TP 14380E

A Protocol for Testing Fluids Applied with Forced Air Systems

Prepared by

APS Aviation Inc.

Prepared for

Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Center

October 2004
Final Version 1.0

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

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

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Un sommaire français se trouve avant la table des matières.

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PREFACE

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

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To compare endurance times from natural snow with those generated from simulations of 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;
- 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, the following interim report is being prepared:

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

This report, TP 14380E, has the following objective:

- To evaluate the current Type II/IV test procedure for testing forced-air equipment.

To satisfy this objective, APS Aviation Inc. personnel travelled to Rochester, New York to participate in forced-air systems testing with a deicing operator. APS Aviation Inc. measured in-situ viscosities of fluids applied with and without forced-air systems.

PROGRAM ACKNOWLEDGEMENTS

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

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Stephanie Bendickson, Nicolas Blais, 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, contributed and provided guidance in the preparation of these documents.

PROJECT ACKNOWLEDGEMENTS

APS Aviation Inc. would like to acknowledge the contribution of FedEx to this project. The Rochester test session was instigated and coordinated by FedEx, who also provided the test facility and equipment, obtained test fluids, and arranged for interested parties to attend. APS Aviation Inc. would also like to thank the FedEx personnel working in the FedEx hangar in Rochester for their support and assistance during the Rochester test session.

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

16. Abstract

Operators are interested in forced air as an alternative approach to deicing, predominantly because of the possibility of achieving an increased spray distance and improving the distribution of Type II/IV fluids over the aircraft wing. There are various ways it may be used, including with Type I and Type II/IV fluids. Over the past five years, APS Aviation Inc. (APS) has worked with Transport Canada, the Federal Aviation Administration, and the Society of Automotive Engineers G-12 Equipment Subcommittee Forced Air Working Group to develop this technology. This work has included the development of test procedures for both Type I and Type II/IV testing.

In January 2004, APS assisted in forced air testing that was conducted with six Type IV fluids and two models of deicing trucks in Rochester, New York. APS measured in-situ viscosities of fluids applied with forced air assist and compared them to in-situ viscosities of fluids applied conventionally. The viscosities of fluids applied with forced air assist were found to be lower than the viscosities of fluids applied conventionally. This may have been the result of the forced air equipment setup, as these results were not seen in previous test sessions.

It is recommended that testing be conducted to investigate the equipment setup variables and to establish a fixed equipment setup. Distance between the air spray and fluid spray, distance between the nozzle and the test surface, nozzle opening, orientation of the nozzle and nozzle type should be examined. Once the equipment setup has been fixed, it is recommended a new Type II/IV test procedure be prepared and testing with the new procedure be conducted to determine if any fluids meet the requirements for certification.

If no Type IV fluids are deemed to be suitable for use with forced air assist, Type II and/or Type III fluids should be tested. Although they have shorter holdover times than Type IV fluids, Type II and Type III fluids also have lower initial viscosities that will be less influenced by the shearing of a forced air assist application.

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

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

16. Résumé

Les exploitants aériens s'intéressent au recours à l'air forcé comme autre outil de dégivrage, principalement parce qu'il offre la possibilité d'augmenter la distance de pulvérisation et d'améliorer la distribution des liquides de types II/IV sur les ailes des aéronefs. Il existe diverses façons de l'utiliser, y compris avec les liquides de type I et ceux de types II/IV. Au cours des cinq dernières années, APS Aviation Inc. (APS) a collaboré avec Transports Canada, la Federal Aviation Administration (FAA) et le groupe de travail sur les systèmes à air forcé du sous-comité G-12 de la Society of Automotive Engineers afin de mettre au point cette technologie. Ce travail a inclus la mise en place de procédures d'essai pour les tests menés sur les liquides de type I et sur ceux de types II/IV.

En janvier 2004, APS a participé aux essais sur des systèmes à air forcé effectués avec six liquides de type IV et deux modèles de camions de dégivrage à Rochester, dans l'État de New York. APS a mesuré la viscosité in situ des liquides appliqués à l'aide de systèmes à air forcé et l'a comparée à la viscosité in situ des liquides appliqués de façon traditionnelle. La viscosité des liquides appliqués à l'aide de systèmes à air forcé s'est avérée plus basse que celle des liquides appliqués de façon traditionnelle. Ces résultats, qui n'avaient pas été observés lors des séances d'essai précédentes, pourraient s'expliquer par la configuration de l'équipement à air forcé.

Il est recommandé que des tests soient menés afin d'étudier les variables de configuration de l'équipement et d'établir des réglages définitifs pour ces dernières. La distance entre le jet d'air et le jet de liquide, la distance entre la buse et la surface de test, l'ouverture de la buse, l'orientation de la buse et le type de buse devraient être examinés. Une fois la configuration de l'équipement déterminée, il est recommandé qu'une nouvelle procédure d'essai pour les liquides de types II/IV soit préparée, et que des tests appliquant cette nouvelle procédure soient effectués afin de déterminer si des liquides répondent aux exigences de certification.

Si aucun liquide de type IV n'est jugé approprié pour une utilisation à l'aide de systèmes à air forcé, les liquides de type II ou de type III devraient faire l'objet de tests. Bien que leurs durées d'efficacité soient plus courtes que celles des liquides de type IV, les liquides de types II et III présentent également une viscosité initiale plus basse, moins susceptible d'être influencée par le cisaillement associé à une application à l'aide de systèmes à air forcé.

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EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), with financial support from the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology. In recent years one of these research activities has been the advancement of forced air deicing systems.

Background

Operators are interested in forced air as an alternative approach to deicing, predominantly because of the possibility of achieving an increased spray distance and improving distribution of Type II/IV fluids over the aircraft wing. There are various ways it may be used, including with Type I and Type II/IV fluids.

After initial testing was conducted in the winter of 1999-2000, the need for an official process whereby operators could test the use of forced air in certain deicing applications was identified. The main goal was to ensure the holdover time guidelines were appropriate for forced air applications. APS worked with the Society of Automotive Engineers G-12 Equipment Subcommittee Forced Air Working Group to address this need.

It was agreed that test procedures for both Type I and Type II/IV fluids were required. A Type I procedure was issued in November 2001. It was developed as a tool to help operators evaluate the use of forced air in first-step deicing with Type I fluids. This decision does not require the approval of regulatory authorities.

The first Type II/IV procedure went through several modifications between July 2001 and June 2002. After this procedure was formally issued in June 2002, the FAA requested that endurance time tests be added to the procedure as a test requirement. Endurance time tests were conducted in February 2003. When the results were analysed it was concluded that viscosity tests were sufficient for evaluating forced air systems. Following this testing and its subsequent recommendations, a second version of the Type II/IV procedure was issued in December 2002. The procedure has two phases: operator assessment and viscosity measurement. Testing was conducted using this procedure in January 2004 in Rochester, New York.

Rochester Testing

APS assisted in forced air testing that was conducted in January 2004 with six Type IV fluids and two models of deicing trucks in Rochester, New York. APS measured in-situ viscosities of fluids applied with forced air assist and compared them to in-situ viscosities of fluids applied conventionally. The viscosities of fluids applied with forced air assist were found to be lower than the viscosities of fluids applied conventionally.

Conclusions

Tests conducted in 2003-04 showed that applying Type IV fluids using forced air assist causes fluid viscosity to decrease more than when fluids are applied conventionally. This is contrary to 2002-03 testing and to other previous research. It is believed that the equipment setup was responsible for the differences seen between the 2002-03 and 2003-04 results.

Recommendations

It is recommended that testing be conducted to investigate the influence of equipment setup variables on fluid viscosity. Some variables that should be examined are: distance between the air spray and fluid spray, distance between the nozzle and the test surface, nozzle opening, orientation of the nozzle and nozzle type. Since the influence of these variables on conventional fluid application systems has never been examined, it is recommended that conventional fluid application systems and forced air assist application systems are examined at the same time. The forced air equipment setup should subsequently be fixed (e.g. made non-changeable) to ensure that the influence of a forced air application on fluid viscosity is comparable to that of a conventional application.

Once the equipment setup has been fixed, it is recommended that a new Type II/IV test procedure be prepared. One change that could be made is to eliminate the requirement to compare forced air applications to conventional applications and instead to compare the viscosity of fluids applied with forced air to the lowest on-wing viscosity. Testing with the new procedure should be conducted to find out if any Type IV fluids meet the test requirements.

If no Type IV fluids are deemed suitable for use with forced air assist, Type II and/or Type III fluids could be tested. Although they have shorter holdover times than Type IV fluids, Type II and Type III fluids also have lower initial viscosities that will be less influenced by the shearing of a forced air assist application.

SOMMAIRE

En vertu d'un contrat avec le Centre de développement des transports (CDT) de Transports Canada (TC) et avec l'appui financier de la Federal Aviation Administration (FAA), APS Aviation Inc. (APS) a entrepris des activités de recherche visant à faire progresser les technologies associées au dégivrage et à l'antigivrage d'aéronefs au sol. Au cours des dernières années, l'une de ces activités de recherche s'est concentrée sur le développement de systèmes de dégivrage à air forcé.

Contexte

Les exploitants aériens s'intéressent au recours à l'air forcé comme autre outil de dégivrage, principalement parce qu'il offre la possibilité d'augmenter la distance de pulvérisation et d'améliorer la distribution des liquides de types II/IV sur les ailes des aéronefs. Il existe diverses façons de l'utiliser, y compris avec les liquides de type I et ceux de types II/IV.

Après des essais initiaux menés durant l'hiver 1999-2000, la nécessité d'une procédure officielle permettant aux exploitants aériens de tester l'utilisation d'air forcé pour certaines opérations de dégivrage a été établie. L'objectif principal était alors de s'assurer que les lignes directrices relatives aux durées d'efficacité étaient toujours pertinentes. APS a travaillé de concert avec le groupe de travail sur les systèmes à air forcé du sous-comité G-12 de la Society of Automotive Engineers afin de répondre à ce besoin.

Il a été convenu que des procédures d'essai pour les liquides de type I et pour ceux de types II/IV étaient requises. Une procédure pour les liquides de type I a été mise en place en novembre 2001. Elle a été élaborée pour servir d'outil permettant aux exploitants aériens d'avoir recours, dans une première étape, à l'air forcé pour le dégivrage avec des liquides de type I. Une telle décision ne requiert pas l'approbation des organismes de réglementation.

La première procédure pour les liquides de types II/IV a été modifiée à de nombreuses reprises entre juillet 2001 et juin 2002. À la suite de la mise en œuvre officielle de cette procédure en juin 2002, la FAA a demandé que des essais d'endurance y soient ajoutés comme critère d'évaluation. Des essais d'endurance ont ainsi été menés en février 2003. L'analyse des résultats a permis de conclure que les tests de viscosité étaient suffisants pour permettre l'évaluation des systèmes à air forcé. À la suite de ces essais et des recommandations qui les ont suivis, une seconde version de la procédure relative aux liquides de types II/IV a été présentée en décembre 2002. Cette dernière comporte deux phases, soit l'évaluation par l'exploitant aérien et la mesure de la viscosité. Des essais utilisant cette procédure ont été effectués en janvier 2004 à Rochester, dans l'État de New York.

Essais menés à Rochester

APS a participé aux essais sur des systèmes à air forcé effectués en janvier 2004 avec six liquides de type IV et deux modèles de camions de dégivrage à Rochester, dans l'État de New York. APS a mesuré la viscosité *in situ* des liquides appliqués à l'aide de systèmes à air forcé et l'a comparée à la viscosité *in situ* des liquides appliqués de façon traditionnelle. La viscosité des liquides appliqués à l'aide de systèmes à air forcé s'est avérée plus basse que celle des liquides appliqués de façon traditionnelle.

Conclusions

Les tests menés en 2003-2004 ont démontré que l'application de liquides de type IV à l'aide de systèmes à air forcé entraîne une diminution de la viscosité du liquide supérieure à celle observée lors d'une application traditionnelle. Ces résultats sont contraires à ceux des essais menés en 2002-2003 et dans le cadre de recherches antérieures. Il semble que la configuration de l'équipement permette d'expliquer les différences constatées entre les séances d'essai de 2002-2003 et celles de 2003-2004.

Recommandations

Il est recommandé que des tests soient menés afin d'étudier l'influence des variables de configuration de l'équipement sur la viscosité des liquides. Parmi les variables qui devraient été examinées, on note : la distance entre le jet d'air et le jet de liquide, la distance entre la buse et la surface de test, l'ouverture de la buse, l'orientation de la buse et le type de buse. Puisque l'influence de ces variables sur les systèmes traditionnels d'application des liquides n'a jamais été étudiée, il est recommandé que ces systèmes traditionnels d'application des liquides et les systèmes d'application à air forcé soient examinés conjointement. La configuration de l'équipement à air forcé devrait par la suite être définitive (c'est-à-dire non modifiable), afin d'assurer que l'influence d'une application à l'aide de systèmes à air forcé sur la viscosité des liquides est comparable à celle d'une application traditionnelle.

Une fois la configuration de l'équipement déterminée, il est recommandé qu'une nouvelle procédure d'essai pour les liquides de types II/IV soit préparée. Un changement qui pourrait être apporté serait d'éliminer les exigences de comparaison entre les applications à air forcé et les applications traditionnelles, pour plutôt comparer la viscosité des liquides appliqués à l'aide de systèmes à air forcé à la plus basse viscosité sur l'aile. Des essais appliquant la nouvelle procédure devraient être effectués dans le but de vérifier si des liquides de type IV répondent aux critères d'évaluation.

Si aucun liquide de type IV n'est jugé approprié pour une utilisation à l'aide de systèmes à air forcé, les liquides de type II ou de type III pourraient faire l'objet de tests. Bien que leurs durées d'efficacité soient plus courtes que celles des liquides de type IV, les liquides de types II et III présentent également une viscosité initiale plus basse, moins susceptible d'être influencée par le cisaillement associé à une application à l'aide de systèmes à air forcé.

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GLOSSARY

APS	APS Aviation Inc.
FAA	Federal Aviation Administration
FMC	FMC Technologies
LOWV	Lowest On-Wing Viscosity
SAE	Society of Automotive Engineers
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), with financial support from the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology. In recent years one of these research activities has been the advancement of forced air deicing systems.

This report summarizes the forced air system test procedures and tests that have been developed/conducted by APS on behalf of TC and the FAA over the past five years. New testing that was carried out in 2003-04 is presented in detail.

The scope of work for this project in 2003-04 is outlined in an excerpt from the TDC work statement provided in Appendix A.

1.1 Report Format

The remainder of this report is organized into the following sections:

a) Section 2 (Background) describes forced air system applications and provides the history of forced air systems test procedures from 2000 to the summer of 2003, and testing in the winter of 2002-03;

b) Section 3 (Testing in 2003-04) describes the tests that were conducted in Rochester, New York in January 2004;

c) Section 4 (Conclusions) provides conclusions from 2003-04 testing and the subsequent actions of TC and the FAA; and

d) Section 5 (Recommendations) provides recommendations for future testing.

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2. BACKGROUND

In response to deicing operator requests, deicing vehicle manufacturers have incorporated forced air deicing systems into their vehicles. Operators are interested in forced air as an alternative approach to deicing, predominantly because of the possibility of achieving an increased spray distance and improved distribution of Type II/IV fluids over the aircraft wing. Operators foresee various ways of using forced air systems in the deicing process, including:

a) Using forced air alone to remove most snow from aircraft surfaces before conventional heated fluid deicing;

b) Using forced air with Type II or Type IV fluid either sprayed over or injected into the air stream in a way that allows the use of holdover time guidelines;

c) Using forced air with Type I fluid either sprayed over or injected into the air stream in a way that allows it to be used as the first step followed by an approved application of Type II or Type IV fluid as the second step;

d) Using forced air with Type I fluid either sprayed over or injected into the air stream in a way that allows it to be used as the first step followed by Type I fluid application in the second step;

e) Using forced air with Type I fluid either sprayed over or injected into the air stream in a one-step de/anti-icing process that allows the use of the holdover time guidelines;

f) Using forced air with Type I fluid either sprayed over or injected into the air stream to remove frost in a non-active condition; and

g) Using forced air alone to deice an aircraft during non-active precipitation.

Forced air systems are generally designed to deliver a stream of air, either with or without fluid. Both Type I and Type II/IV fluids can be delivered with the air-assist capability of various deicing trucks. Photo 2.1 shows a typical configuration for an air-assisted fluid application.

2.1 Initial Testing

Testing was conducted in the winter of 1999-2000 on forced air systems to identify any safety problems that might arise from their use in field operations. This examination was reported in the TC report, TP 13664E, *Safety Issues and Concerns of Forced Air Deicing Systems* (1).

2.2 Development of Test Methods for Forced Air Fluid Applications

At the 2001 annual meeting of the Society of Automotive Engineers (SAE) G-12 Aircraft Ground Deicing Equipment Subcommittee, the need for an official process whereby operators could test the use of forced-air assist in certain deicing applications was identified. In addition, based on successful outcomes, operators needed a formal process to request approval from authorities to use the forced air deicing systems.

