table 5: Viscosity vs. Draining Time for Sheared Kilfrost ABC-S Samples (Carboy Tester)

Sample #	Shearing	Viscosity * (mPa.s)	Draining Time (s)
J12	Virgin	22,750	Not measured
J13	Sheared while sprayed by LMD 2000 Truck (Bubbly Sample)	19,050	1047
J14	Sample # J13 with very less bubbles (after 10 days)	19,050	980

* Method used: Brookfield Spindle SC4-31/13R, 10 ml of centrifuged fluid, 20°C, 0.3 rpm, 10 minutes.

Table 5 shows that the draining time method did not provide the expected results. In fact, based on the regression equation provided in Figure 7, the calculated viscosity values are 14,030 mPa.s and 12,379 mPa.s for samples J13 and J14 respectively. The real viscosity measured with the Brookfield viscometer is 19,050 mPa.s. The average error for these two samples is about 36 percent. This difference might be related to the fact that the mixer used in our laboratory might not reproduce the same shearing effect.

In order to improve this field viscosity estimation technique, additional viscosity and draining time measurements should be carried out on samples collected from full-scale standard spray tests. The results should be then integrated to the ones performed in the lab. A refined regression (Figure 7) will be then provided to take into consideration the actual shearing that happens during deicing operations.

Notes:

1. The shearing process usually causes bubbles in the fluid. In order to study the bubble effect on the accuracy of the method, the draining time for Sample# J6, Sample# J11 and Sample# J13 was measured following the mixer shearing process and also 10 days later. With these samples, it was noticed that bubbles increase the draining time by no more than 8 percent.
2. Prior to any draining time measurement, the fluid to test should be filtered. The results might be biased by small objects (e.g.: little rocks, flies, etc.) that might be blocking the draining tubing.

2.3 Conclusion

As shown previously with the syringe device, the draining time measured with the carboy viscosity tester could be also an efficient method to predict the viscosity of fluids exposed to shearing, and to compare it roughly to the minimum HOT viscosity.

Comparing the syringe and carboy devices that we tested, the results are more accurate with the carboy viscosity device since it provides longer draining time.

This page intentionally left blank.

APPENDIX H

PROCEDURE:
VIDEO DOCUMENTATION OF SNOWFALL INTENSITIES

CM1892.001 (04-05)

PROCEDURE
VIDEO DOCUMENTATION OF SNOWFALL INTENSITIES

Winter 2004-05

Prepared for

The Federal Aviation Administration

and

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson p.p

Reviewed by: John D'Avirro



November 10, 2004
Version 1.0

PROCEDURE
VIDEO DOCUMENTATION OF SNOWFALL INTENSITIES

Winter 2004-05

1. BACKGROUND

At the request of the Federal Aviation Administration and Transport Canada, APS will coordinate the production of an educational video documenting different snowfall intensities. The video will be made available to pilots and possibly to airlines, ground deicing crews, and other individuals and/or companies involved in ground de/anti-icing with the goal of improving airport safety.

This project was started in the winter of 2003-04. A procedure was prepared and initial footage was collected in 2003-04; however, due to a lack of snow events, additional footage will be collected in 2004-05. This procedure is very similar to the procedure issued in 2003-04. Some minor changes have been made to reflect the actual procedure used to collect footage last year.

2. OBJECTIVES

The objective is to create a video to document the four types of snowfall intensity: very light, light, moderate and heavy.

3. SETUPS

Three setups are required and are described below. Footage of the three setups will subsequently be edited together to give multiple perspectives of each given snowfall intensity.

3.1 Setup A: Long Distance View

The first setup requires an unobstructed view of at least 2½ miles in order to document the relative difference in visibility between snowfall intensities. A number of markers from one-quarter mile to 2½ miles must be visible in the setup. Montreal-Trudeau airport at the corner of Hervé-St-Martin Road has been selected for Setup A. A map with the exact filming location and distance markers is shown in Figure 3.1. A perspective of the horizon is shown in Figure 3.2.

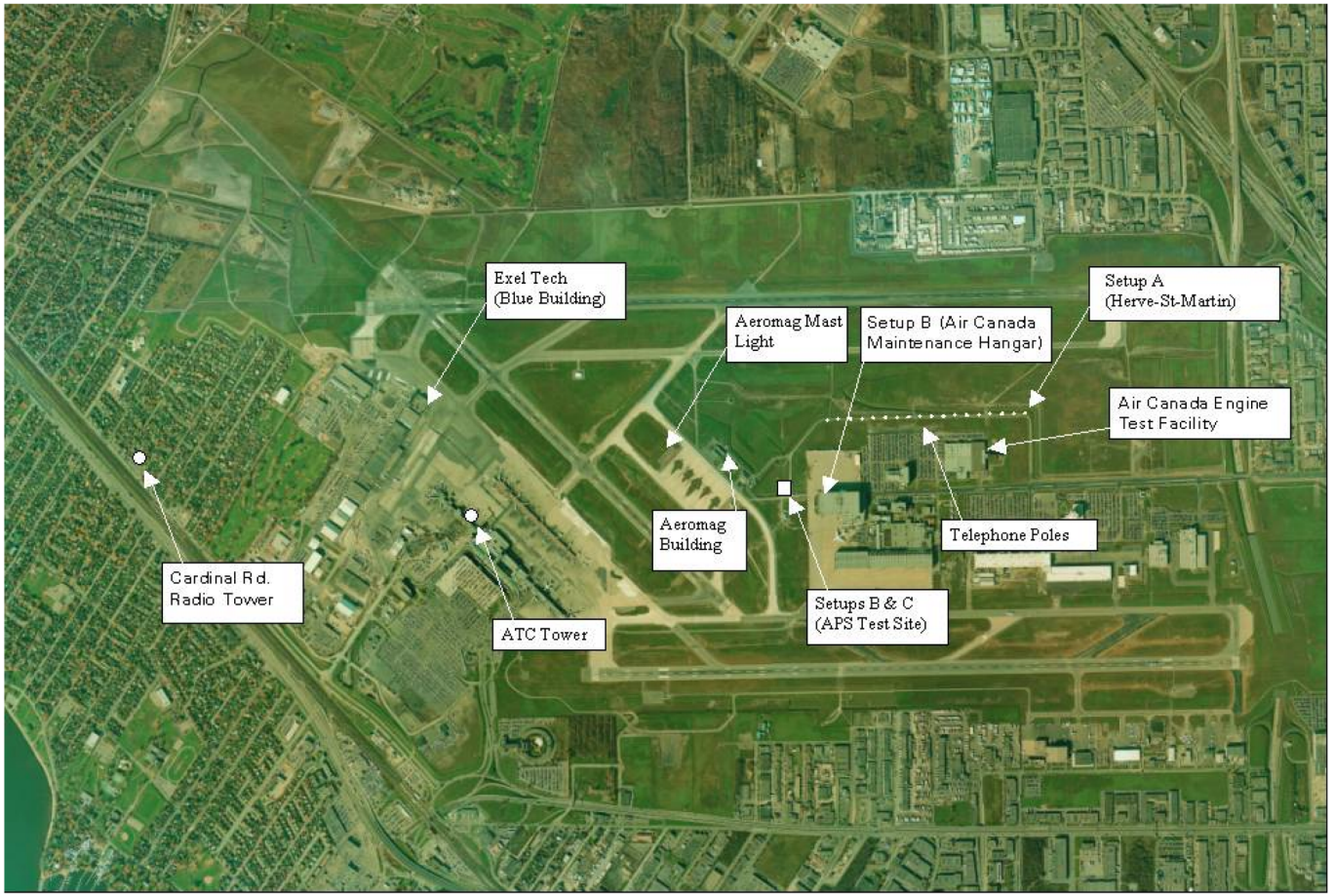


Figure 3.1: Location of Setups and Distance Markers

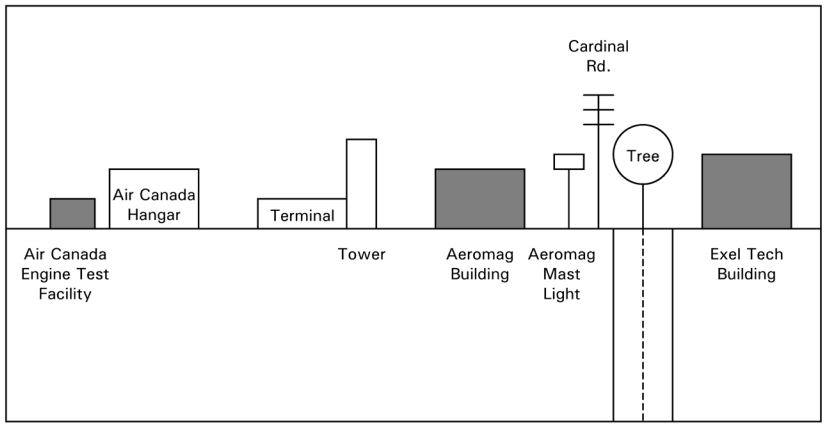


Figure 3.2: View of Horizon from Setup A

3.2 Setup B: Dark Background

Setup B is required to document a closer view of different snowfall intensities. A dark background will allow for better viewing of individual snowflakes. The Air Canada maintenance hangar, which is easily viewed from the APS test site at Trudeau Airport, will be used for Setup B. It is shown in Figure 3.1.

3.3 Setup C: Airfoil

Setup C requires footage be taken of a section of a Fokker F-28 airfoil in order to replicate snowfall intensity on a wing. The airfoil will be mounted on a stand at the APS test site and placed in front of a dark background. This background can be provided by covering the side of one of the APS test site buildings with tarpaper or another dark covering.

4. WEATHER AND LIGHTING CONDITIONS

If conditions permit, footage should be collected in "wet snow" (above -1°C) and in "dry snow" (-1°C or below). Footage should be taken during conditions of calm or low winds during daylight hours. Five test sessions are anticipated.

If the opportunity presents itself (i.e. a snow event continues into the night when the videographer is present), footage should be collected during darkness on one occasion. This footage will be used in the future to assess methods for documenting snowfall intensity at nighttime.

5. PROCEDURE

5.1 Rate Collection

During testing, precipitation rates will be measured using standard endurance time testing procedures. Rates will be measured continuously every 5 minutes in order for new information to be available frequently.

5.2 Collecting Footage

The services of a professional videographor will be retained to collect video footage. The following procedure will be followed when collecting footage:

1. Synchronize the date and time on the camera with the rate collection clocks.
2. Set up the camera at the designated Setup A location. Film 10 seconds.
3. Relocate the camera to the APS test site (Setup B & C) and position to film Setup B. Film 10 seconds.
4. Reposition the camera for Setup C. Film 10 seconds.
5. Repeat steps 2 to 4 as snowfall intensity and/or snow type changes. Snowfall intensities are defined as follows:
   - Heavy snow is greater than 25 g/dm²/h;
   - Moderate snow is 10 to 25 g/dm²/h;
   - Light snow is 4 to 10 g/dm²/h; and
   - Very light snow is less than 4 g/dm²/h.

5.3 Video Editing

After adequate footage has been collected, the footage from 2003-04 and 2004-05 will be edited together by the videographer. In addition, a voice-over will need to be scripted and recorded.

6. PERSONNEL

A minimum of two individuals will be required to obtain the video footage: a professional videographor and an individual to coordinate the video shots and measure precipitation rates.

7. TEST PLAN

The conditions required for the video are indicated in Table 7.1. The list is shown by priority.

Table 7.1: Session Test Plan

Priority	Wind	Lighting	Temperature
1	Calm or Low	Day	-1°C or below
2	Calm or Low	Day	Above -1°C
3	Calm or Low	Night	Any

8. EQUIPMENT

Table 8.1 lists the equipment required.

Table 8.1: Equipment List

Equipment
JetStar Airfoil
Digital Video Equipment
Vehicle
Cell Phone
Rate Measurement Equipment
Tar Paper

9. DATA FORMS

Two data forms are required: a Test Session Log (Figure 9.1) to log the video footage and the standard Meteorological and Precipitation Rate Data Form (Figure 9.2) to record precipitation rates.

10. SAFETY PRECAUTIONS

The following precautions will be taken when conducting tests at the APS test

site to ensure the safety of all personnel:

- Pathways, stairs and test areas are to be cleared of snow regularly;
- Appropriate footwear is to be worn by all personnel at the test site to prevent slipping;
- Warm clothing is to be worn by all personnel to prevent frostbite;
- Electrical appliances (including computers) are to be unplugged before any wires or connections are altered. If necessary, the affected breaker is to be turned off;
- If fluid comes into contact with skin, rinse hands under running water;
- If fluid comes into contact with eyes, flush with the portable eye wash station located inside the main trailer; and
- When operating snow blower use ear protection.

Date: _____ Written By: _____

Location: _____ Video By: _____

Start Time	Setup (A, B or C)	Approximate Rate ($g/dm^2/h$)	Comments

Figure 9.1: Test Session Log

PROCEDURE: VIDEO DOCUMENTATION OF SNOWFALL INTENSITIES

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME VERSION 1.0 Winter 2002-03

LOCATION: DATE: RUN # : STAND # :

HAND HELD VIDEO CASSETTE #:

PLATE PAN WEIGHT MEASUREMENTS *

PAN #	t TIME BEFORE (h:min:s)	BUFFER TIME (s)	t TIME AFTER (h:min:s)	BUFFER TIME (s)	w WEIGHT BEFORE (g)	w WEIGHT AFTER (g)	COMPUTE RATE (Δ w*4.7/Δ t) ($g/dm^2/h$)

*measurements every 15 min. and at failure time of each test panel.

METEO OBSERVATIONS **

TIME (h:min)	TYPE (Fig. 4) ZR, ZL,S, SG IP, IC, BS, SP	CLASSIF. (See snow classification diagram.)	If SNOW, WET or DRY

**observations at beginning, end, and every 10 min. intervals.
Additional observations when there are significant changes.

TEMPERATURE AT START OF TEST _____ °C

WIND SPEED AT START OF TEST _____ kph

WIND DIRECTION AT START OF TEST _____ °

COMMENTS : _____

	PRINT	SIGN
WRITTEN & PERFORMED BY :		
VIDEO BY :		
TEST SITE LEADER :		

M:\Groups\CM1747\Procedures\HOT\data forms

Figure 9.2: Meteorological and Precipitation Rate Data Form

This page intentionally left blank.

APPENDIX I

TRANSPORT CANADA
HOLDOVER TIME (HOT) GUIDELINES
WINTER 2005-2006

Transport Canada
Holdover Time (HOT) Guidelines
Winter 2005-2006

Original Issue, July 2005

CHANGE CONTROL RECORDS

This page indicates the changes made to individual pages within the document and those changed pages have the appropriate date in the footer. Sidebars are shown to assist in identifying the changes from the previous version.

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

REVISION	*DATE*	*DESCRIPTION OF CHANGES*	*AFFECTED PAGES*	*AUTHOR*

SUMMARY OF CHANGES FROM PREVIOUS YEAR

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

General

Ground Icing Operations and Holdover Time (HOT) Guideline information is provided in two documents. The two documents complement each other and should be used together for a more thorough understanding of the subject matter. The first document (TP 14052E) includes reference material related to Ground Icing Operations. The most recent version of TP 14052E is Edition 2, published April 2005. The second document consists of the HOT Guidelines, provided in this dedicated Transport Canada website.

Type I Fluid

No changes were made to the HOT values from last year. However, some format changes have been made to the Type I table to reflect changes made to the Type II/IV tables (see below).

Type II / IV Fluid

No new Type II fluids were introduced.

One new Type IV fluid, Octagon MaxFlo, has been certified and will be introduced in the 2005-06 winter season. A fluid-specific table has been created for this fluid. The addition of this fluid caused reductions to the holdover times in two snow cells of the generic Type IV guidelines.

Type IV fluid Clariant Safewing MP IV 1957 was removed from the generic table analysis, as it has not been commercially available for four years. Its removal resulted in increases in three cells in the generic HOT table: two changes in one freezing fog cell and three changes in two snow cells. All were in the "-3ºC and above" temperature range. The fluid-specific table has been deleted.

Changes were made to the format of all Type II and Type IV tables. There were several changes including:

i) The "above 0ºC" temperature band was removed and incorporated within the newly modified "-3ºC and above" temperature range;
ii) Viscosity information was removed from each fluid-specific table and placed in a separate viscosity table (Table 9), which also includes the viscosity value measured using the Aerospace Information Report 9968 method;
iii) Words previously abbreviated, including outside air temperature (OAT) and volume (vol), were replaced with their full spellings;
iv) The title of the frost column was changed from "Frost" to "Active Frost";
v) The title of the snow column was changed from "Snow" to "Snow or Snow Grains";
vi) The Cautions section was changed so each sentence forms a new bullet; and
vii) One note was modified in the generic tables and added to the fluid-specific tables to explain how the holdover time values are derived.

Type III Fluid

As a result of testing with dilutions of Clariant Safewing MP III 2031 ECO, rows for 75/25 and 50/50 dilutions have been added to the Type III generic holdover time guidelines. Format changes have been made to the Type III table to reflect changes made to the Type II/IV tables.

Transport Canada Holdover Time Guidelines **Winter 2005-2006**

HOLDOVER TIME (HOT) GUIDELINES FOR WINTER 2005-2006

Table 1	SAE Type I Fluid Holdover Guidelines
Table 2-Generic	SAE Type II Fluid Holdover Guidelines
Table 2-C-2025	Clariant Type II Fluid Holdover Guidelines Safewing MP II 2025 ECO
Table 2-K-ABC-2000	Kilfrost Type II Fluid Holdover Guidelines ABC-2000
Table 2-K-ABC-II+	Kilfrost Type II Fluid Holdover Guidelines ABC-II PLUS
Table 2-O-EM-II	Octagon Type II Fluid Holdover Guidelines E Max II
Table 2-S-E26	SPCA Type II Fluid Holdover Guidelines Ecowing 26
Table 3	SAE Type III Fluid Holdover Guidelines
Table 4-Generic	SAE Type IV Fluid Holdover Guidelines
Table 4-C-2001	Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2001
Table 4-C-2012	Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2012 Protect
Table 4-C-2030	Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2030 ECO
Table 4-D-ULTRA+	Dow Chemical Type IV Fluid Holdover Guidelines UCAR™ ADF/AAF ULTRA+
Table 4-K -ABC-S	Kilfrost Type IV Fluid Holdover Guidelines ABC-S
Table 4-O-MF	Octagon Type IV Fluid Holdover Guidelines Max-Flight
Table 4-O-MF-04	Octagon Type IV Fluid Holdover Guidelines Max-Flight 04
Table 4-O-MFLO	Octagon Type IV Fluid Holdover Guidelines MaxFlo
Table 4-S-AD-480	SPCA Type IV Fluid Holdover Guidelines AD-480
Table 5	Currently Qualified Fluids
Table 6	SAE Type I Deicing Fluid Application Procedures
Table 7	SAE Type II, Type III and Type IV Anti-Icing Fluid Application Procedures
Table 8	Visibility in Snow vs. Snowfall Intensity Chart
Table 9	Lowest On-Wing Viscosity Values for Anti-Icing Neat Fluids

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 1

SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006

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

Outside Air Temperature[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 criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 2-Generic

SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]

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

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

NOTES

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

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 2-C-2025

CLARIANT TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
SAFEWING MP II 2025 ECO

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 2-K-ABC-2000

KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
ABC-2000

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 2-K-ABC-II+

KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
ABC-II PLUS

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

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

NOTES

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

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

TABLE 2-O-EM-II

OCTAGON TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]

E MAX II

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

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

NOTES

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

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 2-S-E26

SPCA TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]

Ecowing 26

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

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

NOTES

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

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006

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

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

NOTES

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

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

TABLE 4-Generic

SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]

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

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

NOTES

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

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 4-C-2001

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
SAFEWING MP IV 2001

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 4-C-2012

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
SAFEWING MP IV 2012 PROTECT

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

TABLE 4-C-2030

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
SAFEWING MP IV 2030 ECO

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 4-D-ULTRA+

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
UCAR™ ADF/AAF ULTRA+

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

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

NOTES

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

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

TABLE 4-K-ABC-S

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
ABC-S

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 4-O-MF

OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
MAX-FLIGHT

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 4-O-MF-04

OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
MAX-FLIGHT 04

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

TABLE 4-O-MFLO

OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
MAXFLO

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 4-S-AD-480

SPCA TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
AD-480

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

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

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

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 5

CURRENTLY QUALIFIED FLUIDS (2005-2006)

NOTE:
Concentrate fluids have also been qualified at 50/50 (glycol/water) dilution.

Table 5-1: Qualified Type I Anti-icing Fluids†

#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
1-1	Arcton Ltd.	Arctica DG	06-03-30
1-2	*Aviation Xi' an High-tech*	*KHF-1*	*05-02-24*
1-3	Beijing Wangye Aviation Chemical Product Co. Ltd.	KLA-1	05-09-26
1-4	Clariant GmbH	Clariant Safewing MP I 1938 TF	06-08-25
1-5	Clariant GmbH	Clariant Safewing MP I 1938 TF Pre-Mix	*
1-6	Clariant GmbH	Clariant Safewing MP I 1938 ECO	06-08-30
1-7	Clariant GmbH	Clariant Safewing EG I 1996	06-08-24
1-8	Dow Chemical Company	Dow UCAR™ Aircraft Deicing Fluid Concentrate	06-10-26
1-9	Dow Chemical Company	Dow UCAR™ ADF XL-54	07-03-10
1-10	Dow Chemical Company	Dow UCAR™ PG Aircraft Deicing Fluid	06-01-30
1-11	Dow Chemical Company	Dow UCAR™ PG ADF Dilute 55/45	06-05-17
1-12	Inland Technologies Inc.	Inland Duragly-P ready to use	05-09-11
1-13	Inland Technologies Inc.	Inland Duragly-E ready to use	05-10-20
1-14	Kilfrost Limited	Kilfrost DF PLUS	05-09-11
1-15	Kilfrost Limited	Kilfrost DF PLUS (80)	06-07-05
1-16	Kilfrost Limited	Kilfrost DF PLUS (88)	05-09-03
1-17	Lyondell Chemical Co.	Lyondell ARCOPlus	06-03-29
1-18	Lyondell Chemical Co.	Lyondell ARCTIC Plus	06-03-15
1-19	Newave Aerochemical Co. Ltd.	FCY-1A	05-06-04*
1-20	Octagon Process Inc.	Octagon Octaflo EF	05-07-25*
1-21	Octagon Process Inc.	Octagon Octaflo EG	05-07-24*
1-22	SPCA	SPCA DE-950	06-06-08
1-23	Viterbo S.A.	Jarkleer SAE Type I	07-01-20

† Qualified solely with respect to anti-icing performance and aerodynamic acceptance by the Anti-icing Materials International Laboratory, Université du Québec à Chicoutimi. Web site: http://www.uqac.uquebec.ca/amil/
For other specification requirements for Type I fluids, see SAE AMS 1424 (latest version). Fluids that successfully qualify after the issuance of this list will appear in a later update.

Fluids listed in italics have expired and will be removed from this listing four years after expiry.

* Currently in re-qualification process.

TABLE 5 (cont.)

CURRENTLY QUALIFIED FLUIDS (2005-2006)

Table 5-2: Qualified Type II Anti-icing Fluids†

#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
2-1	Clariant GmbH	Clariant Safewing MP II 1951	07-06-02
2-2	Clariant GmbH	Clariant Safewing MP II 2025 ECO	06-08-24
2-3	Kilfrost Limited	Kilfrost ABC-II PLUS	05-10-29
2-4	Kilfrost Limited	Kilfrost ABC-3	06-08-22
2-5	Kilfrost Limited	Kilfrost ABC-2000	06-07-05
2-6	Octagon Process Inc.	Octagon E Max II	06-07-22
2-7	SPCA	SPCA Ecowing 26	07-05-24

Table 5-3: Qualified Type III Anti-icing Fluids†

#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
3-1	Clariant GmbH	Clariant Safewing MP III 2031 ECO	05-12-08

CAUTION: The lowest operational use temperature (LOUT) is -16.5°C (2°F) for aircraft with rotation speeds less than 100 knots or -29°C (-20°F) for aircraft with higher rotation speeds.

