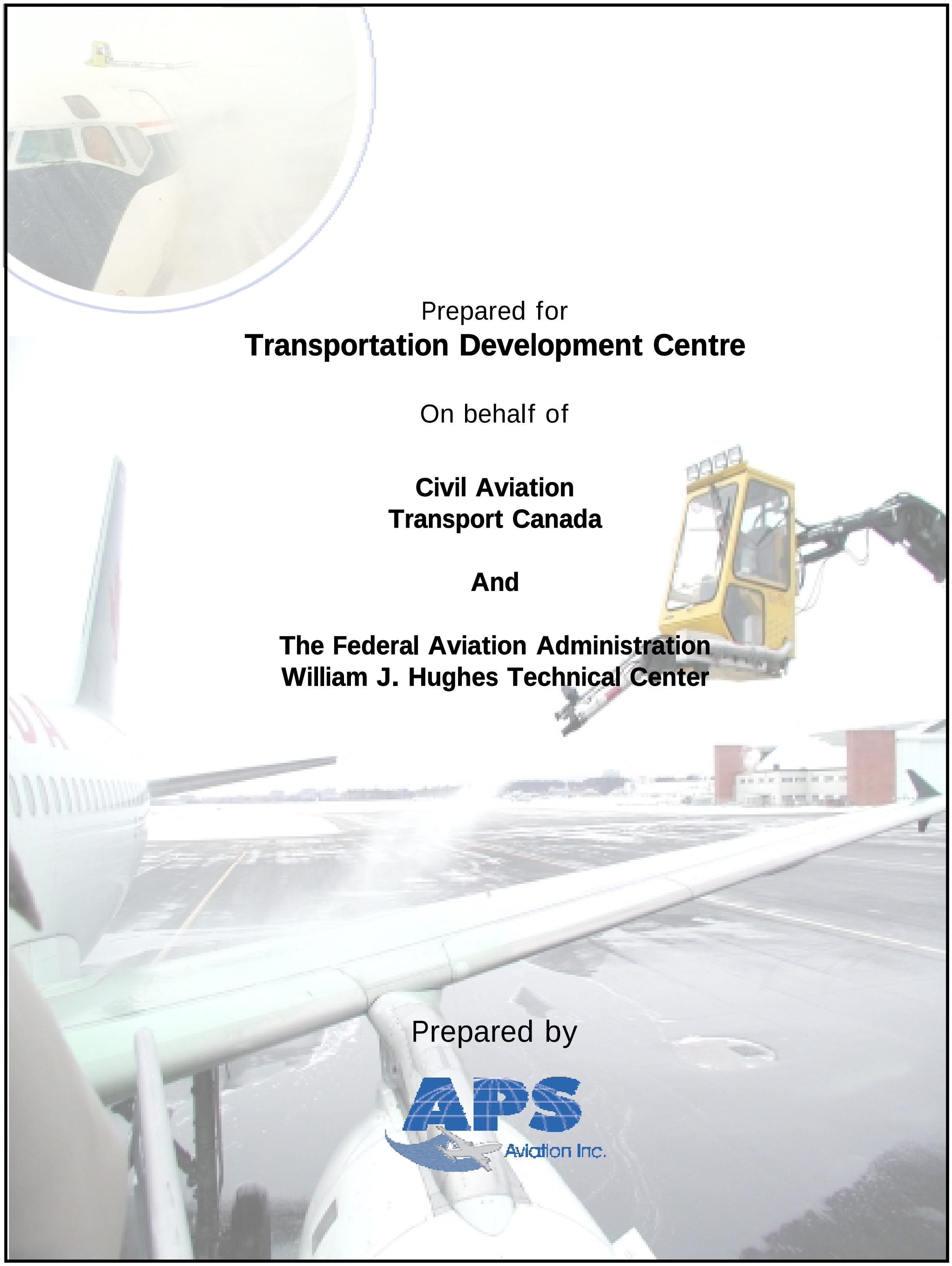
TP 14153E

Endurance Times of Fluids Applied with Forced Air Systems



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Transportation Development Centre

On behalf of

Civil Aviation
Transport Canada

And

The Federal Aviation Administration
William J. Hughes Technical Center

Prepared by

APS Aviation Inc.