A Forced Air Working Group was nominated to work on this project on behalf of the Aircraft Ground Deicing Equipment Subcommittee.

Members of the subcommittee requested the cooperation and assistance of the FAA Technical Centre and TDC to develop an official test procedure and to define an approval process for selected applications of forced air systems. The two authorities agreed to the request and assigned APS to work with the Forced Air Working Group.

2.2.1 Type I Test Procedure

A test procedure for the examination of Type I fluid used as the first-step when followed by a second-step application of Type II/IV fluid was developed in November 2001. The procedure was developed as a tool for operators to evaluate the use of forced air in first-step deicing with Type I fluids. This use of forced air does not require the approval of regulatory authorities.

The test procedure, entitled *Type I Fluid Applied Over or Injected into the Forced Air Stream*, is included as Appendix B.

APS has not been involved in subsequent testing with Type I fluids.

2.2.2 Type II/IV Test Procedure

The Forced Air Working Group gave priority to developing a test procedure to determine whether holdover time guidelines can be used when Type II/IV fluid is applied with forced air. Two versions of this procedure were developed in response to input from the regulatory bodies.

2.2.2.1 Version 1 (July 2001 to June 2002)

An initial version of a test procedure and approval process, Version 1.0, was developed in 2001 in the months following the 2001 annual SAE G-12 meeting.

Acceptance criteria in this test procedure were based on a comparison of forced air assist results versus conventional application results. The test procedure assumed that if the viscosity of the fluid applied with air-assist is not lower than the viscosity of the fluid applied in a conventional application, then endurance times should be similar.

The test procedure examined three specific criteria:

a) Fluid viscosity measured from samples lifted from the wing (conventional vs. forced air assist);

b) Fluid thickness measured at various points on the wing; and

c) Consistency of distribution of the fluid layer over the sprayed area.

This test procedure was subsequently used by several carriers: American Airlines at Chicago O'Hare Airport in October 2001, US Airways at Boston Logan Airport in November 2001, and Air Canada at Ottawa International Airport in January 2002. Fluid samples were collected, and the fluid manufacturer measured the viscosity of the samples several days later. APS conducted some supplementary measurements of fluid viscosity.

Editorial changes to the procedure resulted in its final form, Version 1.4, dated June 2002. The test procedure, entitled *Type II/Type IV Fluid Applied Over or Injected into the Forced Air Stream*, is included as Appendix C.

This procedure was accepted by TC and the FAA.

2.2.2.2 Endurance time procedure (December 2002)

In November 2002, the FAA requested that endurance time tests be conducted with Type IV fluids applied with forced air deicing systems. Measuring endurance times of fluids applied with forced air deicing systems would examine the validity of the assumption that if conventional and air assist viscosities are similar, so are their endurance times.

A procedure for the conduct of these tests was developed in December 2002. The procedure, entitled *Experimental Program: Endurance Times for SAE Type II/IV Fluids when Applied with Forced Air Assist*, is included as Appendix D.

2.2.2.3 Endurance time tests (February 2003)

In February 2003, US Airways and FedEx collected samples from Type IV fluids applied using forced air assist and fluids applied conventionally. These samples were sent to APS for endurance time, viscosity, and density testing. The results of these tests are documented in the TC report, TP 14153E, *Endurance Times of Fluids Applied with Forced Air Systems* (2).

The tests found that endurance times of forced air fluid over air applications and conventional applications were similar when their viscosities were similar. As a result, it was concluded that measurement of fluid viscosities is sufficient for decision-making on use of forced air systems with holdover time guidelines, and that measurement of endurance times would not be required. However, the regulatory authorities did require some changes to the test procedure, including:

1. Ambient temperature for the tests must be below freezing;

2. Tests must be conducted on aircraft wing surfaces, not on a substitute surface;

3. Viscosity must be measured on-site by an independent third-party test agency at the time of fluid spray, and results must be reported by that agency; and

4. Regulatory authority decision criteria would be based solely on measured fluid viscosity values.

This meant that there was no longer any need to report test results (as measured in accordance with Version 1.0) of fluid thickness at various points on the wing, nor the consistency of distribution of the fluid layer over the sprayed area. A second version of the procedure was subsequently developed to incorporate these changes.

2.2.2.4 Version 2 (December 2003)

In December 2003, a second version of the Type II/IV forced air test procedure was issued. The procedure, entitled *Type II/Type IV Fluid Applied Over or Injected into the Forced Air Stream*, is included as Appendix E. Prior to its publication, input was requested from TC and the FAA, and the procedure was sent to the chairs of the SAE G-12 Equipment Subcommittee Forced Air Working Group.

The procedure has two phases: operator assessment and viscosity measurement. The operator assessment phase involves measuring fluid thickness at various points on the wing and measuring the consistency of distribution of the fluid layer over the sprayed area on the wing. This phase is intended to assist the operator in developing suitable spray techniques that will result in application of a satisfactory layer of fluid on the aircraft surface. Results of the operator assessment phase do not need to be reported. The viscosity measurement phase requires an independent testing agency measure the viscosity of fluid samples from conventional application and forced air application. The measured fluid viscosity values are then reported to the regulatory authorities by the independent testing agency.

2.2.2.5 Viscosity tests (January 2004)

FedEx conducted a forced air assessment in Rochester, New York in January 2004. APS acted as the independent testing agency who conducted the required viscosity tests. The results of these tests are presented in detail in Section 3.

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Photo 2.1: Typical Application of Type II/IV using Forced Air

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3. TESTING IN 2003-04

In January 2004, APS personnel travelled to Rochester, New York to participate in Type IV forced air system testing conducted by FedEx. The role of APS was to collect fluid samples and measure fluid viscosities. In 2002-03, fluid samples were shipped to the APS laboratory from various test locations. It was theorized that the shipment of the samples and the time lapse between spraying the fluids and measuring their viscosities could have altered the test results. For this reason, TC and the FAA requested APS personnel travel to the test location and measure viscosities immediately after sample collection.

3.1 Objective

APS' objective for the Rochester test session was to measure and compare the viscosities of anti-icing fluids applied using a conventional application system and using an air assist application system. Air assist systems were tested on two deicing truck models made by FMC Technologies (FMC): the FMC LMD 2000 and the FMC Tempest II.

3.2 Procedure

The 2003-04 tests were carried out using the procedure *Test Program – Viscosity Tests of Fluids Applied with FedEx Forced Air Systems*, which is included in Appendix F. This procedure was based on the more general procedure *Test Program – Forced Air Systems: Type II/Type IV Fluid Applied Over or Injected into the Forced Air Stream*, which was developed by APS in the fall of 2003. This procedure is included in Appendix E.

As noted in Section 2, the test procedure has two phases: operator assessment and viscosity measurement. The operator assessment is the responsibility of the operator and does not need to be reported to the regulatory bodies. The operator assessment was not conducted during the Rochester test session. The viscosity measurement phase requires an independent testing agency to conduct in-situ viscosity measurements and report the results. APS acted as the independent testing agency for the Rochester tests.

The TC Lockheed JetStar wing was transported from Montreal to Rochester International Airport and used as a test bed. To avoid contamination from natural precipitation, all fluids were applied to the wing inside the FedEx hangar. A photo of the wing inside the FedEx hangar is shown in Photo 3.1. Photo 3.2 shows fluid application in the hangar. The ambient temperature inside the hangar ranged from 0°C to -13°C during the test session.

Immediately following fluid application, fluid samples were collected from the wing (see Photo 3.3). Care was taken not to shear the samples as they were collected. A Brookfield DV-I Digital Viscometer was used to measure viscosity using standard viscosity test procedures. The viscometer was setup indoors in an employee lunchroom (see Photo 3.4).

After each fluid application, the wing was taken outside and cleaned with Type I fluid (see Photo 3.5). After the wing was de-iced, the Type I fluid was blown off the wing using forced air. This procedure prevented the next test fluid from being contaminated by either the previous test fluid or Type I fluid. Contamination would significantly change the viscosity of the samples and render the tests unusable.

3.2.1 Samples

For each fluid and truck combination, four viscosity samples were collected and measured: one sample from the fluid tote, one sample from the truck tank, one sample from the wing after fluid was applied using a conventional application, and one sample from the wing after fluid was applied using an air assist application. The viscosities of the spray samples were measured immediately following collection. The viscosity of the fluid tote samples was measured in Rochester, usually on the same day the fluid was tested, as were approximately half of the truck tank samples. The remaining truck tank samples were returned to the APS laboratory and tested the following week.

3.2.2 Fluids Tested

Initially, four fluids were scheduled to be tested: Lyondell/Clariant Safewing 2001, Octagon Max-Flight, Kilfrost ABC-S, and Clariant Safewing MP IV 2012 Protect. Octagon Max-Flight 04 and another certified propylene-glycol based Type IV fluid, Fluid “Y” were added to the test plan just prior to the start of testing. Fluid “Y” has been coded at the request of the fluid manufacturer.

3.2.3 Viscosity Measurement Methods

When possible, the official fluid manufacturer viscosity measurement methods for the fluids were used. Due to time constraints, it was not feasible to use methods that required large sample volumes. In cases where the official methods required large sample volumes, fluid manufacturers provided alternate measurement methods that employed smaller sample volumes, which enabled tests to be conducted using the small sample adaptor rather than large beakers.

The following viscosity measurement methods were used:

- Clariant Safewing 2001: Spindle 34, 10 mL, 20°C, 0.3 rpm, 15 minutes;
- Clariant Safewing 2012: Spindle 34, 10 mL, 20°C, 0.3 rpm, 15 minutes;
- Octagon Max-Flight: Spindle 34, 10 mL, 20°C, 0.3 rpm, 10 minutes;
- Octagon Max-Flight 04: Spindle 34, 10 mL, 20°C, 0.3 rpm, 10 minutes;
- Kilfrost ABC-S: Spindle 31, 10 mL, 20°C, 0.3 rpm, 10 minutes; and
- Fluid "Y": Spindle 34, 10 mL, 20°C, 0.3 rpm, 15 minutes.

It should be noted that, as per standard viscometer measurement procedure, two measurements were taken per sample. The viscosity reported is an average of the two measurements. All samples were centrifuged before viscosity tests were conducted.

3.3 Results

3.3.1 Fluid Viscosity

Variability is inherent in viscosity measurements. However, according to the ASTM method (D 2196-99), if two samples have the same viscosity there will not be more than 7 percent difference in their measured viscosities. This assumes a Brookfield viscometer is used and the same operator conducts the tests. Thus, if the difference in viscosities of two samples is more than 7 percent, it can be assumed that the samples have different viscosities.

The objective of these tests was to compare conventional application and forced air application fluid viscosities. If conventional and forced air applications have the *same* influence on fluid viscosity, then the viscosities of air assist samples and conventional application samples would be within 7 percent.

None of the fluid/truck combinations tested provided forced air viscosities that were within 7 percent of the conventional system viscosities. In fact, the viscosities of the forced air samples were all lower than the viscosities of the conventional application samples. Therefore, it appears that the use of forced air assist has a stronger influence on fluid viscosity than a conventional application.

There were also differences in the viscosities of the samples collected from fluids applied with the Tempest II and the LMD 2000. The Tempest II air assist samples had lower viscosities than the LMD 2000 air assist samples. Complete results are shown in Table 3.1.

Table 3.1: Viscosity Measurements

Fluid	Truck	Fluid Sample				Forced Air-Conventional Difference
		Fluid Tote (mPa.s)	Truck (mPa.s)	Conven. (mPa.s)	Forced Air (mPa.s)	
Lyondell/Clariant 2001	LMD 2000	29,100	23,200	24,700	21,100	-15%
Lyondell/Clariant 2001	Tempest II	29,100	27,600	25,500	19,000	-25%
Clariant 2012	LMD 2000	15,600	15,900	14,500	10,400	-28%
Clariant 2012	Tempest II	15,600	14,000	14,800	8,800	-41%
Octagon Max-Flight	LMD 2000	11,000	10,600	7,900	5,700	-28%
Octagon Max-Flight	Tempest II	11,000	10,400	7,800	4,900	-37%
Octagon Max-Flight 04	LMD 2000	11,200	10,700	7,900	6,100	-23%
Octagon Max-Flight 04	Tempest II	11,200	10,200	8,200	4,600	-44%
Kilfrost ABC-S	LMD 2000	19,650	19,300	19,600	12,900	-34%
Kilfrost ABC-S	Tempest II	19,650	19,200	20,750	11,400	-45%
Fluid "Y"	LMD 2000	16,100	16,600	13,300	8,700	-35%
Fluid "Y"	Tempest II	16,100	15,700	12,700	6,600	-48%

M:\Groups\CM1892 (TC-Deicing 03-04)\Analysis\Forced Air\Viscosities At: Table 3.1

3.3.2 Fluid Density

Fluid densities of the samples were measured when possible. Results are shown in Table 3.2.

Table 3.2: Fluid Densities

Fluid	Truck	Fluid Tote (g/mL)	Conven. (g/mL)	Forced Air (g/mL)	Forced Air / Conven.
Lyondell/Clariant 2001	LMD 2000	0.983	0.943	0.944	100%
Lyondell/Clariant 2001	Tempest II	n/a	0.955	0.932	98%
Clariant 2012	LMD 2000	1.059	1.004	1.020	102%
Clariant 2012	Tempest II	1.059	1.020	1.039	102%
Octagon Max-Flight	LMD 2000	0.964	1.009	0.983	97%
Octagon Max-Flight	Tempest II	0.964	1.054	0.978	93%
Octagon Max-Flight 04	LMD 2000	1.049	1.015	0.947	93%
Octagon Max-Flight 04	Tempest II	1.049	1.028	0.995	97%
Kilfrost ABC-S	LMD 2000	1.030	1.008	1.000	99%
Kilfrost ABC-S	Tempest II	1.030	0.995	1.020	103%
Fluid "Y"	LMD 2000	1.053	0.957	0.937	98%
Fluid "Y"	Tempest II	1.053	0.979	0.977	100%

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3.3.3 Fluid Thickness

Following fluid application, fluid thickness measurements were taken on the wing. Results are shown in Table 3.3.

Table 3.3: Fluid Thickness after Application

Fluid	Truck	Fluid Thickness (mm)	
		Conventional Application	Forced Air Application
Lyondell/Clariant 2001	LMD 2000	1.8	1.8
Lyondell/Clariant 2001	Tempest II	2.2	1.8
Clariant 2012	LMD 2000	n/a	n/a
Clariant 2012	Tempest II	n/a	n/a
Octagon Max-Flight	LMD 2000	1.8 to 2.2	1.8 to 2.2
Octagon Max-Flight	Tempest II	2.2 to 2.5	1.4 to 1.8
Octagon Max-Flight 04	LMD 2000	2.2 to 2.5	1.8 to 2.2
Octagon Max-Flight 04	Tempest II	2.2 to 2.5	1.8 to 2.2
Kilfrost ABC-S	LMD 2000	2.2 to 2.5	1.4 to 1.8
Kilfrost ABC-S	Tempest II	2.2 to 2.5	1.8 to 2.2
Fluid "Y"	LMD 2000	1.8 to 2.5	2.2
Fluid "Y"	Tempest II	n/a	n/a

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n/a = not measured

3.4 Analysis

3.4.1 Comparison of Test Viscosities to Lowest On-Wing Viscosities

Although the objective of these tests was to compare the viscosities of fluids applied using the two types of fluid application systems, it is also interesting to compare the viscosities to the lowest on-wing viscosity (LOWV) values included in the holdover time tables. The LOWV is a value provided by the fluid manufacturer and represents the lowest viscosity that a fluid should have after it has been applied to the wing. If a fluid has a viscosity below this value, the holdover times may be shorter than those given in the holdover time tables. As a result, it is not recommended to use fluids with viscosities below the LOWV.

Results of the Rochester viscosity tests are shown by fluid in Figures 3.1 to 3.6. The LOWVs are indicated with a horizontal line on each chart. Because alternate viscosity measurement methods were used for Kilfrost ABC-S and Octagon

Max-Flight, a conversion factor was used to find the relative LOWV. The conversion factors were provided by the fluid manufacturers.

As can be seen in the figures, some fluids applied with air assist systems had viscosities below the LOWVs (Kilfrost ABC-S, Fluid "Y"), some had viscosities above the LOWVs (Clariant 2012, Clariant 2001), and some had viscosities either above or below the LOWVs depending on the truck used to apply the fluid (Octagon Max-Flight, Octagon Max-Flight 04).