Table 5-4: Qualified Type IV Anti-icing Fluids†

#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
4-1	Clariant GmbH	Clariant Safewing MP IV 2001	06-06-02
4-2	Clariant GmbH	Clariant Safewing MP IV 2012 Protect	05-03-31*
4-3	Clariant GmbH	Clariant Safewing MP IV 2030 ECO	06-07-27
4-4	Dow Chemical Company	Dow UCAR ADF/AAF ULTRA+	06-12-20
4-5	Dow Chemical Company	UCAR AAF AD-480 (1)	05-07-01*
4-6	Ely Chemical Company	Octagon Max-Flight	06-07-06
4-7	Kilfrost Limited	Kilfrost ABC-S	05-08-06
4-8	Octagon Process Inc.	Octagon Max-Flight	06-07-06
4-9	Octagon Process Inc.	Octagon Max-Flight 04	06-05-05
4-10	Octagon Process Inc.	Octagon MaxFlo	07-03-24
4-11	SPCA	SPCA AD-480	05-07-01*

(1) This product is identical to SPCA AD-480; the SPCA AD-480 holdover time table applies.

† Qualified solely with respect to anti-icing performance and aerodynamic acceptance by the Anti-icing Materials International Laboratory, Université du Québec à Chicoutimi. Web site: http://www.uqac.uquebec.ca/amil/ For other specification requirements for Type II, III or IV fluids, see SAE AMS 1428 (latest version). Fluids that successfully qualify after the issuance of this list will appear in a later update.

* Currently in re-qualification process.

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[1]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 7

SAE TYPE II, Type III and TYPE IV ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type II, III and IV fluid mixtures
(minimum concentrations in % by volume) as a function of outside air temperature (OAT)

Outside Air Temperature (OAT)	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[1]
-3°C (27°F) and above	50/50 Heated[2] Type II/III/IV	Heated water or a heated mix of Type I, II, III or IV with water	50/50 Type II/III/IV
-14°C (7°F) and above	75/25 Heated[2] Type II/III/IV	Heated suitable mix of Type I, Type II/III/IV and water with FP not more than 3°C (5°F) above actual OAT	75/25 Type II/III/IV
-25°C (-13°F) and above	100/0 Heated[2] Type II/III/IV	Heated suitable mix of Type I, Type II/III/IV and water with FP not more than 3°C (5°F) above actual OAT	100/0 Type II/III/IV
Below -25°C (-13°F)	Type II/III/IV fluid may be used below -25°C (-13°F) provided that the freezing point of the fluid is at least 7°C (13°F) below OAT and that aerodynamic acceptance criteria are met. Consider the use of Type I when Type II/III/IV fluid cannot be used (see Table 6).		

1 To be applied before first step fluid freezes, typically within 3 minutes.
2 Clean aircraft may be anti-iced with unheated fluid.

NOTES
- For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable.
- Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.

CAUTIONS
- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**
- **Whenever frost or ice occurs on the lower surface of the wing in the area of the fuel tank, indicating a cold soaked wing, the 50/50 dilutions of Type II, III or IV should not be used for the anti-icing step because fluid freezing may occur.**
- **An insufficient amount of anti-icing fluid may cause a substantial loss of holdover time. This is particularly true when using a Type I fluid mixture for the first step in a two-step procedure.**

TABLE 8

VISIBILITY IN SNOW VS. SNOWFALL INTENSITY CHART[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	ºC	ºF	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤½	>½ to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

1 Based on: *Relationship between Visibility and Snowfall Intensity* (TP 14151E), Transportation Development Centre, Transport Canada, November 2003; and *Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility* (TP 12893E), Transportation Development Centre, Transport Canada, November 1998.

HOW TO READ THE TABLE

Assume that the daytime visibility in snowfall is 1 statute mile and the temperature is -7°C. Based on these conditions, the snowfall intensity is light. This snowfall intensity is used to determine which holdover time guideline value is appropriate for the fluid in use.

Transport Canada Holdover Time Guidelines — Winter 2005-2006

TABLE 9

LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING NEAT FLUIDS

	FLUID NAME	LOWEST ON-WING VISCOSITY [a] (mPa.s)	
		MANUFACTURER METHOD	AIR 9968 REVISION A METHOD
TYPE II	Clariant Safewing MP II 2025 ECO	5,500 [b]	5,750 [g]
	Kilfrost ABC-II Plus	3,600 [c]	3,600 [g]
	Kilfrost ABC-2000	2,350 [c]	2,350 [g]
	Octagon E Max II	13,520 [d]	13,520 [g]
	SPCA Ecowing 26	4,900 [e]	4,600 [g]
TYPE IV	Clariant Safewing MP IV 2001	18,000 [b]	18,000 [c]
	Clariant Safewing MP IV 2012 Protect	7,800 [b]	7,250 [g]
	Clariant Safewing MP IV 2030 ECO	10,500 [b]	10,500 [c]
	Dow UCAR ADF/AAF ULTRA+	36,000 [f]	28,000 [c]
	Octagon Max-Flight	5,540 [d]	5,540 [g]
	Octagon Max-Flight 04	5,540 [d]	5,540 [g]
	Octagon MaxFlo	8,670[g]	8,670[g]
	Kilfrost ABC-S	17,000 [c]	17,000 [c]
	SPCA AD-480	15,200 [e]	12,800 [c]

[a] The Aerospace Information Report (AIR) 9968 Revision A (December 2004) viscosity method should only be used for field verification and auditing purposes; when in doubt as to which method is appropriate, use the manufacturer method.

[b] Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of neat fluid, at 20°C, 0.3 rpm, for 15 minutes 0 seconds.

[c] Brookfield Spindle LV2-disc with guard leg, 150 mL of neat fluid, at 20°C, 0.3 rpm, for 10 minutes 0 seconds.

[d] Brookfield Spindle LV1 with guard leg, 500 mL of neat fluid, at 20°C, 0.3 rpm, for 33 minutes 20 seconds.

[e] Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of neat fluid, at 20°C, 0.3 rpm, for 30 minutes 0 seconds.

[f] Brookfield Spindle SC4-31/13R, small sample adapter, 10 mL of neat fluid, at 0°C, 0.3 rpm, for 10 minutes 0 seconds.

[g] Brookfield Spindle LV1 with guard leg, 500 mL of neat fluid, at 20ºC, 0.3 rpm, for 10 minutes 0 seconds.

SIGNIFICANCE OF THIS TABLE

The viscosity of the fluids in this table are those that the fluid manufacturers provided for holdover time testing. For the holdover time guidelines to be valid, the viscosity of the neat fluid on the wing shall not be lower than that listed in this table. The user should periodically ensure that the viscosity value of a fluid sample taken from the wing is not lower than that listed.

Note: The fluid manufacturer should be consulted for lowest on-wing viscosity associated with dilutions.

APPENDIX J

PRESENTATIONS: SAE G-12 STANDING COMMITTEE MEETINGS, SAE G-12 WORK GROUP MEETINGS, FAA MEETINGS, AND SAE G-12 SUBCOMMITTEE AIRCRAFT GROUND DEICING MEETINGS

PRESENTATIONS: SAE G-12 STANDING COMMITTEE MEETINGS, SAE G-12 WORK GROUP MEETINGS, FAA MEETINGS, AND SAE G-12 SUBCOMMITTEE AIRCRAFT GROUND DEICING MEETINGS

Two presentations were prepared for the Standing Committee meetings held in Ottawa from September 29-30, 2004:

1) Aircraft De/Anti-Icing Fluid Holdover Time Guideline Developments, 2004-05 Winter Operations; and
2) Aircraft Anti-Icing Fluid Lowest On-Wing Viscosity.

One presentation was prepared for the SAE G-12 Work Group and HOT meetings held in Montreal from October 20-22, 2004:

1) Revisions to HOT Table Format, Notes and Cautions for Future Years.

Two presentations were prepared for the FAA meetings held in Atlantic City on November 16, 2004 and January 18, 2005:

1) Test History Air-Assisted Application of Type II/IV Fluid; and
2) Ice Making Feasibility Study for Ice Detection Threshold Tests.

Seven presentations were prepared for the SAE G-12 meetings held in Pittsburgh from May 23-26, 2005:

1) Proposed ARP 5945 Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type I;
2) Exploratory Endurance Time Tests;
3) Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2004-05 Winter Test Season – Type I;
4) Aircraft De/Anti-Icing Fluid Endurance Time Results for The 2004-05 Winter Test Season – Type II/IV;
5) Type III Aircraft Ground De/Anti-Icing Fluid Endurance Time Test Results and Holdover Time Table Developments;
6) Type III De/Anti-Icing Fluid Developments 2004-05 Winter; and
7) Type IV Fluid Application with Forced Air.

This page intentionally left blank.

AIRCRAFT DE/ANTI-ICING FLUID HOLDOVER TIME GUIDELINE DEVELOPMENTS

2004-05 WINTER OPERATIONS







Transport Canada

TRANSPORT CANADA STANDING COMMITTEE MEETING
OTTAWA, CANADA
SEPTEMBER 29-30, 2004

APS Aviation Inc.

RESEARCH CONDUCTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

BACKGROUND

This past winter (2003-04), the following holdover time guidelines were available:

- Type I generic table
- Type II generic table
- Five Type II fluid-specific tables
- Type III generic table
- Type IV generic table
- Nine Type IV fluid-specific tables



FLUIDS TESTED

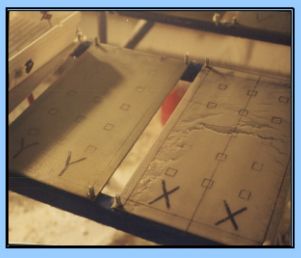
2003-04 ENDURANCE TIME TESTS



- Type II
- Type III

Transport Canada

NEW PRODUCT TESTING 2003-04



TYPE II FLUID

One Type II Fluid

Will not be commercialized

Transport Canada

NEW PRODUCT TESTING 2003-04



TYPE III FLUID

Clariant Safewing MPIII 2031 Eco

Transport Canada

TEST CONDITIONS

2003-04 ENDURANCE TIME TESTS



- Natural Snow
- Freezing Fog
- Freezing Drizzle
- Light Freezing Rain
- Rain on a Cold-Soaked Wing

Transport Canada

VIEW OF TEST STANDS AND FLAT PLATES



DORVAL TEST SITE

DORVAL TEST SITE AND ASSOCIATED EQUIPMENT



Transport Canada

EXTERIOR VIEW OF NRC CLIMATIC ENGINEERING FACILITY



NRC CEF - OTTAWA

INTERIOR VIEW OF NRC CLIMATIC ENGINEERING FACILITY



Transport Canada

TYPE I / TYPE II / TYPE IV

ENDURANCE TIME TESTING AND HOLDOVER TIME GUIDELINE CHANGES

SUMMARY OF TYPE I / II / IV ENDURANCE TIME TESTING

- No new Type I / Type IV fluids were tested
- One new Type II fluid was tested in all conditions
- The new Type II fluid will not be commercialized in 2004-05

Transport Canada

REMOVAL OF OBSOLETE DATA

- Process for the removal of obsolete anti-icing fluid data was discussed and implemented by the SAE G-12 HOT Subcommittee in New Orleans in 2001
  - Not commercially available for 4 years
  - Not re-certified
- Since that time, data for three obsolete Type IV fluids were removed from the Type IV data set and analysis, resulting in increases to the Type IV Generic table

Transport Canada

REMOVAL OF OBSOLETE DATA

- One fluid (Type IV) met both criteria
- This Type IV fluid, Clariant Safewing Four, was tested for holdover times in 1999-2000, but was never produced commercially
- Fluid was not re-certified
- Data were removed from the Type IV analysis

Transport Canada

REMOVAL OF OBSOLETE DATA

CONSEQUENCES 2004-05

- Clariant Safewing Four is not responsible for any of the Generic Type IV holdover times
- No changes have been made to the Type IV Generic table as a result of the removal of Clariant Safewing Four
- Fluid-Specific holdover time table for Clariant Safewing Four has been removed

Transport Canada

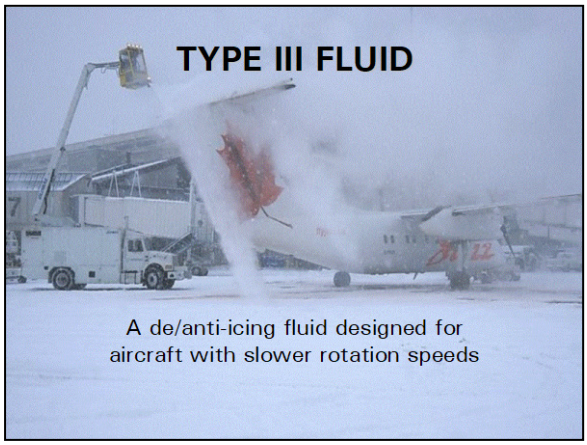
SUMMARY OF TYPE I / II / IV HOLDOVER TIME GUIDELINE CHANGES

- No changes have been made to the Type I / Type II / Type IV Generic fluid holdover time guidelines
- One additional Type IV Fluid-Specific table has been made available (Octagon Max-Flight 04), based on previous testing
- One Type IV Fluid-Specific table has been removed (Clariant Safewing Four)

Transport Canada

TYPE III

ENDURANCE TIME TESTING AND HOLDOVER TIME GUIDELINE CHANGES



OVERVIEW OF PAST TYPE III FLUID ENDURANCE TIME TESTING

- Two Type III fluids were previously tested:
  - 1991-92
  - 1996-97
- One fluid, Union Carbide 250-3, was produced commercially but later discontinued
- The other fluid, Union Carbide Ultra+ (66%), was never used commercially

Transport Canada

TRANSPORT CANADA TYPE III FLUID HOLDOVER TIME GUIDELINES 2003-04

(Based on the results of 1996-97 tests)

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
°C	°F	*FROST	FREEZING FOG	SNOW	**FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING
above 0°	above 32°	05:00	50-90	15-30	25-50	15-25	5-35
0 to -3	32 to 27	04:00	50-90	15-25	25-50	15-25	
below -3 to -14	below 27 to 7	04:00	50-90	10-20	**25-50	**15-25	
below -14	below 7	SAE TYPE II fluid may be used below -14°C (7°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consult service of SAE Type I when SAE Type II fluid cannot be used.					

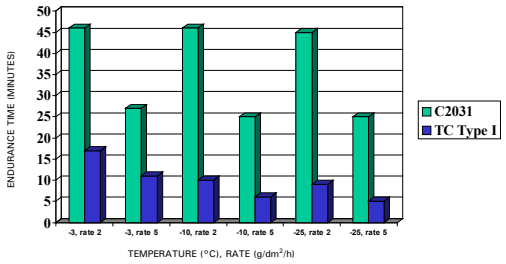
Transport Canada

SUMMARY OF TYPE III ENDURANCE TIME TESTING

- In Winter 2003-04, APS was provided with samples of Clariant MP III Safewing 2031 Eco for endurance time testing
- Tests were performed in all conditions and temperatures covered by the holdover time tables

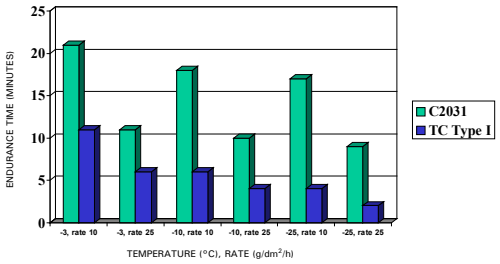
Transport Canada

FREEZING FOG ENDURANCE TIME TEST RESULTS



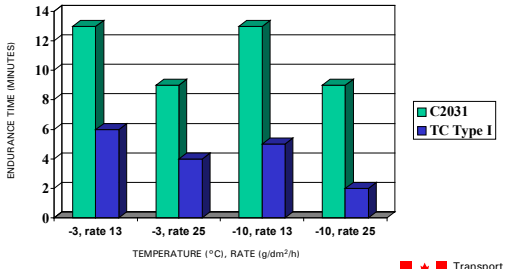
Transport Canada

SNOW ENDURANCE TIME TEST RESULTS



Transport Canada

LIGHT FREEZING RAIN ENDURANCE TIME TEST RESULTS



Transport Canada

TRANSPORT CANADA TYPE III HOT GUIDELINES 2004-05

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005

Outside Air Temperature[4]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Very Light Snow[1]	Light Snow[2]	Moderate Snow[3]	Freezing Drizzle[1]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[3]
-3 and above	27 and above	120	20 - 40	35	20 - 35	10 - 20	10 - 20	8 - 10	6 - 20	
below -3 to -10	below 27 to 14	120	20 - 40	30	15 - 30	9 - 15	10 - 20	8 - 10	CAUTION: No holdover time guidelines exist	
below -10	below 14	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. Snow includes snow grains.
4. Ensure that the lowest operational use temperature (LOUT) is respected, otherwise consider use of Type I when Type III fluid cannot be used.

CAUTIONS
- The only acceptable decision criteria time is the shortest 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 do not provide ice protection during flight.

Transport Canada

TYPE III APPLICATION PROCEDURES

- Fluid may be applied in one-step or two-step application procedure
- Fluid may be applied heated, similar to Type I fluid
- Fluid may be applied at high pressure

Transport Canada

TYPE III AVAILABILITY

2004-05

- Clariant Safewing MPIII 2031 Eco will only be made available at selected sites in the US in 2004-05 for operational testing (American Eagle stations)
- Fluid will not make widespread entry into commercial marketplace until Winter 2005-06

Transport Canada

SUMMARY

TRANSPORT CANADA HOLDOVER TIME GUIDELINE CHANGES FOR 2004-05 WINTER OPERATIONS

TRANSPORT CANADA TYPE I HOT GUIDELINES 2004-05

SAE TYPE I[4] FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005

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

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

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature FP = Freezing Point

NO CHANGES

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 During conditions that apply to aircraft protection for ACTIVE FROST.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
5 Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT.

CAUTIONS
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
- The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
- Fluids used during ground deicing do not provide ice protection during flight.

Transport Canada

TRANSPORT CANADA TYPE II HOT GUIDELINES 2004-05

SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005[1]

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

OAT		Type II Fluid Concentration Neat Fluid/Water (Vol% / Vol%)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
°C	°F		Frost[2]	Freezing Fog	Snow[3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[5]
above 0	above 32	100/0	12:00	0:35 – 1:30	0:20 – 0:55	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	6:00	0:25 – 1:00	0:15 – 0:40	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	4:00	0:15 – 0:30	0:05 – 0:15		0:05 – 0:10		
0 to -3	32 to 27	100/0	8:00	0:35 – 1:30	0:20 – 0:55		0:15 – 0:30	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:25 – 1:00	0:15 – 0:40		0:10 – 0:25		
		50/50	3:00	0:15 – 0:30	0:05 – 0:15		0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	8:00	0:15 – 0:55	0:15 – 0:35	0:15 – 0:45[6]	0:10 – 0:25[6]		
		75/25	4:00	0:15 – 0:55	0:15 – 0:35	0:15 – 0:30[6]	0:10 – 0:20[6]		
below -14 to -25	below 7 to -13	100/0	8:00	0:15 – 0:20[7]	0:15 – 0:30[7]				
below -25	below -13	100/0	6 Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature Vol = Volume

NO CHANGES

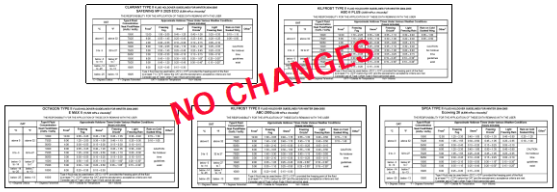
NOTES
1 Based on tests of neat fluids with the lowest viscosity deliverable on the aircraft, yet meeting Type II WSET and HHET.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 The lowest use temperature is limited to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
6 Snow includes snow grains.
7 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
- The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
- Fluids used during ground deicing do not provide ice protection during flight.

Transport Canada

TRANSPORT CANADA TYPE II FLUID-SPECIFIC HOT GUIDELINES 2004-05

1) CLARIANT SAFEWING MP II 2025 ECO
2) KILFROST ABC 2000
3) KILFROST ABC II PLUS
4) OCTAGON E MAX II
5) SPCA ECOWING 26



NO CHANGES

TRANSPORT CANADA TYPE III HOT GUIDELINES 2004-05

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005

Outside Air Temperature[4]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Very Light Snow[3]	Light Snow[3]	Moderate Snow[3]	Freezing Drizzle	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	120	20 - 40	35	25 - 30	10 - 20	15	6 - 20	
below -3 to -10	below 27 to 14	120	15 - 30	25	15 - 25	8 - 15	10 - 20	5 - 10	CAUTION: No holdover time guidelines exist
below -10			20 - 40	35	25 - 30	8 - 15			

NUMEROUS CHANGES
NEW TYPE III TABLE
NEW CERTIFIED FLUID

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 Snow includes snow grains.
4 Ensure that the lowest operational use temperature (LOUT) is respected, otherwise consider use of Type I when Type III fluid cannot be used.

CAUTIONS
- The only acceptable decision criteria time is the shortest 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 do not provide ice protection during flight.

Transport Canada

TRANSPORT CANADA TYPE IV HOT GUIDELINES 2004-05

SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005[1]

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

OAT		Type IV Fluid Concentration Neat Fluid/Water (Vol% / Vol%)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
°C	°F		Frost[2]	Freezing Fog	Snow[4]	Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[3]
above 0	above 32	100/0	18:00	1:05 – 2:15	0:35 – 1:05	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	
		75/25	6:00	1:05 – 1:45	0:30 – 1:05	0:35 – 0:55	0:15 – 0:30	0:05 – 0:35	
		50/50	4:00	0:15 – 0:35	0:05 – 0:20	0:10 – 0:15	0:05 – 0:10		
0 to -3	32 to 27	100/0	12:00	1:05 – 2:15	0:30 – 0:55	0:40 – 1:10	0:25 – 0:40	CAUTION: No holdover time guidelines exist	
		75/25	5:00	1:05 – 1:45	0:30 – 0:55	0:35 – 0:55	0:15 – 0:30		
		50/50	3:00	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	12:00	0:20 – 0:40	0:20 – 0:40	0:20 – 0:40[6]	0:10 – 0:25[6]		
		75/25	5:00	0:20 – 0:40	0:20 – 0:35	0:20 – 0:35	0:15 – 0:30[6]	0:10 – 0:20[6]	
below -14 to -25	below 7 to -13	100/0	12:00	0:15 – 0:40[7]	0:15 – 0:30[7]				
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 OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature Vol = Volume

NOTES
1 Based on tests of neat fluids with the lowest viscosity deliverable on the aircraft, yet meeting Type IV WSET and HHET.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 The lowest use temperature is limited 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 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
6 Snow includes snow grains.
7 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
- The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
- Fluids used during ground deicing do not provide ice protection during flight.

NO CHANGES

Transport Canada

TRANSPORT CANADA TYPE IV FLUID-SPECIFIC HOT GUIDELINES 2004-05

1) CLARIANT SAFEWING MP IV 1957
2) CLARIANT SAFEWING MP IV 2001
3) ~~CLARIANT SAFEWING FOUR~~
4) CLARIANT SAFEWING MP IV PROTECT 2012
5) CLARIANT SAFEWING MP IV 2030 ECO
6) DOW ULTRA +
7) KILFROST ABC-S
8) OCTAGON MAX-FLIGHT
9) SPCA AD-480

X

TRANSPORT CANADA TYPE IV FLUID-SPECIFIC HOT GUIDELINES 2004-05

1) CLARIANT SAFEWING MP IV 1957
2) CLARIANT SAFEWING MP IV 2001
3) CLARIANT SAFEWING MP IV PROTECT 2012
4) CLARIANT SAFEWING MP IV 2030 ECO
5) DOW ULTRA +
6) KILFROST ABC-S
7) OCTAGON MAX-FLIGHT
8) SPCA AD-480
9) **OCTAGON MAX-FLIGHT 04**

NEW

TRANSPORT CANADA VISIBILITY TABLE 2004-05

Transport Canada Holdover Time Guidelines — Winter 2003-2004

TABLE 8
VISIBILITY IN SNOW VS. SNOWFALL INTENSITY CHART[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)		
	°C	°F	Heavy	Moderate	Light
Darkness	-1 and above	30 and above	≤1	>1 to ≤3	>3 to ≤ 4
	Below -1	Below 30	≤3/4	>3/4 to ≤1½	>1½ to ≤2
Daylight	-1 and above	30 and above	≤1	>1 to ≤ 3	>3
	Below -1	Below 30	≤1/2	>1/2 to ≤1	>1 to ≤ 2

HOW TO READ THIS TABLE

Assume that the daytime visibility in snowfall is 1 statute mile and the temperature is -7°C. Based on these conditions, the snowfall intensity is light. This snowfall intensity is used to determine which holdover time guideline value is appropriate for the fluid in use.