October 2003
Final Version 1.0

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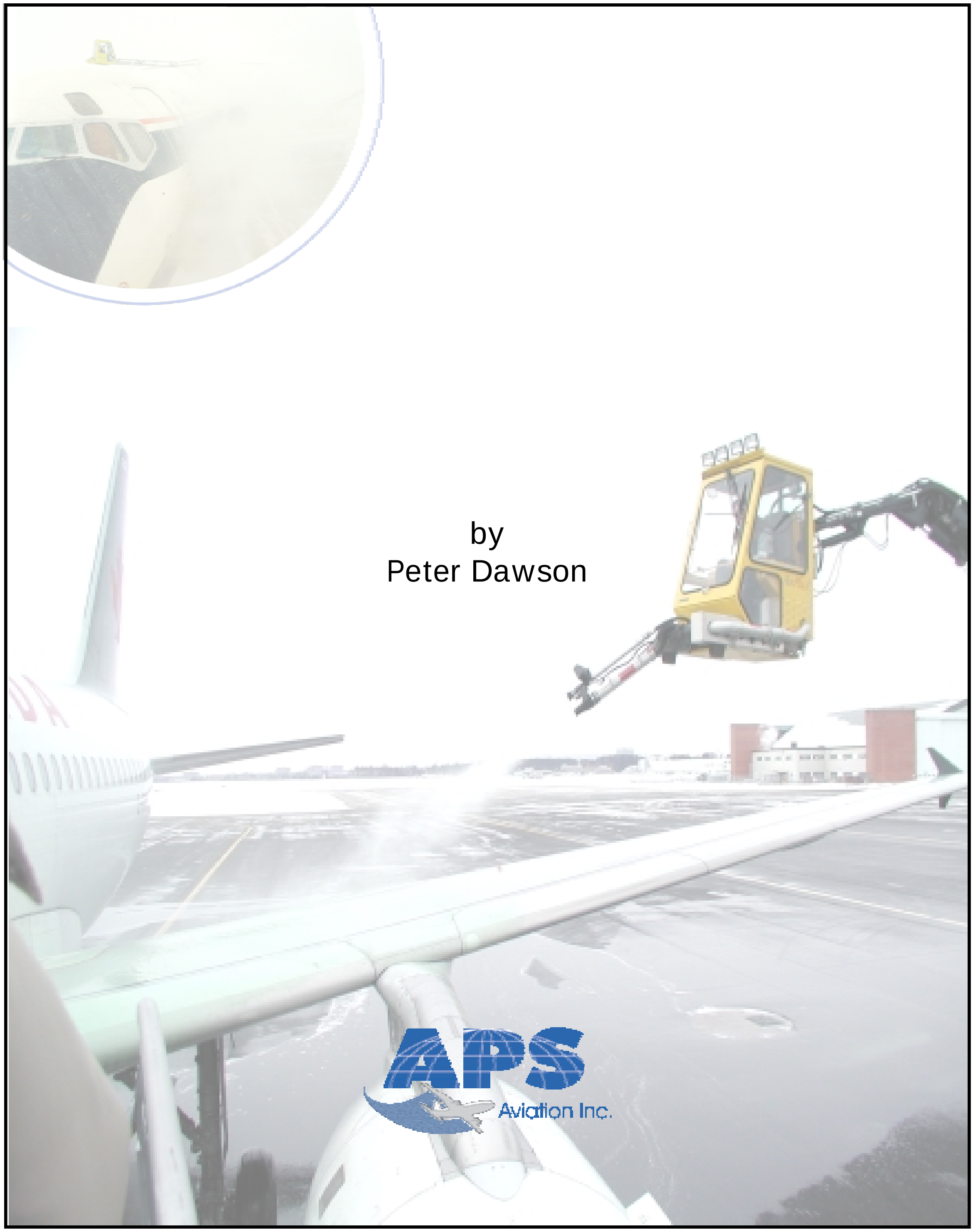

by
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Un sommaire français se trouve avant la table des matières.