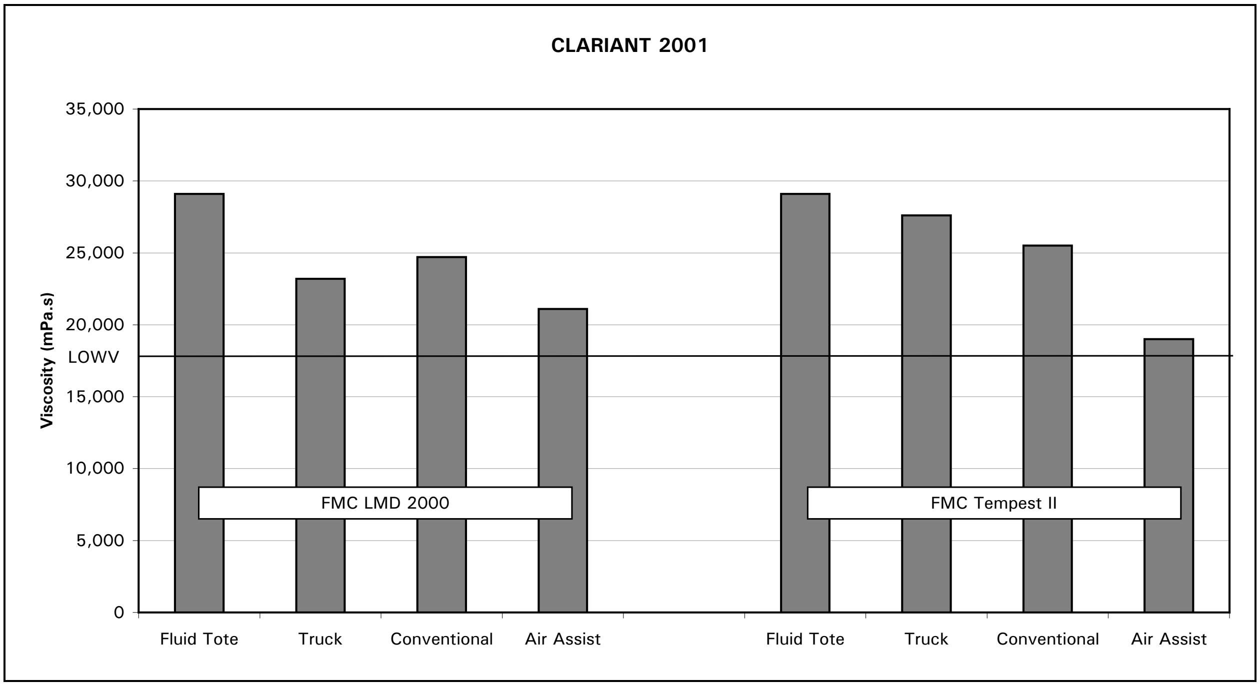

Figure 3.1: Lyondell/Clariant 2001

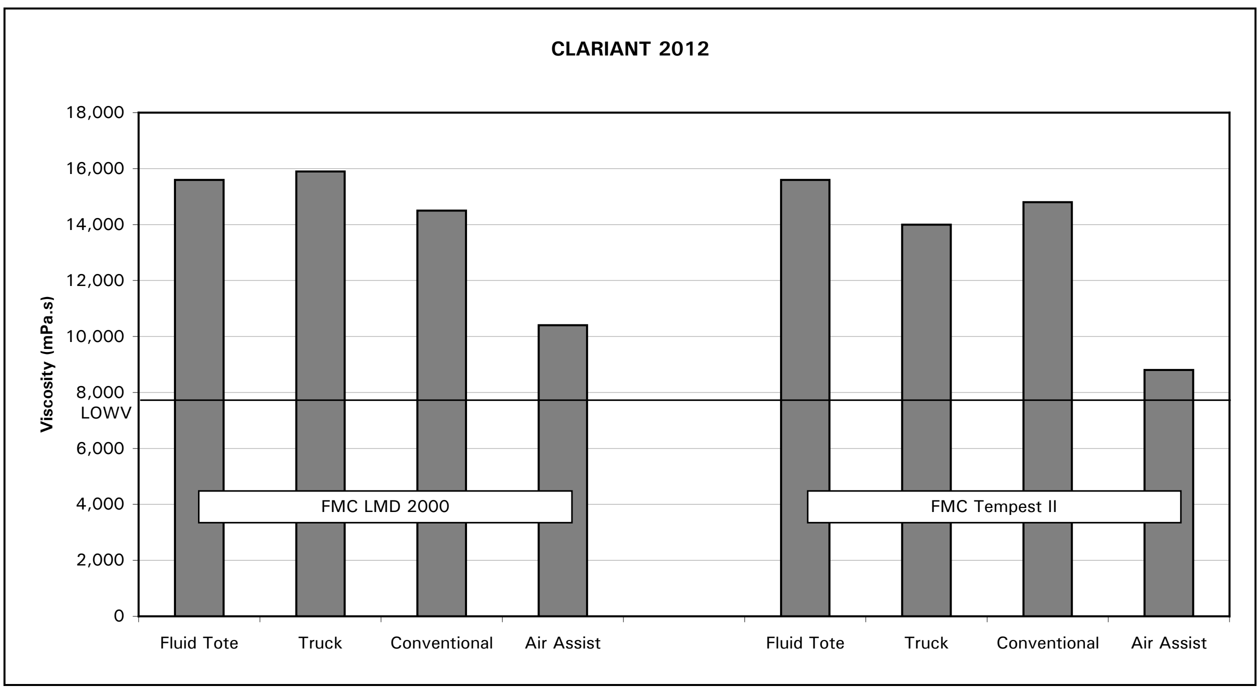

Figure 3.2: Clariant Safewing MP IV 2012 Protect

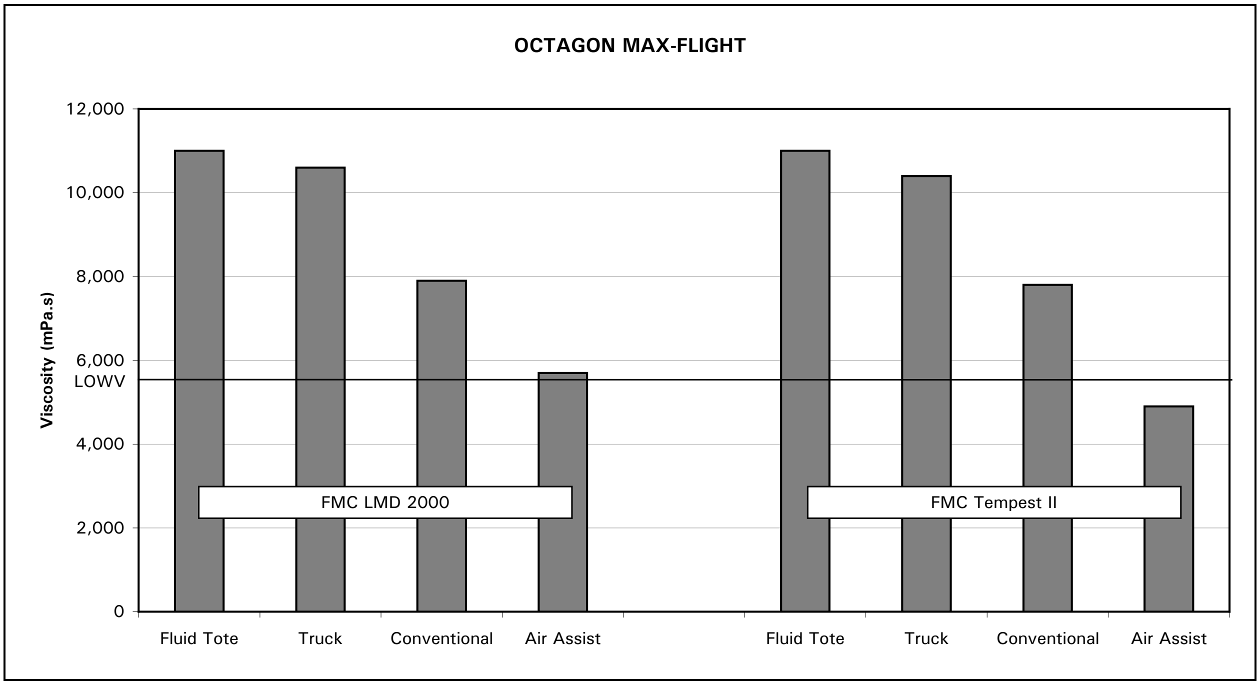

Figure 3.3: Octagon Max-Flight

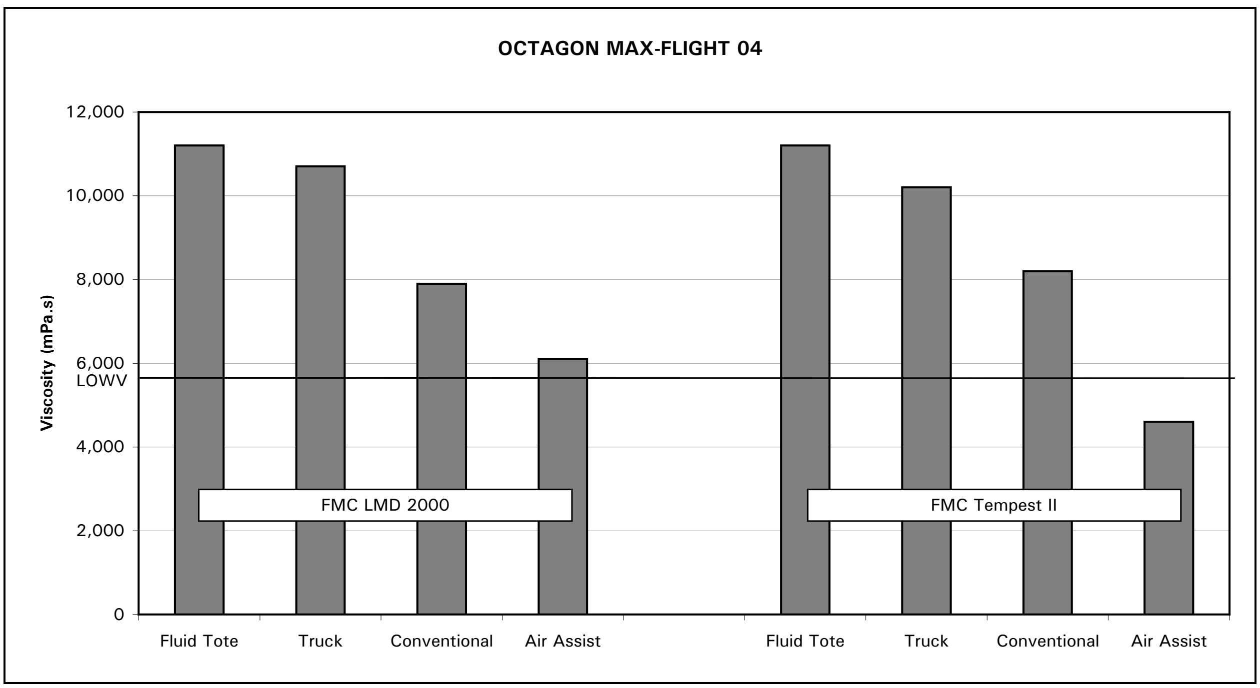

Figure 3.4: Octagon Max-Flight 04

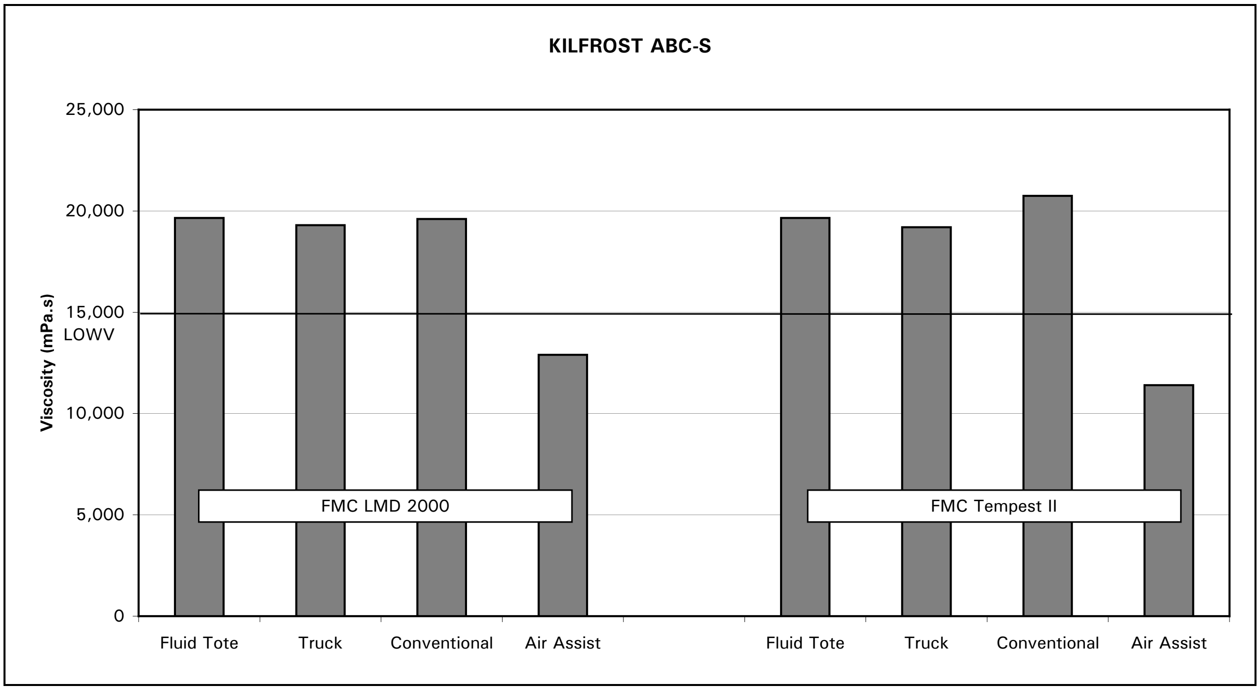

Figure 3.5: Kilfrost ABC-S

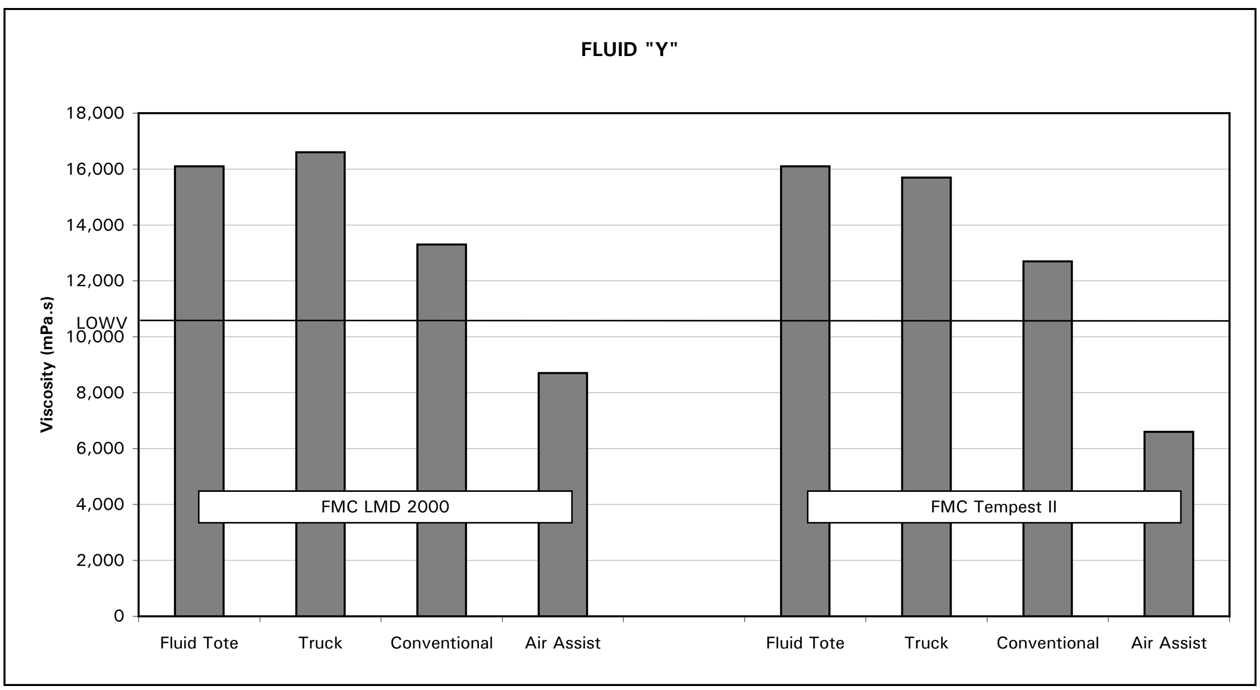

Figure 3.6: Fluid "Y"

3.4.2 Guarantee of Viscosity Value

It should be noted that as a result of the Rochester testing, the viscosity of a fluid applied with forced air cannot be guaranteed to be above the LOWV. This is true even for the fluids whose viscosities were above the LOWV when applied with forced air in Rochester. The reason for this is that manufacturers produce fluids for operators with a viscosity guaranteed to be within a given range, known as the production range. Most of the samples provided for the Rochester test session were not at the bottom of their respective production range; therefore, a different shipment of the same fluid could have a lower in-tank viscosity than the fluid tested. If this were to happen, then the further viscosity reduction associated with the forced air application could produce a final viscosity below the LOWV.

