TP 14379E

Development of Holdover Time Guidelines for Type III Fluids

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.

November 2004
Final Version 1.0

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Development of Holdover Time Guidelines for Type III Fluids

By

Michael Chaput

APS Aviation Inc.

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

Neither the Transportation Development Centre nor the co-sponsoring organizations endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by:	Michael Chaput Manager, Projects and Business Development	Aug. 23, 2005 Date
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Un sommaire français se trouve avant la table des matières.

PREFACE

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

- To develop holdover time data for all newly qualified de/anti-icing fluids;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To compare endurance times in natural snow with those in laboratory snow;
- To compare fluid endurance time, holdover time and protection time;
- To compare snowfall rates obtained with a real-time snow precipitation gauge with rates obtained using rate pans;
- To further develop and to assist with the commercialization of Type III fluids;
- To develop a test procedure for evaluating forced-air assist systems;
- To conduct general and exploratory de/anti-icing research; and
- To evaluate the possibility of using a fluid failure sensor in holdover time testing.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2003-04 are documented in nine reports. The titles of the reports are as follows:

- TP 14374E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2003-04 Winter;
- TP 14375E Winter Weather Impact on Holdover Time Table Format (1995-2004);
- TP 14376E Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2003-04;
- TP 14377E Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces (2003-04);
- TP 14378E Evaluation of a Real-Time Snow Precipitation Gauge for Aircraft Deicing Operations (2003-04);
- TP 14379E Development of Holdover Time Guidelines for Type III Fluids;
- TP 14380E A Protocol for Testing Fluids Applied with Forced Air Systems;
- TP 14381E Aircraft Ground Icing General and Exploratory Research Activities for the 2003-04 Winter; and
- TP 14382E A Sensor for Detecting Anti-Icing Fluid Failure: Phase I.

In addition, an interim report entitled *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions* has been drafted.

This report, TP 14379E has the following objective:

- To develop holdover time data for Type III fluids.

This objective was met by conducting endurance time tests with one Type III fluid in simulated freezing precipitation at National Research Council Canada's Climatic Engineering Facility in Ottawa, and by carrying out tests in natural snow conditions at a test facility operated by APS at Montreal-Trudeau Airport and at mobile test stations in Val d'Or and Sainte-Adèle, Quebec.

ACKNOWLEDGEMENTS

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

APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Stephanie Bendickson, Nicolas Blais, Richard Campbell, Michael Chaput, Sami Chebil, John D'Avirro, Peter Dawson, Marco Di Zazzo, Miljana Horvat, Mark Mayodon, Chris McCormack, Nicoara Moc, Catalin Palamaru, 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 in, contributed to and provided guidance in the preparation of these documents.

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. TP 14379E	2. Project No. 5499-5501	3. Recipient's Catalogue No.
4. Title and Subtitle Development of Holdover Time Guidelines for Type III Fluids		5. Publication Date November 2004
		6. Performing Organization Document No. CM1892
7. Author(s) Michael Chaput		8. Transport Canada File No. 2450-BP-14
9. Performing Organization Name and Address APS Aviation Inc. 634 St. Jacques Street West 4th Floor Montreal, Quebec Canada H3C 1C7		10. PWGSC File No. MTB-3-01379
		11. PWGSC or Transport Canada Contract No. T8200-033534/001/MTB
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 800 René Lévesque Blvd. West Suite 600 Montreal, Quebec H3B 1X9		13. Type of Publication and Period Covered Final
		14. Project Officer Barry B. Myers

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

Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.

16. Abstract

Type III de/anti-icing fluid is designed for aircraft with lower rotation speeds and shorter takeoff rolls. Two Type III fluids were previously tested for endurance times in 1991-92 and 1996-97. One fluid was produced commercially but later discontinued; the other fluid was never produced commercially. Despite no Type III fluids existing in the marketplace, Transport Canada (TC) continued to publish the Type III generic table annually in its Commercial and Business Aviation Advisory Circular (CBAAC) and on its website, based on the previous test results. In 2003-04, a new Type III fluid, Clariant Safewing MP III 2031 ECO, was certified to Aerospace Material Specifications (AMS) 1428 and was submitted to TC for endurance time testing.

The endurance time tests performed with Clariant Safewing MP III 2031 ECO provided very good results. Although generally below the holdover time numbers in the 2003-04 TC Type III Fluid Holdover Time Table (which were based on the endurance time results of a fluid tested in 1996-97 but never commercialized), the endurance times of the Clariant Safewing MP III 2031 ECO fluid were all much longer than the Type I de/anti-icing fluid holdover times.

TC and the U.S. Federal Aviation Administration (FAA) produced similar Type III holdover time tables for inclusion within their operator guidance material for use in 2004-05 winter operations, containing values generally based on the endurance times of Clariant Safewing MP III 2031 ECO fluid. The only differences between the two tables reside in the very light snow columns, where TC has a single value and the FAA provides a holdover time range. Neither regulator will publish a fluid-specific holdover time table for the Clariant Type III product.

17. Key Words Deicing, anti-icing, endurance time, Type III fluid, holdover time		18. Distribution Statement Limited number of copies available from the Transportation Development Centre		
19. Security Classification (of this publication) Unclassified	20. Security Classification (of this page) Unclassified	21. Declassification (date) —	22. No. of Pages xx, 44, apps	23. Price Shipping/ Handling

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada: TP 14379E

2. N° de l'étude: 5499-5501

3. N° de catalogue du destinataire:

4. Titre et sous-titre: Development of Holdover Time Guidelines for Type III Fluids

5. Date de la publication: Novembre 2004

6. N° de document de l'organisme exécutant: CM1892

7. Auteur(s): Michael Chaput

8. N° de dossier - Transports Canada: 2450-BP-14

9. Nom et adresse de l'organisme exécutant:
APS Aviation Inc.
634, rue Saint-Jacques Ouest, 4e étage
Montréal (Québec)
Canada H3C 1C7

10. N° de dossier - TPSGC: MTB-3-01379

11. N° de contrat - TPSGC ou Transports Canada: T8200-033534/001/MTB

12. Nom et adresse de l'organisme parrain:
Centre de développement des transports (CDT)
800, boul. René-Lévesque Ouest
Bureau 600
Montréal (Québec)
H3B 1X9

13. Genre de publication et période visée: Final

14. Agent de projet: Barry B. Myers

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

Les rapports de recherche produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs peuvent être obtenus auprès du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à neuf rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports.

16. Résumé

Les liquides de dégivrage/antigivre de type III sont conçus pour des avions qui se caractérisent par de faibles vitesses de rotation et de brèves courses au décollage. Deux liquides de type III ont été soumis à des essais d'endurance en 1991-1992 et en 1996-1997. Un de ces liquides était un produit commercial, mais il a été retiré du marché depuis; l'autre liquide n'a jamais été produit à l'échelle commerciale. Malgré l'absence de liquides de type III sur le marché, Transports Canada (TC) a continué de publier chaque année un tableau générique des durées d'efficacité des liquides de type III, dans sa Circulaire d'information de l'Aviation commerciale et d'affaires (CIACA) et sur son site Web, à partir des résultats des essais antérieurs. En 2003-2004, un nouveau liquide de type III, le Clariant Safewing MP III 2031 ECO, a été homologué selon la norme Aerospace Material Specifications (AMS) 1428, puis soumis à TC pour des essais d'endurance.

Les essais d'endurance du liquide Clariant Safewing MP III 2031 ECO ont donné de très bons résultats. Bien que généralement inférieurs aux valeurs du tableau des durées d'efficacité 2003-2004 de TC pour les liquides de type III (valeurs relatives à un liquide qui a été mis à l'essai en 1996-1997 mais qui n'a jamais été commercialisé par la suite), les temps d'endurance du liquide Clariant Safewing MP III 2031 ECO étaient tous beaucoup plus longs que ceux des liquides de dégivrage/antigivre de type I.

TC et la Federal Aviation Administration (FAA) des États-Unis ont publié des tableaux de durées d'efficacité similaires pour les liquides de type III, lesquels devaient servir de documents d'orientation aux exploitants pour leurs opérations hivernales de la saison 2004-2005. Les valeurs de ces tableaux correspondaient généralement aux temps d'endurance déterminés pour le liquide Clariant Safewing MP III 2031 ECO. La seule différence entre les deux tableaux est que, à la colonne «neige très légère», le tableau de TC comporte une valeur unique, tandis que celui de la FAA comprend un intervalle de temps. Ni TC ni la FAA n'ont l'intention de publier un tableau de durées d'efficacité exprès pour le liquide Clariant de type III.

17. Mots clés: Dégivrage, antigivre, endurance, liquide de type III, durée d'efficacité

18. Diffusion: 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, 44, ann.	Port et manutention

EXECUTIVE SUMMARY

Background

Due to the holdover time restrictions of Type I fluid, many operators of commuter aircraft were forced to adopt Type IV anti-icing operations, despite the fact that these fluids are not recommended for use with many commuter aircraft with slow rotation speeds and short takeoff rolls. Many airlines incurred penalties in icing conditions as a result of the use of Type IV fluid. As no Type III fluids existed in the marketplace, manufacturers and operators of commuter aircraft were forced to live with this reality.

Type III is a de/anti-icing fluid designed for aircraft with lower rotation speeds and shorter takeoff rolls. Two Type III fluids, Union Carbide 250-3 and Ultra+ (66%), were previously tested for endurance times in 1991-92 and 1996-97, respectively. Union Carbide 250-3 was produced commercially but later discontinued; Ultra+ (66%) was never produced commercially. Despite no Type III fluids existing in the marketplace, Transport Canada (TC) continued to publish the Type III generic table annually in its Commercial and Business Aviation Advisory Circular (CBAAC) and on its website. The generic Type III table was based on the Ultra+ (66%) endurance time results from 1996-97 testing.

Under contract to the Transportation Development Centre (TDC) of TC and the U.S. Federal Aviation Administration (FAA), APS Aviation Inc. (APS) examined in 2002-03 a potential solution for the de/anti-icing of commuter aircraft with fluids that have improved holdover time performance relative to Type I fluids. One potential solution examined was the spraying of heated Type IV fluids through Type I spray equipment to produce a lower viscosity fluid. The idea was based on the assumption that production samples of heated Type IV fluid would retain sufficient viscosity following a spray through a Type I delivery system to provide a minimum of 15 minutes of holdover time in snow.

Testing was conducted at three North American airports in 2003. Viscosity and endurance time tests were performed with the Type IV samples collected at the three sites. Even when the Type IV fluid was severely sheared by the Type I spray equipment, the endurance time results of these samples were much longer than Type I endurance times. The positive test results led to the belief that a severely sheared anti-icing fluid could be certified to Aerospace Material Specifications (AMS) 1428 as a Type III fluid. Also in 2002-03, APS produced three simulated Type III fluids by mechanically shearing certified Type II fluids to low viscosity levels. Tests were performed in natural snow and simulated precipitation using standard endurance time testing procedures. The endurance time tests produced very encouraging results. One product's endurance times were all above the values in the 2002-03 TC Type III holdover time guidelines.

The activities performed in 2002-03 led to the development of a new-generation Type III fluid. In 2003-04, APS was tasked by TC and the FAA to develop endurance time data for Type III fluids.

Prior to the start of the 2003-04 winter testing season, de/anti-icing fluid manufacturers were encouraged to produce and submit candidate Type III fluids, based on a low-viscosity anti-icing fluid formulation, for endurance time testing. Only one fluid, Clariant Safewing MP III 2031 ECO, was received.

Spray Tests with Heated Type III Fluid at Dallas/Fort Worth International Airport (DFW)

Prior to the onset of the fluid endurance time tests with the Clariant Safewing MP III 2031 ECO product, a series of spray tests were performed at DFW using an American Eagle Saab 340 aircraft. The objective of these tests was to spray heated Type III fluid through a Type I spray nozzle and to compare the viscosities of the sprayed and virgin fluids to determine the appropriate viscosity for this fluid for endurance time testing.