PREFACE

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

- To develop holdover time data for all newly qualified de/anti-icing fluids;
- To evaluate the parameters specified in Proposed AS 5485 for frost endurance time tests in a laboratory;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To further evaluate the flow of contaminated fluid from the wing of an aircraft during simulated takeoff runs;
- To compare endurance times in natural snow with those in laboratory snow;
- To compare fluid endurance time, holdover time and protection time;
- To compare snowfall rates obtained using the National Center for Atmospheric Research hotplate with rates obtained using rate pans;
- To further analyse the relationship between snowfall rate and visibility;
- To stimulate the development of Type III fluids;
- To measure endurance times of fluids applied using forced air-assist systems;
- To conduct exploratory research, including measuring temperatures of applied Type IV fluids, measuring the effect of lag time on holdover time, evaluating the effectiveness of fluid coverage, and assessing the impact of taxi time on deicing holdover time; and
- To provide support services to Transport Canada.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2002-03 are documented in thirteen reports. The titles of the reports are as follows:

- TP 14144E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter;
- TP 14145E Laboratory Test Parameters for Frost Endurance Time Tests;
- TP 14146E Winter Weather Impact on Holdover Time Table Format (1995-2003);
- TP 14147E Aircraft Takeoff Test Program for Winter 2002-03: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid;
- TP 14148E Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2002-03;
- TP 14149E Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces;

- TP 14150E Evaluation of a Real-Time Snow Precipitation Gauge for Aircraft Deicing Operations;
- TP 14151E Relationship Between Visibility and Snowfall Intensity;
- TP 14152E A Potential Solution for De/Anti-Icing of Commuter Aircraft;
- TP 14153E Endurance Times of Fluids Applied with Forced Air Systems;
- TP 14154E Aircraft Ground Icing Exploratory Research for the 2002-03 Winter;
- TP 14155E Aircraft Ground Icing Research Support Activities for the 2002-03 Winter; and
- TP 14156E Variance in Endurance Times of De/Anti-icing Fluids.

This report, TP 14153E has the following objective:

- To determine whether the test procedure that examines the use of holdover time guidelines for forced-air assist applications of SAE Type II/IV fluid should include the measurement of endurance times.

To satisfy this objective, participation was sought from operators interested in this use of forced air systems. Operators who volunteered collected samples of fluids sprayed with air-assist and with the conventional method of application. The samples were subsequently measured for viscosity, density and endurance time.

ACKNOWLEDGEMENTS

This research has been funded by Transport Canada with support from the U.S. Federal Aviation Administration, William J. Hughes Technical Center. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Civil Aviation Group and the Transportation Development Centre of Transport Canada, the U.S. Federal Aviation Administration, National Research Council Canada, the Meteorological Service of Canada, and several fluid manufacturers. Special thanks are extended to US Airways Inc., Federal Express, American Eagle Airlines Inc., the National Center for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, Ottawa International Airport Authority, GlobeGround North America, and Dow Chemical Company for provision of personnel and facilities and for their co-operation with the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Alia Alwaid, Stephanie Bendickson, Nicolas Blais, Richard Campbell, Mike Chaput, Sami Chebil, John D'Avirro, Peter Dawson, Caroline Duclos, Miljana Horvat, Luis Lopez, Bob MacCallum, Mark Mayodon, Chris McCormack, Nic Moc, Marco Ruggi, Sherry Silliker, Ben Slater, and Kim Vepsa.

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

16. Abstract

This report examines the need to include the measurement of endurance times when examining whether holdover time guidelines can be employed for forced air-assist applications of SAE Type II/IV fluid.

Samples of fluids sprayed with air-assist and with the conventional method of application were collected. The samples were measured for viscosity, density and endurance time.

The air-assist method in which the fluid nozzle was positioned over the forced air nozzle had little effect on the fluid viscosity, level of aeration, or fluid endurance times under the test conditions.

The air-assist method in which the fluid was injected into the forced air stream within the air nozzle resulted in a large reduction in fluid viscosity, a high level of aeration, and much-reduced endurance times.

It was concluded that measurement of fluid viscosity degradation adequately indicates that fluid endurance time has also been degraded, and that the current test method need not be augmented by including the measurement of actual endurance times for these configurations and fluid.

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

16. Résumé

Le présent rapport examine la nécessité d'inclure la mesure de l'endurance des liquides dans la méthode d'essai conçue pour déterminer si les tableaux des durées d'efficacité peuvent être utilisés pour les liquides de type II ou de type IV de la SAE appliqués à l'aide d'un système à air forcé.