For example, consider a fluid with a production range between 17,000 and 23,000 and an LOWV of 13,000. If the Rochester fluid tote sample had a viscosity of 20,000 and the air assist sample had a viscosity of 14,000, it would appear the fluid could safely be used with an air assist system. However, if the user received a different batch of fluid with a viscosity of 18,000, it is likely that the viscosity of the fluid would be below the LOWV if applied with air assist. As a result, it cannot be assumed that a fluid/truck combination tested in Rochester would always produce on-wing viscosities above the LOWV.

3.4.3 Comparison to Previous Test Results

The results obtained in the 2003-04 Rochester testing differed from the results obtained in 2002-03 testing; in 2002-03 the viscosities of fluids applied with forced air assist were similar to viscosities of fluids applied conventionally but in 2003-04 they were not. Several variables may have influenced the 2003-04 results, including the equipment setup, timing of the viscosity measurements and the application method.

a) *Equipment Setup*: The truck manufacturer (FMC) did not provide a fixed setup for the trucks outfitted with forced air equipment. As a result, the distance between the forced air stream and the fluid stream could have varied widely between the two test sessions. Other factors, such as nozzle opening, orientation and spray angle, could also have influenced the results, as they were not fixed.

b) *Timing of Viscosity Measurements*: In 2003-04 samples were tested on-site immediately following sample collection; in 2002-03 samples were tested approximately two weeks following collection after being shipped to the APS laboratory.

c) *Application Method*: In 2003-04, fluids were sprayed on an aircraft wing; in 2002-03 fluids were sprayed on a substitute surface (tarps on the ground).

To examine the influence of timing of viscosity measurements, samples of Lyondell/Clariant 2001 collected from the FMC LMD 2000 truck in Rochester were brought back to the APS laboratory and retested three weeks following collection. The results are shown in Table 3.4, along with the initial on-site measurements and the 2002-03 measurements.

Table 3.4: Comparison of 2002-03 and 2003-04 Viscosity Measurements

Test Session	Time between Collection and Testing	Conventional (mPa.s)	Forced Air (mPa.s)	Forced Air-Conventional Difference
2002-03 FedEx	~2 weeks	25,600	26,400	3%
2002-03 US Air	~2 weeks	29,200	26,600	-9%
2003-04 FedEx	immediately	24,700	21,100	-15%
2003-04 FedEx	~3 weeks	22,400	18,800	-16%

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Although the viscosities of the 2003-04 samples changed after three weeks had passed, the difference between the air assist and conventional application samples stayed almost the same (-16 percent versus -15 percent). In both cases the difference between the air assist and conventional application samples was significantly more than the difference between the air assist and conventional application samples in the 2002-03 tests, which was only three percent.

It is not possible to evaluate the influence of the application method, as the 2002-03 test session is the only in test session in which a test surface other than an aircraft wing was used. However, it should be noted that previous independent tests on aircraft wings have given similar results to the 2002-03 tests. These tests were conducted with Vestergaard in 2000, Global in 2001 and US Airways in 2001. They showed that the use of forced air did not have a significant effect on fluid viscosity. In conclusion, even if the application method impacted the 2003-04 test results, there must have also been another variable influencing the results.

Most likely, the equipment setup is the variable that caused the results to differ.

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Photo 3.1: TC JetStar Wing in FedEx Hangar

Photo 3.2: Fluid Application

Photo 3.3: Collection of Conventional and Forced Air Application Samples

Photo 3.4: Brookfield DV-I Viscometer in Rochester

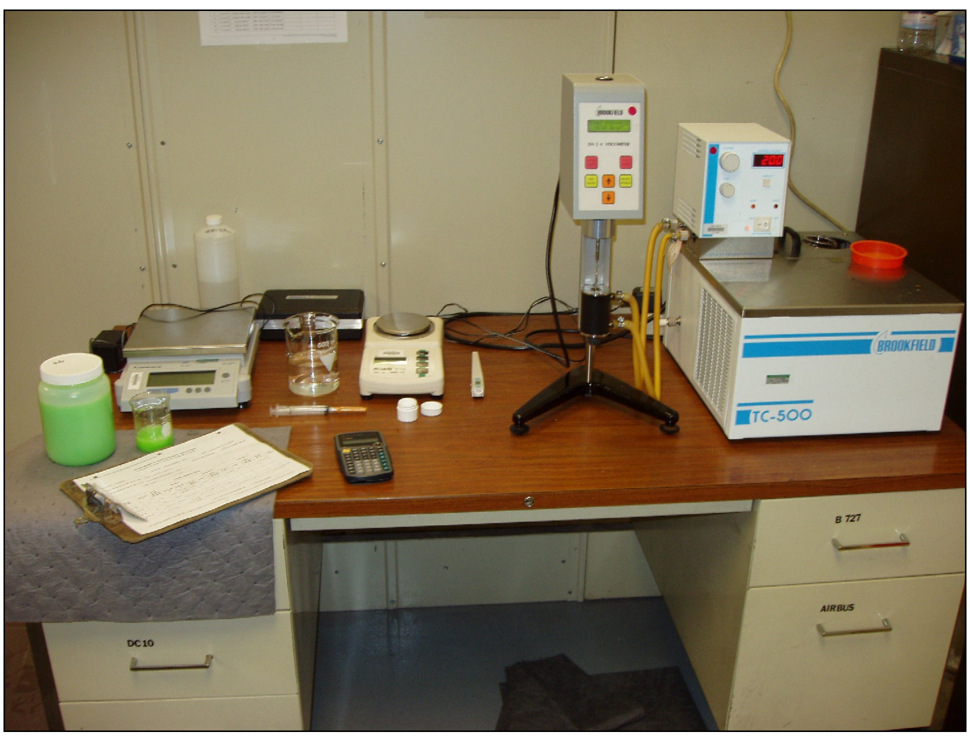

Photo 3.5: Cleaning Wing Between Fluid Applications

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4. CONCLUSIONS

Work completed in the winter of 2002-03 led to the conclusion that fluid viscosity could be used in place of endurance times as a gauge for approval of forced air assist systems for use with holdover time guidelines. As a result, a new procedure was developed using viscosity to evaluate forced air assist systems.

When tests were conducted in 2003-04 using the new procedure, fluid viscosity was found to decrease more when fluid was applied using forced air assist compared to when fluid was applied using a conventional application.

These results differed from results seen in 2002-03 testing; in 2002-03, viscosities of fluids applied with and without forced air assist were similar. The differing results may have been caused by the variable equipment setup on the forced air deicing truck. Distance between the forced air stream and the fluid stream, distance between the nozzle and the test surface, and different nozzle openings could all have affected the results.

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5. RECOMMENDATIONS

It is recommended that:

a) Testing be conducted to investigate the influence of the equipment setup variables on fluid viscosity. Some variables that should be examined: distance between the air spray and fluid spray, distance between the nozzle and the test surface, nozzle opening, orientation of the nozzle and nozzle type. The resultant equipment setup should be fixed to ensure that the influence of a forced air application on fluid viscosity is comparable to that of a conventional application.

b) Since the impact of these variables on conventional fluid application systems has never been examined, it is recommended that conventional fluid application systems and forced air assist application systems be examined at the same time.

c) Once the setup has been fixed, it is recommended that a new Type II/IV test procedure be prepared. One change that could be made is to eliminate the requirement to compare forced air applications to conventional applications and to instead compare the viscosity of fluids applied with forced air to the LOWV. In this case the samples requested from the fluid manufacturers should be at the bottom end of the production range, or higher if the manufacturer could ensure that shipped fluids would always arrive with this viscosity. Manufacturers should be consulted to explore this possibility prior to the creation of the new procedure.

d) Testing with the new procedure be conducted to find out if any Type IV fluids meet the test requirements.

e) If no Type IV fluids are deemed suitable for use with forced air assist, Type II and/or Type III fluids could be tested. Although these fluids have shorter holdover times than Type IV fluids, Type II and Type III fluids also have lower initial viscosities which will be less influenced by the shearing applied by a forced air assist application.

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1. Dawson, P., *Safety Issues and Concerns of Forced Air Deicing Systems*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2000, TP 13664E, 100.

2. Dawson, P., *Endurance Times of Fluids Applied with Forced Air Systems,* APS Aviation Inc., Transportation Development Centre, Montreal, October 2003, TP 14153E, 44.

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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

5.7 Forced Air System Evaluation

a) Continue to assist the SAE ground equipment committee in its evaluation of forced air-assisted systems.

b) Subject to approval by TC on a case-by-case basis:

- Monitor and participate in some operator field tests of air-assisted Type II/IV fluids, and report on observations; and
- Monitor and participate in some operator field tests of air-assisted Type I fluid as a first-step procedure.

c) Support the SAE ground equipment committee development of an SAE ARP for forced air deicing systems.

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APPENDIX B

TEST PROGRAM – FORCED AIR DEICING SYSTEMS TYPE I FLUID APPLIED OVER OR INJECTED INTO THE FORCED AIR STREAM

CM1680

TEST PROGRAM - FORCED AIR DEICING SYSTEMS

TYPE I FLUID *APPLIED OVER* or *INJECTED INTO* THE FORCED AIRSTREAM

Prepared for

SAE G-12
Equipment Subcommittee
Forced Air Working Group

Prepared by: For Peter Dawson

Reviewed by: John D'Avirro

APS AVIATION INC.

07 November 2001
Version 1.2

TEST PROGRAM - FORCED AIR DEICING SYSTEMS
TYPE I FLUID *APPLIED OVER* or *INJECTED INTO*
THE FORCED AIR STREAM

1. OBJECTIVE

These tests are designed to assist operators in examining whether air-assisted Type I fluid can be used as the first-step of a two-step process to clean aircraft surfaces, when followed with an application of Type IV anti-icing fluid. The critical factors for consideration are:

- Does the procedure produce a clean surface?
- Does the surface remain uncontaminated long enough to allow the over-spray of Type IV fluid?
- Does the force of the airstream push slush into wing cavities?
- Does flying snow and ice pose a danger of ingestion?

The nature of the air-assistance can take either of two forms:

- The fluid nozzle can be positioned above the forced air nozzle, with the goal of carrying the fluid on top of the airstream.
- The fluid nozzle can be positioned to inject fluid within the airstream, where the fluid is mixed with, and carried as part of the airstream.

2. TEST PROCESS FOR ELAPSED TIME TO FIRST FREEZING

2.1 Background

In a two-step deicing operation, it is a safety requirement that the wing surfaces (or other critical surfaces) remain free of contamination when the second step anti-icing fluid is applied. SAE ARP4737 gives a *3-minute* guideline as the time that the surface might be expected to remain uncontaminated. However this is only a guideline, and the deicing operator is always responsible for ensuring that the surfaces are still uncontaminated when the anti-icing fluid is applied.

The two factors controlling the time to refreeze on a wing are:

- the freeze point of the fluid on the wing, and
- the wing surface temperature.

The interplay of these two factors is shown in the chart in Attachment 1. Freezing will occur when the fluid freeze point matches the wing temperature. If the wing has been heated above OAT, then the intersection of the two curves will occur later than if the wing had not been heated, or had been heated to a lesser degree.

As the fluid progressively dilutes, the fluid freeze point rises. The rate of dilution for the typical thin film of Type I fluid on a wing is very rapid; in the conditions reported on the chart, the fluid freeze point matched OAT within two minutes. If the wing had not been heated at all, this is where first freezing would have occurred. The factors influencing the rate of progression of the fluid freeze point include:

- The initial freeze point of the fluid
- The initial thickness of the fluid layer on the wing
- The rate of precipitation
- The local geometry of the wing surface (affects rate of run-off and fluid feed from other areas).

The factors influencing the wing surface temperature include:

- Initial wing temperature
- Fluid temperature
- Quantity of fluid applied
- Operator technique
- Outside air temperature (OAT)
- Wind
- Cooling from precipitation
- Fuel quantity and temperature.

A universal test to establish elapsed time to first freezing would need to address all of these factors at their most severe conditions (high wind, heavy precipitation, cold OAT, etc). As this is uncontrollable in field testing, and is probably unrealistic for the application, a different approach to determining test conditions is needed.

A second consideration in designing the test is the criteria for success. Two alternatives could be:

- Producing an elapsed time to first freezing equivalent to a standard spray of heated fluid
- Producing an elapsed time to first freezing long enough to allow an application of Type IV fluid. The *3-minute* guideline could be the benchmark for this approach.

The approach where the results from the air-assisted spray are compared to a standard spray may not be satisfactory. Depending on test conditions, the standard spray could produce an elapsed time to first freezing much longer than the air-assist spray, and yet the elapsed time from the air-assist might be sufficient (in the order of 3-minutes).

2.2 Operator Approval Process

From the preceding, it can be seen that results of tests conducted in mild conditions could not be applied to more severe conditions.

Because the field test conditions are uncontrollable, it is suggested that a base of test experience be built up among the various interested operators. The results of these trials could be pooled, and when it is believed that sufficient information has been gathered for a range of conditions, then an operator decision can be made regarding introducing air-assisted first-step deicing into an operation.

If an operator decides to introduce air-assisted Type I fluid as a first-step procedure, then the following would be required in the Operator Procedures and Training:

- Acceptable weather limits (based on test experience) would be identified
- Emphasis would be placed on deicing operator responsibility for ensuring that the deiced surfaces are still uncontaminated when the anti-icing fluid is applied. If the surface refreezes before Type IV fluid can be applied, then the wing would need to be re-deiced using the standard heated fluid spray.

Each forced air deicing truck configuration would require separate investigation. The following steps are suggested:

1. Prior to testing, in-house development of spray techniques and procedures is completed by the operator.
2. When the operator is satisfied that it has evolved a suitable application procedure, the operator schedules a test session, inviting observers.
3. Tests are conducted to gather required data. A set of five tests is suggested, to demonstrate repeatability. Tests are conducted on aircraft wings. Base case tests applying fluid with the operator's standard Type I nozzle and procedure are suggested as a benchmark.
4. Test results are then submitted to other interested operators and to the SAE Forced Air Working Group for pooling with test results from other operators using the same systems, and for discussion. Test results for different manufacturer systems should be treated separately.
5. An operators decision to use an air-assisted Type I fluid application as the first step of a two-step deicing procedure, would then be based on test results for a specific truck type:
   - Ability of the procedure to provide a clean wing
   - Elapsed time following deicing until freezing first appears.

3. TEST PROCEDURE

3.1 General

These tests are designed to be conducted in the field by the equipment operator, who may invite the equipment manufacturer to attend.

It is expected that the test session to produce data to support a decision would be performed only after the equipment user and manufacturer have developed procedures that produce a consistently satisfactory fluid application.

3.2 Test Planning

3.2.1 Weather Conditions

These tests are performed during snow or freezing precipitation, with OAT below freezing (suggest -3°C or colder). More than one test session is recommended to provide results for different ambient conditions.

Perform at least one test in *into-wind* conditions.

3.2.2 Test Surface

Conduct tests on out-of-service aircraft (example, parked overnight).

3.2.3 Test Fluid

The fluid used for test is qualified standard production SAE Type I fluid. Operators using a fluid product at standard strength 50/50 mix, should test with that fluid. Operators who blend fluid based on OAT are to test with fluid mixed to a freeze point of 3°C (5°F) above OAT to ensure the worst case is tested.

3.2.4 Configuration of Forced Air system

The normal operating configuration of the forced air deicing system is to be used for testing, and details are to be recorded on the data forms.

If the air-flow is operator controlled, the test is to be conducted at maximum air flow.

3.2.5 Test Matrix

Five tests are suggested, to examine repeatability. It is suggested that more than one test session be conducted to provide results for varied conditions (precipitation rates, OAT, wind). Tests on standard fluid and air-assisted fluid should be alternated between wings to eliminate any effect of variability of wind and precipitation. An examination of wing cavities for presence of slush is scheduled for one set of tests.

Each test consists of an application of fluid on one wing using air-assist, and on the other wing using the operator's standard Type I fluid nozzle and procedure.

Test Session	Test Number	Weather Condition	Type of Application	Special Test Condition
1	1a	Snow / freezing precipitation	Air-assist	Alternate air-assist / standard tests between wings to eliminate any effect of variation in wind or precipitation. Examine cavities for slush on one test (1a / 1b or 2a / 2b)
	1b		Standard	
	2a		Air-assist	
	2b		Standard	
2	3a	Snow / freezing precipitation	Air-assist	Alternate air-assist / standard tests between wings to eliminate any effect of variation in wind or precipitation.
	3b		Standard	
	4a		Air-assist	
	4b		Standard	
1 or 2	5a	Snow / freezing precipitation	Air-assist	Spray into-wind
	5b		Standard	

3.3 Data Forms

Three data forms are used for these tests as follows.

3.3.1 General Form (Figure 1)

Complete the general form, ensuring that all pertinent data describing the forced air deicing system configuration is recorded. This form is completed only once per test session.

3.3.2 Spray Form (Figure 2)

This form is completed for each wing tested, and is used to record data specific to test conditions, and to the fluid used to deice the wing. As each test consists of an application of fluid on one wing using air-assist, and on the other wing using the operator's conventional Type I fluid spray nozzle and procedure, two forms are completed for each test.

Values for OAT, wind speed and snow / freezing precipitation rate can be retrieved from the local Met office.