The spray tests performed at DFW demonstrated that it is possible to heat a Type III production sample and spray it through a Type I nozzle with enough pressure to deice and anti-ice an aircraft. The consistency of the Type III fluid that was applied with the Type I spray equipment was excellent. The measured viscosities of the fluid sprayed on the wing in the two tests were used by the fluid manufacturer to determine the appropriate delivery viscosity for the Type III fluid that was sent to APS for endurance time testing.

Endurance Time Testing of Clariant Safewing MP III 2031 ECO

The endurance time tests performed with Clariant Safewing MP III 2031 ECO provided very good results. Although generally below the numbers in the 2003-04 TC Type III Fluid Holdover Time Table (which was based on the test results of UCAR Ultra+ 66%, tested in 1996-97), the endurance times were all much longer than the Type I holdover times.

TC and the FAA produced similar Type III holdover time tables for inclusion within their operator guidance material for use in 2004-05 winter operations, containing values generally based on the endurance times of Clariant Safewing MP III 2031 ECO fluid. The only differences between the two tables reside in the very light snow columns, where TC has a single value and the FAA provides a holdover time range. Neither regulator will publish a fluid-specific holdover time table for the Clariant Type III product.

Recommendations

It is recommended that:

a) TC encourage additional fluid manufacturers to formulate new Type III fluids;

b) Any new Type III fluid formulation be evaluated for endurance times over the entire range of conditions covered by the Type III holdover time guidelines;

c) Dilutions of the Clariant Safewing MP III 2031 ECO fluid, as well as any other Type III fluid that may become available, be tested for endurance times during the winter of 2004-05;

d) The thermal stability of using heated Type III fluid with Type I spray equipment be examined;

e) An operational assessment for using Type III fluid in a one-step operation to replace Type I anti-icing be conducted with a commuter operator in 2004-05; and

f) An evaluation of the dry-out and re-hydration problems associated with the use of heated Type III fluid formulations be performed.

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SOMMAIRE

Contexte

En raison des restrictions concernant les durées d'efficacité des liquides de type I, beaucoup d'exploitants d'avions-navettes ont dû se tourner vers les liquides de type IV pour leurs opérations antigivre, même s'il n'est pas recommandé d'utiliser ces liquides sur des avions qui ont une faible vitesse de rotation et une brève course au décollage, comme c'est le cas de beaucoup d'avions-navettes. Or, dans des conditions givrantes, de nombreuses compagnies aériennes ont été pénalisées par l'utilisation d'un liquide de type IV. Mais faute de trouver sur le marché des liquides de type III, les fabricants et les exploitants d'avions-navettes n'avaient d'autre choix que de recourir à des expédients.

Les liquides de dégivrage/antigivre de type III sont conçus pour des avions qui se caractérisent par de faibles vitesses de rotation et de brèves courses au décollage. Deux liquides de type III, le 250-3 et l'Ultra+ (66 %) de Union Carbide, ont été soumis à des essais d'endurance en 1991-1992 et 1996-1997, respectivement. Le 250-3 de Union Carbide était un produit commercial qui a été retiré du marché plus tard; quant à l'Ultra+ (66 %), il n'a jamais été produit à l'échelle commerciale. Malgré l'absence de liquides de type III sur le marché, Transports Canada (TC) a continué de publier chaque année un tableau générique des durées d'efficacité des liquides de type III, dans sa Circulaire d'information de l'Aviation commerciale et d'affaires (CIACA) et sur son site Web. Ce tableau était fondé sur les résultats des essais d'endurance de l'Ultra+ (66 %) réalisés en 1996-1997.

Dans le cadre d'un contrat passé avec le Centre de développement des transports (CDT) de TC et la Federal Aviation Administration (FAA) des États-Unis, APS Aviation Inc. (APS) a examiné, en 2002-2003, une solution potentielle pour le dégivrage et la protection antigivre des avions-navettes, à l'aide de liquides présentant une durée d'efficacité prolongée par rapport aux liquides de type I. Une des solutions examinées consistait à vaporiser des liquides de type IV chauffés, à l'aide d'un équipement de vaporisation prévu pour les liquides de type I, afin d'abaisser la viscosité du liquide. L'hypothèse de base était que des échantillons de production de liquide de type IV chauffés conserveraient une viscosité suffisante, à la sortie d'un équipement de vaporisation pour liquides de type I, pour demeurer efficaces au moins 15 minutes sous des précipitations neigeuses.

En 2003, des essais ont été menés à trois aéroports d'Amérique du Nord. Ces essais visaient à vérifier la viscosité et la durée d'efficacité des échantillons de liquides de type IV recueillis aux trois sites. Malgré le fort cisaillement subi par les échantillons de liquide de type IV vaporisés à l'aide d'un équipement conçu pour des liquides de type I, ils ont affiché des temps d'endurance beaucoup plus longs que les liquides de type I. Ces résultats ont mené les chercheurs à penser qu'un liquide antigivre soumis à un fort cisaillement pouvait être homologué de type III selon la norme Aerospace Material Specifications (AMS) 1428. Toujours en 2002-2003, APS a produit trois liquides de type III simulés, en abaissant, par cisaillement mécanique, la viscosité de liquides homologués de type II. Ces liquides ont été mis à l'essai sous des précipitations de neige naturelle et des précipitations artificielles, conformément aux procédures standard d'essai d'endurance. Ces essais ont donné des résultats très encourageants. Un des produits a même affiché des temps d'endurance tous supérieurs aux valeurs des lignes directrices sur les durées d'efficacité des liquides de type III de TC pour 2002-2003.

Les travaux réalisés en 2002-2003 ont mené au développement d'un liquide de type III de nouvelle génération. En 2003-2004, TC et la FAA ont demandé à APS de produire des données d'endurance pour les liquides de type III.

Avant le début de la saison d'essais de l'hiver 2003-2004, les fabricants de liquides de dégivrage/antigivre avaient été invités à produire et soumettre des liquides de type III candidats, soit des formules de liquides antigivre à faible viscosité, pour des essais d'endurance. Un seul liquide, le Clariant Safewing MP III 2031 ECO, a été reçu.

Essais de vaporisation de liquides de type III chauffés à l'aéroport international de Dallas/Fort Worth (DFW)

Avant les essais d'endurance du liquide Clariant Safewing MP III 2031 ECO, une série d'essais de vaporisation ont été réalisés à l'aide d'un avion Saab 340 d'American Eagle, à l'aéroport de DFW. Ces essais consistaient à vaporiser un liquide de type III chauffé à l'aide d'un ajutage pour liquide de type I, pour comparer la viscosité du liquide vaporisé à celle du liquide vierge, afin de déterminer la viscosité appropriée de ce liquide pour les essais d'endurance.

Les essais de vaporisation effectués à DFW ont révélé qu'il est possible de chauffer un échantillon de production de type III et de le vaporiser à l'aide d'un ajutage pour liquide de type I avec assez de pression pour dégivrer un avion et le protéger contre le givre. Le liquide de type III appliqué à l'aide de l'équipement de vaporisation pour liquide de type I a offert une excellente consistance. Le fabricant du liquide a utilisé les valeurs mesurées de la viscosité du liquide vaporisé sur l'aile, lors des deux essais, pour déterminer la viscosité à la livraison du liquide de type III envoyé à APS pour les essais d'endurance.

Essais d'endurance du Clariant Safewing MP III 2031 ECO

Les essais d'endurance réalisés avec le Clariant Safewing MP III 2031 ECO ont donné de très bons résultats. Bien que généralement inférieurs aux valeurs du tableau des durées d'efficacité 2003-2004 de TC pour les liquides de type III (valeurs concernant le liquide Ultra+ 66 % de Union Carbide, mis à l'essai en 1996-1997), les temps d'endurance étaient tous beaucoup plus longs que ceux des liquides de dégivrage/ antigivre de type I.

TC et la FAA ont publié des tableaux de durées d'efficacité similaires pour les liquides de type III, lesquels devaient servir de documents d'orientation aux exploitants pour leurs opérations hivernales de la saison 2004-2005. Les valeurs de ces tableaux correspondaient généralement aux temps d'endurance déterminés pour le liquide Clariant Safewing MP III 2031 ECO. La seule différence entre les deux tableaux est que, à la colonne «neige très légère», le tableau de TC comporte une valeur unique, tandis que celui de la FAA comprend un intervalle de temps. Ni TC ni la FAA n'ont l'intention de publier un tableau de durées d'efficacité exprès pour le liquide Clariant de type III.

Recommandations

Il est recommandé que :

a) TC encourage d'autres fabricants de liquides à formuler de nouveaux liquides de type III;

b) les temps d'endurance de toute nouvelle formule de liquide de type III soient évalués dans toute la gamme des conditions couvertes par les tableaux des durées d'efficacité des liquides de type III;

c) des dilutions du Clariant Safewing MP III 2031 ECO, de même que de tout autre liquide de type III qui pourrait devenir disponible, soient soumises à des essais d'endurance au cours de l'hiver 2004-2005;

d) la stabilité thermique du liquide de type III chauffé et vaporisé à l'aide d'un équipement de vaporisation pour liquide de type I soit étudiée;

e) l'on évalue en situation réelle l'utilisation d'un liquide de type III, selon une procédure de dégivrage/antigivre à une seule étape, en lieu et place d'un liquide antigivre de type I, avec un exploitant de service aérien de navette, en 2004-2005;

f) l'on étudie les problèmes d'assèchement et de réhydratation associés à l'utilisation de diverses formules de liquides de type III chauffés.

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GLOSSARY

AMS	Aerospace Material Specifications
APS	APS Aviation Inc.
CBAAC	Commercial and Business Aviation Advisory Circular
CEF	Climatic Engineering Facility
cP	Centipoise
DBQ	Dubuque Regional Airport
DFW	Dallas/Fort Worth International Airport
EPA	Environmental Protection Agency (U.S.)
FAA	Federal Aviation Administration (U.S.)
NRC	National Research Council Canada
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers
SCOUIC	Standing Committee on Operations Under Icing Conditions
TC	Transport Canada
TDC	Transportation Development Centre
YQB	Jean Lesage International Airport (Quebec City)
YUL	Montreal-Pierre-Elliot-Trudeau International Airport

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1. INTRODUCTION

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC) and the U.S. Federal Aviation Administration (FAA), APS Aviation Inc. (APS) examined a potential solution for the de/anti-icing of commuter aircraft with fluids that have improved holdover time performance relative to Type I fluids. An associated TC report TP 14152E, *A Potential Solution for De/Anti-Icing of Commuter Aircraft* (1), contains a detailed description of the background information and the preliminary testing activities that were performed in 2002-03 to examine potential solutions for the de/anti-icing of commuter aircraft. These activities led to the development of a new-generation Type III fluid.

In 2003-04, APS was tasked to develop endurance time data for Type III fluid. This report discusses the endurance time tests that were performed with Type III fluid and the development of a new Type III fluid holdover time table based largely on the Type III endurance time results.

1.1 Background

Due to the holdover time restrictions of Type I fluid, many operators of commuter aircraft were forced to adopt Type IV anti-icing operations, despite the fact that these fluids are not recommended for use with many commuter aircraft with slow rotation speeds and short takeoff rolls. Many airlines incurred penalties in icing conditions as a result of the use of Type IV fluid. As no Type III fluids existed in the marketplace, manufacturers and operators of commuter aircraft were forced to live with this reality.