Des échantillons de liquides, appliqués avec assistance pneumatique et selon la méthode classique, ont été recueillis et soumis à des essais de viscosité, de densité et d'endurance.

La méthode pneumatique selon laquelle la buse à liquide était placée au-dessus de la buse à air forcé a eu peu d'effet sur la viscosité, le niveau d'aération et l'endurance du liquide, dans les conditions d'essai.

L'autre méthode pneumatique, selon laquelle le liquide était injecté dans la veine d'air forcé, à l'intérieur même de la buse, a entraîné une baisse importante de la viscosité du liquide, un niveau élevé d'aération et une diminution marquée de l'endurance.

Il a été conclu que la mesure de la dégradation de la viscosité du liquide constitue une bonne indication que son endurance s'est aussi dégradée, et qu'il n'est pas nécessaire d'ajouter à la méthode d'essai actuelle la mesure de l'endurance réelle, pour les configurations et les liquides étudiés.

17. Mots clés Endurance, durée d'efficacité, système à air forcé, application pneumatique de liquide, dégivrage, viscosité du liquide, vaporisation	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) has undertaken research activities, co-sponsored by the U.S. Federal Aviation Administration (FAA), to further advance aircraft ground de/anti-icing technology.

This study explores the need to include the measurement of endurance times in the test procedure and examines the use of holdover time (HOT) guidelines for forced air-assist applications of the Society of Automotive Engineers, Inc (SAE) Type II/IV fluid. The study is based on results from endurance time testing on samples of SAE Type II/IV fluids that had been sprayed with the assistance of forced air systems.

Forced Air Systems

In response to deicing operator requests, deicing vehicle manufacturers have incorporated forced air deicing systems. These systems are generally designed to deliver a stream of air either with or without fluid. Both SAE Type I and Type II/Type IV fluids can be delivered with the air-assist capability of various deicing trucks.

Some previous testing was conducted on forced air systems to identify any safety problems that might arise from their use in field operations (see TC report TP 13664E, *Safety Issues and Concerns of Forced Air Deicing Systems).*

Test Procedures for Forced Air-Assist Fluid Applications

At the 2001 annual meeting of the SAE G-12 Aircraft Ground Deicing Equipment Subcommittee, a need was identified for an official process whereby operators could test the use of forced air-assist in certain deicing applications and, based on successful outcomes, request approval from regulatory authorities to use the forced air deicing systems in operator deicing programs. A Forced Air Working Group was established to develop test procedures.

The subcommittee requested the cooperation and assistance of TDC and the FAA Technical Centre 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.

Of the various potential applications, the working group gave priority to developing a test procedure to learn whether HOT guidelines can be used when

Type II or Type IV fluid is either sprayed over or injected into the forced air stream. A test procedure, intended for use by interested operators, and an approval process were developed.

The examination of whether Type I fluid, when sprayed over or injected into forced air, can be used as the first step when followed by a second-step application of Type II or Type IV fluid was given second priority. A test procedure for this application was also developed. This procedure is intended for use by operators to develop an understanding of the implications of using forced air in conjunction with Type I fluid for first-step deicing, and to decide whether the procedure should be implemented in their operation. Approval of regulatory authorities is not required for this decision.

Development of test procedures/approval processes for other potential uses of forced air systems has not yet been requested.

Approval to Use Holdover Time Guidelines for Air-Assist Type II or Type IV Fluid Application

The main operator interest in this use of forced air systems lies in the possibility of achieving an increased spray distance and improved distribution of Type II or Type IV fluids over the aircraft wing.

Forced air-assist for the Type II/IV fluid application can be provided in either of two ways:

a) The fluid nozzle can be placed above the forced air nozzle so that the fluid is carried on top of the air stream; or

b) The fluid nozzle can be placed to inject fluid directly into the air stream so that the fluid is mixed with and carried within the air stream.

Test and Approval Process

The approval process requires that each combination of forced air deicing truck and Type II/IV fluid brand that interests an operator be tested individually.