3.3.3 Wing Form (Figure 3)

This form is used to record the occurrence of earliest freezing on the wing following deicing, and the extent of refreezing at five minutes following deicing. A diagram of a generic wing is used to indicate where freezing occurred.

Condition of wing cavities (presence of slush) is also recorded on this form.

3.4 Conducting Tests for Elapsed Time to First Freezing

3.4.1 Synchronizing Time Pieces

As this test examines the elapsed time from deicing to first freezing, it is very important that observers' timepieces be synchronized at the start of the test session.

3.4.2 Wing Condition at Start of Tests

The first test in a session should be conducted with the snow or ice that is already present on the wing. This may involve greater depths of snow or ice which will add to the realism of the test.

For subsequent tests, allow a covering of snow or ice to accumulate on the wings prior to each test (0.25 to 0.5 in. of snow or 0.1 in. of ice is suggested). Record depth of snow or ice on the wing by measuring at several locations and averaging the results.

3.4.3 Measuring Fluid Temperature and Brix

Use Data Form Figure 2 to record the fluid temperature at the nozzle prior to spraying the wing. This will serve to clear the line of cold fluid. For the standard spray, this can be done by spraying into a bucket or measuring the temperature of the fluid in the fluid stream. For the air-assisted fluid, it will be necessary to insert a hand-held temperature probe into the fluid stream at the nozzle. Tank fluid temperature is also measured. Record the freeze point of the test fluid.

3.4.4 Deicing the Wing

Start the test by deicing the entire wing according to the operator's procedure. Accurately record (Data Form Figure 2) the start and finish times for spray. Record the quantity of fluid sprayed. Note the direction of wind and the operator's position, on the wing sketch.

For the test requiring deicing by spraying *into-wind*, the operator must position the truck accordingly. This may require spraying from the rear of the wing.

When the operator completes deicing the wing, examine the wing surface. Note and record whether the wing is completely cleaned, or the extent and location of any remaining contamination.

3.4.5 Recording The Time Of First Freezing

Following completion of spraying, observe the wing for first indication of refreezing. As this may occur very quickly, access stands must be moved immediately to the wing to allow observers a good view of the wing surface. More than one observer may be needed for this activity. Typically, first failure will occur either on the leading edge or rear control surfaces. The outer end of the wing is also more susceptible to early freezing.

Using Data Form Figure 3, record the location and time that first freezing occurred, on the wing diagram.

Continue to observe the wing until 5 minutes following deicing. At that time, note the time, and sketch the area of any freezing on the wing.

3.4.6 Assessing Flying Snow or Ice

During the forced air application, observe the way the snow or ice is removed from the wing, for example, did it come off in sheets, chunks or powder. Record this as well as the size of any pieces of blown contamination. Indicate whether any pieces of blown contamination might have been ingested in a rear-mounted engine.

3.4.7 Conducting Tests for Condition Of Wing Cavities

There is a potential concern that the airstream might force slush into wing cavities. To examine this possibility, cavities at flight control surfaces need to be examined. It is suggested that this be done on two occasions.

This test involves operating the leading edge slats and other control surfaces to enable observation of the cavities. Planning of personnel to operate the aircraft systems and associated aircraft power will be required.

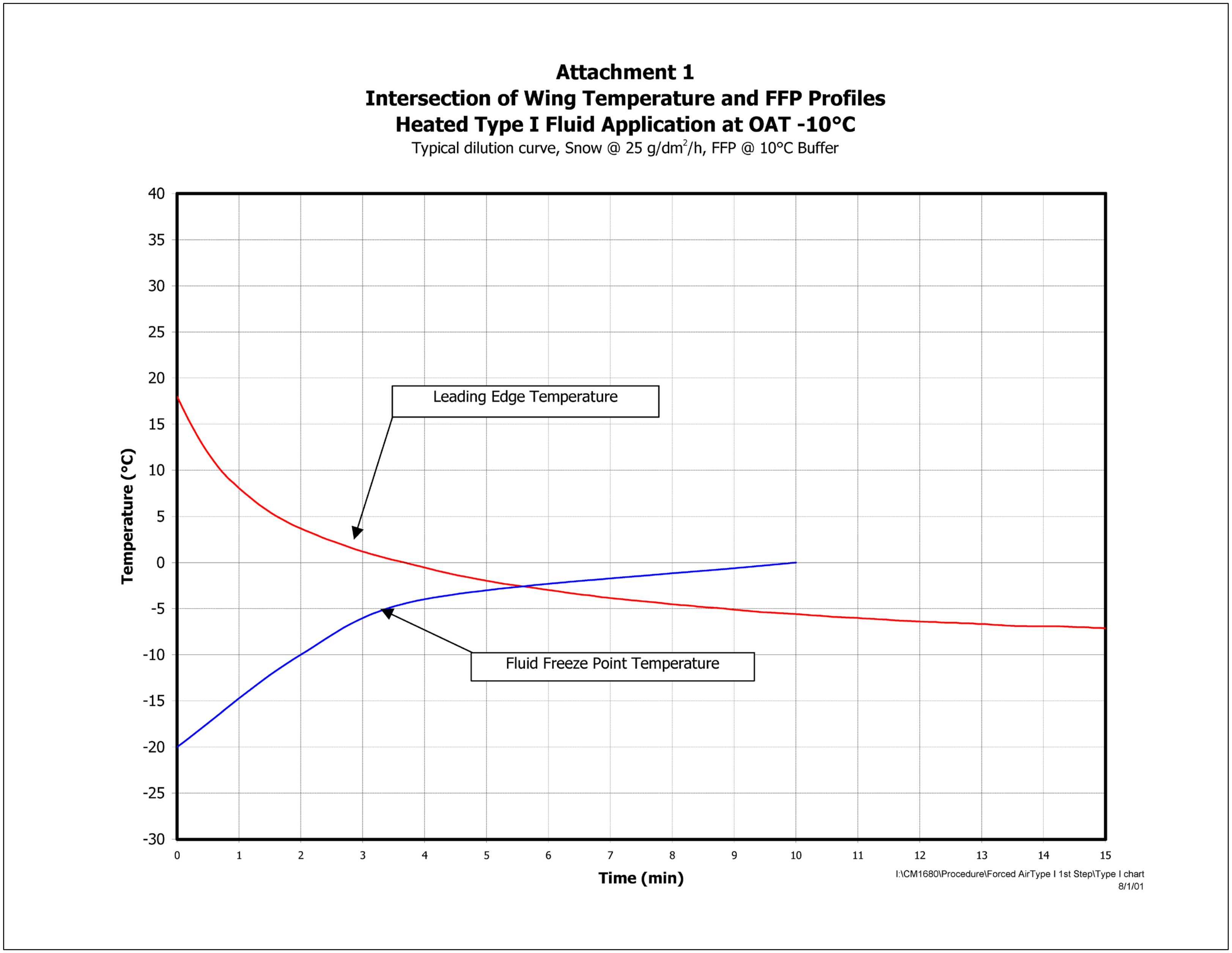
This examination is conducted twice:

- before the spray test to ensure that the cavities are clean to start with, and
- following the final recording of wing condition at five minutes after deicing.

Operate the control surfaces to expose the underlying cavities. Note and record on the wing diagram the presence of any contamination, and its location, extent and nature.

3.5 Preparing for Next Test

Following each test, allow a covering of snow or ice to accumulate on the wings prior to the next test.


Attachment 1
Intersection of Wing Temperature and FFP Profiles
Heated Type I Fluid Application at OAT -10°C
Typical dilution curve, Snow @ 25 g/dm²/h, FFP @ 10°C Buffer
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
Temperature (°C)
Leading Edge Temperature
Fluid Freeze Point Temperature
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (min)
I:\CM1680\Procedure\Forced AirType I 1st Step\Type I chart
8/1/01

ATTACHMENT II

TEST EQUIPMENT CHECKLIST
TRIALS FOR AIR-ASSISTED TYPE I FLUID
AS FIRST-STEP OF A TWO-STEP PROCEDURE

TASK	***STATUS***
Logistics For Every Test Session	
Schedule test with truck and fluid manufacturers	
Advise FAA, TDC	
Arrange for test aircraft	
Arrange for personnel and power to operate aircraft control surfaces	
Test Equipment	
Forced air deicing truck	
Test procedures	
Data Forms	
Clipboards	
Pencils	
Wiping rags	
Ruler or gauge for snow / ice thickness	
Refractometer	
Watches	
Fluid thermometer	
Fluid temperature probe	
Access stands for observers at wing	
Flashlights	

Figure 1

SAE G-12 EQUIPMENT SUBCOMMITTEE

TYPE I FLUID WITH AIR ASSIST - GENERAL FORM

(Complete One Per Test Session For Each Truck / Fluid Combination)

OPERATOR ____________ LOCATION____________________ DATE__________________

AIRCRAFT TYPE ____________________________________

FLUID MANUFACTURER AND TYPE ____________________________________

TRUCK MANUFACTURER AND TYPE ____________________________________

TRUCK SERIAL NUMBER (S) ________________ ________________ ________________

________________ ________________ ________________

(System specifications can be provided by completion of the following or by submission of the manufacturer's system description.)

OPERATOR REPRESENTATIVE NAME (BLOCK LETTERS), SIGNATURE AND TELEPHONE

______________________________ _____________________________ ____________________

APPLICATION OF TYPE II / IV WITH AIR - SYSTEM DESCRIPTION

INJECTED INTO AIR STREAM ____

OR OVER AIR STREAM ____

FLUID FLOW RATE ________________________

FLUID NOZZLE TYPE ________________________

FLUID PRESSURE ________________________

AIR PRESSURE ________________________

AIR FLOW RATE ________________________

TYPE II / IV STANDARD APPLICATION - SYSTEM DESCRIPTION

FLUID NOZZLE TYPE ________________________

FLUID PRESSURE ________________________

FLUID FLOW RATE ________________________

APS AVIATION INC.

I:\Groups\CM1680(exBM3833)\Procedures\Forced Air\Type I 1st step\Las Vegas\following Las Vegas\Figure I following Las Vegas.doc

9

November 01

FIGURE 2

SAE G-12 EQUIPMENT SUBCOMMITTEE
TYPE I FLUID - SPRAY FORM (EVERY TEST)

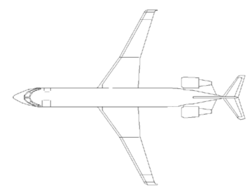
Operator: ______________________ Location: ______________________

Date: ______________________ Aircraft Type: ______________________

Run #: ______________________ DRAW DIRECTION OF SPRAY AND WIND WRT WING:

Type of Application ☐ FLUID OVER AIR
☐ AIR/INJECTED FLUID
☐ FLUID

Truck #: __________



TEST CONDITIONS			
Type of Precipitation:	________	Rate:	Light Moderate Heavy
Depth of Snow or Ice on Wing	________ in		
OAT	________ °F/°C	Wind:	________ mph

DEICING APPLICATION			
Start Time:	________ hh:mm:ss	End Time:	________ hh:mm:ss
Amount of Fluid Sprayed:	________ gal / L	Type of Fluid:	________
Fluid Temperature:	Tank: ______ °F / °C	Nozzle:	______ °F / °C
Fluid Freeze Point:	________ °F / °C		

PROJECTILES DURING DEICING	
Describe how the snow or ice was removed from the wing, example in sheets, chunks or powder.	________
Record the size of any pieces of blown contamination, and if there was any risk of ingestion for rear mounted engines.	________

CONDITION OF WING AT END OF DEICING: ______________________

MEASUREMENTS BY: ______________________

HANDWRITTEN BY: ______________________

Figure 2 following Las Vegas.XLS

FIGURE 3

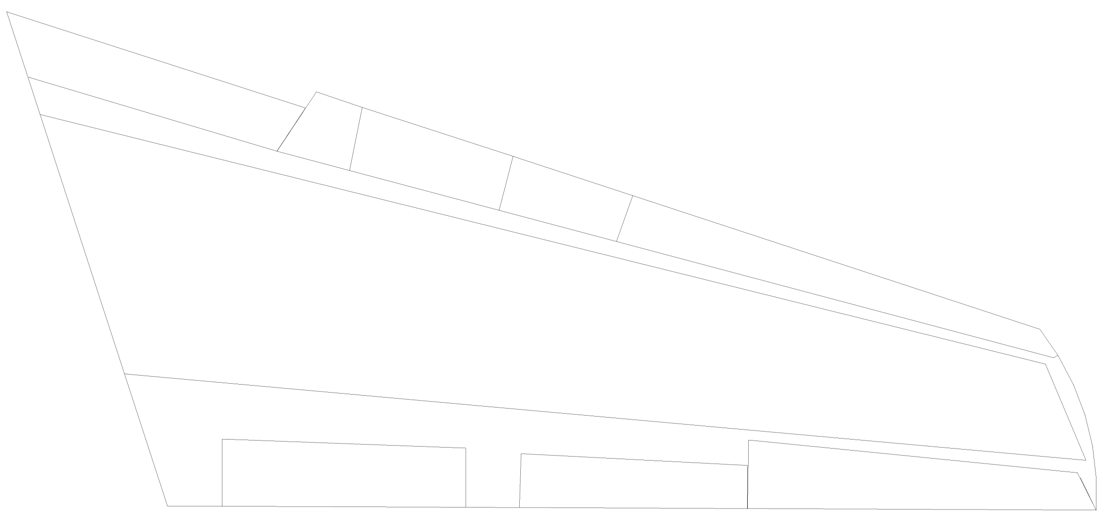
SAE G-12 EQUIPMENT SUBCOMMITTEE

TYPE I FLUID - WING FORM (EVERY TEST**)**

DATE: ____________________ **RUN #:** ______________

RECORDING INFORMATION:

- At time of 1st freezing:	- Note location and time on wing form.
- 5 minutes after Deicing:	- Record patterns of ice on the wing form.
- Wing Cavity Inspection:	- Record appearance of any ice formation. Use additional forms as needed.



COMMENTS: ____________________________________

____

____

ICING RECORD BY: ____________________

HANDWRITTEN BY: ____________________

Type I first step wing form.XLS

APPENDIX C

TEST PROGRAM – FORCED AIR SYSTEMS
TYPE II/TYPE IV FLUID APPLIED OVER OR INJECTED INTO THE FORCED AIR STREAM (VERSION 1.4)

CM1680

TEST PROGRAM - FORCED AIR SYSTEMS

TYPE II / TYPE IV FLUID *APPLIED OVER* or *INJECTED INTO* THE FORCED AIR STREAM

Prepared for

SAE G-12
Equipment Subcommittee
Forced Air Working Group

Prepared by: For Peter Dawson

Reviewed by: John D'Avirro

APS AVIATION INC.

Version 1.4
05 June 2002

TEST PROGRAM - FORCED AIR SYSTEMS
TYPE II / TYPE IV FLUID *APPLIED OVER* or *INJECTED INTO*
THE FORCED AIR STREAM

1. OBJECTIVE

These tests are designed to examine whether published SAE holdover time guidelines can be approved for use when Type II / Type IV fluid is applied to aircraft surfaces with the assistance of forced air systems.

The nature of the assistance typically can take either of two forms:

a. The fluid nozzle can be positioned above the forced air nozzle, with the goal of carrying the fluid stream on top of the air stream.
b. The fluid nozzle can be positioned to inject fluid within the air stream, where the fluid is mixed with, and carried as part of the air stream.

This examination compares the quality of fluid application produced by the forced air assist application, with the quality of a standard application.

2. APPROVAL PROCESS

Each combination of forced air deicing truck configuration and SAE Type II / Type IV fluid requires individual approval. The following steps are involved in the approval process:

1. A standard procedure for testing and data gathering is developed and approved; by FAA, TC and the SAE G-12 Equipment Subcommittee Forced Air Working Group.
2. Prior to testing, in-house development of spray techniques and procedures is completed by the operator. The forced air systems planned for use in testing are to be verified by the manufacturer or operator's maintenance staff to confirm that they are operating within manufacturer specifications.
3. When the operator is satisfied that it has evolved a suitable application procedure, the operator schedules a test session, inviting observers from FAA Technical Center and Transport Canada (TDC).
4. Tests are conducted to gather required data. A set of five tests is required, to demonstrate repeatability. Tests are conducted on aircraft wings. Each test involves applying fluid with air assist on one wing, and applying fluid with the operator's standard Type II / Type IV nozzle and procedure on the other wing, as a benchmark.

5. If deemed satisfactory by the operator, test results are submitted to the following FAA/TC addressees to be considered for approval to use Type II / Type IV published HOT guidelines, for that specific truck / Type II / Type IV fluid combination.

Charles O. Masters Manager, Flight Safety Research FAA Technical Centre Building 210 AAR 421 Atlantic City International Airport Atlantic City, NJ 08405 mastersc@tc.faa.gov	Barry Myers Senior Development Officer Transport Canada Transportation Development Centre 800 René-Lévesque Blvd. West 6th Floor Montréal, Québec H3B 1X9 Canada myersbb@tc.gc.ca

6. The approval decision rests on whether the forced air assist process produces results that are equivalent to the standard fluid application process. The factors considered are:
   - Fluid viscosity as measured from samples lifted from the wing
   - Fluid thickness measured at various points on the wing
   - Consistency of distribution of the fluid layer over the sprayed area on the wing.