Type III de/anti-icing fluid is designed for aircraft with lower rotation speeds and shorter takeoff rolls. Two Type III fluids, Union Carbide 250-3 and Ultra + (66%), were previously tested for endurance times in 1991-92 and 1996-97, respectively. The results of these tests appear in the TC reports TP 11454E, *Aircraft Ground De/Anti-Icing Holdover Time Field Testing Program for the 1991-92 Winter* (2), and TP 13131E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1996-97 Winter* (3). Union Carbide 250-3 was produced commercially but later discontinued; Ultra + (66%) was never produced commercially. Despite no Type III fluids existing in the marketplace, TC continued to publish the Type III generic table annually in its Commercial and Business Aviation Advisory Circular (CBAAC) and on its website. The generic Type III table was based on the Ultra + (66%) endurance time results from 1996-97 testing. Table 1.1 shows the TC Type III holdover time guidelines that were published for use in 2003-04.

Table 1.1: TC Type III Generic Holdover Time Guidelines for Use in 2003-04

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2003-2004[1]

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

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
°C	°F	Frost[2]	Freezing Fog	Snow[6]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[5]
above 0	above 32	5:00	0:50 – 1:30	0:15 – 0:30	0:25 – 0:50	0:15 – 0:25	0:05 – 0:35	CAUTION: No holdover time guidelines exist
0 to -3	32 to 27	4:00	0:50 – 1:30	0:15 – 0:25	0:25 – 0:50	0:15 – 0:25	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	4:00	0:30 – 1:00	0:10 – 0:20	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14	below 7	Type III 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. Consider use of Type I when Type III fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature

NOTES

1 Based on tests of neat fluids meeting Type III 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.

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.**

In 2002-03, APS examined potential solutions to address the holdover time restrictions of Type I fluid. One potential solution examined was the spraying of heated Type IV fluids through Type I spray equipment to produce a lower viscosity fluid. The idea was based on the assumption that production samples of heated Type IV fluid would retain sufficient viscosity following a spray through a Type I delivery system to provide a minimum of 15 minutes of holdover time in snow.

Testing was conducted at three airports (American Eagle stations) in 2003: Dubuque (DBQ), Quebec City (YQB), and Dallas/Fort Worth (DFW). Viscosity and endurance time tests were performed with the Type IV samples collected at the three sites. Even when the Type IV fluid was severely sheared by the Type I spray equipment, the endurance time results of these samples were much longer than Type I endurance times. The positive test results led to the belief that a severely sheared anti-icing fluid could be certified to Aerospace Material Specifications (AMS) 1428 as a Type III fluid. These tests are described in detail in TP 14152E (1).

Also in 2002-03, APS produced three simulated Type III fluids by mechanically shearing certified Type II products to low viscosity levels. Tests were performed in natural snow and simulated precipitation using standard endurance time testing procedures. The endurance time tests produced very encouraging results. One product's endurance times were all above the values in the 2002-03 TC Type III holdover time guidelines.

The general conclusions of the test program conducted in 2002-03 were as follows:

a) Despite having a very low viscosity, simulated Type III fluids provide vastly superior holdover time performance than Type I fluid;

b) The holdover times provided by the simulated Type III fluids could provide the industry with operationally useful holdover times;

c) Type III fluids could potentially be used in one-step de/anti-icing operations, as Type I fluids currently are;

d) Because a Type III fluid based on a low viscosity anti-icing fluid formulation is undiluted, it would provide fluid freezing point protection across the holdover time table;

e) Type III fluid could likely be applied with Type I fluid spray equipment; and

f) Due to the lower viscosity, Type III fluid would likely provide improved aerodynamics for commuter aircraft and alleviate current penalties imposed on operators.

Prior to the start of the 2003-04 winter testing season, de/anti-icing fluid manufacturers were encouraged to produce and submit candidate Type III fluids, based on a low-viscosity anti-icing fluid formulation, for endurance time testing. Only one fluid, Clariant Safewing MP III 2031 ECO, was received.

This report describes the testing that was performed to develop holdover time guidelines for Type III fluid, based on the results of endurance time tests conducted with the Clariant Safewing MP III 2031 ECO fluid.

1.2 Work Statement

The work statement for these tests is provided in Appendix A.

1.3 Project Objectives

The primary objectives of this research program, taken from the Work Statement in Appendix A, were to:

a) Provide support to a potential airline that has demonstrated interest in proceeding with Type III fluid technology;

b) Assist in the conduct of spray tests to evaluate the effectiveness of the coverage of Type III fluids on a wing;

c) Assist in the evaluation of the effectiveness of Type III fluid sprayed through a Type I nozzle;

d) Conduct flat plate tests under conditions of natural snow to record fluid endurance times with new Type III fluid formulations. All testing will be performed using the methodology developed in the conduct of similar tests for TC in past years; and

e) Conduct flat plate tests under conditions of freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface to record fluid endurance times with new Type III fluid formulations. All testing will be performed using the methodology developed in the conduct of similar tests for TC in past years.

1.4 Special Credits and Acknowledgements

The author of this report would like to acknowledge the contributions of Captain Ron Whipple of American Eagle Airlines. Discussions with Captain Whipple in Fall 2002 led to the inception of this two-year research project, and his commitment and vision provided the project with a guiding light in the months that ensued. Without Captain Whipple's input, feedback, cooperation and persistence, this research project would not have been accomplished.

The author would also like to acknowledge and thank the American Eagle station manager and employees who supported the spray tests at DFW.

As a final acknowledgement, the author would like to thank the fluid manufacturer, Clariant GmbH, for the development of the Clariant Safewing MP III 2031 ECO fluid that was used in the various field and laboratory tests described in this report.

2. SPRAY TESTS WITH AMERICAN EAGLE AT DALLAS/FORT WORTH INTERNATIONAL AIRPORT (DFW)

This section describes the Type III spray tests that were performed in conjunction with American Eagle at DFW in January 2004.

2.1 Introduction

Prior to the onset of fluid endurance time tests with the Clariant Safewing MP III 2031 ECO product, a series of spray tests were performed at DFW using an American Eagle Saab 340 aircraft. The objectives of these tests were to:

- Spray heated Clariant Safewing MP III 2031 ECO fluid through a Type I spray nozzle; and
- Determine a suitable viscosity for the Type III fluid used in endurance time testing, based on comparisons of the viscosities of the sprayed and virgin fluids from DFW tests.

In 1999, the Society of Automotive Engineers (SAE) G-12 Holdover Time Subcommittee recommended that all future anti-icing fluid endurance time testing be performed with fluids that were representative of the lowest on-wing viscosity for each anti-icing product.

It was believed that if the endurance times were developed using fluid at the very bottom of the viscosity scale, the holdover time values for each product would be conservative. The responsibility for selecting the lowest on-wing viscosity for each fluid was left to the individual manufacturer, and this viscosity value was then subsequently included in the fluid-specific holdover time table for each fluid, indicating the lowest viscosity at which the fluid could be used for the holdover times in the fluid-specific table to apply.

The underlying motivation for the spray tests at DFW was to compare the viscosities of sprayed and virgin Type III fluid. The fluid manufacturer would examine the results of the viscosity tests and select an appropriate and conservative viscosity at which the fluid would be tested for endurance times.

2.2 Methodology

2.2.1 Test Sites

2.2.1.1 Type III fluid spray tests at DFW

Tests to collect heated Type III fluid samples following a spray were performed at DFW in January 2004. DFW was selected because as an American Eagle hub of operations it possessed a wealth of personnel and equipment resources.

Due to stringent environmental restrictions at DFW, all spraying of glycol-based fluid was performed at a designated area of the airport that is equipped with drains to collect the sprayed fluid. Spray tests were performed at a remote location near the threshold of Runway 35 Left (35L). The precise location of the spray tests at DFW has been circled in Figure 2.1.

2.2.1.2 Type III fluid viscosity tests

Viscosity measurements of the fluid samples retrieved from the spray tests at DFW were performed at the APS laboratory in Montreal.

2.2.2 Description of Test Procedures

2.2.2.1 Type III fluid spray tests at DFW

The procedure for heated Type III fluid spray tests is included in Appendix B of this report.

Prior to the arrival of test personnel at DFW, an American Eagle deicing vehicle was emptied of its Type I contents, flushed repeatedly with water and then loaded with the Clariant Safewing MP III 2031 ECO Type III fluid. A sample of the virgin fluid was retained from the transportation container for viscosity verification. Photo 2.1 shows the deicing vehicle used for Type III fluid spray tests at DFW.

Test personnel were transported to the test area by van. A Saab 340 aircraft was taxied from the American Eagle maintenance facility to the test area by American Eagle personnel. Photo 2.2 shows the Saab 340 aircraft used in testing. The Clariant Type III fluid in the Type I spray truck was heated prior to the application of the fluid to the wings of the aircraft. A hand-held temperature gauge was used to verify the fluid temperature.

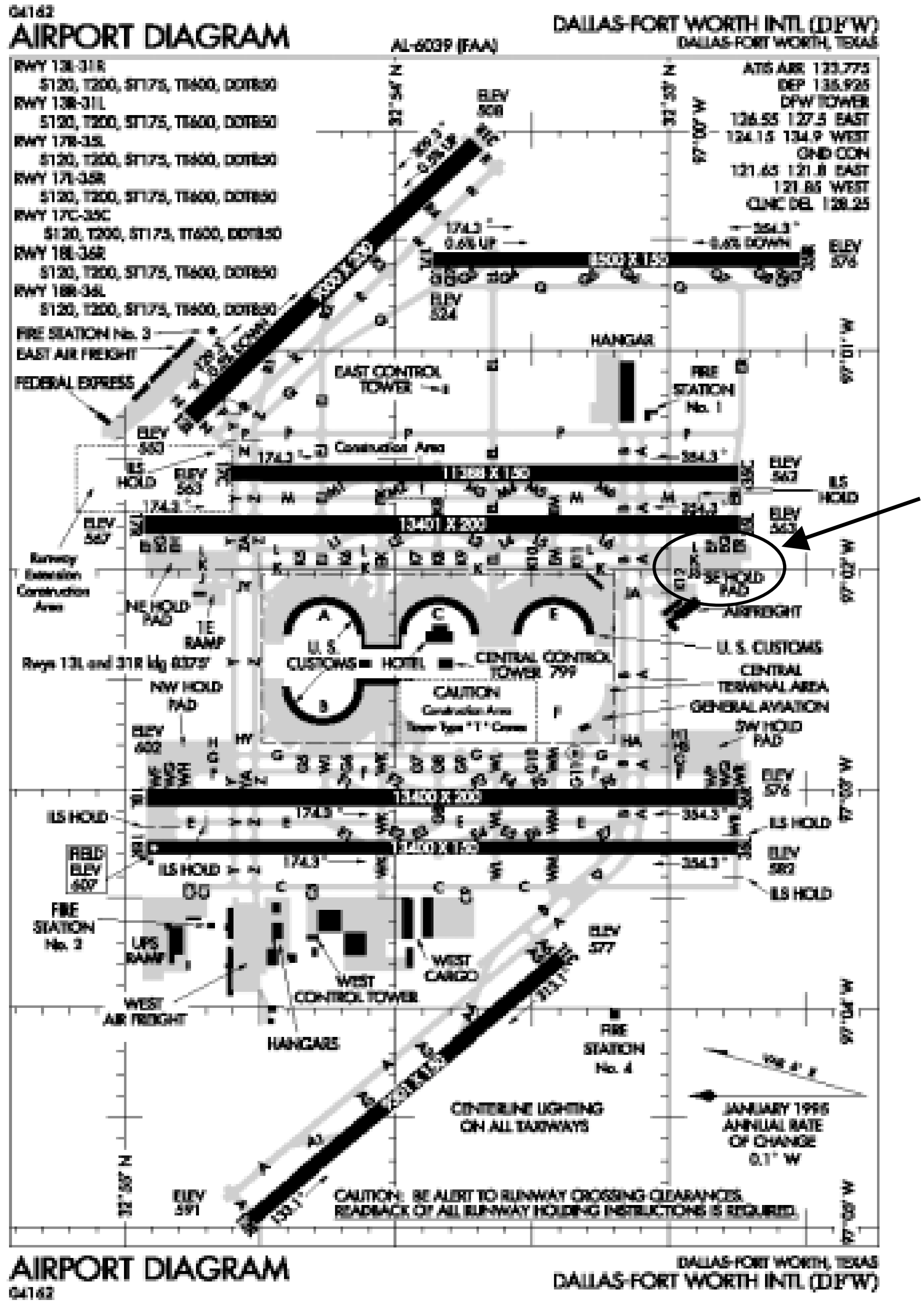

Figure 2.1: Diagram of DFW
(Test Location has been Circled)

Data such as the outside air temperature (OAT), fluid temperature, and information pertaining to the deicing vehicle used in testing were recorded on a prepared form by an APS observer.