Page 27 of 27 July 2003

NO CHANGES

Transport Canada

GUIDANCE MATERIAL

- Holdover Time Tables for 2004-05
  - http://www.tc.gc.ca/civilaviation/commerce/holdovertime/menu.htm
- Transport Canada Ground Icing Operations Update TP 14052E

Transport Canada



AIRCRAFT ANTI-ICING FLUID

LOWEST ON-WING VISCOSITY







Transport Canada

TRANSPORT CANADA STANDING COMMITTEE MEETING
OTTAWA, CANADA
SEPTEMBER 29-30, 2004

APS Aviation Inc.

PRESENTED ON BEHALF OF:

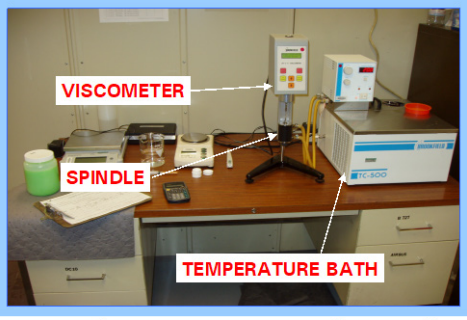
TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transport Canada

FLUID VISCOSITY

- A measure of the resistance to flow of a liquid
  - Molasses: High Viscosity / Water: Low Viscosity
  - Type II/IV Fluids: High Viscosity
  - Type I Fluids: Low Viscosity

Transport Canada



Rotational viscosity measurement employs a spindle immersed in a fluid sample to sense torque resistance when running at constant speed

FLUID VISCOSITY

- Since 1999-2000, the viscosity of the Type II/IV fluids tested for holdover times has been included on the Fluid-Specific holdover time tables
- Viscosity included on the Fluid-Specific table is referred to as Lowest-on-Wing Viscosity (LOWV)

Transport Canada

HOLDOVER TIME TABLE VISCOSITY

CLARIANT TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005
SAFEWING MP II 2025 ECO (6,500 mPa.s viscosity)

LOWV

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

OAT °C	OAT °F	Type II Fluid Concentration Neat Fluid/Water (Vol% / Vol%)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes) Frost[1]	Freezing Fog	Snow[2]	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[4]
above 0	above 32	100/0	12:00	1:30 – 2:05	0:45 – 1:20	0:40 – 1:00	0:25 – 0:35	0:10 – 1:15	
		75/25	6:00	0:55 – 1:45	0:25 – 0:45	0:25 – 0:45	0:20 – 0:25	0:05 – 0:50	
		50/50	4:00	0:20 – 0:35	0:10 – 0:25	0:10 – 0:15	0:05 – 0:10		
0 to -3	32 to 27	100/0	8:00	1:30 – 2:05	0:40 – 1:10	0:40 – 1:00	0:25 – 0:35	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:55 – 1:45	0:25 – 0:45	0:25 – 0:45	0:20 – 0:25		
		50/50	3:00	0:20 – 0:35	0:05 – 0:15	0:10 – 0:15	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	8:00	0:45 – 1:50	0:35 – 1:00	0:35 – 1:05[5]	0:20 – 0:35[5]		
		75/25	5:00	0:40 – 1:20	0:25 – 0:45	0:30 – 0:40[5]	0:15 – 0:25[5]		
below -14 to -25	below 7 to -13	100/0	8:00	0:25 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature Vol = Volume

NOTES
1. Lowest on-wing viscosity - Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of neat fluid, at 20°C, 0.3 rpm, for 15 minutes 0 seconds.
2. Snow, including Blowing Snow, is only to be used for protection by ACTIVE FROST.
3. The lowest use temperature is limited 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. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
6. Snow includes snow grains.

CAUTIONS
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
- The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
- Fluids used during ground deicing do not provide ice protection during flight.

VISCOSITY METHOD

Transport Canada

LOWEST ON-WING VISCOSITY

- Determined by the fluid manufacturer
- Minimum required viscosity of a particular anti-icing fluid on an aircraft for the Fluid-Specific holdover times to apply

Transport Canada

VISCOSITY MEASUREMENT METHODS

- In the past, many fluid manufacturers have employed different viscosity measurement methods
  - Spindle size
  - Amount of fluid
  - Beaker or sample container size
  - Temperature of the fluid
  - Measurement speed and duration
- Testing agencies and operators performing field viscosity verifications complained of complications due to the vast differences in the viscosity measurement methods from one fluid to the next

Transport Canada

STANDARD VISCOSITY MEASUREMENT METHODS

- Due to these complications, there has been a strong industry push in recent years to standardize viscosity measurement methods
- This has led to the development of the proposed SAE Aerospace Information Report (AIR) 9968
  - Viscosity Test of Thickened Aircraft Deicing-Anti-Icing Fluids

Transport Canada

FUTURE

- AIR 9968 has been adopted
- Transport Canada has proposed removing the fluid viscosity information from the Fluid-Specific tables to include them in a separate Fluid Viscosity Table, together with using the AIR 9968 method
- This will enable standardized methods for viscosity measurement to be employed, which will greatly simplify the process of performing field viscosity auditing

Transport Canada



This page intentionally left blank.

REVISIONS TO HOT TABLE FORMAT, NOTES AND CAUTIONS FOR FUTURE YEARS

CURRENT TC TII/IV HOLDOVER TIME TABLE

Fluid X (23,100 mPa.s viscosity)[1]

OAT		Type IV Fluid Concentration (Vol/Vol)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)						
°C	°F		FROST[2]	FREEZING FOG	SNOW[3]	FREEZING DRIZZLE[4]	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER[5]
above 0	above 32	100/0							CAUTION No holdover time guidelines exist
		75/25							
		50/50							
0 to -3	32 to 27	100/0							
		75/25							
		50/50							
below -3 to -14	below 27 to 7	100/0					[6]	[6]	
		75/25					[6]	[6]	
below -14 to -25	below 7 to -13	100/0							
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside air temperature Vol = Volume

Notes (6) and Cautions (3)

CURRENT TC TII/IV HOLDOVER TIME TABLE

NOTES AND CAUTIONS

- **Notes:**
  1. Lowest on-wing viscosity- Brookfield Spindle LV1, 20°C, 0.3 rpm, 15 minutes
  2. During conditions that apply to aircraft protection for active frost
  3. The lowest use temperature is limited 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. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail
  6. Snow includes snow grains

- **Cautions:**
  1. The real time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
  2. The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
  3. Fluids used during ground de-icing do not provide ice protection during flight.

POTENTIAL FORMAT CHANGES

RECOMMENDED CHANGE #1

REMOVAL OF ABOVE 0°C TEMPERATURE BAND

CURRENT TC TII/IV HOLDOVER TIME TABLE

OAT		Type IV Fluid Concentration (Vol/Vol)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)						
°C	°F		FROST[2]	FREEZING FOG	SNOW[3]	FREEZING DRIZZLE[4]	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER[5]
above 0	above 32	100/0							CAUTION No holdover time guidelines exist
		75/25							
		50/50							
0 to -3	32 to 27	100/0							
		75/25							
		50/50							
below -3 to -14	below 27 to 7	100/0					[6]	[6]	
		75/25					[6]	[6]	
below -14 to -25	below 7 to -13	100/0							
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside air temperature Vol = Volume

TII/IV HOLDOVER TIME TABLE WITH TEMPERATURE BAND REMOVED

OAT		Type IV Fluid Concentration (Vol/Vol)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)						
°C	°F		FROST[2]	FREEZING FOG	SNOW[3]	FREEZING DRIZZLE[4]	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER[5]
Above -3	Above 27	100/0							CAUTION No Holdover time guidelines exist
		75/25							
		50/50							
below -3 to -14	below 27 to 7	100/0					[6]	[6]	
		75/25					[6]	[6]	
below -14 to -25	below 7 to -13	100/0							
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside air temperature Vol = Volume

RECOMMENDED CHANGE #2

REMOVAL OF VISCOSITY INFORMATION

REMOVAL OF VISCOSITY INFORMATION

~~Fluid X (23,100 mPa.s viscosity)[1]~~

OAT		Type IV Fluid (Vol/Vol)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hour:minutes)						
°C	°F	Fluid/water Mixture (Vol/Vol)	FROST[3]	FREEZING FOG	SNOW[4]	FREEZING DRIZZLE[5]	LIGHT FRZ RAIN	AIN ON COLD SOAKED WING	OTHER[6]
Above -3	Above 27	100/0							
		75/25							
		50/50							CAUTION
below -3 to -14	below 27 to 7	100/0				3	3		No Holdover time guidelines exist
		75/25				3	3		
below -14 to -25	below 7 to -13	100/0							
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside air temperature Vol = Volume

CURRENT TC TII/IV HOLDOVER TIME TABLE

NOTES AND CAUTIONS

- **Notes:**
  1. ~~Lowest on-wing viscosity -Brookfield Spindle LV1, 20°C, 0.3 rpm, 15 minutes.~~
  2. During conditions that apply to aircraft protection for active frost
  3. The lowest use temperature is limited 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. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail
  6. Snow includes snow grains
- **Cautions:**
  1. The real time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
  2. The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
  3. Fluids used during ground de-icing do not provide ice protection during flight.

RECOMMENDED CHANGE #3

REMOVAL OF ABBREVIATIONS

REMOVAL OF ABBREVIATIONS

Outside Air Temperature		Type IV Fluid (Vol/Vol)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hour:minutes)						
Degrees Celsius	Degrees Fahrenheit	Fluid/water Mixture Volume	FROST[3]	FREEZING FOG	SNOW[4]	FREEZING DRIZZLE[5]	LIGHT FRZ RAIN	AIN ON COLD SOAKED WING	OTHER[6]
		100/0							
above -3	above 27	75/25							
		50/50							No Holdover
below -3 to -14	below 27 to 7	100/0				3	3		time guidelines
		75/25				3	3		
below -14 to -25	below 7 to -13	100/0							exist
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

~~°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside air temperature Vol = Volume~~

POTENTIAL CHANGE #4

CHANGES TO NOTES

CURRENT TC TII/IV HOLDOVER TIME TABLE

NOTES AND CAUTIONS

- **Notes:**
  1. ~~Lowest on-wing viscosity, Brookfield Spindle LV1, 20°C, 0.3 rpm, 15 minutes~~
  2. ~~During conditions that apply to aircraft protection for active frost~~
  3. The lowest use temperature is limited 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. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail
  6. Snow includes snow grains

- **Cautions:**
  1. The real time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
  2. The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
  3. Fluids used during ground de-icing do not provide ice protection during flight.

ADDITION OF THE WORD "ACTIVE" TO THE FROST COLUMN

Outside Air Temperature		Type IV Fluid Concentration (volume/volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Acceptable Mixes	ACTIVE FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE*	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER*
		100/0							
above	above	75/25							
-3	27								
		50/50							No Holdover
below	below	100/0				2	2		time
-3	27								guidelines
to	to	75/25				2	2		
-14	7								exist
below	below								
-14	7	100/0							
to	to								
-25	-13								
below	below		SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point						
-25	-13	100/0	of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance						
			criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used						

POTENTIAL CHANGE #5

CHANGES TO NOTES

CURRENT TC TII/IV HOLDOVER TIME TABLE

NOTES AND CAUTIONS

- **Notes:**
  1. ~~Lowest on-wing viscosity, Brookfield Spindle LV1, 20°C, 0.3 rpm, 15 minutes~~
  2. ~~During conditions that apply to aircraft protection for active frost~~
  3. The lowest use temperature is limited 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. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail
  6. ~~Snow includes snow grains~~

- **Cautions:**
  1. The real time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
  2. The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
  3. Fluids used during ground de-icing do not provide ice protection during flight.

ADDITION OF "SNOW GRAINS" TO THE SNOW COLUMN

? ? ? ?

Outside Air Temperature		Type IV Fluid Concentration (volume/volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit	Acceptable Mixes	ACTIVE FROST	FREEZING FOG	SNOW SNOW GRAINS	FREEZING DRIZZLE*	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER*
		100/0							
above	above	75/25							
-3	27								
		50/50							No Holdover
below	below	100/0				2	2		time
-3	27								guidelines
to	to	75/25				2	2		
-14	7								exist
below	below								
-14	7	100/0							
to	to								
-25	-13								
below	below		SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point							
-25	-13	100/0	of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance							
			criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used							

POTENTIAL CHANGE #6

CHANGES TO CAUTIONS

CURRENT TC TII/IV HOLDOVER TIME TABLE

CAUTIONS

- **Current TC Type II/IV HOT Table Cautions:**
  1. The real time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
  2. The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
  3. Fluids used during ground de-icing do not provide ice protection during flight.

- **Current TC Type III HOT Table Cautions:**
  1. The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
  2. High wind velocity or jet blast may reduce holdover time.
  3. Holdover time may also be reduced when aircraft skin temperature is lower than outside air temperature.
  4. Fluids used during ground de-icing do not provide ice protection during flight.

CURRENT TC TII/IV HOLDOVER TIME TABLE

Fluid X (23,100 mPa.s viscosity)[1]

OAT		Type IV Fluid Concentration (% by volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)						
°C	°F		FROST[2]	FREEZING FOG	SNOW[4]	FREEZING DRIZZLE[5]	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER[6]
above 0	above 32	100/0							
		75/25							
		50/50							
0 to -3	32 to 27	100/0							
		75/25							
		50/50							
below -3 to -14	below 27 to 7	100/0				[3]	[3]		
		75/25				[3]	[3]		
below -14 to -25	below 7 to -13	100/0							
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

CAUTION No holdover time guidelines exist

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside air temperature Vol = Volume

Notes (6) and Cautions (3)

CURRENT TC TII/IV HOLDOVER TIME TABLE

NOTES AND CAUTIONS

- **Notes:**
  1. Lowest on-wing viscosity- Brookfield Spindle LV1, 20°C, 0.3 rpm, 15 minutes
  2. During conditions that apply to aircraft protection for active frost
  3. The lowest use temperature is limited 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. Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail
  6. Snow includes snow grains

- **Cautions:**
  1. The real time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
  2. The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
  3. Fluids used during ground de-icing do not provide ice protection during flight.

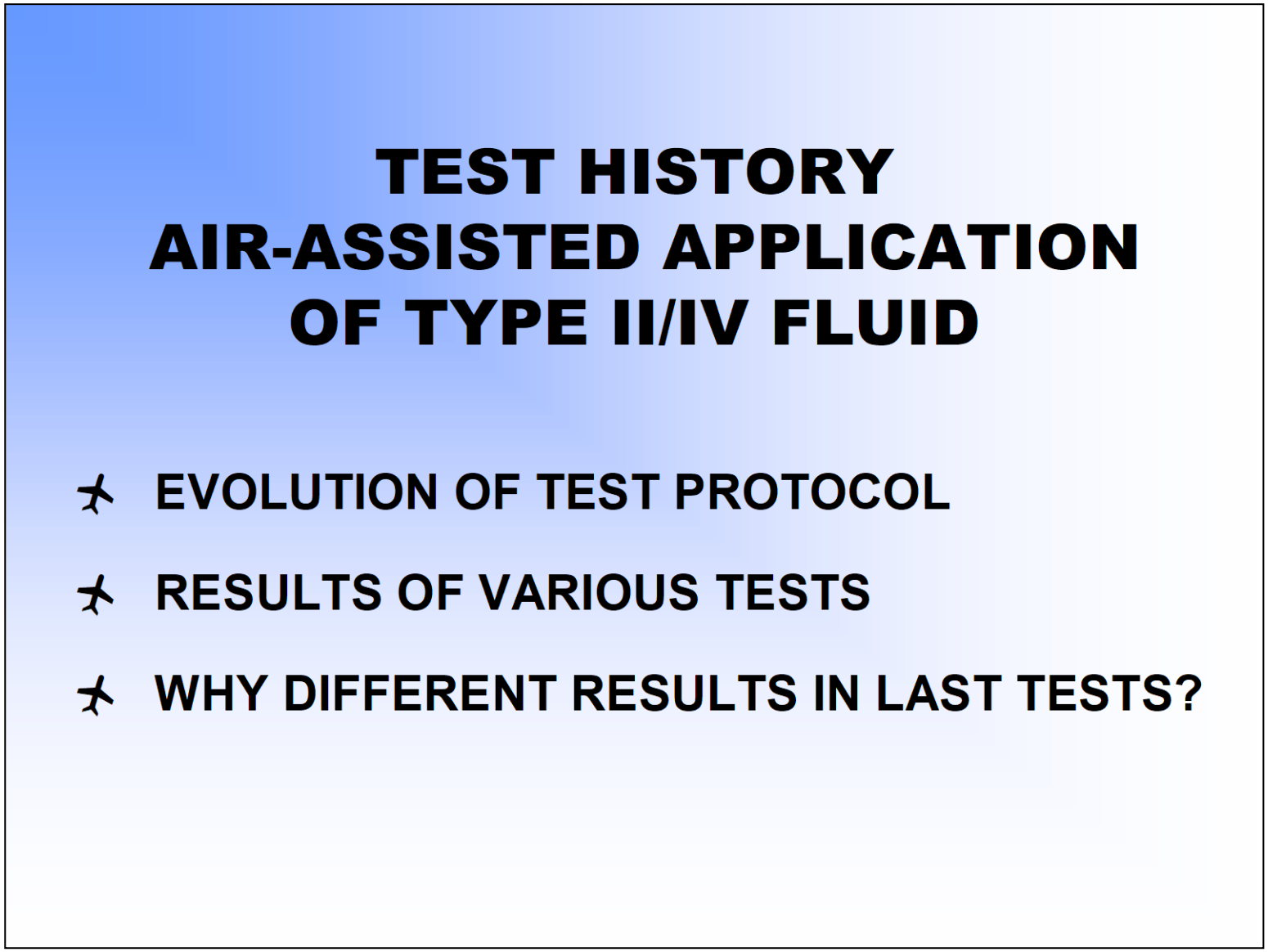
POTENTIAL NEW TII/IV HOLDOVER TIME TABLE

Outside Air Temperature		Type IV Fluid Concentration (% by volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit		ACTIVE FROST	FREEZING FOG	SNOW SNOW GRAINS	FREEZING DRIZZLE[3]	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER[4]
above -3	above 27	100/0							
		75/25							
		50/50							
below -3 to -14	below 27 to 7	100/0				[3]	[3]		
		75/25				[3]	[3]		
below -14 to -25	below 7 to -13	100/0							
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

No Holdover time guidelines exist

Notes (3) and Cautions (3 or 4)

This page intentionally left blank.


TEST HISTORY
AIR-ASSISTED APPLICATION
OF TYPE II/IV FLUID
EVOLUTION OF TEST PROTOCOL
RESULTS OF VARIOUS TESTS
WHY DIFFERENT RESULTS IN LAST TESTS?

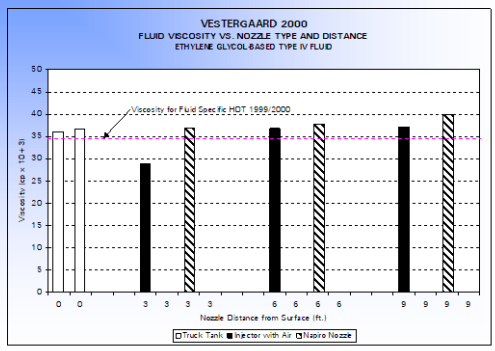
EXAMINATION OF SAFETY ISSUES – APRIL, 2000

- Structured tests at NRC Cold Chamber Ottawa
- Conducted on Jetstar Test Wing

SAFETY ISSUES EXAMINED

- Noise levels, effect on visibility, ice and snow projectiles, pressure and temperature on wing skin, elapsed time to refreeze, residue in quiet areas.
- Shearing of Type IV fluid.
- Results presented at SAE G-12E 2000.

VESTERGAARD 2000



SAE G-12E MEETING – 2001

- Identified need for an official process to examine whether SAE Type II/IV fluid HOT tables can be used with air-assisted fluid applications.
- Transport Canada/FAA agreed to support development of test specs and approval process.

APPROVAL PROCESS

1. A standard test protocol was developed with participation from FAA, TC and the SAE G-12 Equipment Subcommittee Forced Air Working Group.
2. Test based on *comparison to conventional application*:
   - If quality of fluid application (including viscosity) with air-assist is equivalent to conventional application, then endurance times should be equivalent .
3. Each combination of forced air deicing truck and Type II/Type IV fluid brand requires individual testing and approval.

APPROVAL PROCESS (Cont'd)

4. Prior to testing
   - Operator develops in-house air-assist spray techniques.
   - Forced air systems are verified to be within manufacturer specs - Declaration of Conformity.
   - Operator schedules a test session, inviting observers from FAA Technical Center and Transport Canada (TDC).
5. Tests conducted on aircraft wings. Measure results of fluid application; both air-assisted and conventional.
   - Fluid viscosity
   - Fluid thickness and distribution
6. Test data and declaration of conformity submitted to FAA/TC for approval decision on that specific truck/fluid combination.

TEST PROCEDURE

- **Test fluid**
  - The fluid used for tests is qualified standard production fluid.
- **Weather conditions**
  - Tests in *dry conditions.*
  - Some of the five required tests may be performed in non-winter conditions, with OAT wing skin temperature not warmer than 15°C.
  - At least one test is to be performed in *freezing conditions.*
  - At least one test performed in *into-wind conditions.*

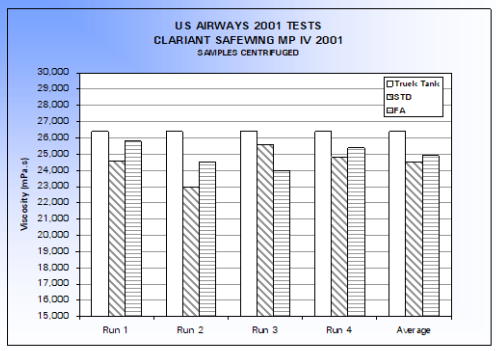
TEST PROCEDURE (Cont'd)

- **Test surface**
  - Tests on *dry wings* of out-of-service aircraft (example, parked overnight).
  - *Clean Type II/Type IV fluid from wings* between consecutive tests.
  - Care must be taken to ensure that there is *no residue of Type I fluid on the wings* to avoid inaccurate viscosity measurements.

APPLICATION OF TEST PROCEDURE

- American Airlines ORD – October 2001
  - Viscosity results not released.
- US Airways BOS – November 2001
  - Viscosity and other data collected on 18 tests.
  - Results reported in SAE Future Deicing Technology Subcommittee website under "Research in Progress".
- Air Canada YOW – January 2002
  - Viscosity and other data collected on 9 tests.
  - Results not promulgated.
  - Air Canada decision to not proceed further with air-assisted Type IV application.

US AIRWAYS 2001 TESTS



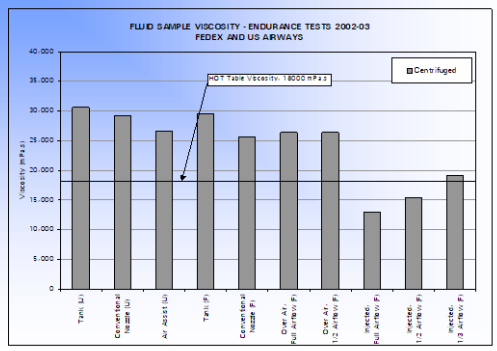
EXAMINATION OF TEST PROCEDURE

- In November 2002, FAA requested examination of effect on endurance times.
- Examine the assumption that endurance times will be similar when conventional and forced-air assisted applications have similar viscosities.
- Tests conducted in winter 2002-03 on fluid samples provided by FedEx and US Airways.