3. TEST PROCEDURE

3.1 General

These tests are designed to be conducted in the field by the equipment operator. Equipment and fluid manufacturers will be invited to test sessions. Fluid samples are to be tested under laboratory conditions.

3.2 Test Planning

3.2.1 Weather Conditions

These tests are performed in dry conditions.

Some of the set of five required tests may be performed in non-winter conditions, with wing skin temperature not warmer than 15ºC. At least one test is to be performed in freezing conditions as confirmation that warm OAT does not affect test results related to fluid viscosity.

At least one test is performed in *into-wind* conditions.

3.2.2 Test Surface

Tests are to be conducted on dry wings of out-of-service aircraft (example, parked overnight).

Care must be taken to ensure that there is no residue of Type I fluid on the wings, as this will result in some mixing of Type I within the Type II / Type IV fluid, and will produce inaccurate viscosity measurements.

To avoid the risk of presence of Type I fluid, removal of Type II / Type IV fluid between consecutive tests can be performed by use of heated water or heated Type I fluid, followed by an application of forced air to dry the wing. Ensure that the wing temperature has cooled to ambient before conducting subsequent tests.

If the tests are conducted in freezing temperatures, the final cleaning of Type II / Type IV fluid following the last test is to be performed with heated Type I fluid, prior to returning the aircraft to service.

3.2.3 Test Fluid

The fluid used for test purposes is qualified standard production fluid.

3.2.4 Configuration of Forced Air System

The normal operating configuration of the forced air systems is to be used for testing. If the air-flow is operator controlled, the test is to be conducted at maximum air flow.

The operating performance of forced air systems planned for use in these tests is to be checked prior to tests. This may be done by the manufacturer or by the operator's technical staff in accordance with manufacturer's guidelines. Certification that systems are operating within manufacturers specifications is required for each truck used in testing. A completed and signed **DECLARATION OF**

CONFORMITY (Attachment 1a) is to be submitted for each forced air deicing vehicle used in the tests. A sample completed form (Attachment 1b) is included for guidance.

3.2.5 Test Matrix

Five tests are to be conducted, to examine repeatability. If the main series of tests is conducted in warm weather, test number 5 in the test matrix must be conducted below freezing condition.

Table 3.1: Test Matrix

Test Number	Type of Application	Special Test Condition
1a	Air-assist	Alternate air-assist test between port and starboard wings to eliminate any effect of wind-direction
1b	Standard	
2a	Air-assist	
2b	Standard	
3a	Air-assist	Duplicate of test 1 or 2
3b	Standard	
4a	Air-assist	Spray into-wind (conduct consecutive tests on the same wing to ensure the same wind affect)
4b	Standard	
5a	Air-assist	Cold OAT (below 0°C)
5b	Standard	

3.2.6 Test Equipment

A list of equipment needed to conduct the tests is provided in Attachment 2.

3.3 Data Forms

Two data forms are used for these tests as follows.

3.3.1 General Form (Figure 1)

This is a cover form for all tests completed during a single test session. An operator signature verifies that deicing trucks used for tests have been checked to confirm that they operate in accordance with manufacturer's specifications. The specifications for the forced air system may be provided by completing the form, or by attaching a copy of the manufacturer's equipment description.

This form is completed only once per test session.

3.3.2 Test Data Form (Figure 2)

This form is completed for each wing tested. Each test consists of an application of fluid on one wing using air-assist, and on the other wing using the operators standard Type II / Type IV fluid nozzle and procedure; thus two forms are completed for each test.

The form is designed to record data specific to fluid applied at minimum and maximum distances.

Values for OAT and wind speed can be retrieved from the local Met office.

3.4 Conducting the Tests

3.4.1 Fluid Application

To enable measurement of minimum and maximum distance of effective spray, the operator should be positioned at a fixed location relative to the test wing. Fluid is then applied over the wing (span-wise and chord-wise) from the fixed position, with the objective of determining the reach limitations.

Record the start and finish times for spray. If the truck is equipped, record the quantity of fluid sprayed.

The minimum and maximum distances from nozzle are measured, and the angle of the fluid stream to the horizontal is estimated.

For the test of spray *into-wind*, the operator should be positioned accordingly. This may require spraying from the rear of the wing.

3.4.2 Measuring Fluid Thickness

Allow at least 3 minutes for the fluid to settle, and measure fluid thickness on the wing at the locations where minimum distance and maximum distance was observed. The boundary of the area where satisfactory coverage was achieved may take the shape of an arc across the wing. In that case, the measurements should be taken within that arc, at the chord locations indicated.

Refer to Attachment 3 for equipment and procedures.

3.4.3 Noting Appearance of Fluid Layer

Grade the appearance as noted on the data form. This may be somewhat subjective, however the intent is simply to allow comparison between the air-assist and standard methods of application, so the important thing is consistency in grading. For continuity in each test, the same person should report the fluid appearance on both wings (the wing treated with the forced air assist, and the other wing treated with a standard application).

3.4.4 Taking Fluid Samples for Aeration and Viscosity Test

Sample containers as described by the appropriate fluid manufacturer for submission of fluid samples are suitable for this test. In preparation for measuring fluid aeration, first label each bottle and cap. The empty bottle with its cap is then weighed and the weight recorded. The volume capacity of each bottle when filled to overflowing and then capped, is measured and recorded. Maintain a list of container labels along with measured weight (empty and capped), and volume capacity.

An initial sample is required from the truck tank, to serve as a reference base. This sample may be taken directly from the tank by dipping from the top, or from the bottom drain valve. If taken from the drain valve, allow enough fluid to drain to completely flush the line before taking the sample.

Two samples are lifted from the wing surface for each test; one at minimum and one at maximum distance. At least 4 ounces (120 ml) is required for each sample. Fluid will need to be gathered from a fairly large area (in the order of 4 ft^2) to accumulate this amount, so this activity should take place after recording of other test data (thickness and appearance).

To gather samples from the wing surface, it is recommended that the fluid be pulled together on the wing surface using flexible plastic sheets as scrapers. Then flow the accumulated fluid onto one plastic sheet, and, by bending the plastic sheet, pour the lifted fluid into the sample bottle. Plastic dustpans are also suitable for fluid collection. Two people are needed for this activity. Alternatively, if the wing structure allows it, the fluid can be flowed to the edge of the wing, and captured as it flows off.

As each bottle is filled, ensure that a record is maintained clearly linking the sample bottle label to test number, maximum or minimum position and date/time of test.

Samples are to be sent to a qualified lab within 24 hrs, for prompt testing.

To measure fluid aeration, first weigh the filled bottles without removing with their caps. Calculate the fluid density based on the recorded empty bottle weight and volume capacity. Calculate the percentage change to fluid density due to aeration by comparison to the density of the virgin sample taken from the truck tank as a base of reference.

Fluid viscosity is to be measured in accordance with the fluid manufacturer's procedure. Fluid samples are to be centrifuged before testing for viscosity.

Test results received back from the fluid manufacturer are to be entered on the test data form, prior to submitting the completed test data forms for approval to use holdover times.

3.4.5 Preparing for Next Test

To prepare for the next test, remove all Type II / Type IV fluid from the wing. This can be done with heated water or heated Type I fluid, and then dried using forced air.

Attachment Ia

Declaration of Conformity

Manufacturer or Operator Maintenance Department:

____
____
____
____

Notify that the machine hereunder mentioned:

Equipment: ____________________
Type: ____________________
Serial Number: ____________________

Complies with the Manufacturers Specifications.

Date: ________________________

Signature: ________________________

Attachment Ib

Sample of a Completed Declaration of Conformity

Manufacturer or Operator Maintenance Department:

Global Ground Support
540 East US Hwy 56
Olathe, KS 66061

Notify that the machine hereunder mentioned:

Equipment:	Aircraft Deicer
Type:	2100 LFTE
Serial Number:	TE21-1099-0020

Complies with the Manufacturers Specifications.

Date: ____________________

Signature: ____________________

Attachment II

Test Equipment Checklist
Trials for Type II / Type IV Fluid Applied over or Injected into the Forced Air Stream

TASK	*STATUS*
Logistics For Every Test Session	
Schedule test with truck and fluid manufacturers	
Advise FAA, TDC	
Arrange for test aircraft	
Test Equipment	
Forced air deicing truck	
Test procedures	
Data Forms	
Clipboards	
Pencils	
Wiper rags	
Fluid thickness gauges	
Fluid sample containers with labels (24)	
Plastic to pick up fluid samples from wing	
Lighting for stands	
Access stands for observers at wing	
Flashlights	

ATTACHMENT III

Measuring Fluid Film Thickness

Fluid thickness can be measured with use of a wet film thickness gauge. Two types are recommended as follows.

The Octagon wet film thickness gage ranges from 0.4 to 400 mils. It is available with a micron scale on the reverse side. This gauge is suitable for normal on-wing thickness for Type II / Type IV fluid. Part number WF-OCT.

The second gauge is a standard stock gage ranging from 1 to 80 mil. This gauge gives better accuracy for thinner films, such as seen with Type I fluid on wings, or thinner applications of Type II / Type IV fluid. Part number WF-CCA.

Both gauges are available from:

Paul N. Gardner Company, Inc.
316 NE 1st St. POMPANO BEACH, Fl 33060
1-800-762-2478 (954) 946-9454 FAX (954) 946-9309

Instructions for Use

1. Place the gauge in the fluid at 90º to the underlying surface, selecting the gauge side that allows a tooth to touch the fluid surface.
2. Note the last tooth that is wetted. This can be done by withdrawing the gauge and observing which is the last tooth wetted, or by peering under the gauge while inserted in the fluid, noting which is the last tooth touching the fluid surface. With clear fluid, the latter method usually works better.
3. Record the value of the last tooth wetted.
4. Dry the gauge before next use.
5. If repeat measurements are taken, ensure that the gauge is slightly offset from the previously measured location as the fluid surface may still be indented from the earlier measure.

Figure 1: SAE G-12 EQUIPMENT SUBCOMMITTEE
TYPE II / TYPE IV FLUID WITH AIR ASSIST - GENERAL FORM
(Complete One Per Test Session For Each Truck / Fluid Combination)

OPERATOR____________________ LOCATION____________________ DATE__________________

AIRCRAFT TYPE ______________________________

FLUID MANUFACTURER AND TYPE ___________________________________

TRUCK MANUFACTURER AND TYPE ___________________________________

TRUCK SERIAL NUMBER (S) ________________ ________________ ________________

(Operator verifies that deicing trucks used for these tests have been checked to confirm operation in accordance with manufacturer's specifications. System specifications can be provided by completion of the following or by submission of the manufacturer's system description.)

OPERATOR REPRESENTATIVE NAME (BLOCK LETTERS), SIGNATURE AND TELEPHONE

_________________________ ________________________ ________________

APPLICATION OF TYPE II / IV WITH AIR
- SYSTEM DESCRIPTION
INJECTED INTO AIR STREAM _____
OR OVER AIR STREAM _____
FLUID FLOW RATE ___________________________
FLUID NOZZLE TYPE __________________________
FLUID PRESSURE ____________________________
AIR PRESSURE _____________________________
AIR FLOW RATE ______________________________

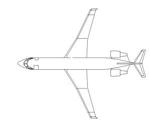
TYPE II / IV STANDARD APPLICATION
- SYSTEM DESCRIPTION
FLUID NOZZLE TYPE ___________________________
FLUID PRESSURE ______________________________
FLUID FLOW RATE ____________________________

Figure 2: SAE G-12 EQUIPMENT SUBCOMMITTEE
TYPE II / TYPE IV FLUID WITH AIR ASSIST - DATA FORM
(Complete One Form for Each Wing Tested)

OPERATOR _________ **LOCATION**______________________ **DATE**__________ **TIME** _______ **RUN #** ______
TRUCK MANUFACTURER AND TYPE _____________ TRUCK NUMBER ____________________________________
OAT _______ WIND SPEED ___________ FLUID MANUFACTURER AND TYPE ____________________
TYPE OF APPLICATION Over Air Stream ____ Injected In Air Stream ____ Standard Application ___________
SPRAY PATTERN SETTING ___ % Fan; Solid Stream _______; Other ____
SPRAY START TIME _________ SPRAY END TIME __________ FLUID QUANTITY APPLIED ____________________

LOCATION FOR FLUID THICKNESS MEASUREMENT

- CIRCLE WING SPRAYED
- PENCIL IN WIND DIRECTION RELATIVE TO WING TESTED



AT MINIMUM EFFECTIVE DISTANCE	AT MAXIMUM EFFECTIVE DISTANCE
Minimum distance from nozzle _____ ft	**Maximum distance from nozzle** _____ ft
Estimated angle of stream to horizontal _____ °	**Estimated angle** of stream to horizontal _____ °
Fluid thickness on wing chord at Min distance	**Fluid thickness** on wing chord at Max distance
a ________ mil b ______ mil	a ________ mil b ______ mil
c ________ mil d ______ mil	c ________ mil d ______ mil
Appearance of Fluid Layer at Min distance	***Appearance of Fluid Layer at Max distance***
(grade each line from 1 to 5)	(grade each line from 1 to 5)
1 **5**	**1** **5**
Very ridged _______________ Consistent thickness	Very ridged _______________ Consistent thickness
Patchy colour _______________ Consistent colour	Patchy colour _______________ Consistent colour
Highly aerated _______________ Few bubbles	Highly aerated _______________ Few bubbles
Surface appears as if contaminated	Surface appears as if contaminated
Yes _______________ No	Yes _______________ No
Other comments:	Other comments:
Label on Fluid Sample ______ **Aeration** ____ %	**Label on Fluid Sample** ______ **Aeration** ____ %
Sample Viscosity _________ **Brix** __________	**Sample Viscosity** _________ **Brix** __________
Recorded by: ______________________________	Recorded by: ______________________________

APPENDIX D

EXPERIMENTAL PROGRAM –
ENDURANCE TIMES FOR SAE TYPE II/IV FLUIDS
WHEN APPLIED WITH FORCED AIR ASSIST

CM1747.001

EXPERIMENTAL PROGRAM
ENDURANCE TIMES FOR SAE TYPE II/IV FLUIDS
WHEN APPLIED WITH FORCED AIR ASSIST

Winter 2002-03

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Peter Dawson

Reviewed by: John D'Avirro

December 12, 2002
Version 1.0

EXPERIMENTAL PROGRAM
ENDURANCE TIMES FOR SAE TYPE II/IV FLUIDS
WHEN APPLIED WITH FORCED AIR ASSIST
Winter 2002-03

1. BACKGROUND

In response to a request from the SAE G-12 Equipment subcommittee, Transport Canada and FAA jointly agreed to support development of test procedures and an approval process for specific functional applications of forced air deicing systems. The test procedures were to be designed to be performed by operators of forced air deicing systems.

Consequently, test procedures were developed for two types of applications, of which one examined spraying of SAE Type II and IV fluids with forced air assist. This test was designed to examine whether published SAE holdover time guidelines could be approved for use when Type II / Type IV fluid is applied to aircraft surfaces with the assistance of forced air systems.

The current approval process rests on whether the forced air assisted spray produces a layer of fluid on the wing that is equivalent to the standard fluid application spray, and that the fluid viscosity is not degraded below the fluid manufacturer's stated *lowest on-wing viscosity*. The factors considered are:

- Fluid viscosity measured from samples lifted from the wing;
- Fluid thickness measured at various points on the wing;
- Consistency of distribution of the fluid layer over the sprayed area on the wing.

The Federal Aviation Administration (FAA) has requested that a supplementary check be performed to examine endurance times for fluids applied in this manner, to ensure that no other fluid property has been altered which might result in shorter times.

2. OBJECTIVES

The objective of this procedure is to examine endurance times for SAE Type II and IV fluids which have been sprayed with forced air assist.

To achieve this objective, arrangements will be made with forced air deicing system operators to retrieve samples of fluids which have been sprayed with the assistance of forced air and samples sprayed with conventional nozzles. The fluid samples will be measured for viscosity, and subjected to endurance trials in natural snow conditions.

3. PROCEDURE/TEST REQUIREMENTS

The procedure has two parts, retrieving fluid samples from operators, and then testing those samples.

3.1 Obtaining Fluid Samples

Airlines or deicing operators known to have tested or to have a potential interest in using forced air assisted Type II or IV fluid application will be contacted for possible submission of fluid samples.

A fluid collection data form will be provided to the prospective fluid sample providers for completion, as shown in Attachment A.

Samples of fluid sprayed with air-assist and sprayed with conventional nozzles will be requested. A quantity of 5 litres will be requested for each type of spray application, to enable several endurance tests to be conducted in snow conditions at different temperatures.

As well, a sample of unsprayed fluid from the truck tank will be requested, to serve as a base case for fluid viscosity values.

3.2 Conducting Fluid Endurance Trials

When the samples are received, fluid viscosity will be measured.

Endurance trials will be conducted at the earliest opportunity following receipt of each sample, when the next snowfall occurs. Endurance trials will be conducted outdoors, using the standard SAE Type II/IV Fluid test procedure in natural snow outdoor conditions.