When the fluid reached the minimum spray temperature (60°C), it was sprayed onto one wing of the Saab 340 using the Type I spray apparatus. Standard industry Type I procedures for fluid application were employed. Photo 2.3 shows the Type III fluid being sprayed onto the starboard wing of the Saab 340.

Fluid samples were collected from the wing by using a large rubber scraper to drag the fluid into a large plastic container. From there, the fluid was transferred to one-litre sample containers. Photo 2.4 shows the procedure and equipment used to collect the fluid samples. The sample containers were returned to Montreal for viscosity verification.

Fluid thickness measurements on the wing were also taken once the fluid had stabilized, and an overall appearance of the fluid (uniformity of coverage, etc.) was recorded for each run. Photo 2.5 shows APS personnel taking a fluid thickness measurement on the Saab 340 wing.

Following the completion of the spray testing, the American Eagle deicing truck was emptied of the remaining Type III fluid, rinsed with water and then replenished with Type I. The aircraft was cleaned with Type I fluid and returned to the American Eagle maintenance facility.

2.2.2.2 Type III fluid viscosity tests

Viscosity measurement tests of the samples collected at DFW were conducted in Montreal. Viscosities of the sheared samples were measured and compared to those of the virgin production samples to assist Clariant in the determination of an appropriate viscosity at which to test the fluid for endurance times.

Viscosity tests were run using the fluid manufacturer’s recommended method of viscosity measurement.

Due to its low viscosity, Clariant Safewing MP III 2031 ECO required a much more sensitive viscosity measurement method compared with that employed for more viscous fluids. The manufacturer proposed an alternative method to measure the viscosity of the fluid. The viscosity method proposed by Clariant consisted of the following:

a) Spindle: LV1;
b) Temperature: 0°C;
c) Spindle rotation: 0.3 rpm;
d) Test duration: 15 minutes; and
e) Fluid quantity: 500 mL of fluid.

2.2.3 Data Forms

2.2.3.1 Type III fluid spray tests at DFW

One data form (Figure 2.2) was used to record the specific information for each spray test at DFW.

2.2.3.2 Type III fluid viscosity tests

Viscosity data was recorded on an internal APS spreadsheet (Table 2.1).

2.2.4 Equipment

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan developed by APS and based on approved ISO 9001:2000 standards.

2.2.4.1 Type III fluid spray tests at DFW

The DFW Type I spray vehicle was manufactured by Premier, model MT 35175 (see Photo 2.1), and equipped with a Task Force Tips Type I nozzle, model BGH HT-150. The fluid pump on the Type I spray vehicle was manufactured by Goulds, model JPM3616. The fluid spray was performed by American Eagle personnel at the typical Type I fluid pressure of 150 psi.

The following additional equipment was used in the DFW spray tests:

- Hand-held temperature gauge;
- Plastic collection pans (oil pans);
- One-litre sample containers;
- Fluid thickness gauges;
- Funnels;
- Large rubber scrapers to remove fluid samples from wing surfaces; and
- Data forms.

Date / Time of Spray:	______________________
Air Temperature (°C):	______________________
Fluid Type:	______________________
Fluid Temperature:	______________________
Deicing Vehicle:	______________________
Vehicle ID#:	______________________
Fluid Pump:	______________________
Nozzle Type:	______________________
Flow Rate and Spray Pattern:	______________________
Aircraft Type:	______________________
Fluid Thickness Measurements:	______________________
Additional Comments:	______________________
	______________________
Observer:	______________________

Figure 2.2: General Form for Testing of Heated Type III Fluid Sprayed Through Type I Spray Delivery Systems

Table 2.1: APS Viscosity Data Log

Test #	Bottle #	Date	Fluid Name	Batch #	Conc.	Temp [°C]	Time [mm:ss]	Spindle	Rpm	Torque	Viscosity Stated [cP]	Viscosity Measured [cP]	Signature	Comments

2.2.4.2 Type III fluid viscosity tests

Viscosity measurements were carried out using a Model DV-1+ Brookfield viscometer (Photo 2.6) fitted with a Brookfield TC-500 constant temperature bath. The refrigerated TC-500 bath allows viscosity tests to be conducted from -10°C to 130°C, with a stability of ± 0.03°C.

2.2.5 Fluids

One Type III fluid was used in heated Type III fluid spray tests. The fluid was Clariant Safewing MP III 2031 ECO.

2.2.6 Personnel

2.2.6.1 Type III fluid spray tests at DFW

One APS employee was present at DFW to manage the fluid spray tests and collect the fluid samples.

American Eagle personnel tended to the deicing vehicles and sprayed the Clariant fluid.

Personnel from Clariant, the DFW airport authority and the U.S. Environmental Protection Agency (EPA) were also present for these tests.

2.2.6.2 Type III fluid viscosity tests

One APS technician was required to conduct the in-house viscosity measurements.

2.3 Description and Processing of Data

2.3.1 Overview of Tests – Type III Fluid Spray Tests at DFW

On January 20, 2004, a Saab 340 aircraft was taxied to a designated "deicing friendly" area at DFW. Clariant Type III fluid, heated to a temperature of 64°C at the nozzle, was then applied to the aircraft, using the standard Type I fluid application method (narrow stream, high pressure). The fluid was allowed to stabilize on the wing for about 30 seconds. Fluid thickness measurements were taken at several leading edge locations. The thickness of the fluid varied between 35 and 48 mils (one mil is one thousandth of an inch) as measured on the paint gauge, or approximately one millimetre. Fluid was then squeegeed from the wing and placed in one-litre sample containers for viscosity tests.

The heated fluid was applied to the wing in a manner and at a pressure that would have easily deiced the wing if, for example, an accumulation of snow had been present.

To examine the effect of repetitive shearing on the fluid, the fluid was re-circulated in the deicing vehicle for a period of 25 minutes prior to the second spray test. To do so, the top cover of the fluid tank in the deicing vehicle was removed and the American Eagle operator climbed on top of the truck and sprayed the fluid through the Type I nozzle back into the fluid tank.

For the spray test with the re-circulated fluid, the Type III fluid was again applied to the aircraft using the Type I fluid application method. The fluid was allowed to stabilize on the wing for about 30 seconds prior to recording thickness measurements on the leading edge. The thickness of the fluid in this spray again varied between 35 and 48 mils. Fluid was then squeegeed from the wing and placed in one-litre sample containers for viscosity tests. The recirculation of the fluid in the tank and the repeated shearing of the fluid through the spray nozzle did not affect the fluid thickness measurements on the wing.

Table 2.2 provides a summary of the Type III spray tests at DFW.

Table 2.2: Summary of Type III Fluid Spray Tests at DFW

Date	Test	Test Location	Fluid Applied	Truck	Nozzle	OAT (°C)	Fluid Temp. (°C)
20-Jan-04	1	DFW	Clariant Safewing MP III 2031 ECO	Premier MT 35175	Type I	12	64
20-Jan-04	2	DFW	Clariant Safewing MP III 2031 ECO	Premier MT 35175	Type I	12	64

2.3.2 Overview of Tests – Type III Fluid Viscosity Tests

Prior to each spray test at DFW, virgin samples of the Clariant Safewing MP III 2031 ECO fluids were gathered. After the fluid was heated and sprayed onto the aircraft, fluid samples were collected from the wing and were returned to Montreal for viscosity testing. A summary of the viscosity results for the sprayed Type III tests appears in Table 2.3.

Table 2.3: Summary of the Viscosity Results of the Heated Type III Fluid Samples Sprayed Through Type I Equipment

Date	Test Location	Fluid Applied	Sample	Avg. Measured Viscosity (cP)*
20-Jan-04	DFW	Clariant Safewing MP III 2031 ECO	Barrel Sample	5220
20-Jan-04	DFW	Clariant Safewing MP III 2031 ECO	Truck Sample - Spray 1	4140
20-Jan-04	DFW	Clariant Safewing MP III 2031 ECO	Sample Collected off Wing - Spray 1	980
20-Jan-04	DFW	Clariant Safewing MP III 2031 ECO	Truck Sample - Spray 2 (Recirculated)	1620
20-Jan-04	DFW	Clariant Safewing MP III 2031 ECO	Sample Collected off Wing - Spray 2 (Recirculated)	1200

*Viscosity Measurement Method: Spindle LV1, 0°C, 0.3 rpm, 15 minutes, 500 mL of fluid

2.4 Summary of Tests

The tests performed at DFW with Clariant Safewing MP III 2031 ECO demonstrated that it is possible to heat a Type III production sample and spray it through a Type I nozzle with enough pressure to deice and anti-ice an aircraft.

The measured viscosities of the fluid sprayed on the wing in the two tests, 980 cP and 1 200 cP respectively, were used by Clariant to determine an appropriate viscosity at which the fluid would be tested for endurance times. To be conservative, the viscosity of the Type III fluid sample subsequently sent to APS by Clariant for endurance time testing (810 cP) was lower than those viscosities collected from the spray tests on the wing. The endurance time results with this fluid are discussed in detail in Section 3 of this report.

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Photo 2.1: Type I Spray Vehicle Used in Type III Fluid Spray Tests at DFW

Photo 2.2: Saab 340 Aircraft Used in Type III Fluid Spray Tests at DFW

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Photo 2.3: Type III Fluid Spray on Saab 340 Aircraft

Photo 2.4: Collecting a Type III Fluid Sample from a Wing

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Photo 2.5: APS Personnel Taking a Fluid Thickness Measurement

Photo 2.6: Brookfield Digital Viscometer Model DV-1 + and Temperature Bath

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3. ENDURANCE TIME PERFORMANCE

This section provides an evaluation of the endurance time performance of the Clariant Safewing MP III 2031 ECO Type III fluid. A fluid manufacturer report containing the comprehensive results of this testing was provided to Clariant.

3.1 Introduction

In February 2004, APS was provided with samples of the Clariant Safewing MP III 2031 ECO fluid for endurance time testing. The viscosity of the fluid received was 810 cP (viscosity measurement method: Spindle LV1, 0°C, 0.3 rpm, 15 minutes, and 500 mL of fluid).

Endurance time tests were performed to update the generic Type III holdover time guidelines, based on the performance of the Clariant Safewing MP III 2031 ECO product.

3.2 Methodology

3.2.1 Test Sites

Natural snow endurance time testing of Clariant Safewing MP III 2031 ECO was performed at the APS Montreal-Trudeau Airport (YUL) test site. The location of the site is shown on the plan view of the airport shown in Figure 3.1. Photo 3.1 was taken at the test site and shows the trailer and the associated equipment. Photo 3.2 shows an exterior view of the test site seen from the main trailer during a natural snow event. The APS test site is located near the NAV CANADA automated weather observation station (formerly operated by Environment Canada/Meteorological Service of Canada), shown in Photo 3.3.