RESULTS OF EXAMINATION OF TEST PROCEDURE

- Endurance times for the two types of applications were seen to be similar when their viscosities were similar.
- Concluded that measurement of viscosities is sufficient for decision-making.

FLUID SAMPLE VISCOSITY



SOME CHANGES TO PROCEDURE WERE REQUIRED

- Injected form of air-assist not eligible for consideration.
- Decision by regulatory authorities would be based solely on measured viscosity values.
- Test ambient temperature must be below freezing.
- Tests must be conducted on an aircraft wing surface, not a substitute surface.
- Viscosity must be measured by an independent 3rd party on-site immediately following application.

REVISED (CURRENT) VERSION OF TEST PROCEDURE 2003

Previous procedure divided into two phases, *still based on comparison to conventional application:*

Phase 1: *operator assessment – voluntary*

- Results need not be reported to regulatory authority.
- Intended to assist operator in determining whether layer of applied fluid is satisfactory.

Phase 2: *viscosity measurement – required*

- Measured in conformance with new requirements.
- Submitted to regulatory authorities.

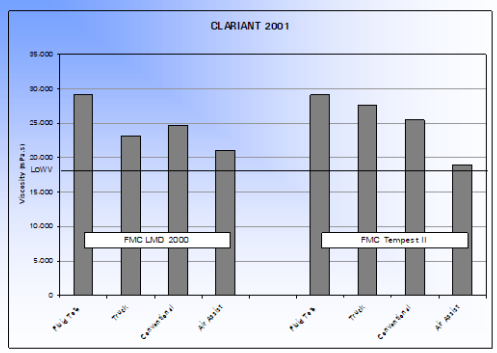
ROC FORCED AIR TESTS RESULTS

ROC FORCED AIR TESTS: RESULTS

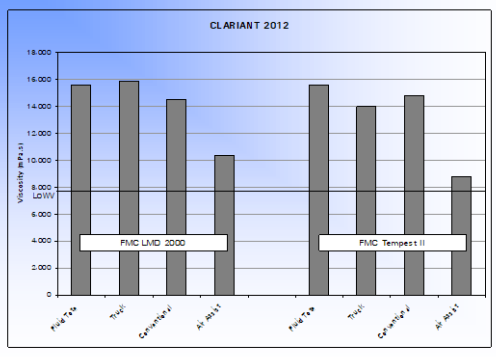
Fluid	Truck	Fluid Sample				Forced Air - Conventional Difference
		Fluid Tote (mPa.s)	Truck (mPa.s)	Conven. (mPa.s)	Forced Air (mPa.s)	
Lyondell/Clariant 2001	LMD 2000	29,100	23,200	24,700	21,100	-15%
Lyondell/Clariant 2001	Tempest II	29,100	27,600	25,500	19,000	-25%
Clariant 2012	LMD 2000	15,600	15,900	14,500	10,400	-28%
Clariant 2012	Tempest II	15,600	14,000	14,800	8,800	-41%
Octagon Max-Flight	LMD 2000	11,000	10,600	7,900	5,700	-28%
Octagon Max-Flight	Tempest II	11,000	10,400	7,800	4,900	-37%
Octagon Max-Flight 04	LMD 2000	11,200	10,700	7,900	6,100	-23%
Octagon Max-Flight 04	Tempest II	11,200	10,200	8,200	4,600	-44%
Kilfrost ABC-S	LMD 2000	19,650	19,300	19,600	12,900	-34%
Kilfrost ABC-S	Tempest II	19,650	19,200	20,750	11,400	-45%
Fluid "Y"	LMD 2000	16,100	16,600	13,300	8,700	-35%
Fluid "Y"	Tempest II	16,100	15,700	12,700	6,600	-48%

Average: -34%
Average (LMD): -27%
Average (Tempest): -40%

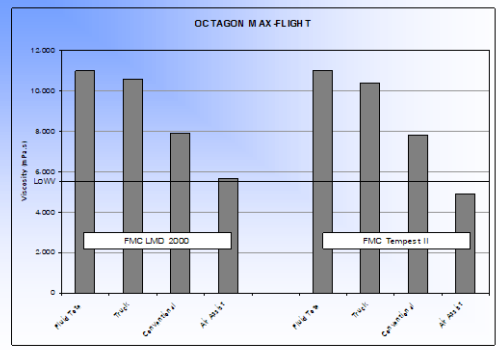
CLARIANT 2001



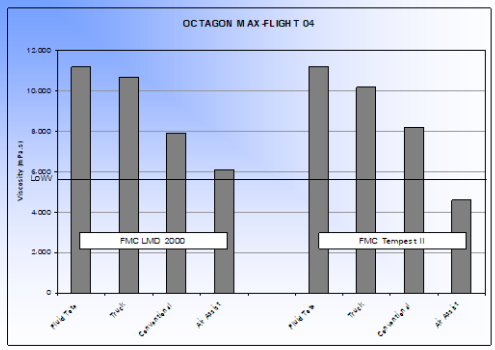
CLARIANT 2012



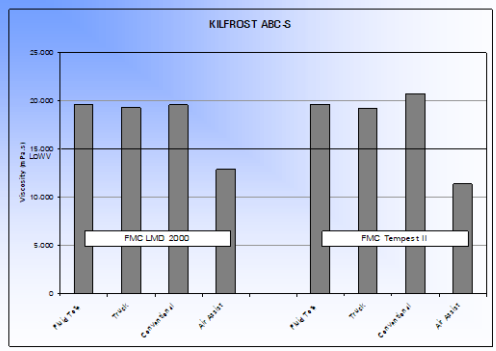
OCTAGON MAX-FLIGHT



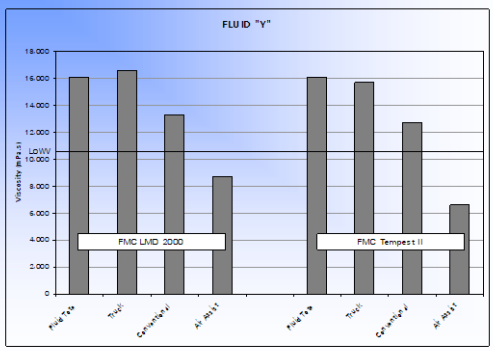
OCTAGON MAX-FLIGHT 04



KILFROST ABC-S



FLUID "Y"



EFFECT OF DELAYED MEASUREMENT OF VISCOSITY VALUES

Test Session	Time between Collection and Testing	Conventional (mPa.s)	Forced Air (mPa.s)	Forced Air Conventional Difference
2003-04 FedEx	Immediately	24,700	21,100	-15%
2003-04 FedEx	~ 3 weeks	22,400	18,800	-16%
2002-03 FedEx	~ 2 weeks	25,600	26,400	3%
2002-03 US Air	~ 2 weeks	29,200	26,600	-9%

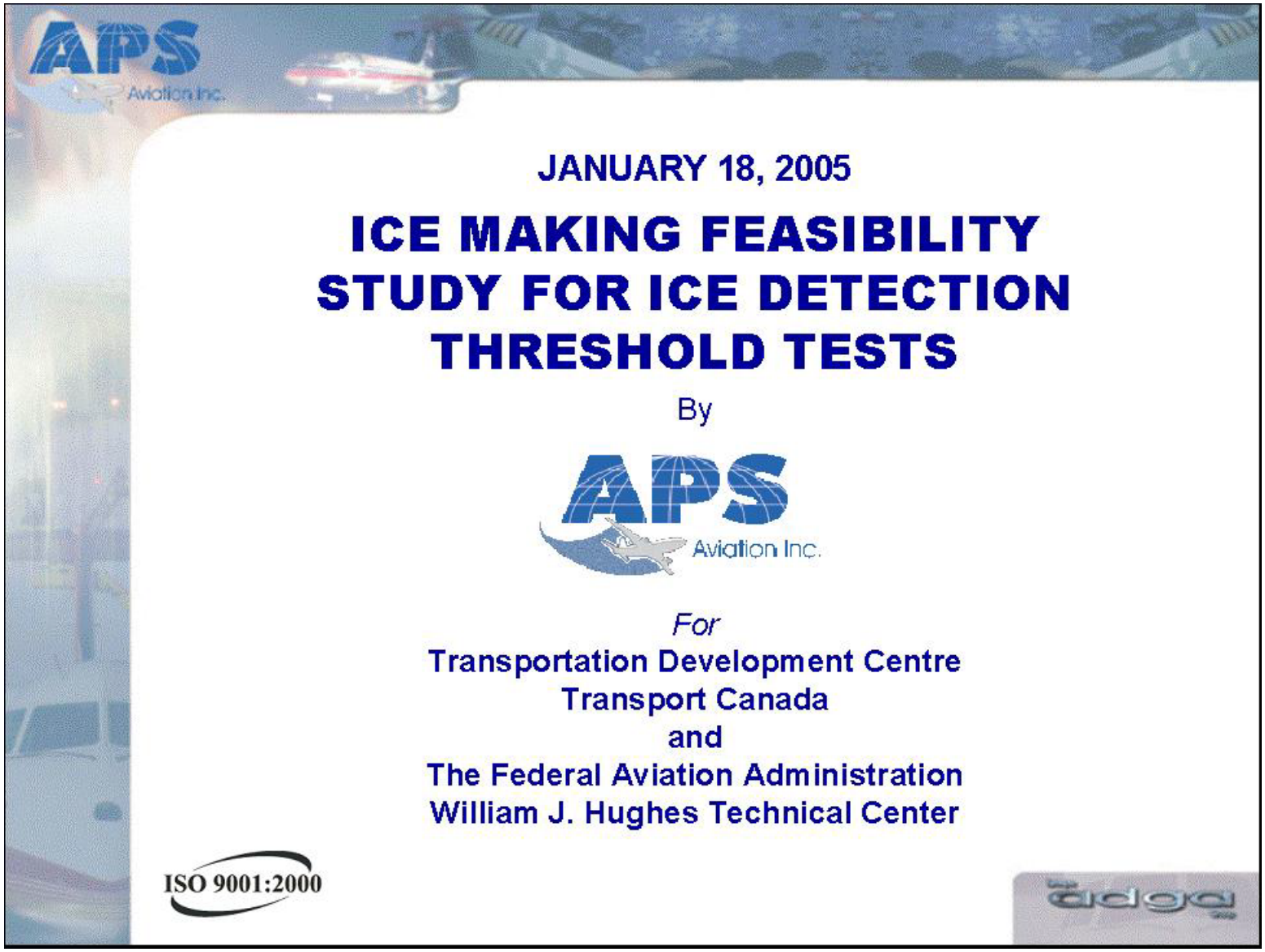
Observation on 2003-04 FedEx Samples:

- Later measurement did not influence the comparison between the air assist and conventional application samples.
- Similarly, comparison between the air assist and conventional application samples for earlier tests, such as the 2002-03 tests, should be valid.

WHY DIFFERENT RESULTS?

- Equipment setup?
  - Angle and distance of intersection of fluid and air streams
  - Fluid spray pattern
- Spray technique?
  - Distance from surface
  - Angle of incidence
- If tests are successful, how will variances be avoided in future operational use?

This page intentionally left blank.


APS
Aviation Inc.
JANUARY 18, 2005
ICE MAKING FEASIBILITY STUDY FOR ICE DETECTION THRESHOLD TESTS
By
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and
The Federal Aviation Administration
William J. Hughes Technical Center
ISO 9001:2000

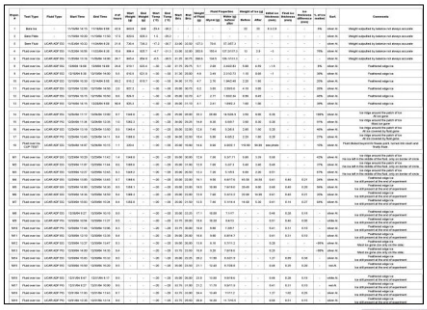
PRESENTATION OUTLINE

- OBJECTIVES
- TESTS CONDUCTED
- CALIBRATION
- ICE AND FLUID RESULTS
- CONCLUSIONS
- FUTURE INVESTIGATIONS REQUIRED
- TENTATIVE SCHEDULE

TESTS WERE CONDUCTED AS FOLLOWS:

- INITIALLY, EXPLORATORY TESTS WERE CONDUCTED TO EVALUATE WHETHER THE ICE DEGRADES AFTER THE APPLICATION OF FLUID.
- AFTER GETTING THE "GO AHEAD" FROM TRANSPORT CANADA ON DEC. 15, TESTS WERE CARRIED OUT TO:
  - DETERMINE THE FEASIBILITY OF MAKING ICE AT VARIOUS THICKNESSES.
  - DEVELOP A PROCEDURE FOR MAKING ICE AND MEASURE ICE THICKNESS RATE OF CHANGE UNDER FLUID.

LOG OF 35 TESTS



SUMMARY OF THE TEST LOG:

- 19 EXPLORATORY TESTS
- 16 DETAILED TESTS
- TWO TYPE I FLUIDS USED
- TESTING WAS CONDUCTED OVER 20 CALENDAR DAYS
- 350 HOURS OF TESTING

A TOTAL OF 35 TESTS WERE CONDUCTED:

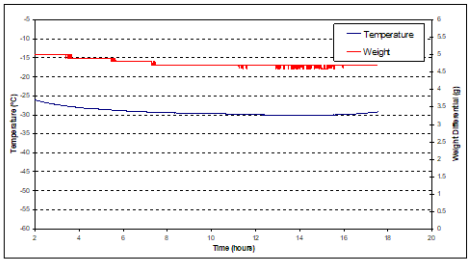
- PRELIMINARY CALIBRATION
  - ONE TEST WITH THE DRY PAN
  - ONE TEST WITH BARE ICE
  - ONE TEST WITH FLUID ONLY
- 32 TESTS WITH FLUID APPLIED OVER ICE

PRELIMINARY CALIBRATION WORK

WEIGHT VARIATION OVER TIME FOR:

- DRY PAN
- BARE ICE
- FLUID ONLY

DRY PAN

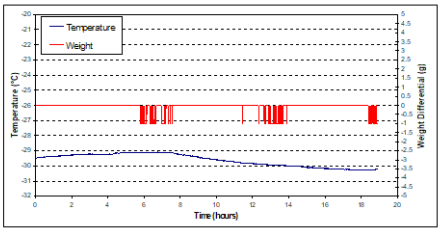


Initial weight: 829.6g

Final Weight: 829.3g

BARE ICE

Ice = 22 g

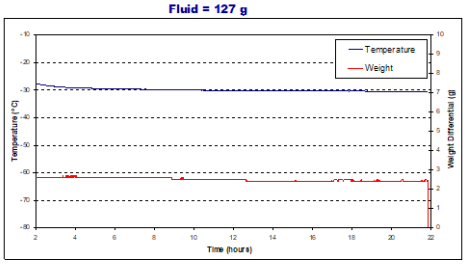


Initial weight: 849g (pan+ice)

Final Weight: 848g (pan+ice)

FLUID ONLY

Fluid = 127 g

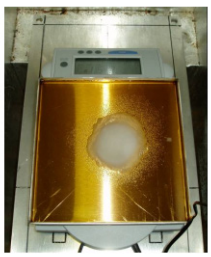


Initial weight: 736.4g (pan+fluid)

Final Weight: 736.2g (pan+fluid)

✈ WHAT HAPPENS WITH THE ICE IF FLUID IS APPLIED?

EXPERIMENT #6 – DIMINISHMENT OF ICE

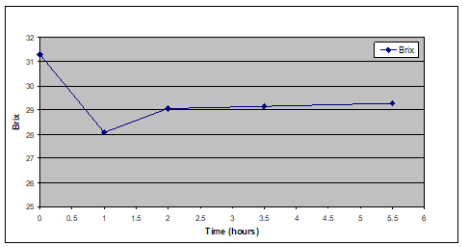


TIME = 0
BRIX = 31.25



TIME = 24 HRS.
BRIX = 30.75

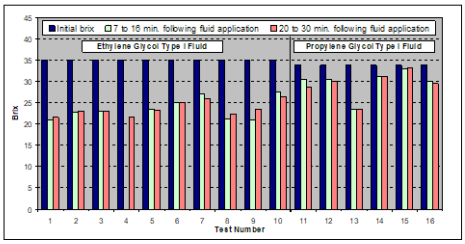
FLUID DILUTION PROFILE EXPERIMENT #9



- **BASED ON THE FINDINGS FROM EXPRORATORY TESTING, 16 DETAILED TESTS WERE ONLY RUN FOR APPROXIMATELY ½ HRS FOLLOWING FLUID APPLICATION.**

14

FLUID DILUTION PROFILE FOR ALL 16 DETAILED TESTS



15

- **HOW MUCH DOES THE ACTUAL THICKNESS DIMINISH?**

16

THE CHANGE IN ICE THICKNESS UNDER FLUID WAS EVALUATED FOR THE FOLLOWING:

- **TYPE I FLUID:**
  - ETHYLENE GLYCOL-BASED
  - PROPYLENE GLYCOL-BASED
- **TEST SURFACES:**
  - BARE ALUMINUM
  - PAINTED ALUMINUM
- **ICE THICKNESSES:**
  - 0.2, 0.4, 0.6 and 1.3 mm

17

ETHYLENE GLYCOL TYPE I ON BARE ALUMINUM – ICE 0.2 mm



TIME = 0 (before application)
BRIX = 35
ICE THICKNESS =0.2 mm



TIME = 20 min
BRIX = 26
ICE THICKNESS = 0 mm

18

PROPYLENE GLYCOL TYPE I ON BARE ALUMINUM – ICE 0.4 mm



TIME = 0 (before application)
BRIX = 33.75
ICE THICKNESS = 0.41 mm



TIME = 20 min
BRIX = 30
ICE THICKNESS = 0.31 mm

19

ETHYLENE GLYCOL TYPE I ON BARE ALUMINUM – ICE 0.6 mm



TIME = 0 (before application)
BRIX = 35
ICE THICKNESS = 0.61 mm



TIME = 23 min
BRIX = 23
ICE THICKNESS = 0.40 mm

20

PROPYLENE GLYCOL TYPE I ON BARE ALUMINUM – ICE 1.3 mm



TIME = 0 (before application)
BRIX = 33.75
ICE THICKNESS = 1.27 mm



TIME = 40 min
BRIX = 33
ICE THICKNESS = 1.02 mm

21

ICE DEGRADATION MEASUREMENTS SUMMARY OF RESULTS

ETHYLENE GLYCOL			PROPYLENE GLYCOL		
Initial Ice Thickness (mm)	Final Ice Thickness (mm)	Surface	Initial Ice Thickness (mm)	Final Ice Thickness (mm)	Surface
0.20	0	bare Al.	0.25	0	bare Al.
0.41 0.41 0.46 0.46 ± 0.03 0.46	0.31 0.14 0.28 0.25 ± 0.06 0.28	bare Al. bare Al. bare Al. red Al. white Al.	0.41 0.41 0.51 0.44 ± 0.06	0.31 0.31 0.46 0.36 ± 0.09	bare Al. red Al. white Al.
0.60 0.61 0.61 ± 0.01	0.40 0.40 0.40 ± 0.0	bare Al. bare Al. bare Al.	0.66	0.51	bare Al.
1.27	0.89	bare Al.	1.27	1.02	bare Al.

22

CONCLUSIONS OF PHASE I FEASIBILITY STUDY

1) ICE (WITH FLUID) CAN BE MADE AT ANY THICKNESS (AS LOW AS 0.2 MM) AND POSSIBLY LOWER.
2) ICE UNDER FLUID DIMINISHES OVER TIME, MOSTLY FOLLOWING APPLICATION OF FLUID. MOST OF THE REDUCTION OCCURS IN THE FIRST 15 MINUTES.
3) ICE DEGRADATION WAS FOUND TO BE MORE PRONOUNCED WITH EG TYPE I FLUID THAN PG TYPE I FLUID.
4) VARIABILITY BETWEEN SAMPLES IS NOT YET FIRMED UP; HOWEVER IT IS PROMISING.
5) FOR THE PURPOSE OF MAKING ICE, -15°C IS RECOMMENDED BASED ON THE PRELIMINARY WORK.
6) SMOOTHNESS AND OPACITY OF ICE ARE PROMISING.

23

FUTURE INVESTIGATIONS

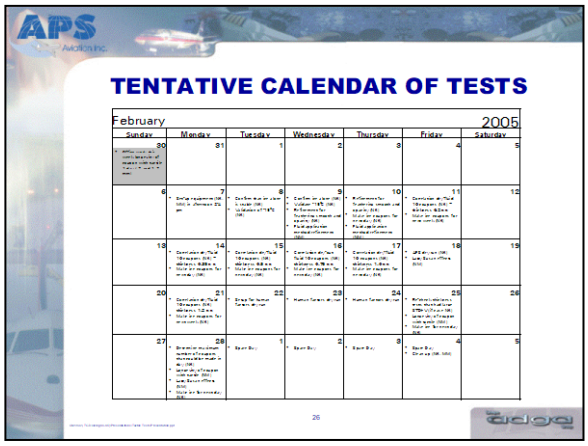
1) **CORRELATION BETWEEN DRY ICE AND ICE WITH FLUID**
   Procedure to make ice needs refinement in the chamber. Determine exactly what the degradation is for various starting ice thicknesses. Attempt to reduce variability by maintaining test variables well controlled.
2) **CONFIRMATION THAT ICE ALONE IS STABLE**
   For procedural purposes (manage many plates simultaneously) during actual tests, confirm ice alone on plates does not change over time.
3) **VALIDATION OF -15ºC**
   Validate most suitable temperature for chamber (-15°C).
4) **REFINEMENT FOR FEATHERING, SMOOTHNESS AND OPACITY**
   Refine procedure to improve the feathering, smoothness and opacity of ice coupons.

24

FUTURE INVESTIGATIONS

5) **LONGEVITY OF COUPON WITH TACTILE**
   Determine through experiments how long a coupon will last for tactile testing.
6) **LAZY SUSAN EFFECTS**
   Verify degradation of ice caused by motion of coupon that is caused by Lazy Susan table.
7) **FLUID APPLICATION METHOD REFINEMENT**
   Determine proper and consistent fluid application method.
8) **MAXIMUM COUPONS FEASIBLE**
   Determine the maximum number of samples that could be made. Consider mixing visual and tactile tests on the same day to minimize number of samples that need to be made.

25


APS
TENTATIVE CALENDAR OF TESTS
February
2005
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
26

1

PROPOSED ARP 5945
ENDURANCE TIME TESTS FOR AIRCRAFT DEICING/ANTI-ICING FLUIDS SAE TYPE I

STATUS REPORT







APS Aviation Inc.

ISO-9001:2000

SAE G-12 HOLDOVER TIME SUBCOMMITTEE
PITTSBURGH - MAY 23, 2005

FIRST BALLOT - ARP 5945

- ARP 5945 was posted on SAE Forums (HOT Subcommittee) on November 12, 2004
- Survey closed on December 10, 2004

Transports Canada Transport Canada

FIRST BALLOT – ARP 5945

BALLOT RESULTS

TOTAL VOTES CAST: 31

APPROVE: 19 (61%)
DISAPPROVE: 4 (13%)
WAIVE: 8 (26%)

Transports Canada Transport Canada

MAY 2005

- ARP 5945 was modified to incorporate the comments received on first ballot
- Outstanding issues were discussed at HOT Workgroup meeting in Montreal in May 2005
  - Issues were resolved

Transports Canada Transport Canada

SECOND BALLOT – ARP 5945

- Proposed ARP 5945 will be provided to SAE for posting on the website immediately following the Pittsburgh SAE G-12 meeting
- Please vote

Transports Canada Transport Canada

EXPLORATORY ENDURANCE TIME TESTS





SAE G-12 HOLDOVER TIME SUBCOMMITTEE
MAY 23, 2005

APS Aviation Inc.