4. EQUIPMENT AND FLUIDS

4.1 Equipment

The standard equipment used for endurance time trials will apply.

4.2 Fluids

Tests will be conducted with fluid samples provided by field operators. The fluids will be at ambient temperature for application.

5. PERSONNEL

Two technicians:
- First calls failures, prepares fluid samples
- Second measures precipitation rates and wind.

6. DATA FORMS

- Attachment A Fluid Sample Data Form
- Attachment B End Condition Data Form
- Attachment C Meteo/Plate Pan Data Form

ATTACHMENT A

SAE TYPE II/IV FLUID SAMPLE DATA FORM

SAMPLES APPLIED WITH FORCED AIR ASSIST AND CONVENTIONAL SPRAY

(Please complete this form and submit it with the fluid samples)

Operator: ____________________

Location: ____________________

Fluid: ____________________
Manufacturer/Name/Concentration

Truck: ____________________ ____________________
Manufacturer/Type Serial Number

Air Compressor: ____________________
Manufacturer/Type

Fluid Nozzle:
Forced Air System ____________________ *Conventional* ____________________
Manufacturer/Type Manufacturer/Type

Type Of Forced Air Assist Application: ❑ Over Air Stream ❑ Injected In Air Stream

Description Of Fluid Sample

When Was The Fluid Sample Sprayed? Date: ____/____/____ Time: ____:____ am pm
(day/month/year)

Quantity Of Sprayed Fluid Supplied (Approximately 5 L each requested):
Air-Assist Spray Sample: __________
Conventional Nozzle Spray Sample: __________

Quantity Of Fluid Sample Taken From Truck Tank (1 L is sufficient): __________

Describe How The Sample Was Collected (was it sprayed onto the wing, onto a plastic sheet on the ground, into a container, etc.):

____

____

____

____

SHIPPING INSTRUCTIONS: Please ship to the following address, and advise by e-mail (pdawson@adga.ca) that the samples have been sent.	APS Aviation Inc. 1100 Rene Levesque Ouest Suite 1340, Montreal (Quebec) CANADA H3B 4N4 Phone: 514 878-4388

ENDURANCE TIMES FOR SAE TYPE II/IV FLUIDS WHEN APPLIED WITH FORCED AIR ASSIST

ATTACHMENT B
END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH ATOMIC CLOCK - USE REAL TIME

VERSION 1.0 Winter 2002/2003

LOCATION: DORVAL TEST SITE DATE: RUN #: STAND # :

*TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (hr:min)

Time of Fluid Application: ______ hr:min:ss ______ hr:min:ss ______ hr:min:ss

	PLATE ____			PLATE ____			PLATE ____		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / FLUID TEMPERATURE AT START	/			/			/		

Time of Fluid Application: ______ hr:min:ss ______ hr:min:ss ______ hr:min:ss

	PLATE ____			PLATE ____			PLATE ____		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / FLUID TEMPERATURE AT START	/			/			/		

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

PRINT SIGN

FAILURES CALLED BY : ______________ ______________

Cm1747\Procedures\Forced Air\Attachment B

M:\Projects\PM1892 (TC Deicing 03-04)\Reports\Forced Air\Final Draft 3.0\Report Components\Appendices\Appendix D\Version 1.0.doc
Version1.0, December 2002

5

ENDURANCE TIMES FOR SAE TYPE II/IV FLUIDS WHEN APPLIED WITH FORCED AIR ASSIST

ATTACHMENT C

METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH ATOMIC CLOCK - USE REAL TIME

VERSION 1.0 Winter 2002-2003

LOCATION: DORVAL TEST SITE **DATE:** **RUN # :** **STAND # :**

PLATE PAN WEIGHT MEASUREMENTS

PAN #	t TIME BEFORE (hh:mm:ss)	BUFFER TIME (Seconds)	t TIME AFTER (hh:mm:ss)	BUFFER TIME (Seconds)	w WEIGHT BEFORE (grams)	w WEIGHT AFTER (grams)	COMPUTE RATE (Δw*4.7/ Δt) ($g/dm^2/h$)

METEO OBSERVATIONS *

TIME (hr:min)	TYPE ZR, ZL,S, SG IP, IC, BS, SP	SNOW CLASSIF. (See Fig. 3)	WIND SPEED at 2 m (Km/h)

*observations at beginning, end, and every 5 min. intervals. Additional observations when there are significant changes.

COMMENTS : ______________________________

____

____

____

	PRINT	SIGN
WRITTEN & PERFORMED BY :	__________	__________
APPROVED BY :	__________	__________

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APPENDIX E

TEST PROGRAM – FORCED AIR SYSTEMS
TYPE II/TYPE IV FLUID APPLIED OVER OR INJECTED INTO THE FORCED AIR STREAM (VERSION 2.0)

CM1892.001

TEST PROGRAM – FORCED AIR SYSTEMS

TYPE II/TYPE IV FLUID *APPLIED OVER* or *INJECTED INTO* THE FORCED AIR STREAM

Prepared for

SAE G-12
Equipment Subcommittee
Forced Air Working Group

Prepared by: Peter Dawson

Reviewed by: John D'Avirro

APS Aviation Inc.

Version 2.0
December 18, 2003

TEST PROGRAM – FORCED AIR SYSTEMS TYPE II/TYPE IV FLUID *APPLIED OVER* or *INJECTED INTO* THE FORCED AIR STREAM

1. OBJECTIVE

These tests are designed to examine whether published holdover time guidelines (HOT) can be approved for use when Type II/Type IV fluid is applied to aircraft surfaces with the assistance of forced air systems.

In the forced air systems currently in operation, the nature of the assistance typically can take either of two forms:

a) The fluid nozzle can be positioned above the forced air nozzle, with the goal of carrying the fluid stream on top of the air stream; and

b) The fluid nozzle can be positioned to inject fluid within the air stream, where the fluid is mixed with and carried as part of the air stream.

Tests to date have indicated that the injected form of air-assist degrades fluid viscosity and does not produce results that support use of HOT guidelines, thus these tests should address the fluid-over-air form of application.

These tests compare the quality of fluid application produced by the forced air assist application with the quality of a standard application. The test procedure is comprised of two phases:

1) The first phase examines the quality of the fluid coverage produced by the air-assisted application. This section is intended as a guide for the operator, providing a procedure to assess whether the fluid layer produced by the air-assisted application is satisfactory. The results help the operator decide whether the air-assist method is acceptable and suitable for implementation in the deicing operation; and

2) The second phase examines whether fluid viscosity has been affected by the air-assisted application. Fluid viscosity data generated by this test forms the basis of the request for approval to use holdover times for air-assisted Type II/IV Fluid applications.

2. PHASE 1 – OPERATOR ASSESSMENT

2.1 General

The equipment operator conducts these tests. Measurement of fluid viscosity is not required in this phase of testing. Although this test phase is voluntary, it is a recommended way of determining whether the desired fluid coverage on the wing is produced by the air-assist application. It is also recommended that the results of such tests be shared within the SAE G-12 Equipment Subcommittee to encourage advancement of these systems.

2.2 Weather Conditions

These tests are performed in dry conditions. As fluid viscosity is not measured in these tests, they may be conducted in non-winter conditions. However, because very warm temperatures may affect the fluid thickness on the wing, it is recommended that wing skin temperatures should not be warmer than 15°C.

At least one spray test should be performed in *into the wind*.

2.3 Test Surface

Tests are to be conducted on wings of out-of-service aircraft (example, parked overnight).

For consecutive tests, Type II/Type IV fluid can be removed with applications of heated water or Type I fluid, followed by an application of forced air to dry the wing. Ensure that the wing temperature has cooled to ambient before conducting subsequent tests.

If the tests are conducted in subzero temperatures, the final cleaning of Type II/Type IV fluid following the last test is to be performed with heated Type I fluid, prior to returning the aircraft to service.

2.4 Test Fluid

The fluid used for test purposes must consist of a qualified standard production fluid.

2.5 Configuration of Forced Air System

The normal operating configuration of the forced air system is used for testing.

2.6 Test Matrix

As this test phase is voluntary, any number of tests may be conducted. Repeating tests improves the operator's confidence that the results can be reproduced in normal deicing operations. The following test matrix (Table 2.1) is recommended as a minimum.

Table 2.1: Test Matrix for Operator Assessment

Test Number	Type of Application	Special Test Condition
1a	Air-assist	Alternate air-assist test between port and starboard wings to eliminate any effect of wind-direction
1b	Standard	
2a	Air-assist	
2b	Standard	
3a	Air-assist	Spray into-wind (conduct consecutive tests on the same wing to ensure the same wind affect)
3b	Standard	

2.7 Test Equipment

A list of equipment to support these tests is provided in Attachment 1.

2.8 Figure 1: Phase 1 – Operator Assessment – Data Form

This form is completed for each wing tested. Each test consists of an application of fluid on one wing using air-assist, and on the other wing using the operators standard Type II/Type IV fluid nozzle and procedure; thus two forms are completed for each test.

The form is designed to record data specific to fluid applied at minimum and maximum distances.

Values for OAT and wind speed can be retrieved from the local Met office or determined using hand-held instrumentation.

Use of this standard data form will facilitate sharing of information with members of the SAE G-12 Equipment Subcommittee.

2.9 Conducting the Tests

2.9.1 Fluid Application

To enable measurement of the minimum and maximum distance of effective spray, the operator should be positioned at a fixed location relative to the test wing. Fluid is then applied over the wing (span-wise and chord-wise) from the fixed position, with the objective of determining the reach limitations.

Record the start and finish times of the fluid spray. If the truck is equipped with measuring instrumentation, record the quantity of fluid sprayed.

The minimum and maximum distances from nozzle are measured, and the angle of the fluid stream to the horizontal is estimated.

For the fluid spray test conducted into the wind, the operator should be repositioned as in an actual deicing operation, selecting a position that will deliver the best fluid application and minimize loss of fluid in the wind. This may require spraying from the rear of the wing.

2.9.2 Measuring Fluid Thickness

The fluid should be allowed to settle for at least 3 minutes, and the fluid thickness should be measured on the wing at the locations where minimum distance and maximum distance was observed. The boundary of the area where satisfactory coverage was achieved may take the shape of an arc across the wing. In that case, the measurements should be taken within that arc, at the chord locations indicated.

Refer to Attachment 2 for equipment and procedures.

2.9.3 Noting Appearance of Fluid Layer

The appearance of the fluid layer on the wing shall be graded and noted on the data form. This may be somewhat subjective, however the intent is simply to allow comparison between the air-assist and standard methods of application, so the important thing is consistency in grading. For continuity in each test, the same person should report the fluid appearance on both wings (the wing treated with the forced air assist, and the other wing treated with a standard application).

3. PHASE 2 – MEASURING FLUID VISCOSITY

3.1 General

Each combination of forced air deicing truck configuration and Type II/Type IV fluid requires individual approval for use of HOT guidelines. The following steps are involved in the approval process:

1) When the operator is satisfied with the air-assist application procedure, the operator coordinates a test session, inviting observers from the FAA Technical Center, Transport Canada (TDC) and APS Aviation. Equipment and fluid manufacturers should also be invited to observe;
2) The manufacturer or operator's maintenance staff shall verify that the forced air systems planned for use in testing are operating within manufacturer specifications;
3) The ambient temperature for the test must be below freezing. Dry conditions are needed;
4) Tests are to be conducted on aircraft wing surfaces, not substitute surface;
5) The test involves applying fluid onto the wing, lifting a fluid sample, and measuring its viscosity. In addition, for information purposes only, aeration will be measured.
6) Viscosity of both air-assisted and conventional Type II/Type IV nozzle spray applications is measured, as well as that of a fluid sample taken from the truck tank;
7) A qualified third party test agency, such as APS Aviation, conducts the fluid viscosity measurement at the test site, immediately following the spray application; and
8) The viscosity test agency submits the results to the following FAA/TC addressees to be considered for approval to use Type II/Type IV published HOT guidelines, for that specific truck/Type II/Type IV fluid combination.

Charles O. Masters Manager, Flight Safety Branch FAA Technical Center Building 210 AAR 470 Atlantic City International Airport Atlantic City, NJ 08405 USA charles.masters@faa.gov	Barry Myers Senior Development Officer Transport Canada Transportation Development Centre 800 René-Lévesque Blvd. West, 6th Floor Montréal, Québec H3B 1X9 Canada myersbb@tc.gc.ca

3.2 Test Procedure

3.2.1 Weather Conditions

Viscosity measurement tests are to be performed in dry conditions at below freezing temperatures.

3.2.2 Test Surface

Tests are to be conducted on dry wings. Out-of-service aircraft (example, parked overnight) are suitable for tests.

Care must be taken to ensure that there is no residue of Type I fluid on the wings, as this will cause mixing of Type I within the Type II/Type IV fluid, and produce inaccurate viscosity measurements.

To avoid the presence of Type I fluid, removal of Type II/Type IV fluid between consecutive tests can be performed by use of heated water or heated Type I fluid, followed by an application of forced air to dry the wing. Ensure that the wing temperature has cooled to ambient before conducting subsequent tests.

As tests will be conducted in freezing temperatures, the final cleaning of Type II/Type IV fluid following the last test is to be performed with heated Type I fluid, prior to returning the aircraft to service.

3.2.3 Test Fluid

The fluid used for test purposes must consist of a qualified standard production fluid.

3.2.4 Configuration of Forced Air System

The normal operating configuration of the forced air systems shall be used for testing. If the air-flow is operator controlled, the test shall be conducted at maximum air flow. The intent of measuring at maximum air flow is to test under the most severe fluid shearing condition.

The operating performance of forced air systems planned for use in these tests is to be checked prior to tests. This may be done by the manufacturer or by the operator's technical staff in accordance with manufacturer's guidelines. Certification that systems are operating within manufacturers specifications is required for each truck used in testing. A completed and signed **DECLARATION**

OF CONFORMITY (Attachment 3) is to be submitted for each forced air deicing vehicle used in the tests.

3.2.5 Test Matrix

Test matrix for viscosity tests is as follows:

- **Type of Application**
  Air-assisted
  Conventional
- **Test Condition**
  Dry wing at ambient temperature
  Cold OAT (below 0°C)

3.2.6 Test Equipment

A list of equipment needed to conduct the tests is provided in Attachment 4.

3.3 Data Forms

Two data forms are used for these tests as follows.

3.3.1 Figure 2: Type II/Type IV Fluid With Air Assist – General Form

This is a cover form for all tests completed during a single test session. An operator signature verifies that deicing trucks used for tests have been checked to confirm that they operate in accordance with manufacturer's specifications. The specifications for the forced air system may be provided by completing the form, or by attaching a copy of the manufacturer's equipment description.

This form is completed only once per test session.

3.3.2 Figure 3: Phase 2 – Fluid Viscosity – Data Form

A single form is completed for each truck/fluid combination tested. A signature of the test agency is required.

3.4 Conducting the Tests

3.4.1 Fluid Application

Fluid is to be applied over the wing following the operator's standard procedures. If the air flow is operator controlled, the test shall be conducted at maximum air flow. The intent of measuring at maximum air flow is to test under the most severe fluid shearing condition.

3.4.2 Lifting Fluid Samples for Viscosity Test

The test agency will provide suitable sample containers. In preparation for measuring fluid aeration, each bottle and cap shall be labelled. The empty bottle with its cap is then weighed and the weight recorded. The volume capacity of each bottle when filled to overflowing and then capped, is measured and recorded for all samples. A list of container labels along with measured weight (empty and capped) and volume capacity will be maintained.

An initial sample is required from the truck tank, to serve as a reference base. This sample may be taken directly from the tank by dipping from the top, or from the bottom drain valve. If taken from the drain valve, fluid should be allowed to drain to completely flush the line before taking the sample.

To gather samples from the wing surface, it is recommended that the fluid be pulled together on the wing surface using flexible plastic sheets as scrapers. Then gather the accumulated fluid onto one plastic sheet, and, by bending the plastic sheet, pour the lifted fluid into the sample bottle. Plastic dustpans are also suitable for fluid collection. Two people are needed for this activity. Alternatively, if the wing structure allows it, the fluid can be directed to the edge of the wing using the plastic dustpans, and then captured as it falls off.

As each bottle is filled, ensure that a record is maintained clearly linking the sample bottle label to test specifics. Fill the bottles to overflowing and cap them.

To measure fluid aeration, first weigh the filled bottles without removing with their caps. Calculate the fluid density based on the recorded weight of the capped empty bottle and its volume capacity.

3.4.3 Measuring Viscosity

Viscosity will be measured according to fluid manufacturers guidelines as noted in the HOT guidelines. Fluids will be centrifuged before measuring viscosity. Before measuring viscosity, fluid samples will be centrifuged until they are substantially free of trapped air bubbles. Centrifugation of 5 to 10 minutes at 3400 r/min is usually sufficient.

3.4.4 Preparing for Next Fluid Application

To prepare for the next test, all Type II/Type IV fluid must be removed from the wing. This can be done with heated water or heated Type I fluid, and then dried using forced air.