Due to a lack of natural snow conditions at the Montreal-Trudeau Airport test site during the 2003-04 winter test season, a mobile test unit – a cube van containing all the required test equipment – was developed for use. Weather forecasts in North Bay, Val d’Or, Rouyn, Quebec City, and Sainte-Adèle were monitored daily, and a two-man crew was mobilized and dispatched to conduct testing if the desired conditions were obtained. Tests were conducted during one snow event in Sainte-Adèle and one snow event in Val d’Or. The test site in Val d’Or was located just outside of the airport property. The test site in Sainte-Adèle was located on a private property.

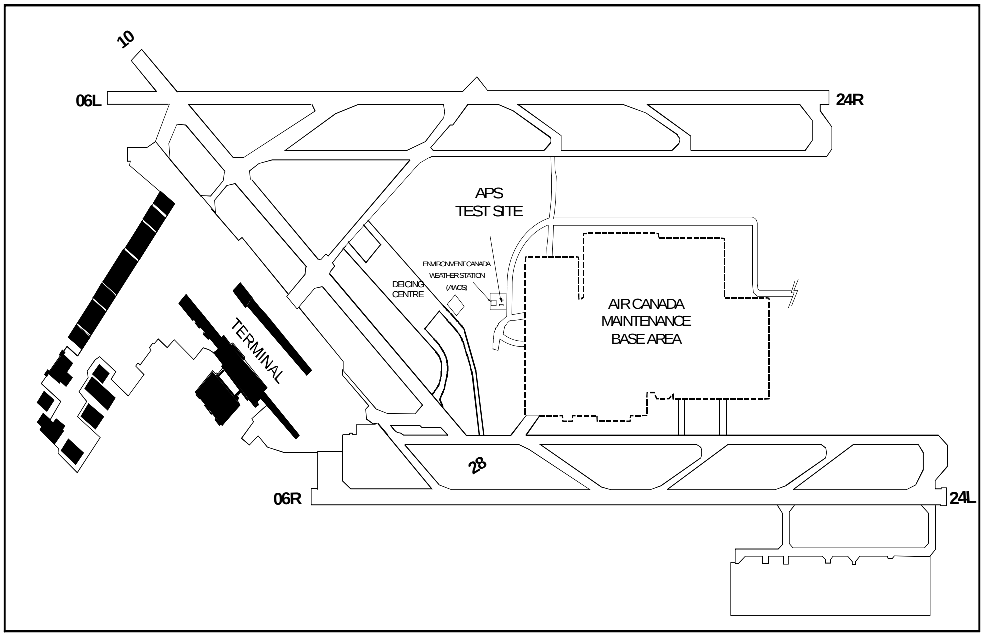

Figure 3.1: APS Test Site Location at Montreal-Trudeau Airport

Tests under conditions of freezing drizzle, light freezing rain, freezing fog and rain on a cold-soaked wing were conducted indoors at the National Research Council (NRC) Climatic Engineering Facility (CEF) in Ottawa, where precipitation was artificially produced. Photo 3.4 provides a view of the building from the outside. Photo 3.5 provides an interior view of the test facility. The size of the chamber is 30 m by 5.4 m, with a height of 8 m. The lowest temperature achievable is -46ºC.

3.2.2 Description of Test Procedures

Standard industry procedures for the conduct of the endurance time testing were employed. These procedures have been described in numerous reports for TC, including TP 14144E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2002-03 Winter* (4).

In general, fluid endurance time tests consisted of pouring one litre of the Clariant Type III fluid (at ambient test temperature) onto clean aluminium plates inclined at 10° from the horizontal. The plates were mounted on a test stand and systematically exposed to a variety of natural or artificially produced icing conditions. For every plate, the elapsed time required to reach a predefined end condition was recorded. Test conditions, test parameters, and test bed specifications were determined based on SAE G-12 Holdover Time Subcommittee guidelines.

3.2.3 Data Forms

Two data forms, one to record fluid failure times, the other to record precipitation rate data, were used during the 2003-04 winter natural snow endurance time tests with the Clariant Type III fluid. Both forms appear in Appendix C of TP 14144E (4).

Two similar data forms were used to manually record test data in the simulated precipitation tests at NRC. These forms appear in Appendix D of TP 14144E (4).

3.2.4 Equipment

The equipment used during the conduct of fluid endurance time tests in natural snow and simulated precipitation conditions with the Clariant Type III fluid was identical to that used in endurance time tests performed in previous years at the APS test site in Montreal and at the NRC. A comprehensive description of the equipment can be found in Appendices C and D of TP 14144E (4).

3.2.5 Fluids

One Type III fluid, Clariant Safewing MP III 2031 ECO, was tested for endurance times in all natural and simulated precipitation conditions.

3.2.6 Personnel

The site at YUL was staffed mainly by technicians and university students, and was supervised by APS project staff. In general, two individuals were required for all tests, one to determine fluid failures, the other to measure precipitation rates and to record other meteorological data. Personnel responsibilities for tests conducted in simulated precipitation conditions at the NRC chamber were similar to those of the natural snow tests.

3.3 Description and Processing of Data

Endurance time tests were performed with the Clariant Safewing MP III 2031 ECO fluid in natural snow and simulated precipitation conditions.

A total of 85 endurance time tests were performed in winter 2003-04 with the Clariant Safewing MP III 2031 ECO fluid. The breakdown of the endurance time tests in the various precipitation conditions is included in Table 3.1.

Table 3.1: Summary of Endurance Time Tests Conducted with Clariant Safewing MP III 2031 ECO

Fluid	Precipitation Condition					
	Natural Snow	Freezing Drizzle	Light Freezing Rain	Freezing Fog	Cold Soak	Total
Clariant Safewing MPIII 2031 ECO	53	8	8	12	4	**85**

The complete data log of the natural snow endurance time tests with the Clariant Type III fluid is included in Table 3.2. The data log of the endurance time tests performed in simulated precipitation conditions is included in Table 3.3.

3.4 Analysis and Observations

Endurance time tests with the Type III Clariant Safewing MP III 2031 ECO were performed in all conditions contained within the 2003-04 TC Type III holdover time table (Table 1.1): snow, freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing were all tested.

3.4.1 Endurance Time Results

Tests were conducted with the Clariant Safewing MP III 2031 ECO over temperature and precipitation rate ranges specific to each category of precipitation. A multi-variable regression analysis was used to evaluate fluid holdover times. This procedure, described in detail in TP 14144E (4), is based on the refinement of an equation for a curve which best represents the fluid failure time test data, and involves solving that equation at the upper and lower limits of a defined precipitation range. To support this procedure, precipitation rate limits for each specific category of precipitation were defined, reviewed, and approved.

The unrounded endurance time values of the Clariant Safewing MP III 2031 ECO Type III fluid, determined by the regression analysis for each condition and temperature, are included within Table 3.4. The values are provided in the form of a time range.

Although generally below the numbers in the 2003-04 TC Type III Fluid Holdover Time Table (which was based on the test results of UCAR Ultra+ 66%, tested in 1996-97), the endurance times were all greatly improved over the generic Type I holdover times.

Table 3.2: Log of Natural Snow Endurance Time Tests with Clariant Safewing MP III 2031 ECO

Test #	Date of Test	Fluid	Endurance Time (minutes)	Precipitation Rate ($g/dm^2/h$)	OAT (°C)	Average Wind Speed (km/h)	Precipitation Condition
1	20-Feb-04	Clariant Type III (2031)	30.0	5.5	-3.2	19	Natural Snow
2	20-Feb-04	Clariant Type III (2031)	21.0	7.4	-3.2	19	Natural Snow
3	21-Feb-04	Clariant Type III (2031)	24.8	8.3	-0.2	21	Natural Snow
4	21-Feb-04	Clariant Type III (2031)	25.3	8.4	-0.2	21	Natural Snow
5	21-Feb-04	Clariant Type III (2031)	24.5	9.0	-0.3	22	Natural Snow
6	21-Feb-04	Clariant Type III (2031)	24.3	9.1	-0.3	22	Natural Snow
7	21-Feb-04	Clariant Type III (2031)	24.5	9.4	-0.3	21	Natural Snow
8	21-Feb-04	Clariant Type III (2031)	23.8	9.3	-0.3	21	Natural Snow
9	21-Feb-04	Clariant Type III (2031)	39.3	5.7	-0.2	20	Natural Snow
10	21-Feb-04	Clariant Type III (2031)	37.3	5.6	-0.2	20	Natural Snow
11	21-Feb-04	Clariant Type III (2031)	39.2	5.8	-0.3	20	Natural Snow
12	21-Feb-04	Clariant Type III (2031)	40.0	5.8	-0.3	20	Natural Snow
13	21-Feb-04	Clariant Type III (2031)	29.7	5.7	-0.3	19	Natural Snow
14	21-Feb-04	Clariant Type III (2031)	29.5	5.6	-0.3	19	Natural Snow
16	14-Mar-04	Clariant Type III (2031)	119.8	1.5	-1.5	12	Natural Snow
17	20-Mar-04	Clariant Type III (2031)	20.7	9.2	-1.5	17	Natural Snow
22	20-Mar-04	Clariant Type III (2031)	32.3	5.9	-2.0	25	Natural Snow
27	20-Mar-04	Clariant Type III (2031)	26.3	8.8	-2.6	30	Natural Snow
32	20-Mar-04	Clariant Type III (2031)	12.0	24.6	-2.0	32	Natural Snow
37	20-Mar-04	Clariant Type III (2031)	14.8	17.1	-2.0	32	Natural Snow
42	20-Mar-04	Clariant Type III (2031)	14.5	19.6	-2.0	32	Natural Snow
50	20-Mar-04	Clariant Type III (2031)	20.0	13.7	-2.0	32	Natural Snow
52	20-Mar-04	Clariant Type III (2031)	19.9	15.4	-0.3	30	Natural Snow
55	20-Mar-04	Clariant Type III (2031)	17.7	15.4	-0.3	30	Natural Snow
59	20-Mar-04	Clariant Type III (2031)	13.2	21.4	-0.9	26	Natural Snow
62	20-Mar-04	Clariant Type III (2031)	11.3	23.1	-1.0	26	Natural Snow
65	20-Mar-04	Clariant Type III (2031)	20.6	11.8	-1.0	26	Natural Snow
67	20-Mar-04	Clariant Type III (2031)	19.7	11.2	-1.0	26	Natural Snow
72	20-Mar-04	Clariant Type III (2031)	19.0	7.4	-0.5	28	Natural Snow
75	20-Mar-04	Clariant Type III (2031)	18.8	9.3	-0.5	24	Natural Snow
79	20-Mar-04	Clariant Type III (2031)	17.8	10.6	-0.3	20	Natural Snow
81	20-Mar-04	Clariant Type III (2031)	41.0	4.4	0.1	19	Natural Snow
86	23-Mar-04	Clariant Type III (2031)	23.3	7.3	-8.0	19	Natural Snow
90	23-Mar-04	Clariant Type III (2031)	23.3	5.1	-8.0	18	Natural Snow
92	23-Mar-04	Clariant Type III (2031)	20.3	7.6	-8.0	19	Natural Snow
95	23-Mar-04	Clariant Type III (2031)	31.0	4.6	-7.9	19	Natural Snow
97	23-Mar-04	Clariant Type III (2031)	39.0	4.4	-7.8	19	Natural Snow
112	23-Mar-04	Clariant Type III (2031)	115.7	0.5	-11.3	NA	Natural Snow
114	23-Mar-04	Clariant Type III (2031)	111.0	0.8	-10.4	NA	Natural Snow
119	23-Mar-04	Clariant Type III (2031)	123.0	0.5	-5.0	NA	Natural Snow
120	23-Mar-04	Clariant Type III (2031)	83.5	4.0	-1.2	NA	Natural Snow
129	23-Mar-04	Clariant Type III (2031)	17.2	11.0	-1.0	NA	Natural Snow
130	23-Mar-04	Clariant Type III (2031)	22.0	6.8	-1.7	NA	Natural Snow
136	23-Mar-04	Clariant Type III (2031)	16.8	10.9	-1.0	NA	Natural Snow
137	4-Apr-04	Clariant Type III (2031)	20.2	16.3	-1.5	19	Natural Snow
141	4-Apr-04	Clariant Type III (2031)	20.2	13.2	-1.6	18	Natural Snow
145	4-Apr-04	Clariant Type III (2031)	23.7	10.3	-1.6	18	Natural Snow
149	4-Apr-04	Clariant Type III (2031)	27.8	6.9	-3.5	14	Natural Snow
150	4-Apr-04	Clariant Type III (2031)	69.7	2.1	-2.7	18	Natural Snow
156	4-Apr-04	Clariant Type III (2031)	29.7	8.0	-3.7	13	Natural Snow
161	5-Apr-04	Clariant Type III (2031)	25.2	10.4	-4.5	15	Natural Snow
165	5-Apr-04	Clariant Type III (2031)	38.5	6.8	-5.0	17	Natural Snow
169	5-Apr-04	Clariant Type III (2031)	50.0	5.2	-5.0	18	Natural Snow