PREPARED AND PRESENTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

TWO PRESENTATIONS

1) ENDURANCE TIMES FOR HEATED ANTI-ICING FLUIDS

2) ENDURANCE TIMES FOR ANTI-ICING FLUIDS ON COMPOSITE SURFACES

ENDURANCE TIMES FOR HEATED ANTI-ICING FLUIDS

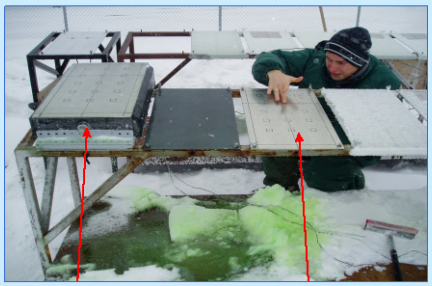
BACKGROUND

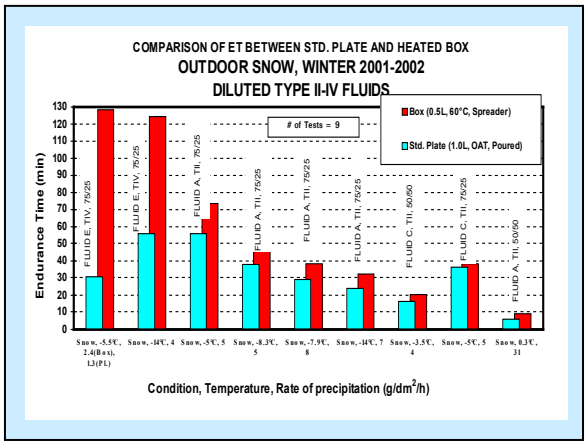
- Preliminary tests 2001-02 winter
  - Objective: to investigate whether heat significantly influenced the endurance times for diluted anti-icing fluids
  - Four different fluid brands were used
- Further tests 2004-05 winter
  - Similar objective with other fluids and including Neat fluids

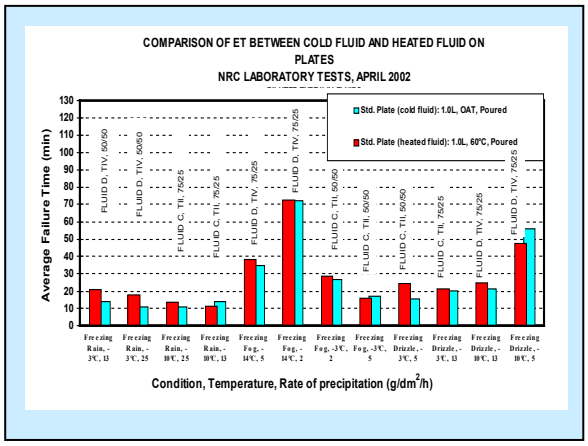
APPLICATION PROCEDURE

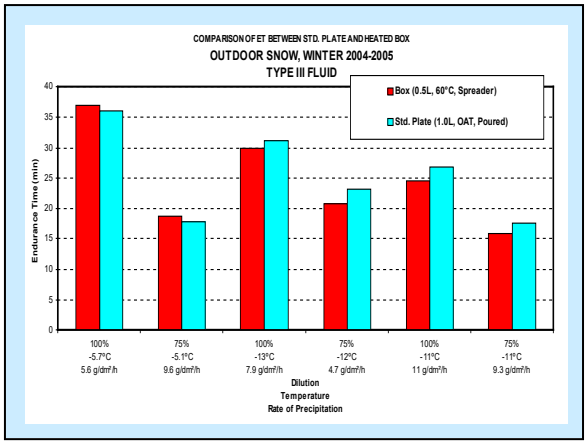
- Outdoor snow endurance tests
  - Standard Type II/III/IV test procedure on plate (1.0 L at OAT)
  - Type I test procedure was used on boxes (0.5 L at 60°C)
- Indoor laboratory endurance tests
  - Standard plate treated with 1.0 L at OAT
  - Heated plate treated with 1.0 L at 60°C

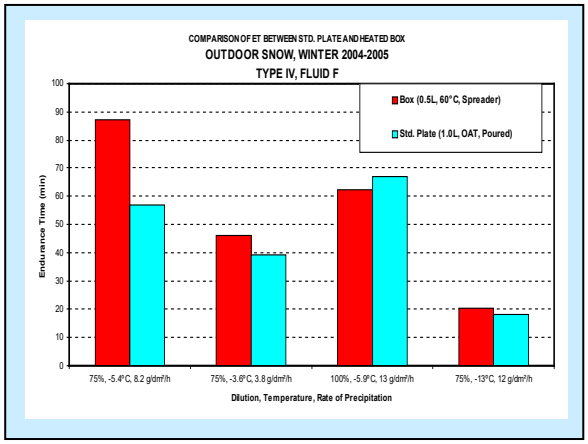
HEATED BOX AND STANDARD PLATE











CONCLUSIONS

- Natural Snow
  - Endurance time performance of heated anti-icing fluids was found to be at least equivalent to that of fluids using the current fluid application protocol (unheated)
- Indoor Lab Tests
  - Results from 2004-05 have not yet been analyzed

SAE G-12 HOLDOVER TIME SUBCOMMITTEE
MAY 23, 2005

APS Aviation Inc.

ENDURANCE TIMES FOR ANTI-ICING FLUIDS ON COMPOSITE SURFACES

SAE G-12 HOLDOVER TIME SUBCOMMITTEE
MAY 23, 2005

APS Aviation Inc.

OBJECTIVE

Measure and evaluate the endurance times of anti-icing fluids on composite plates for comparative purposes

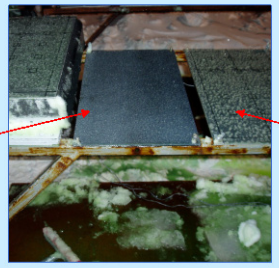
SAE G-12 HOLDOVER TIME SUBCOMMITTEE
MAY 23, 2005

APPLICATION PROCEDURE

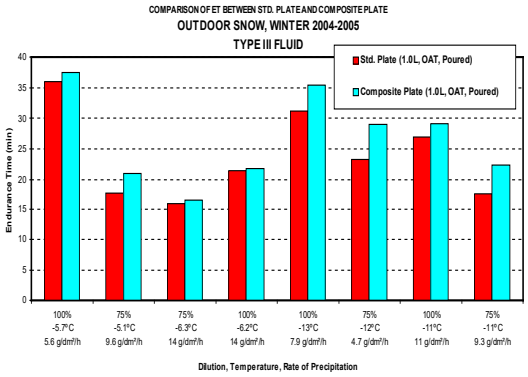
- Outdoor snow endurance tests
  - **For Type II/III/IV:** standard test procedure (1.0 L @ OAT)
  - **For Type I:** 1.0 L @ 20ºC

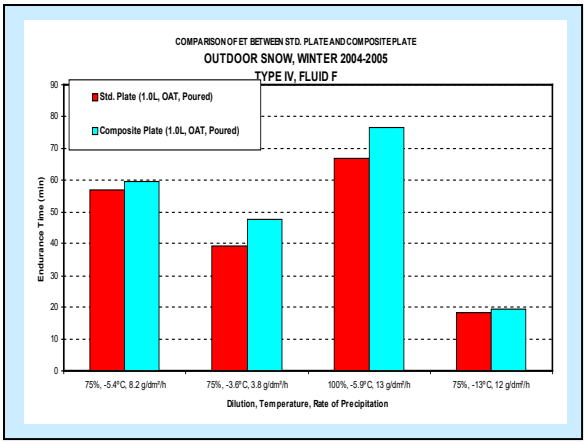
SAE G-12 HOLDOVER TIME SUBCOMMITTEE
MAY 23, 2005

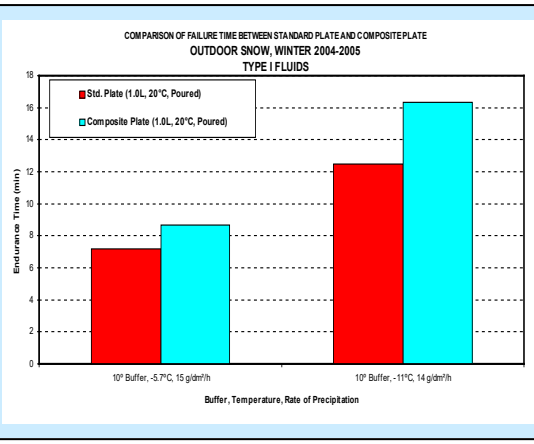
STANDARD PLATE AND COMPOSITE PLATE

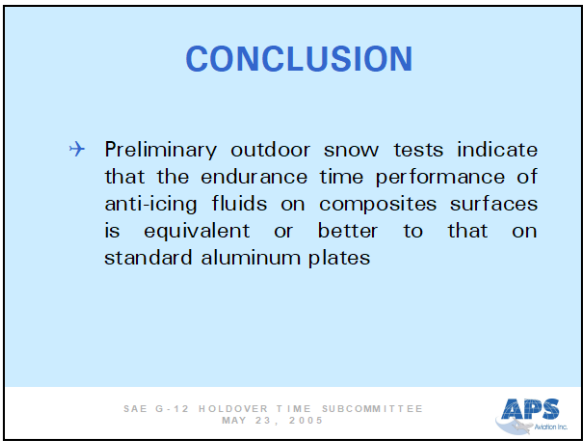


SAE G-12 HOLDOVER TIME SUBCOMMITTEE
MAY 23, 2005








CONCLUSION
Preliminary outdoor snow tests indicate that the endurance time performance of anti-icing fluids on composites surfaces is equivalent or better to that on standard aluminum plates
SAE G-12 HOLDOVER TIME SUBCOMMITTEE
MAY 23, 2005
APS
Aviation Inc.

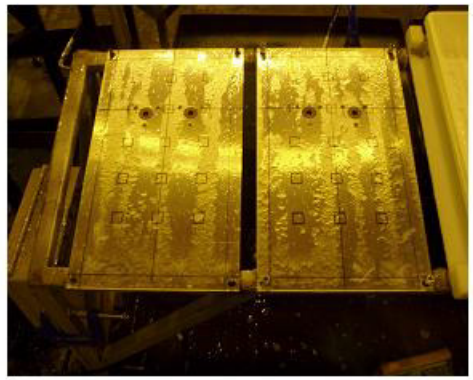
This page intentionally left blank.

AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME RESULTS FOR THE 2004-05 WINTER TEST SEASON

TYPE I FLUID







APS Aviation Inc.

ISO-9001:2000

SAE G-12 HOLDOVER TIME SUBCOMMITTEE
PITTSBURGH - MAY 23, 2005

PREPARED AND PRESENTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

FAA/TC TYPE I HOT GUIDELINES 2004-05

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)								
°C	°F	FROST	FREEZING FOG	VERY LIGHT SNOW①	LIGHT SNOW①	MODERATE SNOW①	*FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD-SOAKED WING	OTHER***
-3 and above	27 and above	0:45	0:11-0:17	0:18-0:22	0:11-0:18	0:06-0:11	0:05-0:13	0:02-0:05	0:02-0:05	
below -3 to -6	below 27 to 21	0:45	0:05-0:13	0:14-0:17	0:06-0:14	0:05-0:08	0:05-0:09	0:02-0:05		
below -6 to -10	below 21 to 14	0:45	0:06-0:10	0:11-0:13	0:06-0:11	0:04-0:06	0:04-0:07	0:02-0:05		
below -10	below 14	0:45	0:05-0:09	0:07-0:08	0:04-0:07	0:03-0:04				

CAUTION: No holdover time guidelines exist

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)								
°C	°F	FROST	FREEZING FOG	VERY LIGHT SNOW①	LIGHT SNOW①	MODERATE SNOW①	*FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD-SOAKED WING	OTHER***
-3 and above	27 and above	0:45	0:11-0:17	0:18	0:11-0:18	0:06-0:11	0:05-0:13	0:04-0:06	0:02-0:05	
below -3 to -6	below 27 to 21	0:45	0:05-0:13	0:14	0:06-0:14	0:05-0:08	0:05-0:09	0:04-0:06		
below -6 to -10	below 21 to 14	0:45	0:06-0:10	0:11	0:06-0:11	0:04-0:06	0:04-0:07	0:02-0:05		
below -10	below 14	0:45	0:05-0:09	0:07	0:04-0:07	0:03-0:04				

CAUTION: No holdover time guidelines exist

Transport Canada

TYPE I FLUID ENDURANCE TIME TESTING

2004-05

- No new Type I products were tested by APS for endurance times in 2004-05
- No changes will be made to the generic Type I guidelines

Transports Canada Transport Canada

FAA/TC TYPE I HOT GUIDELINES 2005-06

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)								
°C	°F	FROST	FREEZING FOG	VERY LIGHT SNOW①	LIGHT SNOW①	MODERATE SNOW①	*FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD-SOAKED WING	OTHER***
-3 and above	27 and above	0:45	0:11-0:17	0:18-0:22	0:11-0:18	0:06-0:11	0:05-0:13	0:02-0:05	0:02-0:05	
below -3 to -6	below 27 to 21	0:45	0:05-0:13	0:14-0:17	0:06-0:14	0:05-0:08	0:05-0:09	0:02-0:05		
below -6 to -10	below 21 to 14	0:45	0:06-0:10	0:11-0:13	0:06-0:11	0:04-0:06	0:04-0:07	0:02-0:05		
below -10	below 14	0:45	0:05-0:09	0:07-0:08	0:04-0:07	0:03-0:04				

NO CHANGES

CAUTION: No holdover time guidelines exist

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)								
°C	°F	FROST	FREEZING FOG	VERY LIGHT SNOW①	LIGHT SNOW①	MODERATE SNOW①	*FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD-SOAKED WING	OTHER***
-3 and above	27 and above	0:45	0:11-0:17	0:18	0:11-0:18	0:06-0:11	0:05-0:13	0:04-0:06	0:02-0:05	
below -3 to -6	below 27 to 21	0:45	0:05-0:13	0:14	0:06-0:14	0:05-0:08	0:05-0:09	0:04-0:06		
below -6 to -10	below 21 to 14	0:45	0:06-0:10	0:11	0:06-0:11	0:04-0:06	0:04-0:07	0:02-0:05		
below -10	below 14	0:45	0:05-0:09	0:07	0:04-0:07	0:03-0:04				

CAUTION: No holdover time guidelines exist

Transport Canada

FAA/TC VISIBILITY TABLES 2005-06

TABLE 1B. SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY, FOR TYPE I HOLDOVER TIME GUIDELINES

NO CHANGES

Transport Canada Holdover Time Guidelines — Winter 2004-2005

TABLE 5
VISIBILITY IN SNOW VS. SNOWFALL INTENSITY CHART

Transports Canada Transport Canada

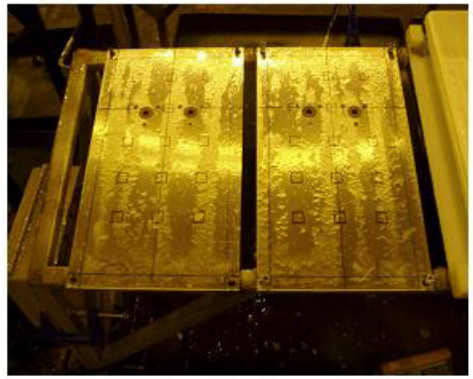


AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME RESULTS FOR THE 2004-05 WINTER TEST SEASON

TYPE II / TYPE IV







APS Aviation Inc.

ISO-9001:2000

SAE G-12 HOLDOVER TIME SUBCOMMITTEE
PITTSBURGH - MAY 23, 2005

PREPARED AND PRESENTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

FLUIDS TESTED



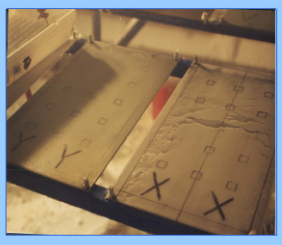
TYPE II

ONE FLUID TESTED

FLUID WILL NOT BE COMMERCIALIZED

Transports Canada Transport Canada

FLUIDS TESTED



TYPE IV

TWO FLUIDS TESTED

ONE FLUID WILL BE COMMERCIALIZED

Transports Canada Transport Canada

FLUID VISCOSITY

FLUID	APS Value using Manufacturer Method (cP)
Octagon MaxFlo	8,670
	Spindle LV1, 0.3 rpm, 20°C, 10 min, 500 mL fluid in 600 mL beaker

Transports Canada Transport Canada

WSET RESULTS

(PERFORMED BY AMIL)

OCTAGON MAXFLO

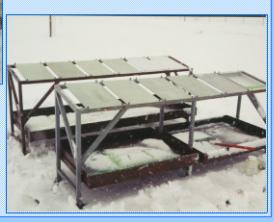
101 minutes

Transports Canada Transport Canada

TEST LOCATIONS



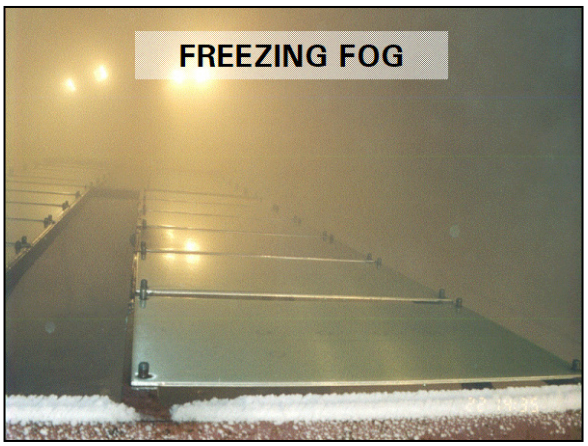
APS TEST SITE



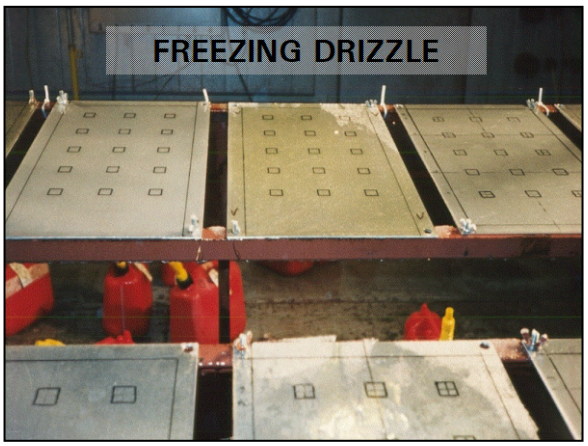
MONTREAL – TRUDEAU INTERNATIONAL AIRPORT


NATURAL SNOW


TEST LOCATIONS
NRC CLIMATIC CHAMBER
OTTAWA, ONTARIO


FREEZING FOG


LIGHT FREEZING RAIN


FREEZING DRIZZLE


RAIN ON A COLD-SOAKED WING

TESTS CONDUCTED IN 2004-05

FLUID TYPE	NATURAL SNOW	FREEZING DRIZZLE	LIGHT FREEZING RAIN	FREEZING FOG	COLD SOAK	TOTAL
Type II (Neat)	21	8	8	12	4	53
Type II (75/25)	25	8	9	8	4	54
Type II (50/50)	7	4	4	4	-	19
Type IV (Neat)	35	10	14	12	4	75
Type IV (75/25)	34	10	15	8	4	71
Type IV (50/50)	15	6	8	4	-	33
TOTAL	137	46	58	48	16	305

Transports Canada Transport Canada

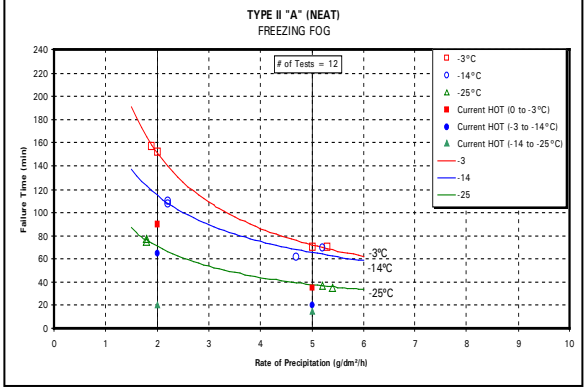
ENDURANCE TIME DATA ANALYSIS METHODOLOGY

- Regression analysis that provides a power law relationship
- General form of the equation for light freezing rain, freezing drizzle, freezing fog, and rain on a cold-soaked wing is $t = aR^b$
- General form of the equation for snow is $t = aR^b(2-T)^b$

where t = Time,
R = Rate of precipitation,
T = Temperature, and
a, b, c = The coefficients determined from the regression

Transports Canada Transport Canada

EXAMPLE OF REGRESSION ANALYSIS

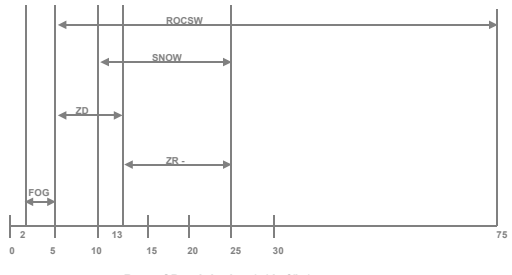


SUMMARY OF PROCEDURE USED TO DETERMINE HOLDOVER TIME LIMITS

- Curves were plotted for each fluid and each cell of the holdover time table using the MOST RESTRICTIVE TEMPERATURE in that cell
- Upper and lower holdover time values were determined using specific precipitation rate ranges for each condition

Transports Canada Transport Canada

DATA RANGES USED FOR EVALUATION OF HOLDOVER TIME LIMITS



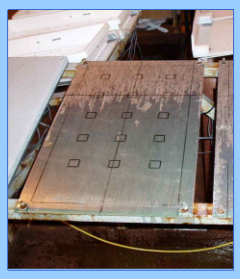
SUMMARY OF PROCEDURE USED TO DETERMINE HOLDOVER TIME LIMITS

Determination of Generic HOT Table Values

- The worst performing fluid values were selected for each cell of the holdover time table
- Round numbers to the nearest *whole "5" value*
- For safety reasons, holdover times below 10 minutes were always rounded down

Transports Canada Transport Canada

FLUID FAILURE



Fluid failure occurs when:

- Accumulation of snow bridging on top of the fluid or plate
- Accumulation of ice on top of the fluid or plate, or ice suspended within the fluid

Transports Canada Transport Canada

PLATE END CONDITION

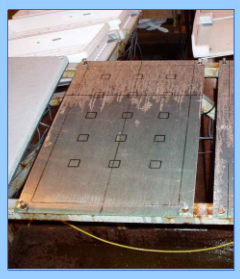
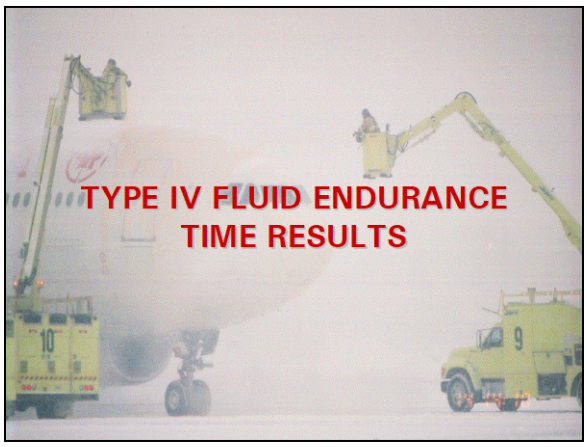


Plate end condition is achieved when fluid failures occur:

- At any 5 of the crosshair markings on the panel; or
- On more than 30% of the entire plate surface

Transports Canada Transport Canada



OVERVIEW OF TYPE IV ENDURANCE TIME TESTING

- Endurance time testing was conducted with two Type IV fluids in 2004-05
- Only one tested fluid, Octagon MaxFlo, will be commercially produced for use in 2005-06 winter operations
- Two minor changes will be made to the generic Type IV holdover time guidelines based on the most recent test results