ATTACHMENT 1

Test Equipment Checklist
Phase 1 – Operator Assessment

TASK	*STATUS*
Test Equipment	
Forced air deicing truck	
Test procedures	
Data Forms	
Clipboards	
Pencils	
Wiper rags	
Fluid thickness gauges	
Lighting for stands	
Access stands for observers at wing	
Flashlights	

ATTACHMENT 2

Measuring Fluid Film Thickness

Fluid thickness can be measured with use of a wet film thickness gauge. Two types are recommended as follows.

The Octagon wet film thickness gauge ranges from 0.4 to 400 mils. It is available with a micron scale on the reverse side. This gauge is suitable for normal on-wing thickness for Type II / Type IV fluid. Part number WF-OCT.

The second gauge is a standard stock gauge ranging from 1 to 80 mils. This gauge gives better accuracy for thinner films, such as seen with Type I fluid on wings, or thinner applications of Type II / Type IV fluid. Part number WF-CCA.

Both gauges are available from:

Paul N. Gardner Company, Inc.
316 NE 1st St. POMPANO BEACH, Fl 33060
1-800-762-2478 (954) 946-9454 FAX (954) 946-9309

Instructions for Use

1) Place the gauge in the fluid at 90º to the underlying surface, selecting the gauge side that allows a tooth to touch the fluid surface;

2) Note the last tooth that is wetted. This can be done by withdrawing the gauge and observing which is the last tooth wetted, or by peering under the gauge while inserted in the fluid, noting which is the last tooth touching the fluid surface. With clear fluid, the latter method usually works better;

3) Record the value of the last tooth wetted;

4) Dry the gauge before next use; and

5) If repeat measurements are taken, ensure that the gauge is slightly offset from the previously measured location as the fluid surface may still be indented from the earlier measure.

ATTACHMENT 3

Declaration of Conformity

Manufacturer or Operator Maintenance Department:

Person's Name: ______________________

Company Name: ______________________

Phone Number: ______________________

Address: ______________________

____

____

Equipment Designation:

Equipment: ______________________

Type: ______________________

Serial Number: ______________________

The machine mentioned complies with the Manufacturers Specifications:

Date: ______________________

Signature: ______________________

ATTACHMENT 4

Test Equipment Checklist
Phase 2 – Fluid Viscosity Measurement

TASK	*STATUS*
Logistics For Every Test Session	
Coordinate test time with FAA, TDC, APS Aviation	
Arrange for test aircraft or wing	
Advise truck and fluid manufacturers	
Location to set-up viscosity measuring equipment	
Test Equipment	
Forced air deicing truck	
Test procedures	
Data Forms	
Clipboards	
Pencils	
Wiper rags	
Fluid sample containers with labels	
Plastic or apparatus to lift fluid samples from wing	
Lighting for stands	
Access stands for observers at wing	
Flashlights	
Viscometer equipment, including centrifuge	
Scale	

Figure 1: SAE G-12 EQUIPMENT SUBCOMMITTEE
Phase 1 – OPERATOR ASSESSMENT – DATA FORM
(Complete One Form for Each Wing Tested)

OPERATOR _________ **LOCATION**______________________ **DATE**__________ **TIME** _______ **RUN#** ______

TRUCK MANUFACTURER AND TYPE _____________ TRUCK NUMBER ___________________________________

OAT _______ WIND SPEED ___________ FLUID MANUFACTURER AND TYPE ___________________

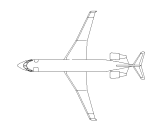
TYPE OF APPLICATION Over Air Stream ___ Injected In Air Stream ____ Standard Application ___________

SPRAY PATTERN SETTING ___ % Fan; Solid Stream _______; Other ______________________________________

SPRAY START TIME _________ SPRAY END TIME _________ FLUID QUANTITY APPLIED ___________________

LOCATION FOR FLUID THICKNESS MEASUREMENT

- CIRCLE WING SPRAYED
- PENCIL IN WIND DIRECTION RELATIVE TO WING TESTED



AT MINIMUM EFFECTIVE DISTANCE	AT MAXIMUM EFFECTIVE DISTANCE
Minimum distance from nozzle _____ ft **Estimated angle** of stream to horizontal _____ ° **Fluid thickness** on wing chord at Min distance a ________ mil b ______ mil c ________ mil d ______ mil **Appearance of Fluid Layer at Min distance** (grade each line from 1 to 5) **1** **5** Very ridged _______________ Consistent thickness Patchy colour _______________ Consistent colour Highly aerated _______________ Few bubbles Surface appears as if contaminated Yes _______________ No Other comments:	**Maximum distance from nozzle** _____ ft **Estimated angle** of stream to horizontal _____ ° **Fluid thickness** on wing chord at Max distance a ________ mil b ______ mil c ________ mil d ______ mil ***Appearance of Fluid Layer at Max distance*** (grade each line from 1 to 5) **1** **5** Very ridged _______________ Consistent thickness Patchy colour _______________ Consistent colour Highly aerated _______________ Few bubbles Surface appears as if contaminated Yes _______________ No Other comments:

Figure 2: SAE G-12 EQUIPMENT SUBCOMMITTEE
TYPE II/TYPE IV FLUID WITH AIR ASSIST – GENERAL FORM
(Complete One Per Test Session For Each Truck/Fluid Combination)

OPERATOR ________________ LOCATION___________________ DATE_________________

AIRCRAFT TYPE ___________________________________

FLUID MANUFACTURER AND TYPE ___________________________________

TRUCK MANUFACTURER AND TYPE ___________________________________

TRUCK SERIAL NUMBER (S) ________________ ________________ ________________

(Operator verifies that deicing trucks used for these tests have been checked to confirm operation in accordance with manufacturer's specifications. System specifications can be provided by completion of the following or by submission of the manufacturer's system description.)

OPERATOR REPRESENTATIVE NAME (BLOCK LETTERS), SIGNATURE AND TELEPHONE

________________________________ __________________________ _____________________

APPLICATION OF TYPE II/IV WITH AIR - SYSTEM DESCRIPTION

INJECTED INTO AIR STREAM ____
OR OVER AIR STREAM ____
FLUID FLOW RATE ________________________
FLUID NOZZLE TYPE ________________________
FLUID PRESSURE ________________________
AIR PRESSURE ________________________
AIR FLOW RATE ________________________

TYPE II/IV STANDARD APPLICATION - SYSTEM DESCRIPTION

FLUID NOZZLE TYPE ________________________
FLUID PRESSURE ________________________
FLUID FLOW RATE ________________________

Figure 3: SAE G-12 EQUIPMENT SUBCOMMITTEE
Phase 2 – FLUID VISCOSITY – DATA FORM
(Complete for Each Truck/Fluid Combination Tested)

OPERATOR ___________ LOCATION ____________________ DATE ______________

TRUCK MANUFACTURER AND TYPE ____

TRUCK SERIAL NUMBER____

FLUID MANUFACTURER AND TYPE

____

OAT _________________________ WIND SPEED _______________________________

FLUID SAMPLE DATA

SAMPLE SOURCE	TIME FLUID APPLIED (HH:MM)	DENSITY		VISCOSITY		
		VOLUME (CC)	WEIGHT (G)	TIME STARTED (HH:MM)	TIME FINISHED (HH:MM)	VALUE (CENTIPOISE)
Truck tank						
Fluid over air						
Conventional nozzle						

Fluid viscosity measured by ____

APPENDIX F

TEST PROGRAM – VISCOSITY TESTS OF FLUIDS APPLIED WITH FEDEX FORCED AIR SYSTEMS

CM1892.001

TEST PROGRAM – VISCOSITY TESTS OF FLUIDS APPLIED WITH FEDEX FORCED AIR SYSTEMS

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson

Reviewed by: John D'Avirro

APS Aviation Inc.

Version 1.0
January 8, 2004

1. OBJECTIVE

These tests are being conducted as part of an evaluation to assess whether published holdover time guidelines (HOT) can be approved for use when Type IV fluid is applied to aircraft surfaces with the assistance of FedEx forced air systems.

The tests will examine whether fluid viscosity is affected by air-assisted fluid application. Fluid viscosity data generated by these tests will form the basis of the request for approval to use holdover times for air-assisted Type IV Fluid applications.

2. TEST PLAN

Tests will be conducted at the Greater Rochester International Airport in Rochester, New York in the FedEx hangar. The viscosity tests will be conducted by APS Aviation. The other elements of the test program, described in the procedure *Test Program – Forced Air Systems; Type II/Type IV Fluid Applied Over or Injected into the Forced Air Stream*, will be conducted by FedEx.

Four fluids, Lyondell Clariant 2001, Octagon Max-Flight, Kilfrost ABC-S and Clariant 2001, will be used. Two deicing trucks, a FMC Tempest II and a FMC LMD 2000, will be used.

Time permitting, two viscosity tests will be run on each sample. Three tests will be run if the results from the first two tests are inconsistent. A matrix of tests is shown in Attachment I. If time constraints limit the number of tests that can be conducted, the following priorities will determine which tests are conducted:

- Priority one: First test of spray samples (4 tests per day);
- Priority two: Second test of spray samples (4 tests per day);
- Priority three: First test of truck tank samples (2 tests per day);
- Priority four: Second test of truck tank samples (2 tests per day); and
- Priority five: Fluid tote samples (2 tests per day).

If required, tests that are not conducted on site will be conducted at the APS laboratory upon return of samples and test equipment from Rochester.

3. PROCEDURE

3.1 Collecting Samples

In preparation for collecting samples, the sample bottles will be labelled. Initial samples are required from the fluid tote and truck tanks, to serve as a reference base. The truck samples may be taken directly from the tank by dipping from the top, or from the bottom drain valve. If taken from the drain valve, fluid should be allowed to drain to completely flush the line before taking the sample.

To gather samples from the wing surface, fluid will be pulled together on the wing surface using flexible plastic sheets as scrapers. The accumulated fluid will be gathered onto one plastic sheet, and, by bending the plastic sheet, the lifted fluid will be poured into the sample bottle. Plastic dustpans are also suitable for fluid collection. Two people are needed for this activity. Alternatively, if the wing structure allows it, the fluid can be directed to the edge of the wing using the plastic dustpans, and then captured as it falls off.

3.2 Measuring Fluid Aeration (optional if time permits)

The volume of a container will be measured prior to testing. This container will become the designated aeration measurement container. To measure fluid aeration, the empty capped container will be weighed. The container will then be filled to overflowing with the sample fluid and capped. The weight of the container will be measured and recorded and the fluid density calculated based on the recorded weight of the capped empty bottle and its volume capacity.

3.3 Measuring Viscosity

Following discussions with fluid manufacturers, it was decided that all viscosity tests will be conducted using the small sample adapter. This will eliminate the use of large samples, which are difficult to centrifuge and require a considerable amount of time to heat and to run. Viscosity of Clariant 2001 and Lyondell/Clariant 2001 will be measured using the fluid manufacturer method. Octagon Max-Flight and Kilfrost ABC-S will be measured using alternate methods. Octagon has requested the fluid tote sample be measured using the manufacturer method.

- Clariant 2001 and Lyondell/Clariant 2001: spindle SC4-34/13, small sample adapter, 10 mL, 20°C, 0.3 rpm, 15 minutes.
- Octagon Max-Flight: spindle SC4-34/13R, small sample adapter, 10 mL, 20°C, 0.3 rpm, 10 minutes.
- Kilfrost ABC-S: spindle SC4-31/13R, small sample adapter, 10 mL, 20°C, 0.3 rpm, 10 minutes.

Before measuring viscosity, fluid samples will be centrifuged until they are substantially free of trapped air bubbles. Centrifugation of 5 to 10 minutes at 3400 r/min is usually sufficient. Consult the procedure *Instructions for Measuring Anti-Icing Fluid Viscosity Using the Brookfield DV-I+ Viscometer* for detailed directions on viscometer usage.

4. PERSONNEL

Two personnel are required. The Project Leader (MC) will coordinate tests and collect samples and the Tester (SB) will run the viscometer and help with sample collection if required.

5. DATA FORM

One data form is required. It is shown in Attachment 2.

6. EQUIPMENT

The equipment required is detailed in Attachment 3.

ATTACHMENT 1: TEST PLAN

Test #	Date	Fluid	Truck	Sample	Viscosity 1	Viscosity 2	Viscosity 3 (if required)
1	12-Jan-04	Lyondell/Clariant 2001	FMC LMD 2000	Tote Sample			
2	12-Jan-04	Lyondell/Clariant 2001	FMC LMD 2000	Truck Sample			
3	12-Jan-04	Lyondell/Clariant 2001	FMC LMD 2000	Conventional			
4	12-Jan-04	Lyondell/Clariant 2001	FMC LMD 2000	Air Assist			
5	12-Jan-04	Lyondell/Clariant 2001	FMC Tempest II	Tote Sample	NR	NR	NR
6	12-Jan-04	Lyondell/Clariant 2001	FMC Tempest II	Truck Sample			
7	12-Jan-04	Lyondell/Clariant 2001	FMC Tempest II	Conventional			
8	12-Jan-04	Lyondell/Clariant 2001	FMC Tempest II	Air Assist			
9	13-Jan-04	Octagon Max-Flight	FMC LMD 2000	Tote Sample			
10	13-Jan-04	Octagon Max-Flight	FMC LMD 2000	Truck Sample			
11	13-Jan-04	Octagon Max-Flight	FMC LMD 2000	Conventional			
12	13-Jan-04	Octagon Max-Flight	FMC LMD 2000	Air Assist			
13	13-Jan-04	Octagon Max-Flight	FMC Tempest II	Tote Sample	NR	NR	NR
14	13-Jan-04	Octagon Max-Flight	FMC Tempest II	Truck Sample			
15	13-Jan-04	Octagon Max-Flight	FMC Tempest II	Conventional			
16	13-Jan-04	Octagon Max-Flight	FMC Tempest II	Air Assist			
17	14-Jan-04	Kilfrost ABC-S	FMC LMD 2000	Tote Sample			
18	14-Jan-04	Kilfrost ABC-S	FMC LMD 2000	Truck Sample			
19	14-Jan-04	Kilfrost ABC-S	FMC LMD 2000	Conventional			

ATTACHMENT 1 (cont'd): TEST PLAN

Test #	Date	Fluid	Truck	Sample	Viscosity 1	Viscosity 2	Viscosity 3 (if required)
20	14-Jan-04	Kilfrost ABC-S	FMC LMD 2000	Air Assist			
21	14-Jan-04	Kilfrost ABC-S	FMC Tempest II	Tote Sample	NR	NR	NR
22	14-Jan-04	Kilfrost ABC-S	FMC Tempest II	Truck Sample			
23	14-Jan-04	Kilfrost ABC-S	FMC Tempest II	Conventional			
24	14-Jan-04	Kilfrost ABC-S	FMC Tempest II	Air Assist			
25	15-Jan-04	Clariant 2001	FMC LMD 2000	Tote Sample			
26	15-Jan-04	Clariant 2001	FMC LMD 2000	Truck Sample			
27	15-Jan-04	Clariant 2001	FMC LMD 2000	Conventional			
28	15-Jan-04	Clariant 2001	FMC LMD 2000	Air Assist			
29	15-Jan-04	Clariant 2001	FMC Tempest II	Tote Sample	NR	NR	NR
30	15-Jan-04	Clariant 2001	FMC Tempest II	Truck Sample			
31	15-Jan-04	Clariant 2001	FMC Tempest II	Conventional			
32	15-Jan-04	Clariant 2001	FMC Tempest II	Air Assist			

NR = Not required - Tote sample is the same for both trucks

ATTACHMENT II: FLUID VISCOSITY DATA FORM

(Complete for Each Truck/Fluid Combination Tested)

OPERATOR ____________________ LOCATION ____________________ DATE ____________________

TRUCK MANUFACTURER AND TYPE ____________________ TRUCK SERIAL NUMBER ____________________

FLUID MANUFACTURER AND TYPE ____________________

OAT ____________ WIND SPEED ____________________

FLUID SAMPLE DATA

SAMPLE SOURCE	BOTTLE #	TIME FLUID APPLIED (HH:MM)	DENSITY			VISCOSITY 1			VISCOSITY 2		
			VOLUME (cc)	WEIGHT (g)	VALUE (g/cc)	DATE	TIME STARTED (HH:MM)	VALUE (mPa.s)	DATE	(TIME STARTED HH:MM)	VALUE (mPa.s)
Fluid Tote											
Truck tank											
Air Assist											
Conventional nozzle											

FLUID VISCOSITY MEASURED BY ____________________

ATTACHMENT 3: TEST EQUIPMENT

Test Equipment	**Status**
Test procedures	
Data Forms	
Clipboards	
Pencils	
Wiper rags	
Fluid sample containers with labels	
Plastic or apparatus to lift fluid samples from wing	
Viscometer equipment, including centrifuge and syringe	
Weigh Scale	
Temperature probe	
Duct Tape	
Funnels	
Test Site Requirements	
Level Table(s) (minimum 6 feet by 2.5 feet)	
Chair	
Electricity	
Hot Water	
Heated Room (20°C), if possible	
Nighttime Facility Access	