Table 3.3: Log of Simulated Precipitation Endurance Time Tests with Clariant

Test #	Date of Test	Fluid	Endurance Time (minutes)	Precipitation Rate ($g/dm^2/h$)	OAT (°C)	Precipitation Condition
NRC-95	19-Apr-04	Clariant Type III (2031)	26.7	4.9	-3.0	Freezing Fog
NRC-96	19-Apr-04	Clariant Type III (2031)	23.8	5.2	-3.0	Freezing Fog
NRC-103	19-Apr-04	Clariant Type III (2031)	45.0	2.1	-3.0	Freezing Fog
NRC-104	19-Apr-04	Clariant Type III (2031)	45.3	2.0	-3.0	Freezing Fog
NRC-87	22-Apr-04	Clariant Type III (2031)	25.3	5.2	-14.0	Freezing Fog
NRC-88	22-Apr-04	Clariant Type III (2031)	24.5	5.2	-14.0	Freezing Fog
NRC-81	22-Apr-04	Clariant Type III (2031)	43.3	1.8	-14.0	Freezing Fog
NRC-82	22-Apr-04	Clariant Type III (2031)	44.8	1.5	-14.0	Freezing Fog
NRC-71	22-Apr-04	Clariant Type III (2031)	25.2	4.8	-25.0	Freezing Fog
NRC-72	22-Apr-04	Clariant Type III (2031)	24.8	4.7	-25.0	Freezing Fog
NRC-75	22-Apr-04	Clariant Type III (2031)	45.2	2.0	-25.0	Freezing Fog
NRC-76	22-Apr-04	Clariant Type III (2031)	44.5	2.0	-25.0	Freezing Fog
NRC-7	19-Apr-04	Clariant Type III (2031)	9.3	25.5	-3.0	Light Freezing Rain
NRC-8	19-Apr-04	Clariant Type III (2031)	8.8	25.9	-3.0	Light Freezing Rain
NRC-15	20-Apr-04	Clariant Type III (2031)	13.2	12.5	-3.0	Light Freezing Rain
NRC-16	20-Apr-04	Clariant Type III (2031)	13.7	12.4	-3.0	Light Freezing Rain
NRC-29	21-Apr-04	Clariant Type III (2031)	10.5	24.6	-10.0	Light Freezing Rain
NRC-30	21-Apr-04	Clariant Type III (2031)	10.7	24.7	-10.0	Light Freezing Rain
NRC-35	21-Apr-04	Clariant Type III (2031)	13.8	12.2	-10.0	Light Freezing Rain
NRC-36	21-Apr-04	Clariant Type III (2031)	14.7	12.4	-10.0	Light Freezing Rain
NRC-23	20-Apr-04	Clariant Type III (2031)	13.5	13.2	-3.0	Freezing Drizzle
NRC-24	20-Apr-04	Clariant Type III (2031)	13.3	13.6	-3.0	Freezing Drizzle
NRC-55	20-Apr-04	Clariant Type III (2031)	27.5	4.8	-3.0	Freezing Drizzle
NRC-56	20-Apr-04	Clariant Type III (2031)	27.8	4.9	-3.0	Freezing Drizzle
NRC-41	21-Apr-04	Clariant Type III (2031)	13.6	12.6	-10.0	Freezing Drizzle
NRC-42	21-Apr-04	Clariant Type III (2031)	13.2	12.6	-10.0	Freezing Drizzle
NRC-47	21-Apr-04	Clariant Type III (2031)	23.5	4.9	-10.0	Freezing Drizzle
NRC-48	21-Apr-04	Clariant Type III (2031)	22.9	5.0	-10.0	Freezing Drizzle
NRC-67	20-Apr-04	Clariant Type III (2031)	7.0	76.2	1.0	Cold-Soak
NRC-68	20-Apr-04	Clariant Type III (2031)	7.3	74.5	1.0	Cold-Soak
NRC-61	20-Apr-04	Clariant Type III (2031)	24.2	5.1	1.0	Cold-Soak
NRC-62	20-Apr-04	Clariant Type III (2031)	24.3	5.6	1.0	Cold-Soak

Safewing MP III 2031 ECO

Table 3.4: Endurance Time Results of Clariant Safewing MP III 2031 ECO

OAT		Approximate Holdover Times Under Various Weather Conditions (minutes)								
°C	**°F**	**Active Frost**	**Freezing Fog**	**Very Light Snow**	**Light Snow**	**Moderate Snow**	**Freezing Drizzle**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other**
-3 and above	27 and above	120	25 - 46	39 - 48	21 - 39	11 - 21	14 - 27	9 - 13	7 - 25	
below -3 to -10	below 27 to 14	120	25 - 40	34 - 42	18 - 34	10 - 18	13 - 23	11 - 14	CAUTION: No holdover time guidelines exist	
below -10	below 27	120	24 - 45	30 - 37	16 - 30	9 - 16				

Two bar charts, Figures 3.2 and 3.3, provide the comparison between the Clariant Safewing MP III 2031 ECO endurance times and the TC/FAA generic Type I holdover times for freezing fog and moderate snow conditions, respectively. In each bar chart, the endurance/holdover time (in minutes) is provided on the "y" axis, and the test temperature (in °C) and rate of precipitation (in g/dm²/h) are provided on the "x" axis. Similar comparisons, demonstrating the superior holdover time performance of the Type III fluid, were also produced for light freezing rain, freezing drizzle and rain on a cold-soaked wing conditions, but are not included in this report.

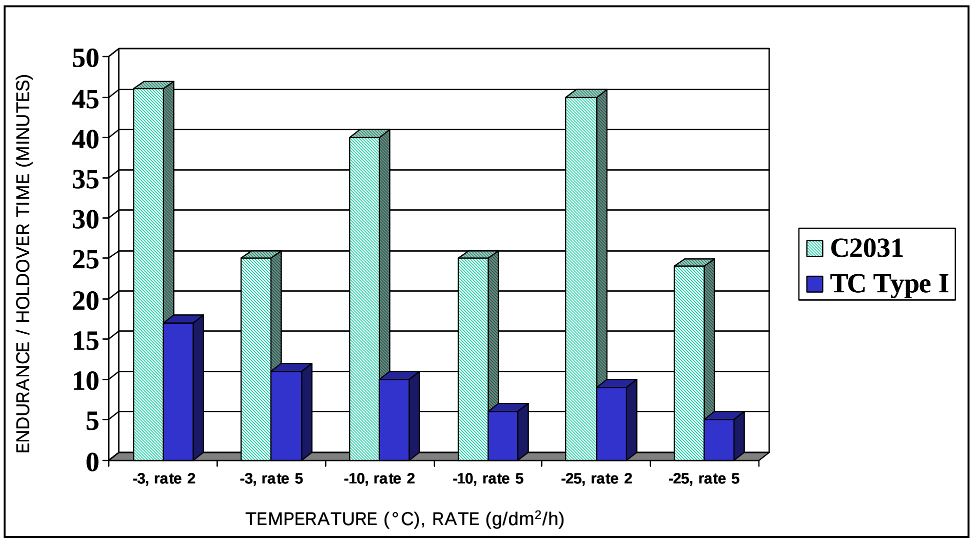

Figure 3.2: Comparison of Clariant Safewing MP III 2031 ECO Endurance Times and Generic TC/FAA Type I Holdover Times – Freezing Fog Conditions

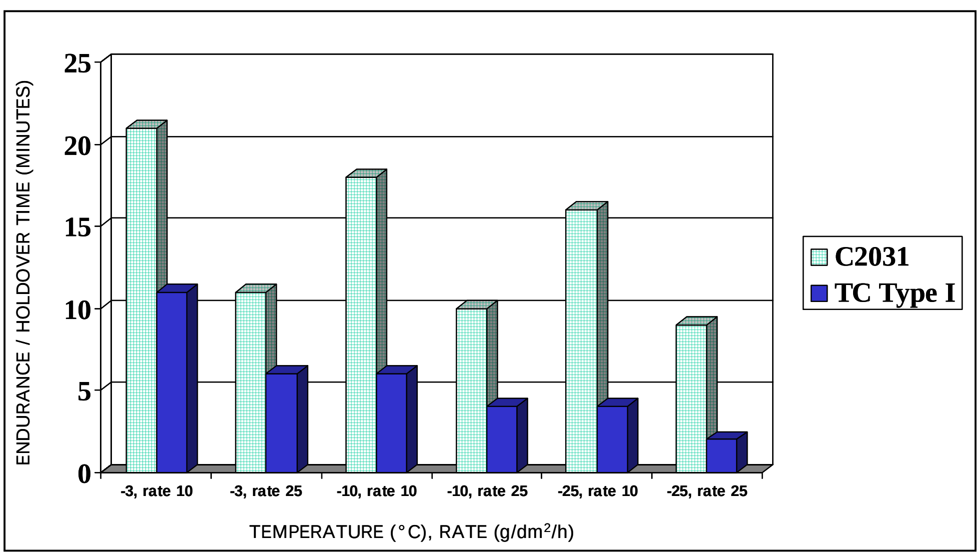

Figure 3.3: Comparison of Clariant Safewing MP III 2031 ECO Endurance Times and Generic TC/FAA Type I Holdover Times – Moderate Snow Conditions

3.4.2 Transport Canada and FAA Generic Type III Holdover Time Tables

The 2003-04 TC Type III holdover time table was produced based on the historical endurance time results of the UCAR Ultra+ (66%) fluid tested in 1996-97. This fluid was never produced commercially. Currently, no Type III fluids, other than Clariant Safewing MP III 2031 ECO, are certified to AMS 1428 as Type III fluids. Therefore, the endurance time data of the Clariant Safewing MP III 2031 ECO fluid are the only existing data to assess the performance of Type III fluid.

In May 2004, TC and the FAA indicated a potential desire to establish a minimum performance standard for Type III fluids, based largely on the generic Type III fluid holdover time table that would be produced using the endurance time results of the Clariant fluid. The performance standard for Type III fluid would establish the minimum holdover time values that all future Type III fluids would have to meet in order to be included in the regulators' list of certified fluids.

To make the values of the generic Type III holdover time table (and potential minimum performance standard) slightly more conservative, a decision was made by the regulators to reduce the endurance time results of the Clariant Safewing MP III 2031 ECO by ten percent and then round the numbers. If the resultant time was below ten minutes, the holdover time value was rounded to the nearest whole value. If the resultant time was above ten minutes, the holdover value was rounded to the nearest whole "five" value. Using this procedure, a holdover time of 9.4 minutes would be rounded down to 9 minutes. A holdover time of 27.9 minutes would be rounded up to 30 minutes.