Transports Canada Transport Canada

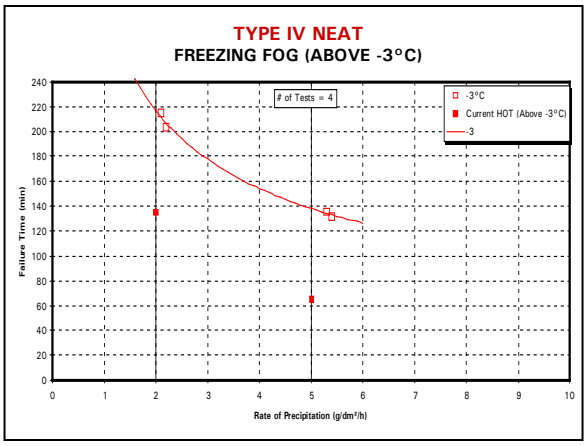


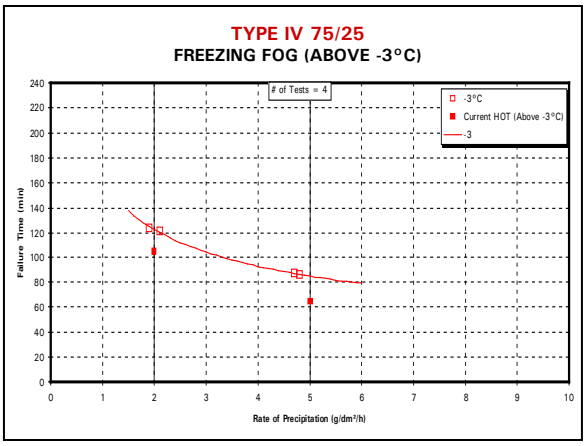
OVERVIEW OF FREEZING FOG TESTS

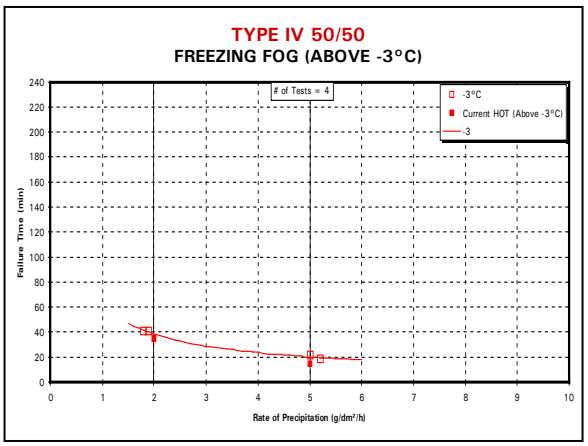
- Tests conducted at the NRC CEF in Ottawa
- Tests conducted at 2 and 5 g/dm²/h
- Temperatures set to –3, -14, and –25°C

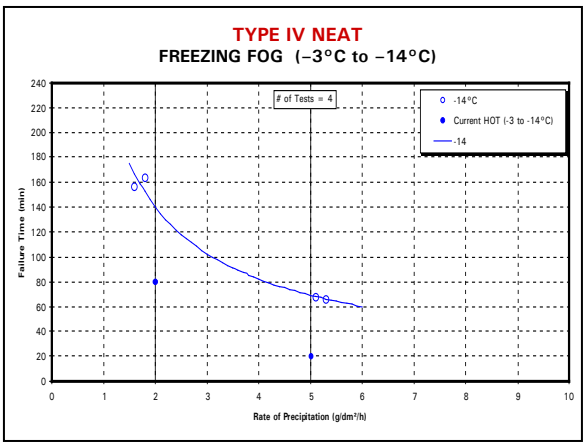


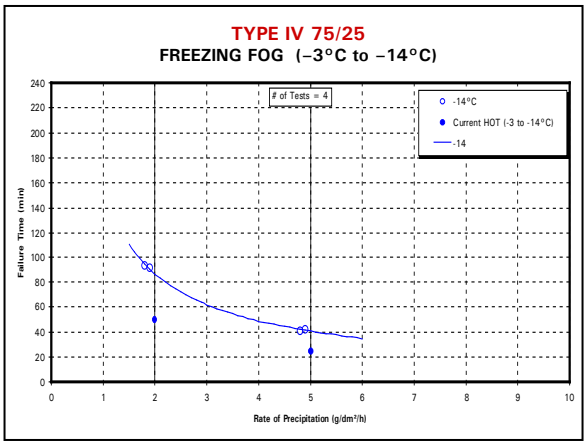
Transports Canada Transport Canada

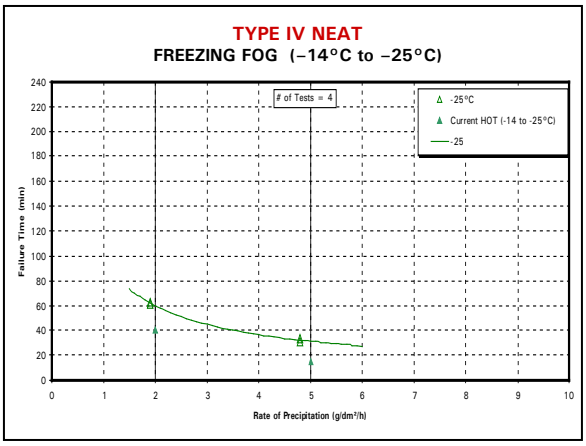

TYPE IV NEAT
FREEZING FOG (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 75/25
FREEZING FOG (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)

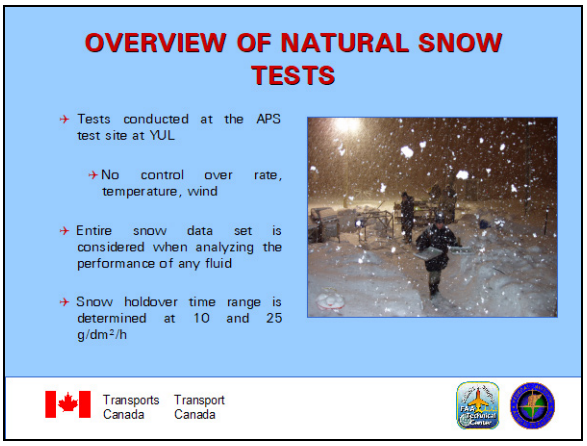

TYPE IV 50/50
FREEZING FOG (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)

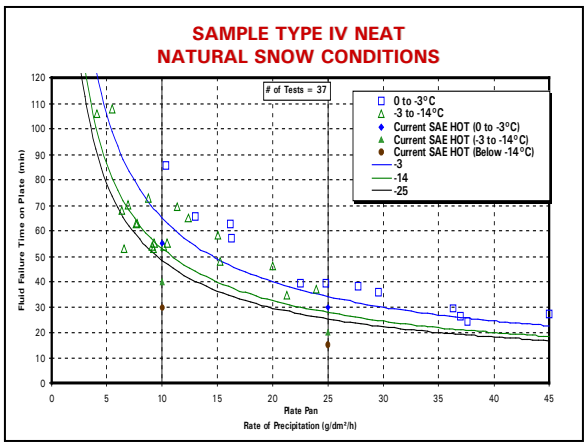

TYPE IV NEAT
FREEZING FOG (–3°C to –14°C)
# of Tests = 4
-14°C
Current HOT (-3 to -14°C)
-14
Failure Time (min)
Rate of Precipitation (g/dm²/h)

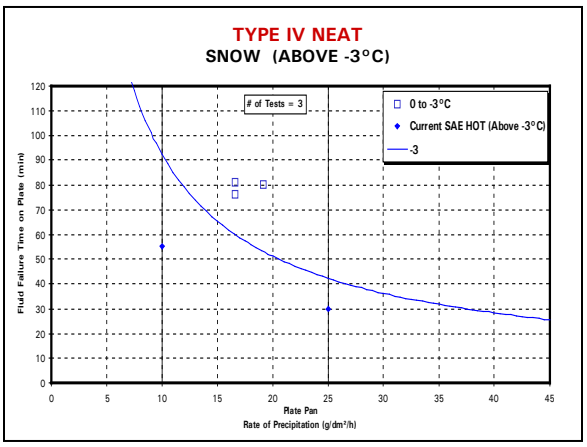

TYPE IV 75/25
FREEZING FOG (–3°C to –14°C)
# of Tests = 4
-14°C
Current HOT (-3 to -14°C)
-14
Failure Time (min)
Rate of Precipitation (g/dm²/h)

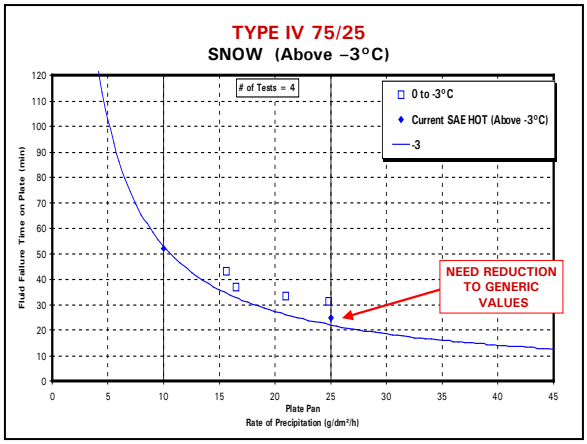

TYPE IV NEAT
FREEZING FOG (–14°C to –25°C)
# of Tests = 4
-25°C
Current HOT (-14 to -25°C)
-25
Failure Time (min)
Rate of Precipitation (g/dm²/h)

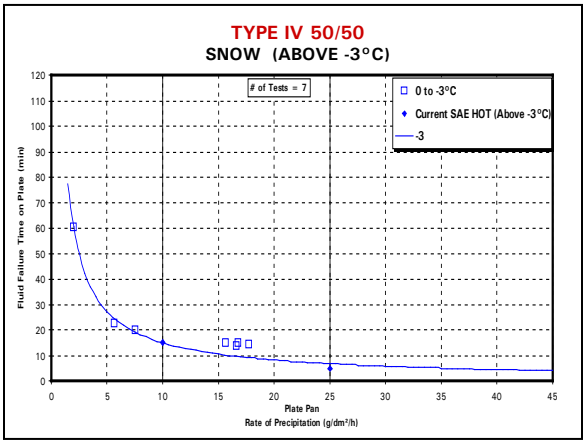

NATURAL SNOW

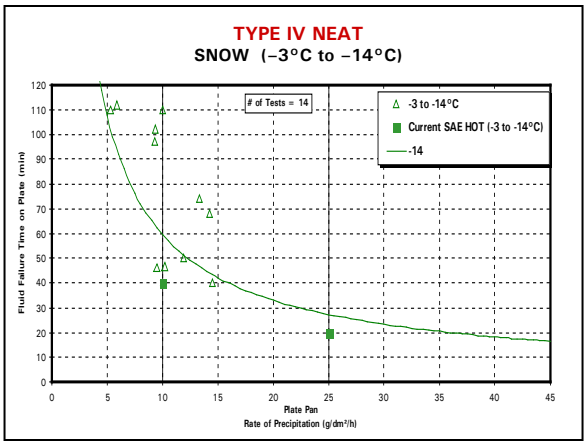

OVERVIEW OF NATURAL SNOW TESTS
Tests conducted at the APS test site at YUL
No control over rate, temperature, wind
Entire snow data set is considered when analyzing the performance of any fluid
Snow holdover time range is determined at 10 and 25 g/dm²/h
Transports Canada
Transport Canada

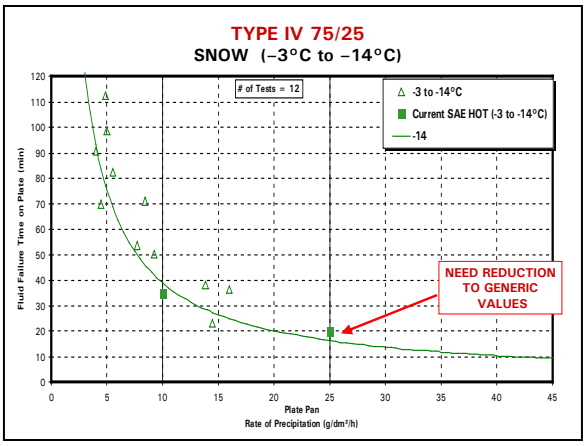

SAMPLE TYPE IV NEAT
NATURAL SNOW CONDITIONS
# of Tests = 37
0 to -3°C
-3 to -14°C
Current SAE HOT (0 to -3°C)
Current SAE HOT (-3 to -14°C)
Current SAE HOT (Below -14°C)
-3
-14
-25
Fluid Failure Time on Plate (min)
Rate Pan
Rate of Precipitation (g/dm²/h)

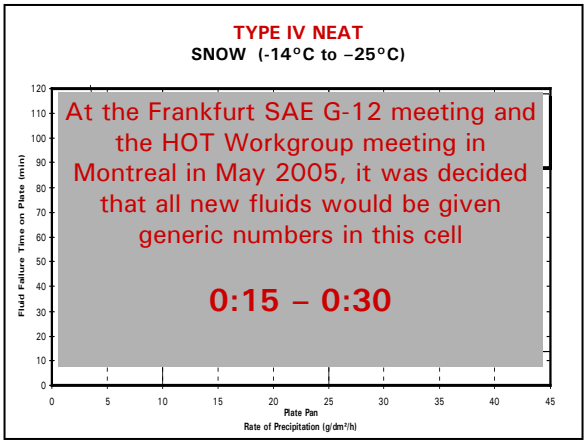

TYPE IV NEAT
SNOW (ABOVE -3°C)
# of Tests = 3
0 to -3°C
Current SAE HOT (Above -3°C)
-3
Fluid Failure Time on Plate (min)
Rate Pan
Rate of Precipitation (g/dm²/h)


TYPE IV 75/25
SNOW (Above –3°C)
# of Tests = 4
0 to -3°C
Current SAE HOT (Above -3°C)
-3
NEED REDUCTION TO GENERIC VALUES
Fluid Failure Time on Plate (min)
Plate Pan
Rate of Precipitation (g/dm²/h)

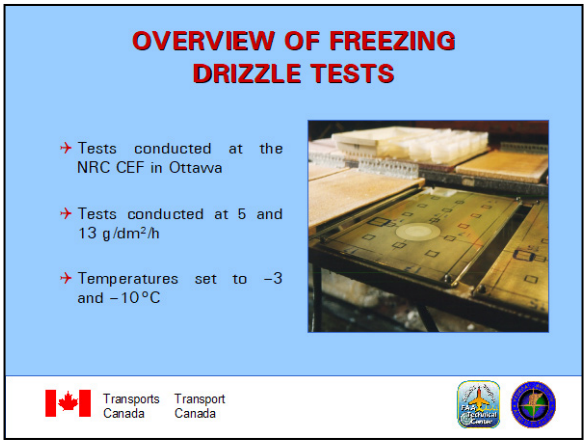

TYPE IV 50/50
SNOW (ABOVE -3°C)
# of Tests = 7
0 to -3°C
Current SAE HOT (Above -3°C)
-3
Fluid Failure Time on Plate (min)
Plate Pan
Rate of Precipitation (g/dm²/h)

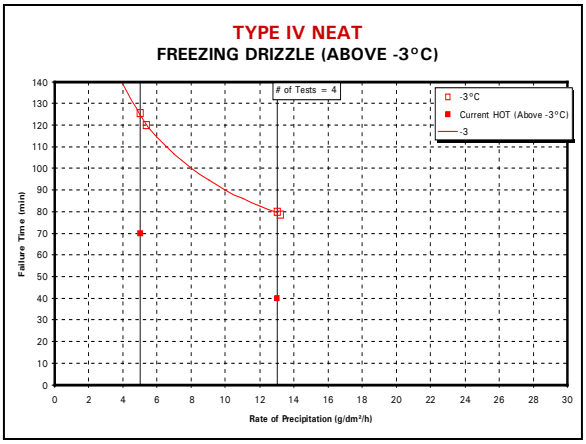

TYPE IV NEAT
SNOW (–3°C to –14°C)
# of Tests = 14
-3 to -14°C
Current SAE HOT (-3 to -14°C)
-14
Fluid Failure Time on Plate (min)
Plate Pan
Rate of Precipitation (g/dm²/h)

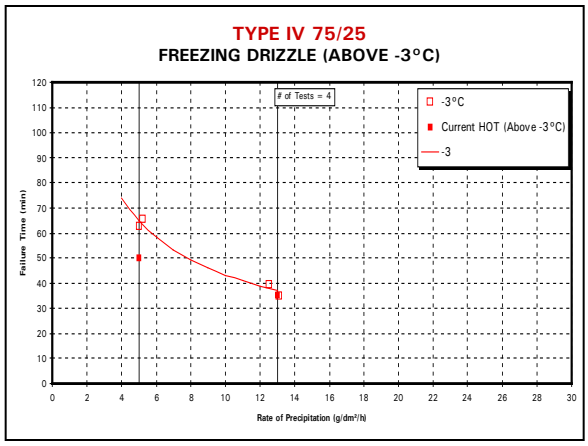

TYPE IV 75/25
SNOW (–3°C to –14°C)
# of Tests = 12
-3 to -14°C
Current SAE HOT (-3 to -14°C)
-14
NEED REDUCTION TO GENERIC VALUES
Fluid Failure Time on Plate (min)
Plate Pan
Rate of Precipitation (g/dm²/h)

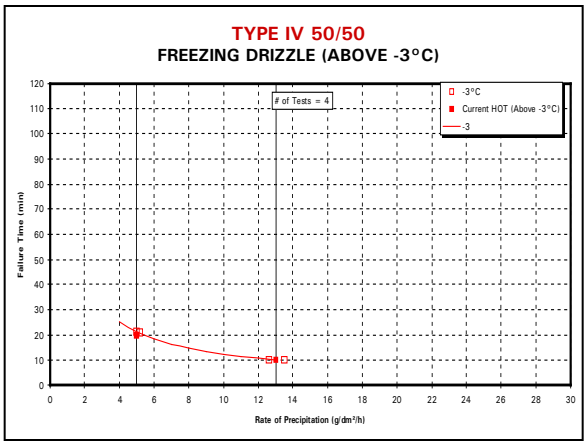

TYPE IV NEAT
SNOW (-14°C to –25°C)
At the Frankfurt SAE G-12 meeting and the HOT Workgroup meeting in Montreal in May 2005, it was decided that all new fluids would be given generic numbers in this cell
0:15 – 0:30
Fluid Failure Time on Plate (min)
Plate Pan
Rate of Precipitation (g/dm²/h)

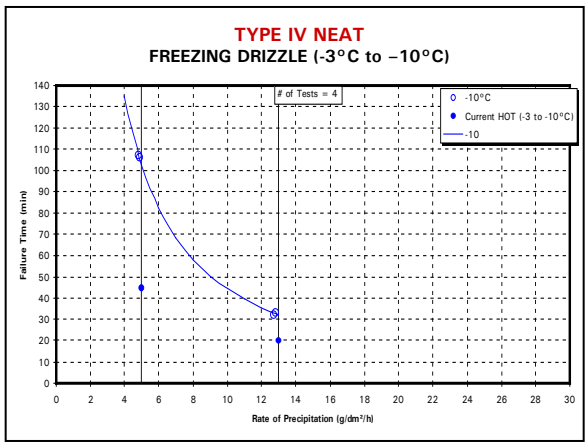

FREEZING DRIZZLE

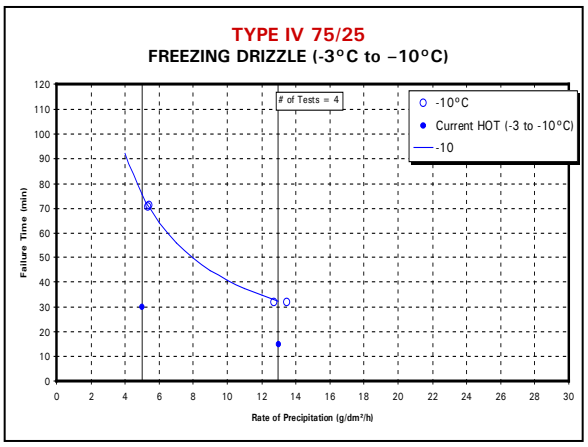

OVERVIEW OF FREEZING DRIZZLE TESTS
Tests conducted at the NRC CEF in Ottawa
Tests conducted at 5 and 13 g/dm²/h
Temperatures set to –3 and –10°C
Transports Canada
Transport Canada

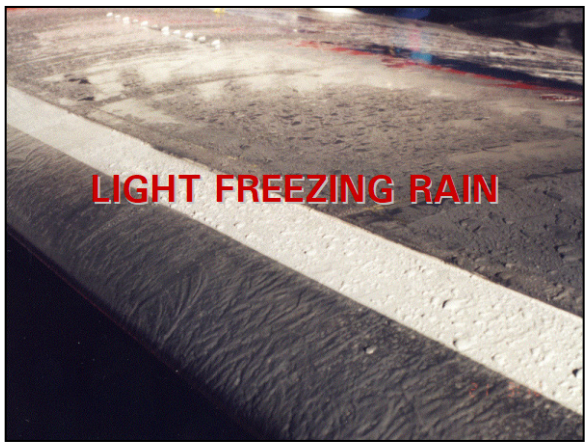

TYPE IV NEAT
FREEZING DRIZZLE (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)

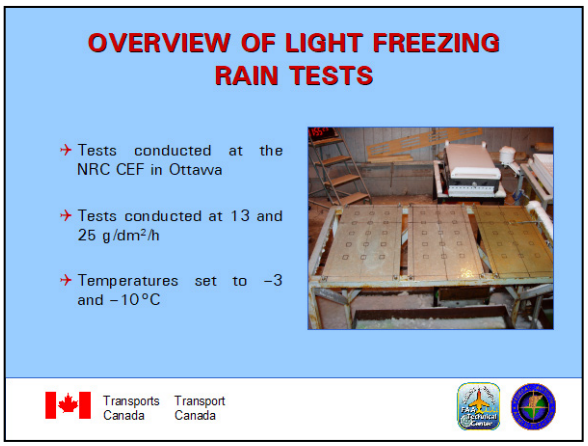

TYPE IV 75/25
FREEZING DRIZZLE (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)

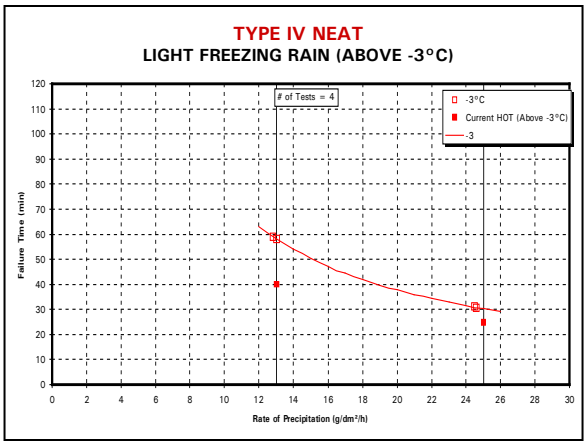

TYPE IV 50/50
FREEZING DRIZZLE (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)

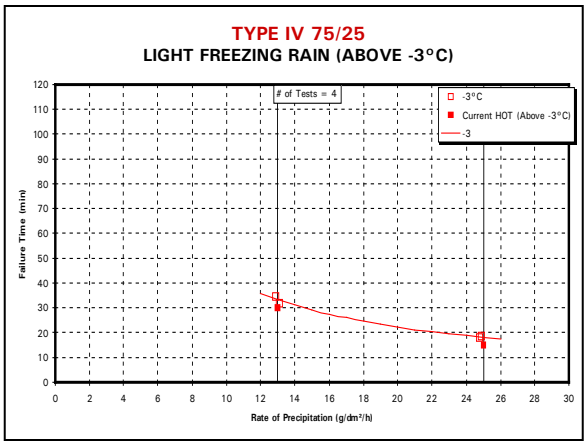

TYPE IV NEAT
FREEZING DRIZZLE (-3°C to –10°C)
# of Tests = 4
-10°C
Current HOT (-3 to -10°C)
-10
Failure Time (min)
Rate of Precipitation (g/dm²/h)

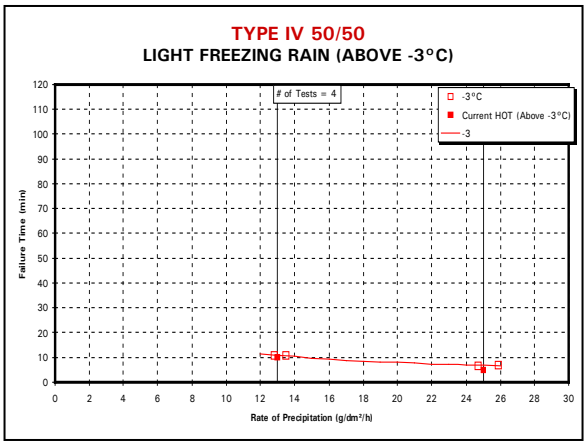

TYPE IV 75/25
FREEZING DRIZZLE (-3°C to –10°C)
# of Tests = 4
-10°C
Current HOT (-3 to -10°C)
-10
Failure Time (min)
Rate of Precipitation (g/dm²/h)

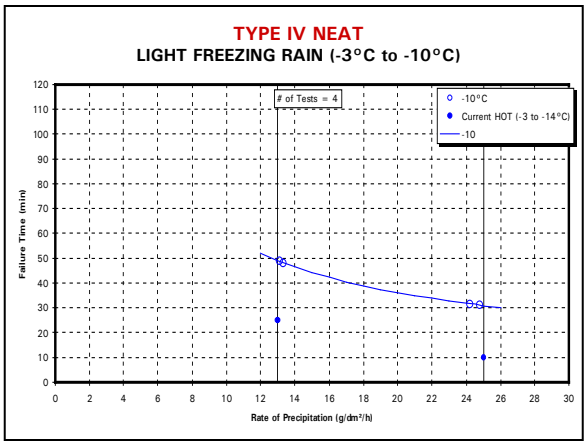

LIGHT FREEZING RAIN

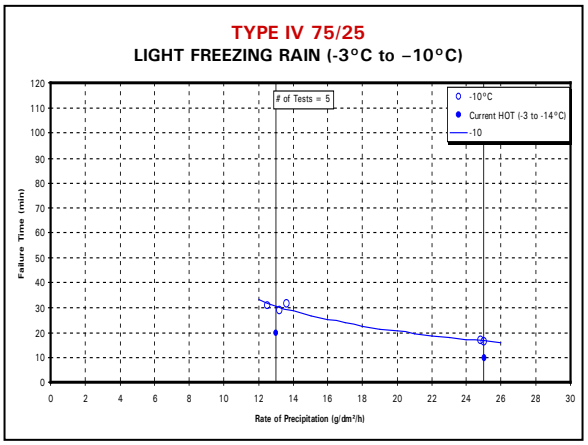

OVERVIEW OF LIGHT FREEZING RAIN TESTS
Tests conducted at the NRC CEF in Ottawa
Tests conducted at 13 and 25 g/dm²/h
Temperatures set to –3 and –10°C
Transports Canada
Transport Canada


TYPE IV NEAT
LIGHT FREEZING RAIN (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 75/25
LIGHT FREEZING RAIN (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 50/50
LIGHT FREEZING RAIN (ABOVE -3°C)
# of Tests = 4
-3°C
Current HOT (Above -3°C)
-3
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV NEAT
LIGHT FREEZING RAIN (-3°C to -10°C)
# of Tests = 4
-10°C
Current HOT (-3 to -14°C)
-10
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 75/25
LIGHT FREEZING RAIN (-3°C to –10°C)
# of Tests = 5
-10°C
Current HOT (-3 to -14°C)
-10
Failure Time (min)
Rate of Precipitation (g/dm²/h)


RAIN ON A COLD-SOAKED WING

OVERVIEW OF RAIN ON A COLD-SOAKED WING TESTS

TEST SITE

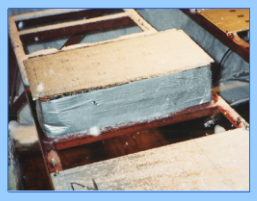
- Laboratory tests conducted at the National Research Council's Climatic Engineering Facility in Ottawa.