Fluid is sprayed on aircraft wings, in dry conditions, using both the air-assist and conventional methods. Fluid samples are taken from the wing surface and viscosity and density are measured. The appearance of the fluid layer on the wing is assessed for consistency, and the thickness of the fluid layer is measured.

If the operator is satisfied, the results are submitted to the FAA and to TC with a request to use published HOT times for the specific combination of a forced air system and a fluid.

The test and approval process is founded on the principle that, if the quality of the fluid layer applied with forced air is equivalent to that of fluid applied with conventional nozzles, and if the fluid viscosity is not degraded below the fluid manufacturer's stated lowest on-wing viscosity, then the fluid application is suitable for the use of HOT guidelines.

FAA Request to Examine Fluid Endurance Times for Forced Air-Assist Applications

In November 2002, the FAA requested an examination of endurance times for Type II/IV fluids applied with forced air. The goal of this supplementary check was to see whether some aspect of the forced air-assist application not examined by the test procedure could degrade endurance times.

To find out, samples of fluids applied with forced air-assist were obtained from field operators, and tested for viscosity and fluid endurance. Operators known to have tested or to have a potential interest in using forced air-assist Type II or Type IV fluid application were contacted. Two operators, FedEx and US Airways, volunteered to participate by providing fluid samples.

Conclusions

It was concluded that:

a) The forced air-assist method in which the fluid nozzle is placed over or beside the forced air nozzle has little effect on the fluid viscosity, level of aeration or fluid endurance times under the test conditions for the forced air system and fluid brand tested;

b) The forced air-assist method in which the fluid is injected into the forced air stream within the air nozzle is unacceptable, as it results in a large reduction in fluid viscosity, a high level of aeration, and reduced endurance times;

c) The measurement of fluid viscosity degradation provides an adequate indication that fluid endurance time also has been degraded, and that the current test method need not be augmented by measuring actual endurance times for these configurations and fluid; and

d) The test/approval process should be modified as follows:

- Test data submitted to the FAA and TC for approval to employ HOT guidelines need include only the fluid viscosity test results (from air-assist and conventional applications, and from the truck tank), along with detailed information identifying the specific forced air system and fluid tested;

- Fluid viscosity should be measured at the test site immediately following fluid spray;

- Test fluid must be sprayed on an actual wing surface, not a substitute surface; and

- Operators can use test procedure data on the thickness and appearance of the fluid layer on the wing, to decide whether this method of application is acceptable in their deicing operation.

SOMMAIRE

À la demande du Centre de développement des transports (CDT) de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris un programme de recherche, coparrainé par la Federal Aviation Administration (FAA) des États-Unis, visant à faire progresser la technologie du dégivrage et de la protection contre le givre des avions au sol.

La présente étude se penche sur la nécessité d'inclure la mesure de l'endurance des liquides dans la méthode d'essai visant à vérifier la validité des tableaux des durées d'efficacité dans le cas où un liquide de type II ou de type IV de la SAE est appliqué à l'aide d'un système à air forcé. L'étude est fondée sur les résultats d'essais d'endurance réalisés sur des échantillons de liquides de type II et de type IV de la SAE (Society of Automotive Engineers, Inc), qui avaient été vaporisés à l'aide de systèmes à air forcé.

Systèmes à air forcé

En réponse à des demandes de responsables du dégivrage, les constructeurs de véhicules de dégivrage ont monté des systèmes à air forcé sur leurs véhicules. Ces systèmes sont généralement conçus pour souffler de l'air ou un mélange d'air et de liquide. Les systèmes à air forcé que l'on trouve sur divers modèles de camions de dégivrage conviennent à l'application des liquides de type I et de types II/IV de la SAE.

Des essais avaient déjà été menés sur des systèmes à air forcé, afin de déterminer les risques que pourrait représenter l'utilisation de ces systèmes en service réel (voir le rapport TP 13664E de TC, *Safety Issues and Concerns of Forced Air Deicing Systems*).