The Clariant Safewing MP III 2031 ECO fluid endurance time data was presented to the SAE G-12 Holdover Time Subcommittee in Frankfurt in May 2004, and the preliminary generic Type III fluid holdover time table was discussed. Following the Frankfurt meetings, TC and the FAA produced similar Type III holdover time tables for inclusion within their operator guidance material for use in 2004-05 winter operations. The TC generic Type III fluid holdover time table for use in 2004-05 operations is shown in Table 3.5. The FAA generic Type III fluid holdover time guideline for use in 2004-05 operations is shown in Table 3.6. The only differences between the two tables reside in the very light snow columns, where TC has a single value and the FAA provides a holdover time range. Neither regulator will publish a fluid-specific holdover time table for the Clariant Type III product. Also, for the time being, the generic Type III holdover time table will not be considered the minimum performance standard for Type III fluids.

Table 3.5: TC Generic Type III Fluid Holdover Time Table for Use in 2004-05 Winter Operations

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[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	CAUTION: No holdover time guidelines exist
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.**

Table 3.6: FAA Generic Type III Fluid Holdover Time Guidelines for Use in 2004-05 Winter Operations

Appendix I

FAA TYPE III HOLDOVER TIME GUIDELINE

Table 3. FAA Guideline for Holdover Times Anticipated for SAE Type III Fluid Mixture as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature (OAT)		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius (°C)	**Degrees Fahrenheit (°F)**	**Frost***	**Freezing Fog**	**Very ♦ Light Snow**	**Light ♦ Snow**	**Moderate♦ Snow**	****Freezing Drizzle**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other‡**
-3 and above	27 and above	2:00	0:20 - 0:40	0:35-0:40	0:20 - 0:35	0:10 - 0:20	0:10 - 0:20	0:08 - 0:10	0:06 - 0:20	CAUTION: No holdover time guidelines exist
below -3 to -10	below 27 to 14	2:00	0:20 - 0:40	0:30-0:35	0:15 - 0:30	0:09 - 0:15	0:10 - 0:20	0:08 - 0:10	CAUTION: Clear ice may require touch for confirmation	
below -10	below 14	2:00	0:20 - 0:40	0:30-0:35	0:15 - 0:30	0:08 - 0:15				

SAE Type III fluid may be used below –10 °C (14°F), provided the freezing point of the fluid is at least 7°C (13°F) below OAT and aerodynamic acceptance criteria are met.

Consider the use of **SAE Type I** when **Type III** fluid cannot be used.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER.
- * During conditions that apply to aircraft protection for ACTIVE FROST
- ** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
- ‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, and hail
- ♦ Snow includes snow grains

CAUTIONS:
- **TO USE THESE TIMES, THE TYPE III FLUID MUST BE APPLIED UNDILUTED**
- THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY, OR JET BLAST WILL REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.
- **SAE TYPE III** FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR – AND DOES NOT PROVIDE – PROTECTION DURING FLIGHT.

Effective October 1, 2004

3.5 Application Procedure for Type III Fluids

At the SAE G-12 Methods Subcommittee meeting held in Frankfurt in May 2004, it was agreed that the application procedure for Type III fluid should be the same as the application procedure for Type II and Type IV fluids. Type III fluid has been added to the Type II and Type IV fluid application procedures table. The TC anti-icing fluid application procedures, which now include Type III fluid, are shown in Table 3.7.

Table 3.7: TC Type II, Type III and Type IV Fluid Application Procedures for 2004-05

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.

NOTE
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.

CAUTION
- **Wing skin temperatures may differ and in some cases may be lower than OAT; 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.**

3.6 Dilutions of Type III Fluids

Dilutions of the Clariant Safewing MP III 2031 ECO fluid were not tested in the winter of 2003-04 because the airline stimulating the development of Type III was not interested in using them. However, when the Type III test results and tables were presented at the SAE G-12 Holdover Subcommittee meeting in May 2004, other companies showed an interest in using Type III fluids in dilute form. The following arguments were given for making Type III dilutions available:

- It would create consistency between Type II, III and IV fluid application procedures and holdover time guidelines;
- It would reduce the environmental impact of Type III deicing because less concentrate fluid would be used; and
- It would reduce the cost of Type III deicing because less concentrate fluid would be used.

It is therefore recommended that dilutions of Clariant Safewing MP III 2031 ECO, as well as any other Type III fluid that may become available, be tested in the winter of 2004-05.

3.7 Thermal Stability

At the TC Standing Committee on Operations Under Icing Conditions (SCOUIC) meeting in Ottawa in September 2004, a concern was raised about the thermal stability of Type III fluids, especially since these fluids are also intended to be applied heated to aircraft using Type I fluid spray equipment.

The current thermal stability tests included within AMS 1428 specify a requirement to test the Type III fluids at a temperature of 70°C. Because the design of the Type III fluid allows for the use of Type I fluid spray equipment, which typically heats fluid above 70°C, there is a belief that the thermal stability test requirements for this fluid may be insufficient. However, it is noteworthy that the Type III fluid thermal stability tests within AMS 1428, which are of concern to some individuals, also apply to Type II and Type IV fluids. Type II and Type IV fluids are typically applied unheated in North America, but the scenario is vastly different in Europe where thickened fluids are often heated for one-step and two-step de/anti-icing operations. Therefore, investigations should not be limited to Type III fluids.

3.8 Fluid Residues and Rehydration

The international aviation industry has grappled with anti-icing fluid dry-out and re-hydration problems for several years. The problems are much more pronounced in Europe where Type II and Type IV anti-icing fluids are heated and used in one-step de/anti-icing operations. As the Type III fluid that has been discussed in this report could be used heated in a similar one-step fashion, the question has been raised whether Type III fluid would cause similar fluid dry-out and re-hydration issues.

In discussions with a fluid manufacturer, it was indicated that the Type III fluid, based on a low viscosity formulation, would contain fewer polymers in the formulation, and therefore would likely have greatly reduced fluid dry-out and re-hydration possibilities. The manufacturer conducted preliminary tests to compare the dry-out and re-hydration properties of a low viscosity Type III formulation versus a high viscosity Type II formulation (based on an identical fluid formulation other than viscosity). The results indicated that the problem was less severe with the low viscosity product.

Additional tests, perhaps based on the Buehler Test contained within SAE AMS 1428, could be performed to verify these concerns.

American Eagle plans to conduct an operational assessment of Type III fluid, based on testing of the Clariant Safewing MP III 2031 ECO fluid at three of its stations during the winter of 2004-05. At these stations, Type III fluid will replace Type I and will be applied with conventional Type I de/anti-icing spray equipment. All aircraft will be de/anti-iced with the heated Type III fluid in a one-step or two-step operation. American Eagle also plans to introduce a rigorous “quiet area” inspection program to examine fluid residue and rehydration issues for aircraft de/anti-iced with Type III fluid.

Support should be provided to American Eagle in its operational assessment of the use of Type III fluid to replace Type I fluid.

Photo 3.1: APS Test Site at Montreal-Trudeau Airport

Photo 3.2: Exterior View of the Test Site Seen from the Main Trailer

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Photo 3.3: NAV CANADA Weather Observation Station

Photo 3.4: Exterior View of the NRC Facility

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Photo 3.5: Interior View of the NRC CEF

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4. CONCLUSIONS

Several years ago, a need was identified for a de/anti-icing fluid that had longer holdover times than Type I fluid but a lower viscosity than Type II or IV fluid for aircraft with slower rotation speeds and shorter takeoff rolls. These fluids are referred to as Type III fluids. In 2003-04, Clariant produced a fluid that was certified to AMS 1428 as a Type III fluid.

4.1 Type III Fluid Spray Tests at DFW

The spray tests performed at DFW with Clariant Safewing MP III 2031 ECO demonstrated that it is possible to heat a Type III production sample and spray it through a Type I nozzle with enough pressure to deice and anti-ice an aircraft. The consistency of the Type III fluid applied with the Type I spray equipment was excellent.

The measured viscosities of the fluid sprayed on the wing in the two tests were used by Clariant to determine an appropriate viscosity at which to run endurance time testing. To be conservative, the viscosity of the Type III fluid sample sent to APS by Clariant for endurance time testing was lower than the viscosities collected from the spray tests on the wing.

4.2 Fluid Endurance Time Tests with Clariant Safewing MP III 2031 ECO

The endurance time tests performed with Clariant Safewing MP III 2031 ECO provided very good results. Although generally below the numbers in the 2003-04 TC Type III Fluid Holdover Time Table (which was based on the test results of UCAR Ultra+ 66%, tested in 1996-97), the endurance times were all greatly improved over Type I holdover times.

4.3 Development of a Type III Fluid Holdover Time Table

TC and the FAA produced similar Type III holdover time tables for inclusion within their operator guidance material for use in 2004-05 winter operations, containing values generally based on the endurance times of Clariant Safewing MP III 2031 ECO fluid. The only differences between the two tables reside in the very light snow columns, where TC has a single value and the FAA provides a holdover time range. Neither regulator will publish a fluid-specific holdover time table for the Clariant Type III product.

4.4 Type III Fluid Application Procedures

At the SAE G-12 Methods Subcommittee meeting held in Frankfurt in May 2004, it was agreed that the application procedure for Type III fluid should be the same as the application procedure for Type II and Type IV fluids. Type III fluid has been added to the TC Type II and Type IV fluid application procedures table.

5. RECOMMENDATIONS

It is recommended that:

a) TC encourage additional fluid manufacturers to formulate new Type III fluids;

b) Any new Type III fluid formulation be evaluated for endurance times over the entire range of conditions covered by the Type III holdover time guidelines;

c) Dilutions of the Clariant Safewing MP III 2031 ECO fluid, as well as any other Type III fluid that may become available, be tested for endurance times during the winter of 2004-05;

d) The thermal stability of using heated Type III fluid with Type I spray equipment be examined;

e) An operational assessment for using Type III fluid in a one-step operation to replace Type I fluid anti-icing be conducted with a commuter operator in 2004-05; and

f) An evaluation of the dry-out and re-hydration problems associated with the use of single-step heated Type III fluid formulations be performed.

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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

5.1 Aircraft De/Anti-icing Fluid Endurance Time Testing

5.1.1 Natural Snow Tests at Dorval

a) Prepare a procedure for testing outdoors during snowfalls;

b) Conduct flat plate tests under conditions of natural snow mainly at the Dorval Airport test site to record fluid endurance times. All testing will be performed using the methodology developed in the conduct of similar tests for Transport Canada in past years;

c) Record individual fluid endurance times for snow, based on samples of newly certified or re-certified Type I, Type II, Type III and Type IV fluids supplied by fluid manufacturers, under as wide a range of temperature, precipitation rate, precipitation type, and wind conditions as can be experienced. (Testing is anticipated with four anti-icing fluids, as well as two Type I fluids); and

d) Analyze the data collected, report the findings, and prepare presentation material.

5.1.2 Endurance Time Tests in Simulated Precipitation at NRC

a) Prepare a test procedure for the conduct of endurance time tests in simulated precipitation at NRC Climatic Environment Facility;

b) Conduct flat plate tests under conditions of freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface at the National Research Council Climatic Engineering Facility in Ottawa to record fluid holdover times. All testing will be performed using the methodology developed in the conduct of similar tests for Transport Canada in past years;

c) Up to four Type IV and three Type III anti-icing fluids as well as two Type I fluids shall be tested;

d) Record individual fluid endurance times for all simulated precipitation conditions based on samples of newly certified or re-certified fluids supplied by fluid manufacturers under defined test parameters, such as temperature and precipitation rate; and

e) Analyze the data collected, report the findings, and prepare presentation material.