TEST CONDITIONS

- Drizzle and moderate rain were simulated:
  - Drizzle (low end) rate: 5 g/dm²/hr
  - Moderate rain (high end) rate: 75 g/dm²/hr

Transports Canada Transport Canada

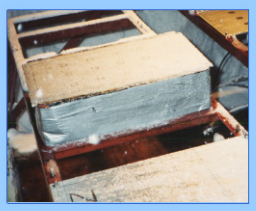
OVERVIEW OF RAIN ON A COLD-SOAKED WING TESTS



- Boxes were filled with 65/35 glycol/water mixture which was cooled
- An insulating jacket was attached on all sides except the top
- Box depth was 7.5 cm
- The top surface was a standard flat plate

Transports Canada Transport Canada

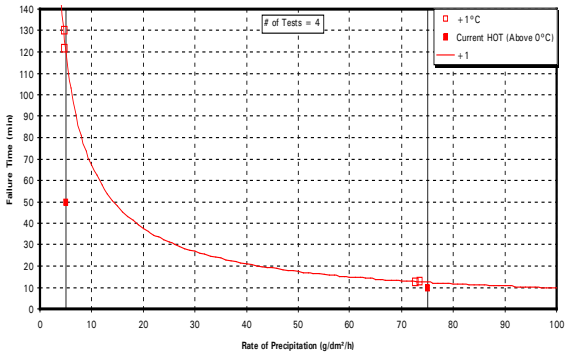
OVERVIEW OF RAIN ON A COLD-SOAKED WING TESTS



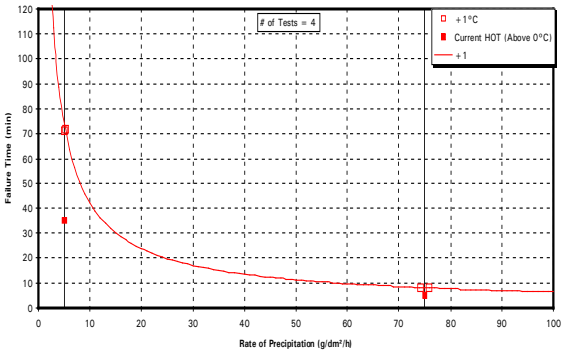
- Plate surface temperatures were recorded using thermocouples embedded in the box
- Tests were started when the skin temperature was -10°C
- Ambient air temperature was 1°C

Transports Canada Transport Canada

TYPE IV NEAT
RAIN ON A COLD-SOAKED WING (+1°C)



TYPE IV 75/25
RAIN ON A COLD-SOAKED WING (+1°C)



SUMMARY OF TYPE IV ENDURANCE TIME TESTING

- One new Type IV fluid will be produced commercially for use in 2005-06 winter operations: Octagon MaxFlo
- Two changes will be made to the generic Type IV holdover time guidelines for use in 2005-06 winter operations, based on the most recent testing

Transports Canada Transport Canada

CHANGES TO TYPE IV GENERIC TABLE BASED ON MAXFLO TEST DATA

Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00	12:00	1:05 - 2:15	0:30 - 0:55	0:40 - 1:10	0:25 - 0:40	0:10 - 0:50	
		75/25	5:00	1:05 - 1:45	~~0:35~~ - 0:50 **0:20**	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	100/00	12:00	0:20 - 1:20	0:20 - 0:40	0:20 - 0:45	0:10 - 0:25	**CAUTION:No Holdover Time Guidelines Exist**	
		75/25	5:00	0:25 - 0:50	~~0:30~~ - 0:35 **0:15**	0:15 - 0:30	0:10 - 0:20		
below -14 to -25	below 7 to -13	100/00	12:00	0:15 - 0:40	0:15 - 0:30				
below -25	below -13	100/00	Type IV fluid may be used below -25°C/below (-13°Fahrenheit) provided the freeze point of the fluid is at least 7°C (13°Fahrenheit) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV cannot be used.						

REMOVAL OF OBSOLETE DATA

- Process for the removal of obsolete data was discussed and implemented by the SAE G-12 HOT Subcommittee at New Orleans G-12 meeting in 2001
- Data for two fluids, Hoechst 1957 and Union Carbide Ultra+ (in dilution), were removed from the Type IV data set and analysis
- In 2003 in Vancouver, data for SPCA AD-404 were removed
- In 2004 in Frankfurt, data for Clariant Safewing Four were removed
- Removal of the data resulted in increases to the Type IV generic table

Transports Canada Transport Canada

OBSOLETE DATA 2005

- Clariant Safewing MP IV 1957 was tested for holdover times in 1997-98 and 1998-99
- Not available for 4 years
- Not re-certified

Transports Canada Transport Canada

INCREASES TO TYPE IV GENERIC TABLE BASED ON THE ELIMINATION OF CLARIANT SAFEWING MP IV 1957

Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00	12:00	~~1:05 - 2:15~~ **1:15 - 2:30**	~~0:30 - 0:55~~ **0:35 - 1:15**	0:40 - 1:10	0:25 - 0:40	0:10 - 0:50	
		75/25	5:00	1:05 - 1:45	~~0:35 - 0:50~~ **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	100/00	12:00	0:20 - 1:20	0:20 - 0:40	0:20 - 0:45	0:10 - 0:25	**CAUTION:No Holdover Time Guidelines Exist**	
		75/25	5:00	0:25 - 0:50	~~0:30~~ - 0:35 **0:15**	0:15 - 0:30	0:10 - 0:20		
below -14 to -25	below 7 to -13	100/00	12:00	0:15 - 0:40	0:15 - 0:30				
below -25	below -13	100/00	Type IV fluid may be used below -25°C/below (-13°Fahrenheit) provided the freeze point of the fluid is at least 7°C (13°Fahrenheit) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV cannot be used.						

Increases due to removal of C1957 Reductions due to MaxFlo

2004-05 WINTER OPERATIONS

This past winter (2004-05), the following Type II and Type IV holdover time guidelines were available:

Type II generic
Five Type II fluid-specific
Type IV generic
Nine Type IV fluid-specific

TC/FAA TYPE II GENERIC HOT GUIDELINES 2005-06

Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00	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	0:20 - 0:45	0:35 - 0:45	0:10 - 0:25	0:05 - 0:25	
		50/50	3:00	0:15 - 0:30	0:05 - 0:15	0:05 - 0:15	0:05 - 0:10		
below -3 to -14	below 27 to 7	100/00	8:00	0:20 - 1:05	0:15 - 0:35	0:15 - 0:45	0:10 - 0:25	**CAUTION:No Holdover Time Guidelines Exist**	
		75/25	5:00	0:20 - 0:55	0:15 - 0:25	0:15 - 0:30	0:10 - 0:20		
below -14 to -25	below 7 to 13	100/00	8:00	0:15 - 0:20	0:15 - 0:30				
below -25	below -13	100/00	Type IV fluid may be used below -25°Celsius (-13°Fahrenheit) provided the freeze point of the fluid is at least 7°C (13°Fahrenheit) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV cannot be used.						

NO CHANGES

TC/FAA TYPE II FLUID-SPECIFIC HOT GUIDELINES 2005-06

1. CLARIANT SAFEWING MP II 2025 ECO
2. KILFROST ABC 2000
3. KILFROST ABC II PLUS
4. OCTAGON E MAX II
5. SPCA ECOWING 26







TC/FAA TYPE IV GENERIC HOT GUIDELINES 2005-06

Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00	12:00	~~1:05 - 2:15~~ **1:15 - 2:30**	~~0:30 - 0:55~~ **0:35 - 1:15**	0:40 - 1:10	0:25 - 0:40	0:10 - 0:50	
		75/25	5:00	1:05 - 1:45	~~0:25 - 0:50~~ **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	100/00	12:00	0:20 - 1:20	0:20 - 0:40	0:20 - 0:45	0:10 - 0:25	**CAUTION:No Holdover Time Guidelines Exist**	
		75/25	5:00	0:25 - 0:50	~~0:20~~ - 0:35 **0:15**	0:15 - 0:30	0:10 - 0:20		
below -14 to -25	below 7 to -13	100/00	12:00	0:15 - 0:40	0:15 - 0:30				
below -25	below -13	100/00	Type IV fluid may be used below -25°C/below (-13°Fahrenheit) provided the freeze point of the fluid is at least 7°C (13°Fahrenheit) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV cannot be used.						

Increases due to removal of C1957

Reductions due to MaxFlo

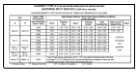
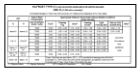
TC/FAA TYPE IV FLUID-SPECIFIC HOT GUIDELINES 2005-06








1. CLARIANT SAFEWING MP IV 2001
2. CLARIANT SAFEWING MP IV PROTECT 2012
3. CLARIANT SAFEWING MP IV 2030 ECO
4. DOW ULTRA+
5. KILFROST ABC-S
6. OCTAGON MAX-FLIGHT
7. OCTAGON MAX-FLIGHT '04
8. OCTAGON MAXFLO
9. SPCA AD-480




This page intentionally left blank.

TYPE III AIRCRAFT GROUND DE/ANTI-ICING FLUID

ENDURANCE TIME TEST RESULTS AND HOLDOVER TIME TABLE DEVELOPMENTS







APS Aviation Inc.

ISO-9001:2000

SAE G-12 HOLDOVER TIME SUBCOMMITTEE
PITTSBURGH - MAY 23, 2005

RESEARCH CONDUCTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA
SAFETY AND SECURITY

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

TRANSPORT CANADA TYPE III HOT GUIDELINES 2004-05

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005

Outside Air Temperature[1]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Very Light Snow[3]	Light Snow[3]	Moderate Snow[3]	Freezing Drizzle[1]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	120	20 - 40	35	20 - 35	10 - 20	10 - 20	8 - 10	6 - 20	
below -3 to -10	below 27 to 14	120	20 - 40	30	15 - 30	9 - 15	10 - 20	8 - 10	CAUTION: No holdover time guidelines exist	
below -10	below 14	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 Snow includes snow grains.
4 Ensure that the lowest operational use temperature (LOUT) is respected, otherwise consider use of Type I when Type III fluid cannot be used.

CAUTIONS
- The only acceptable decision criteria time is the shortest 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 do not provide ice protection during flight.

3

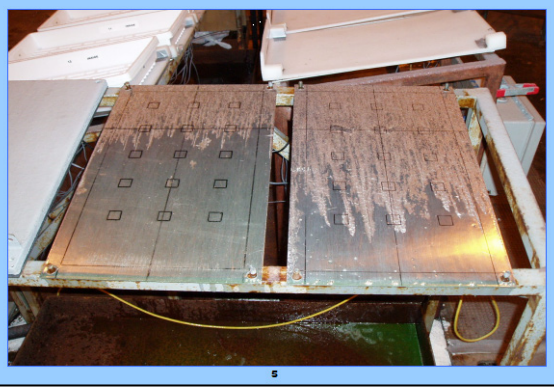
TRANSPORT CANADA TYPE III HOT GUIDELINES 2004-05

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005

DEVELOPED BASED ON THE ENDURANCE TIME RESULTS OF CLARIANT SAFEWING MP III 2031 ECO – 100%

4

PRESENTATION TOPICS



5

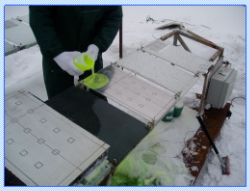
PRESENTATION TOPICS

1) TYPE III ENDURANCE TIME TESTS CONDUCTED DURING THE WINTER 2004-05

2) TYPE III HOLDOVER TIME TABLE DEVELOPMENTS FOR USE IN WINTER 2005-06

6

ENDURANCE TIME TESTS

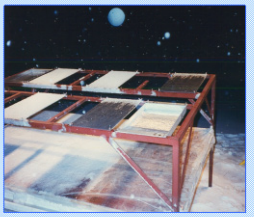


- In January 2005, APS was provided with 75/25 and 50/50 samples of Clariant Safewing MP III 2031 ECO for endurance time testing
- Neat 2031 was not re-tested
- Tests were performed in all conditions and temperatures covered by the Type III holdover time table

Transports Canada Transport Canada

7

ENDURANCE TIME TESTS



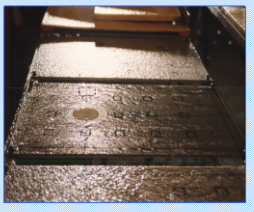
TEST CONDITIONS

- Natural Snow
- Freezing Drizzle
- Light Freezing Rain
- Freezing Fog
- Rain on a Cold-Soaked Wing

Transports Canada Transport Canada

8

ENDURANCE TIME TESTS



TEST CONDITIONS

- Natural Snow
- Freezing Drizzle
- Light Freezing Rain
- Freezing Fog
- Rain on a Cold-Soaked Wing

Transports Canada Transport Canada

9

ENDURANCE TIME TESTS



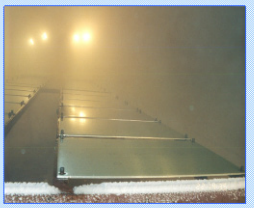
TEST CONDITIONS

- Natural Snow
- Freezing Drizzle
- Light Freezing Rain
- Freezing Fog
- Rain on a Cold-Soaked Wing

Transports Canada Transport Canada

10

ENDURANCE TIME TESTS



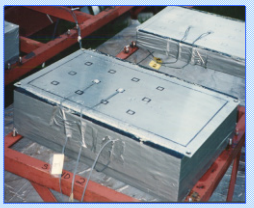
TEST CONDITIONS

- Natural Snow
- Freezing Drizzle
- Light Freezing Rain
- Freezing Fog
- Rain on a Cold-Soaked Wing

Transports Canada Transport Canada

11

ENDURANCE TIME TESTS



TEST CONDITIONS

- Natural Snow
- Freezing Drizzle
- Light Freezing Rain
- Freezing Fog
- Rain on a Cold-Soaked Wing

Transports Canada Transport Canada

12

ENDURANCE TIME TESTS



NRC CLIMATIC CHAMBER



OTTAWA, ONTARIO

13

ENDURANCE TIME TESTS



APS TEST SITE



MONTREAL – TRUDEAU
INTERNATIONAL AIRPORT

14

ENDURANCE TIME TESTS

NUMBER OF TESTS

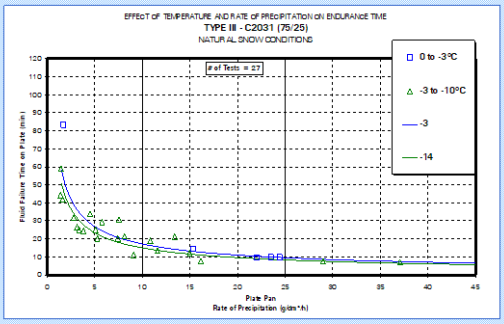
FLUID TYPE	NATURAL SNOW	FREEZING DRIZZLE	LIGHT FREEZING RAIN	FREEZING FOG	COLD SOAK	TOTAL
C2031 50/50	9	4	4	4	0	21
C2031 75/25	27	9	8	8	4	56
TOTAL	36	13	12	12	4	77

Transports Canada Transport Canada

15

CLARIANT SAFEWING MPIII 2031 TEST RESULTS

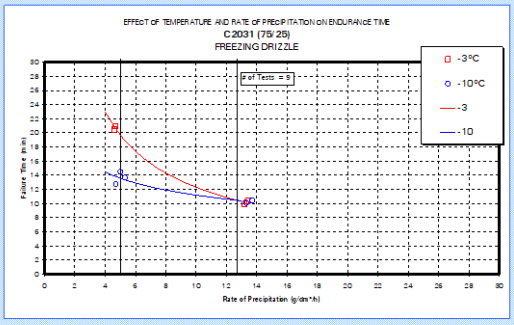
NATURAL SNOW, 75/25 FLUID



16

CLARIANT SAFEWING MPIII 2031 TEST RESULTS

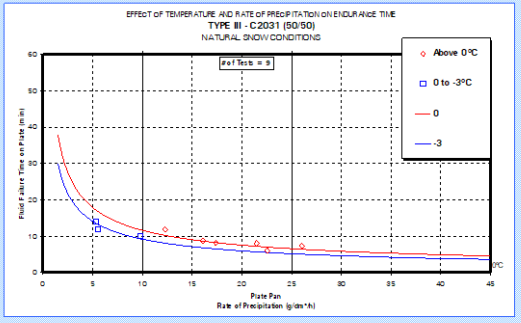
FREEZING DRIZZLE, 75/25 FLUID



17

CLARIANT SAFEWING MPIII 2031 TEST RESULTS

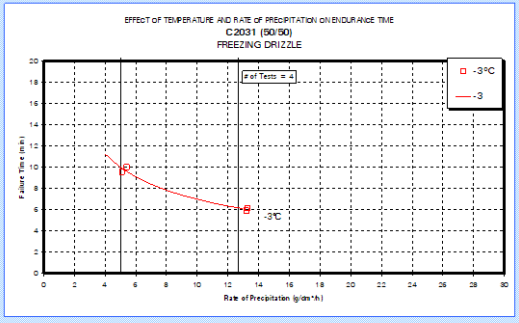
NATURAL SNOW, 50/50 FLUID



18

CLARIANT SAFEWING MPIII 2031 TEST RESULTS

FREEZING DRIZZLE, 50/50 FLUID



19

CLARIANT SAFEWING MPIII 2031 ENDURANCE TIME TEST RESULTS

REGRESSION-GENERATED TIMES

Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit		Frost	Freezing Fog	Very Light Snow	Light Snow	Moderate Snow	Freezing Drizzle	Light FRZ Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00									
		75/25		20 - 35	31 - 37	17 - 31	10 - 17	10 - 20	7 - 12	3 - 14	
		50/50		12 - 21	16 - 19	9 - 16	5 - 9	6 - 10	5 - 7		
below -3 to -10	below 27 to 14	100/00									CAUTION:No Holdover Time Guidelines Exist
		75/25		16 - 33	27 - 33	15 - 27	8 - 15	10 - 14	7 - 10		
below -10	below 14	100/00									

20

ENDURANCE TIMES TO HOLDOVER TIMES

- Same protocol used to treat the 100/00 Type III data in 2003-04 was employed to treat the 75/25 and 50/50 data
  - Diluted Clariant Safewing MP III 2031 endurance time results were reduced by 10%
  - Newly-reduced values were rounded

Transports Canada Transport Canada

21

TYPE III GENERIC HOLDOVER TIME GUIDELINE VALUES 2005-06

PRELIMINARY

Transports Canada Transport Canada

Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit		Frost	Freezing Fog	Very Light Snow	Light Snow	Moderate Snow	Freezing Drizzle	Light FRZ Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00	120	20 - 40	35	20 - 35	10 - 20	10 - 20	8 - 10	6 - 20	
		75/25	60	15 - 30	25	15 - 25	8 - 15	8 - 15	6 - 10	2 - 10	
		50/50	30	10 - 20	15	8 - 15	4 - 8	5 - 9	4 - 6		
below -3 to -10	below 27 to 14	100/00	120	20 - 40	30	15 - 30	9 - 15	10 - 20	8 - 10		CAUTION:No Holdover Time Guidelines Exist
		75/25	60	15 - 30	25	10 - 25	7 - 10	9 - 12	6 - 9		
below -10	below 14	100/00	120	20 - 40	30	15 - 30	8 - 15				

22

TYPE III GENERIC HOLDOVER TIME GUIDELINE VALUES 2005-06

PRELIMINARY

Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit		Frost	Freezing Fog	Very Light Snow	Light Snow	Moderate Snow	Freezing Drizzle	Light FRZ Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00	120	20 - 40	35 - 40	20 - 35	10 - 20	10 - 20	8 - 10	6 - 20	
		75/25	60	15 - 30	25 - 30	15 - 25	8 - 15	8 - 15	6 - 10	2 - 10	
		50/50	30	10 - 20	15 - 20	8 - 15	4 - 8	5 - 9	4 - 6		
below -3 to -10	below 27 to 14	100/00	120	20 - 40	30 - 35	15 - 30	9 - 15	10 - 20	8 - 10		CAUTION:No Holdover Time Guidelines Exist
		75/25	60	15 - 30	25 - 30	10 - 25	7 - 10	9 - 12	6 - 9		
below -10	below 14	100/00	120	20 - 40	30 - 35	15 - 30	8 - 15				

23



24

This page intentionally left blank.

TYPE III DE/ANTI-ICING FLUID DEVELOPMENTS

2004-05 WINTER





SAE G-12 FLUIDS SUBCOMMITTEE MEETING
PITTSBURGH – MAY 24 - 25, 2005

APS Aviation Inc.

ISO-9001:2000

JOINT PRESENTATION

MICHAEL CHAPUT – APS AVIATION

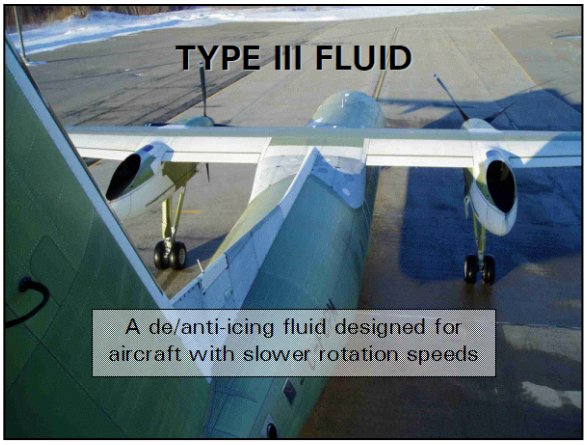
ED LIM - BOMBARDIER

BRYAN McCREARY - CLARIANT

DEAN HAMM - EXECAIR

ACKNOWLEDGEMENTS

Transport Canada	FAA
American Eagle	Horizon Air
Trans States Airlines	Air Tindi
YZF Airport	Aeromag 2000



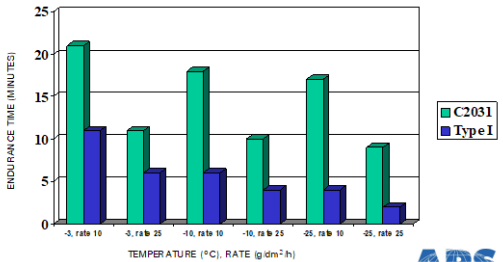
RESEARCH AND DEVELOPMENT Winter 2002-03

- In Winter 2002-03, APS embarked on an R & D project aimed at uncovering new methods for de/anti-icing commuter aircraft
  - Project was funded by Transport Canada and FAA
- Field and laboratory tests showed that heated Type II / IV fluids retained some of their holdover time capability when sheared to low-viscosity levels
- Led to the belief that a low-viscosity thickened fluid could be certified to AMS 1428 as a Type III fluid
- Transport Canada Report TP 14152E

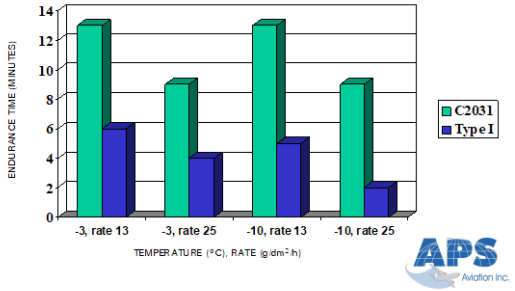
SUMMARY OF TYPE III FLUID ENDURANCE TIME TESTING 2003-04

- In Winter 2003-04, APS was provided with samples of Clariant MP III Safewing 2031 Eco 100% for endurance time testing
- Tests were performed in all conditions and temperatures covered by the holdover time tables

SNOW ENDURANCE TIME TEST RESULTS – C2031 100%



LIGHT FREEZING RAIN ENDURANCE TIME TEST RESULTS – C2031 100%



APS Aviation Inc.

TRANSPORT CANADA TYPE III HOT GUIDELINES 2004-05

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005

Outside Air Temperature[1]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Very Light Snow[3]	Light Snow[3]	Moderate Snow[3]	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	120	20 - 40	35	20 - 35	10 - 20	10 - 20	8 - 10	6 - 20	
below -3 to -10	below 27 to 14	120	20 - 40	30	15 - 30	9 - 15	10 - 20	8 - 10	CAUTION: No holdover time guidelines exist	
below -10	below 14	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 Snow includes snow grains.
4 Ensure that the lowest operational use temperature (LOUT) is respected, otherwise consider use of Type I when Type III fluid cannot be used.

CAUTIONS
- The only acceptable decision criteria time is the shortest 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 do not provide ice protection during flight.

Transport Canada

SUMMARY OF TYPE III FLUID ENDURANCE TIME TESTING 2004-05

- In Winter 2004-05, APS was provided with samples of Clariant MP III Safewing 2031 Eco 75/25 and 50/50 for endurance time testing
- Tests were performed in all conditions and temperatures covered by the holdover time tables

APS Aviation Inc.

PROPOSED TRANSPORT CANADA TYPE III HOT GUIDELINES 2005-06

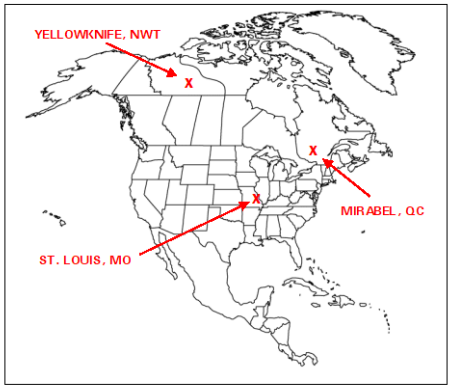
Outside Air Temperature		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit		Frost	Freezing Fog	Very Light Snow	Light Snow	Moderate Snow	Freezing Drizzle	Light FRZ Rain	Rain on a Cold-Soaked Wing	Other
-3 and above	27 and above	100/00	120	20 - 40	35	20 - 35	10 - 20	10 - 20	8 - 10	6 - 20	
		75/25	60	15 - 30	25	15 - 25	8 - 15	8 - 15	6 - 10	2 - 10	
		50/50	30	10 - 20	15	8 - 15	4 - 8	5 - 9	4 - 6		
below -3 to -10	below 27 to 14	100/00	120	20 - 40	30	15 - 30	9 - 15	10 - 20	8 - 10	CAUTION:No Holdover Time Guidelines Exist	
		75/25	60	15 - 30	25	10 - 25	7 - 10	9 - 12	6 - 9		
below -10	below 14	100/00	120	20 - 40	30	15 - 30	8 - 15				

Transport Canada

TYPE III RESEARCH AND DEVELOPMENT ACTIVITIES 2004-05

OPERATIONAL TESTING OF TYPE III







DEMONSTRATION FLIGHT TO EXAMINE THE REMOVAL OF TYPE III FLUID FROM AIRCRAFT WINGS DURING TAKEOFF

- Performed at the request of Embraer
- Lambert- St. Louis International (STL), October 30, 2004
- Embraer 145, operated by Trans States Airlines
- Attendees:
  - American Eagle
  - ExpressJet
  - Clariant
  - Trans States Airlines
  - Embraer
  - APS Aviation



DEMONSTRATION FLIGHT OBJECTIVES

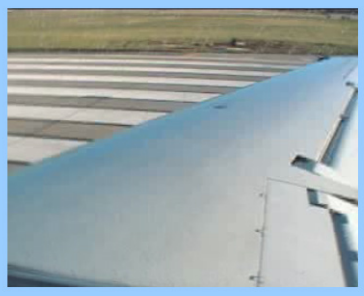
- Observe the flow properties of Type III fluid when shearing off the wings during takeoff roll, rotation and climb-out;
- Examine the amount and location of fluid remaining on aircraft surfaces upon return to the ground;
- Spray windshield on the ground and observe whether the windshield wipers are capable of removing the Type III fluid and restoring adequate windshield visibility; and
- Spray the radome and observe whether the Type III fluid reaches the windshield during takeoff and whether the windshield wipers are capable of removing the fluid and restoring adequate windshield visibility while the airplane is flying.

DATA COLLECTED



- Fluid viscosity
- Fluid thickness
- Photo and video
- Pilot commentaries
- Observer commentaries

FLOW PROPERTIES DURING TAKEOFF

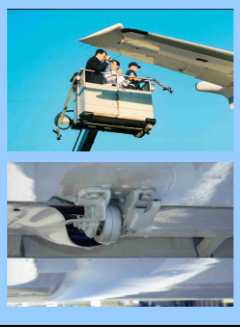


FLOW PROPERTIES DURING TAKEOFF



- Observer: "Fluid came off the wing in a normal fashion prior to rotation of the aircraft"
- Pilot: "Controls were normal; there were no abnormal characteristics and the aircraft operated normally"

INSPECTION OF QUIET AREAS



- Performed by Embraer
- Quiet areas were found to be clean (no fluid); a few small droplets were found on the outside of the quiet area hinges

STATIC WINDSHIELD TEST



- Type III fluid was sprayed onto the windshield
- Pilot indicated that the wipers were able to remove the Type III fluid and restore visibility

STATIC WINDSHIELD TEST



RADOME TEST DURING TAKEOFF



- Type III fluid was sprayed onto the radome
- During takeoff run and while aircraft was climbing, Type III fluid flowed upwards onto two small strips on the windshield

RADOME TEST DURING TAKEOFF



- Pilot: "Small strips were 2 to 5 cm wide and were located on the inner edges of the main windshield panes"
- Pilot: "Strips of fluid did not hinder visibility; fluid was easily removed with wiper following the climb"

RADOME TEST DURING TAKEOFF



Embraer Operations Newsletter
No. 17, Oct-Dec. 2004

"A new Type III anti-icing and deicing fluid is being introduced for the upcoming 2004-05 icing season and Embraer has just certified its use for the ERJ 145 jetliner family."





FLIGHT TESTS TO ASSESS THE EFFECTS OF TYPE III FLUID ON DHC-8 TAKEOFF HANDLING

- APS was contacted in the Fall of 2004 to provide logistic support for Bombardier testing
- Yellowknife Airport (YZF), February 18-25, 2005
- Bombardier DHC-8-200, owned by Horizon Air
- Attendees:

Bombardier	Horizon Air
APS Aviation	Clariant
Air Tindi	YZF Airport Authority



BOMBARDIER FLIGHT TEST OBJECTIVES

- To assess the effects of SAE Type III de/anti-icing fluids on the horizontal stabilizer of the DHC-8 aircraft
- The objectives of APS personnel was to provide logistic support for the testing in Yellowknife, as well as to conduct and/or supervise the application of the Type III fluids to ensure that standard application procedures were employed and that consistency of fluid application was achieved

YELLOWKNIFE TESTING INFORMATION

- 12 Type III fluid tests were performed in Yellowknife
- For different flight tests, Clariant Safewing MP III 2031 Eco fluid was applied:
  - At ambient temperature;
  - At ambient temperature on top of a heated Type I fluid; and
  - Heated to 80°C
- Fluid application was performed by Air Tindi personnel using three different de/anti-icing vehicles
- APS supervised the fluid application process and ensured that the fluid coverage was adequate for all tests

AIR TINDI DE/ANTI-ICING VEHICLES



FLUID APPLICATION

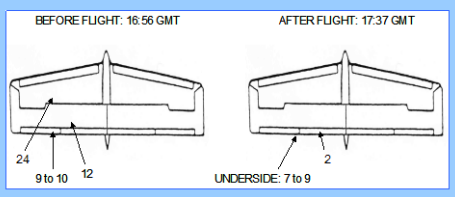


DATA COLLECTED



- Fluid viscosity
- Fluid thickness
- Quiet area inspection
- Photo and video

FLUID THICKNESS



INSPECTION OF QUIET AREAS



TAKEOFF VIDEO





FLIGHT TESTS TO ASSESS THE EFFECTS OF TYPE III FLUID ON DHC-8 TAKEOFF HANDLING

- APS was again contacted by Bombardier following the YZF tests to provide logistic support for additional Bombardier testing
- Montreal International Airport – Mirabel (YMX), March 18-19, 2005
- Bombardier DHC-8-300, owned by Bombardier
- Attendees: Bombardier, Aeromag 2000, APS Aviation, Clariant

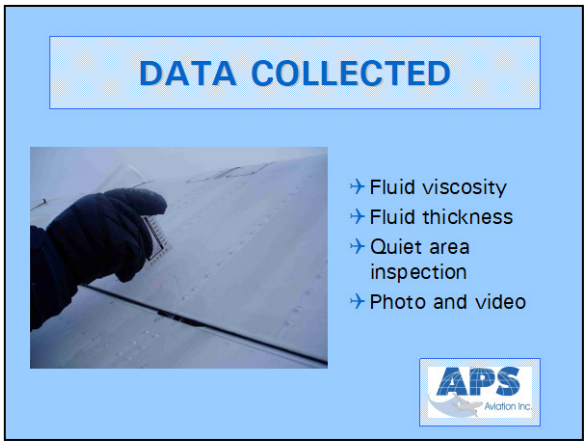


MIRABEL TESTING INFORMATION

- 3 Type III fluid tests were performed in Mirabel
- Clariant Safewing MP III 2031 Eco fluid was applied at ambient temperature for all tests
- De/Anti-Icing vehicle, personnel and facilities were provided by Aeromag 2000 at YMX
- APS personnel performed Type III fluid spray

AEROMAG 2000 DE/ANTI-ICING VEHICLE




DATA COLLECTED
Fluid viscosity
Fluid thickness
Quiet area inspection
Photo and video
APS
Aviation Inc.


TAKEOFF VIDEO

This page intentionally left blank.


Type IV Fluid Application with Forced Air
FedEx Express
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005
APS Aviation Inc.

Acknowledgements

Federal Aviation Administration
Technical Center

Transport Canada
Transportation Development
Centre

Benefits of Using Forced Air

- Provides consistent coating
- Easier application
- Reduces fluid
- Reduces time
- Reduces cost
- Less exposure to environment

Atlantic City Meeting

- November 17, 2004 in Atlantic City
- Attendees
  - FedEx: Ron Thompson, Michael Meadors, David Rogers
  - FAA: Warren Underwood, Charlie Masters, James Riley
  - APS: John D'Avirro, Peter Dawson
  - FMC: Ed Sachs

Atlantic City Meeting

- Test fluids selected
- Deicing trucks selected
- Test protocol established
- Initial fluid viscosity (mid-range) established
- Dates for set-up tests (Jan. 10-12) and test session (Jan. 24-26) selected
- TC JetStar wing to be used as test surface

Preliminary Work

- Jan. 10-12, 2005 in Pittsburgh
- Optimal equipment setup determined
  - Fluid flow rate: 25 GPM
  - Forced air pressure: 6 psi
  - Distance btw fluid and air flows: 7"
  - Air sleeve either inserted or removed



Test Session

- Jan. 24-26, 2005 in Pittsburgh
- Organized by FedEx
- Attendees included:
  - Fluid manufacturers
  - Deicing truck manufacturer
  - FAA, APS and SAE representatives

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Test Session – Attendees

FedEx
- Ron Thompson
- David Rogers
- Michael Meadors
- Steve Zebovitz

APS
- John D'Avirro
- Stephanie Bendickson (Lab)
- Sami Chebil (Lab)

FMC
- Ed Sachs

FAA
- Warren Underwood

SAE/Delta
- Dave Thornton
- Rhonda Gilmore-Daniel

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Test Session – Attendees

Octagon
- Alex Meyers
- Larry Kelley
- Dieter Herman

Dow
- Tim Casto
- Mark Faix
- Todd Miller

Kilfrost
- Peter Haug
- Derek Ogg
- Melissa Holtkamp

Clariant
- Bryan McCreary
- David Johns

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Test Session – Objective

- Evaluate the performance of Type IV fluids applied with forced air using the pre-determined equipment setup

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Test Session – Equipment

- Deicing Trucks
  - FMC LMD 2000
  - FMC Tempest II

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005



SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005



SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Test Session – Equipment

- Wing
  - Transport Canada Lockheed JetStar Wing
  - Assistance provided by AéroMag 2000 for the wing shipment

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005



SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Test Session – Equipment

- Viscometers
  - Brookfield LV DV-I+ (2)
  - Small Sample Adaptor
  - Spindle 31 or 34 (fluid dependent)
  - Two measurements per sample – one per viscometer

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005



SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Test Session – Fluids

- Clariant Safewing MP IV 2001
- Kilfrost ABC-S
- Octagon Max-Flight 04
- Dow/UCAR Ultra+

- Fluids stored at -5ºC in refrigerated truck

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005



SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Samples

- Three samples collected for each fluid/deicing truck combination:
  - Fluid Tote
  - On-Wing: Application with air sleeve
  - On-Wing: Application without air sleeve

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Procedure

- Developed using the 2003-04 procedure with input from FMC, FedEx, FAA and APS
- Criteria developed to ensure fluid applied with forced air is not below the fluid LOWV
- Formula created to determine lowest acceptable delivered viscosity (LADV) for fluids used with forced air

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Procedure – Key Elements

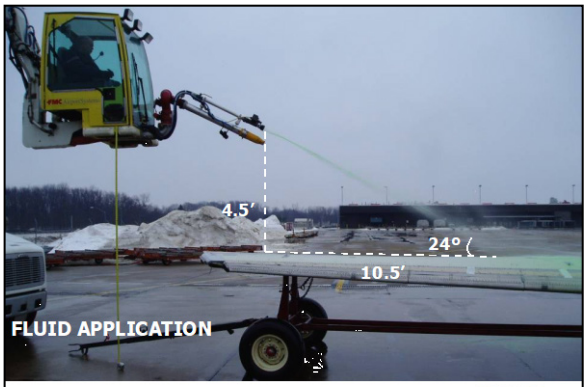
- Fluid temperature ? -5ºC
- OAT < 0ºC
- No precipitation
- Test conducted on wing, not substitute
- Initial viscosity of test fluid in mid production range
  - Ultra+ did not meet this requirement

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Procedure – Key Elements

- Fixed angle of fluid spray
- Fixed distance between nozzle and wing
- Viscosity of on-wing samples measured immediately following application
- Wing cleaned between sprays
- Deicing truck tank cleaned between fluids

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

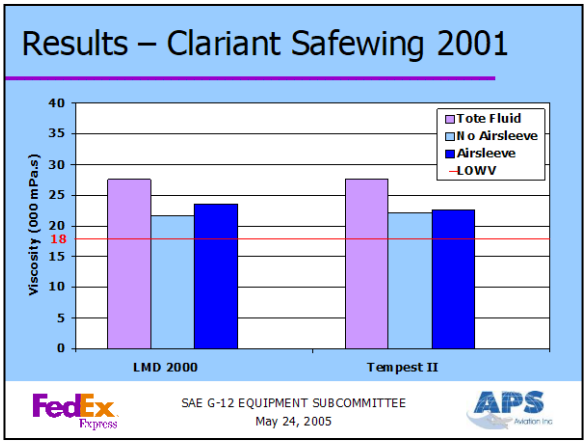


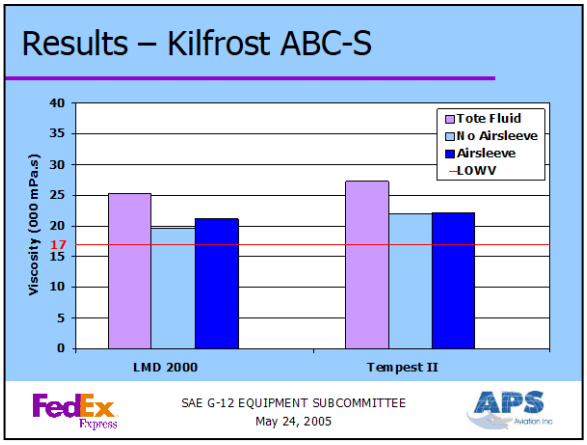
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

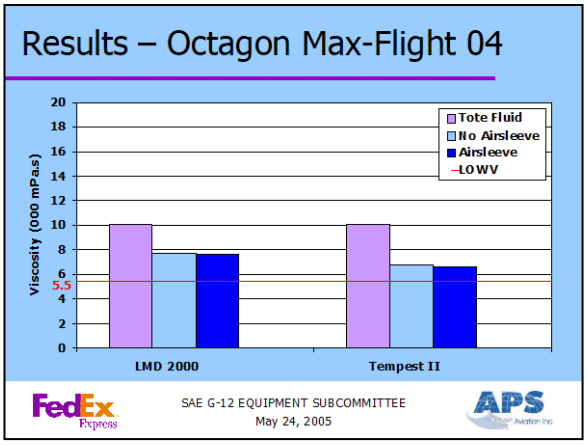

THICKNESS MEASUREMENT
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005


SAMPLE COLLECTION
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005


APS MOBILE LAB
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005


Results – Clariant Safewing 2001
Viscosity (000 mPa.s)
Tote Fluid
No Airsleeve
Airsleeve
LOWV
LMD 2000
Tempest II
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005


Results – Kilfrost ABC-S
Viscosity (000 mPa.s)
Tote Fluid
No Airsleeve
Airsleeve
LOWV
LMD 2000
Tempest II
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005


Results – Octagon Max-Flight 04
Viscosity (000 mPa.s)
Tote Fluid
No Airsleeve
Airsleeve
LOWV
LMD 2000
Tempest II
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Calculation of LADV - Formula

- LADV = Lowest Acceptable Delivered Viscosity
- $\text{LADV} = \text{LOWV} \times \frac{\text{Tote Fluid Viscosity}}{\text{Air Assist Test Viscosity}}$

→ Value is rounded up to nearest 500 mPa.s

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Calculation of LADV - Example

- Clariant Safewing 2001
- Tempest II
- With Air Sleeve
- LOWV = 18,000 mPa.s
- Tote Fluid Viscosity = 27,500 mPa.s
- Air Assist Test Viscosity = 22,600 mPa.s

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Calculation of LADV - Example

- $\text{LADV} = \text{LOWV} \times \frac{\text{Tote Fluid Viscosity}}{\text{Air Assist Test Viscosity}}$
- $\text{LADV} = 18{,}000 \times \frac{27{,}500}{22{,}600}$

$= 21{,}900$ mPa.s

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

Calculation of LADV - Example

- Value is rounded up to nearest 500 mPa.s
- 21,900 mPa.s becomes 22,000 mPa.s
- LADV = 22,000 mPa.s

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

LADV of Tested Fluids

- Clariant Safewing 2001
  - LMD 2000 w/o air sleeve: 23,000 mPa.s
  - LMD 2000 with air sleeve: 21,000 mPa.s
  - Tempest II w/o air sleeve: 22,500 mPa.s
  - Tempest II with air sleeve: 22,000 mPa.s

(Delivery Range: 20,000 to 30,000 mPa.s)

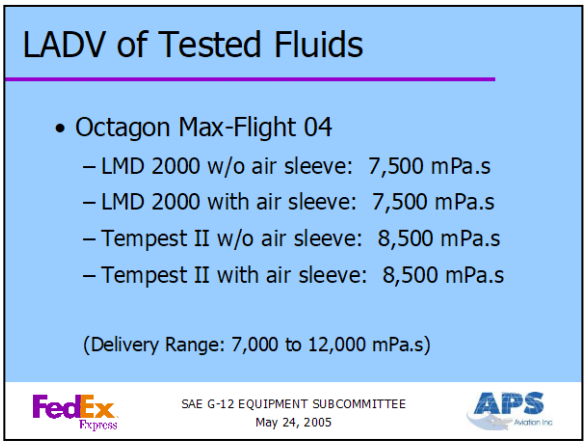
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005

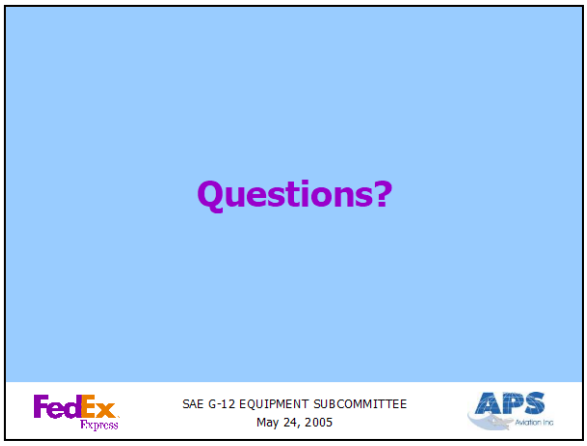
LADV of Tested Fluids

- Kilfrost ABC-S
  - LMD 2000 w/o air sleeve: 22,000 mPa.s
  - LMD 2000 with air sleeve: 20,500 mPa.s
  - Tempest II w/o air sleeve: 21,500 mPa.s
  - Tempest II with air sleeve: 21,000 mPa.s

(Delivery Range: 25,000 to 30,000 mPa.s)

SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005


LADV of Tested Fluids
• Octagon Max-Flight 04
– LMD 2000 w/o air sleeve: 7,500 mPa.s
– LMD 2000 with air sleeve: 7,500 mPa.s
– Tempest II w/o air sleeve: 8,500 mPa.s
– Tempest II with air sleeve: 8,500 mPa.s
(Delivery Range: 7,000 to 12,000 mPa.s)
FedEx Express
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005
APS


Questions?
FedEx Express
SAE G-12 EQUIPMENT SUBCOMMITTEE
May 24, 2005
APS