5.3 Full-Scale Field Tests of Type III Fluids

a) Provide support to a potential airline that has demonstrated interest In proceeding with this new technology. Both American Eagle and DeHavilland Canada have indicated the need and a serious interest. Clariant has indicated an interest in providing fluid;

b) Assist in the conduct of spray tests to evaluate the effectiveness of the coverage of Type III fluids on a wing;

c) Further assist in evaluation of the effectiveness of the fluid sprayed thru a Type I nozzle. Viscosity will be evaluated;

d) Attempt to evaluate the dry-out and re-hydration of the fluid;

e) Assess the effectiveness of the fluid with regards to the outstanding issues described above;

f) Analyse results;

g) Coordinate the activities with the FAA/TC and the airline; and

h) Analyse the results and prepare a report and presentation.

APPENDIX B

EXPERIMENTAL PROGRAM
FIELD SPRAY TESTS OF HEATED TYPE III FLUID SPRAYED WITH A TYPE I DE/ANTI-ICING VEHICLE

CM1892.001

EXPERIMENTAL PROGRAM

FIELD SPRAY TESTS OF HEATED TYPE III FLUID SPRAYED WITH A TYPE I DE/ANTI-ICING VEHICLE

Winter 2003-04

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Michael Chaput

Reviewed by: John D'Avirro

APS Aviation Inc

January 23, 2004
Version 1.0

EXPERIMENTAL PROGRAM
FIELD SPRAY TESTS OF HEATED TYPE III FLUIDS SPRAYED WITH A TYPE I DE/ANTI-ICING VEHICLE

Winter 2003-04

1. BACKGROUND

Recent holdover time reductions have strained the use of Type I fluids as anti-icing agents under certain winter precipitation conditions and temperatures. To protect certain markets, several commuter airlines began to move toward the widespread purchase of conventional Type IV spray vehicles to conduct de/anti-icing operations that were traditionally satisfied with Type I fluids. For certain companies, the cost to equip all winter operating stations with Type IV capability would be astronomically high.

At the request of the Transportation Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) undertook a research program in 2002-03 to examine a potential solution for the de/anti-icing of commuter aircraft.

1.1 History of Type I Holdover Time Table Developments

The commuter aviation industry has traditionally relied heavily on Type I fluid as an aircraft ground anti-icing agent.

Prior to 1992, the Type I fluid holdover time table, published by the Association of European Airlines (AEA) and the International Organization for Standardization (ISO), contained a single value in the snow column, regardless of the ambient temperature: This value was 15 minutes. Beginning in 1992-93, a holdover time range was introduced for Type I fluid in snow, and the values were reduced to 6 to 15 minutes. The SAE Type I table remained the same from 1992-93 until 2000-01. In the winter of 1999-00, several new Type I products entered the marketplace, and a series of fluid endurance time tests was conducted on the new Type I fluids using test parameters developed to test Type II and IV fluids. The results of these tests were presented at the annual meeting of the SAE G-12 Holdover Time Subcommittee held in Toulouse, France, in May 2000. At this meeting, the Holdover Time Subcommittee adopted holdover time values for Type I fluid that were significantly shorter than those published in previous years.

Many new developments in the test protocol for Type I fluids have occurred since 1990, contributing to an increase in the Type I holdover times agreed upon in

Toulouse. Although the snow values generated by the new test protocol were an improvement over the reduced holdover time values agreed upon in Toulouse, the values were, in many cases, below the historical 6 to 15 minute holdover time range for Type I fluid in snow. Commuter operators that had traditionally used Type I fluid as an anti-icing agent continued to express concern that the new snow values would adversely affect their operations.

As a result of these concerns, APS began to examine potential solutions to address the holdover time restrictions of anti-icing operations with Type I fluid.

1.2 2002-03 Testing with Heated Type IV Fluid

One potential solution to the limitations of Type I anti-icing was discussed by American Eagle Airlines and APS in the fall of 2002. Initial discussions centred around the possibility of spraying heated Type IV fluids through existing American Eagle Type I spray equipment as a means of producing a lower viscosity fluid. The idea was based upon the assumption that production samples of heated Type IV fluid would retain sufficient viscosity following a spray through a Type I delivery system to provide the desired 15-minute minimum holdover time.

Testing was conducted at three American Eagle stations in 2003: Dubuque, Quebec City, and Dallas/Fort Worth. Testing was performed to verify the viscosity of Kilfrost ABC-S and Clariant MP IV 2001 production samples when sheared through different Type I truck/pump/nozzle combinations. Heated Type IV fluids were sprayed at the three stations in a one-step de/anti-icing procedure. Fluids were collected off the surface of aircraft wings or from fluid collection containers and returned to APS for viscosity testing and endurance time testing.

In Dubuque, the viscosity of the fluid sprayed through the Type I vehicle and nozzle was above the degraded viscosity of Kilfrost ABC-S that was tested for endurance times by APS in 1999-2000. The degraded viscosity sample of ABC-S tested in 1999-2000 had endurance times in excess of the generic Type II values. The fluid endurance time tests conducted with the ABC-S samples collected in Dubuque had results that were above or within the Type II generic holdover time ranges.

In Quebec City, the Type IV fluid sprayed through the Type I vehicle was severely sheared. The viscosity of the fluid collected in Quebec City was immeasurable using the manufacturer’s suggested viscosity measurement method. Fluid samples were nonetheless collected and returned to Montreal for endurance time testing. The endurance time results of the severely sheared sample from Quebec City were below generic Type II values, but were surprisingly well above the generic Type I values.

The endurance time test results of the Quebec City test samples led to the subsequent testing of simulated Type III products.

1.3 2002-03 Endurance Time Testing of Simulated Type III Products

TC produces a Type III generic holdover time table annually, despite the fact that no Type III fluids currently exist.

In 2002-03, APS produced three simulated Type III fluids by mechanically shearing certified Type II products to low viscosity levels. Tests were performed on the fluids in natural snow and simulated precipitation using standard endurance time testing procedures.

The endurance time tests performed with the simulated Type III products produced very encouraging results. One product in particular had endurance times that were all above the values in the current TC Type III holdover time guidelines.

1.4 2003-04 Testing

Operators and manufacturers of commuter aircraft have indicated the need for Type III fluid technology and have expressed interest in participating in any related study activities. As part of the research and development program put forth by Transport Canada to accelerate the introduction of Type III fluids in the marketplace, APS has been tasked to provide operational assessment support to an airline that has demonstrated interest in proceeding with this new technology.

A new Type III product, Clariant Safewing MP III 2031, has been recently certified to AMS 1428. The fluid will also undergo fluid endurance time testing in winter 2004 to develop holdover time guidelines for this new product.

A series of operational tests will be performed with this new fluid technology in Dallas in January 2004. Tests will be performed with the support of American Eagle, who will provide aircraft, support personnel and equipment.

2. OBJECTIVES

The overall objective of the operational tests in Dallas is to examine the potential use of heated Type III fluid as an alternative to Type I de/anti-icing fluid. To achieve this objective, APS will:

- Collect samples of undiluted Type III fluid when heated to a minimum of 60°C and sprayed through a Type I delivery system onto a wing;

- Verify the viscosity of these samples to ensure that viscosity severe degradation of the fluid does not occur as a result of spraying through the Type I delivery system;
- Conduct a selection of fluid endurance time tests to compare the endurance times of the sprayed and unsprayed fluid from the Dallas tests with those of production samples sent to APS for holdover time testing;
- Examine the overall appearance and uniformity of coverage of the Type III fluid when heated and sprayed on a wing; and
- Measure the thickness of the sprayed Type III fluid on the wing.

3. TEST PROCEDURE

Type III fluid samples will be delivered to American Eagle's Dallas/Fort Worth (DFW) station. DFW was selected because it is a hub of operations of American Eagle and the airline possesses a wealth of personnel and equipment resources at this station.

An AEA deicing vehicle will be emptied of its Type I contents and loaded with the Type III fluid provided. A sample of the virgin fluid will be collected from the transportation container for viscosity verification. The Type III fluid in the truck will be heated to a minimum of 60°C prior to the application of the fluid to the wings of the aircraft. A hand-held temperature gauge will be used to verify the fluid temperature.

When the fluid has reached (or exceeded) the minimum temperature, it will be sprayed onto the wing using the Type I spray apparatus. Standard industry procedures for fluid application will apply.

The heated fluid will be sprayed onto the wings of an aircraft by AEA deicing crews in a one-step operation, under the supervision of APS personnel. Fluid samples on the wing will be collected by APS and placed in 1-litre sample containers. The sample containers will be returned to Montreal for viscosity verification. In addition, APS will collect 20 litres of each sprayed fluid and have it transported to Montreal for endurance time testing in natural snow and simulated precipitation conditions.

Fluid thickness measurements on the wing will also be measured once the fluid has stabilized, and an overall appearance of the fluid (uniformity of coverage etc) will be recorded for each run.

The deicing truck will then be emptied of the remaining Type III fluid, and replenished with Type I. The aircraft will be cleaned with Type I fluid prior to its subsequent departure.

Viscosity tests of the samples collected in Dallas will be conducted upon return to Montreal. Viscosities of the sheared samples will be measured and compared to those of the virgin production samples.
Endurance time tests will be conducted with the sheared samples at the Dorval Airport test site and at the NRC chamber in Ottawa. Standard fluid endurance time test procedures will apply. Fluid will be applied to the plates at ambient temperature. Tests will be conducted in the following conditions:

- Natural snow: Approximately 10 tests in various temperature and rate conditions;
- Freezing drizzle: -10°C, 5 and 13 g/dm^2/h (1 test in each condition); and
- Light freezing rain: -3°C, 13 and 25 g/dm^2/h (1 test in each condition).

One endurance time test will also be conducted in natural snow using fluid heated to 60°C.

4. EQUIPMENT AND FLUIDS

4.1 Equipment

The following equipment will be required for the Dallas tests:

- Hand-held temperature gauge;
- 1-litre sample containers (10);
- Thickness gauges (2);
- Funnels;
- Spatulas to remove fluid samples from wing surfaces (2);
- 20-litre fluid container for transport of endurance time samples to Montreal (2); and
- Data forms.

For endurance time tests with the samples collected in Dallas, the same equipment outlined in an associated procedure, *Experimental Program for Natural Precipitation Flat Plate Testing,* will be used.

4.2 Fluids

Only one fluid manufacturer, Clariant GmbH, has produced a fluid suitable for use in the Type III operational assessment tests: Clariant Safewing MP III 2031. Additional testing could be conducted with any other Type III fluid in the future, provided the results of this preliminary work are promising.

Fluids will be applied heated (to a minimum of 60°C) to aircraft surfaces using standard application techniques.

5. PERSONNEL

One APS employee will be needed to manage the spray tests and collect samples off aircraft wings at the selected airport sites, as well as measure fluid thickness on the wings of the aircraft.

One technician will be required for in-house fluid viscosity tests when the samples return from the airports. Additional personnel will also be required for endurance time testing of the collected samples. These tests will be conducted alongside endurance time tests of new fluids.

6. DATA FORMS

One data form (see Figure B-1), will be to record test information during the collection of fluid samples at the selected airport sites.

For endurance time testing of the samples collected in Dallas, the same data forms presented in an associated procedure, *Experimental Program for Natural Precipitation Flat Plate Testing,* will be used.

Date / Time of Spray: ____________________

Air Temperature (°C): ____________________

Fluid Type: ____________________

Fluid Temperature: ____________________

Deicing Vehicle: ____________________

Vehicle ID#: ____________________

Fluid Pump: ____________________

Nozzle Type: ____________________

Flow Rate and Spray Pattern: ____________________

Aircraft Type: ____________________

Fluid Thickness Measurements: ____________________

Additional Comments: ____________________

____

Observer: ____________________

Figure B-1: General Form

Field Spray Tests of Heated Type III Fluids Sprayed With a Type I Vehicle

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