Méthode d'essai pour l'application pneumatique de liquides

À sa réunion annuelle de 2001, le sous-comité G-12 de la SAE sur les systèmes de dégivrage au sol a reconnu la nécessité d'établir un processus formel pour donner aux exploitants de services de dégivrage la possibilité d'utiliser, à l'essai, un système à air forcé dans certaines applications de dégivrage, et pour demander ensuite, forts de résultats concluants, l'autorisation des organismes de réglementation d'utiliser ces systèmes dans leurs programmes de dégivrage. Un groupe de travail sur les systèmes à air forcé a été mis sur pied, avec le mandat d'élaborer une méthode d'essai.

Le sous-comité a demandé au CDT et au centre technique de la FAA de collaborer à l'élaboration d'une méthode d'essai formelle et à l'instauration d'un

processus d'approbation, pour certaines applications se prêtant à l'utilisation de systèmes à air forcé. Le CDT et la FAA ont accepté de collaborer, chargeant APS de coopérer avec le groupe de travail sur les systèmes à air forcé.

Parmi les multiples utilisations potentielles des systèmes à air forcé, le groupe de travail a choisi de s'intéresser en priorité aux liquides de type II ou de type IV vaporisés au-dessus de la veine d'air ou injectés dans celle-ci. Il a donc élaboré une méthode d'essai et un processus d'approbation, à l'intention des exploitants intéressés.

La deuxième priorité du groupe de travail était de déterminer si un liquide de type I, vaporisé au-dessus de la veine d'air ou injecté dans celle-ci, peut être utilisé pour la première étape d'une procédure de dégivrage en deux étapes, dont la deuxième consiste à appliquer un liquide de type II ou de type IV. Il a aussi élaboré une méthode d'essai pour cette application. Par cette méthode, les responsables du dégivrage devraient être en mesure de cerner les effets de l'utilisation d'air forcé avec un liquide de type I à la première étape d'une procédure de dégivrage en deux étapes, et de décider s'ils devraient mettre en oeuvre cette procédure. Cette décision n'est pas sujette à l'approbation des organismes de réglementation.

Personne n'a encore demandé que des méthodes d'essai/processus d'approbation soient élaborés pour d'autres utilisations potentielles des systèmes à air forcé.

Autorisation d'utiliser les lignes directrices sur les durées d'efficacité dans les cas d'application pneumatique d'un liquide de type II ou de type IV

La principale raison pour laquelle les exploitants de services de dégivrage s'intéressent aux systèmes à air forcé est qu'ils permettent de vaporiser plus loin et de mieux répartir les liquides de type II ou de type IV sur la surface de l'aile.

L'application pneumatique de liquides de type II ou de type IV peut prendre deux formes :

a) la buse à liquide est placée au-dessus de la buse à air forcé, et le liquide voyage au-dessus de la veine d'air;

b) la buse à liquide est placée de façon à injecter le liquide directement dans la veine d'air : le liquide se mélange à la veine d'air, et il voyage à l'intérieur de celle-ci.

Processus d’essai et d’approbation

Le processus d’approbation exige que chaque combinaison de camion de dégivrage à air forcé et marque de liquide de type II ou de type IV susceptible d’intéresser l’exploitant soit mise à l’essai individuellement.

Voici en quoi consiste la méthode d’essai : vaporiser le liquide sur des ailes d’avion propres, en l’absence de précipitations, à l’aide d’un système à air forcé et selon la méthode classique. Prélever des échantillons de liquide sur la surface de l’aile pour en mesurer la viscosité et la densité. Évaluer la consistance de la couche de liquide sur l’aile, selon son apparence, et en mesurer l’épaisseur.

Si l’exploitant juge les résultats satisfaisants, il soumet ceux-ci à la FAA et à TC, avec une demande d’utiliser les durées d’efficacité publiées, pour la combinaison spécifique de système à air forcé et de liquide.

Le processus d’essai et d’approbation est fondé sur le principe selon lequel, si la qualité de la couche de liquide appliquée à l’aide d’un système à air forcé est équivalente à celle d’un liquide appliqué avec des buses classiques, et si la viscosité du liquide n’est pas diminuée au point de ne plus respecter la viscosité minimale sur l’aile établie par le fabricant du liquide, alors le mode d’application du liquide permet l’utilisation des lignes directrices sur les durées d’efficacité.

Demande de la FAA d’examiner l’endurance de liquides appliqués avec assistance pneumatique

En novembre 2002, la FAA a demandé que l’on examine l’endurance des liquides de type II ou de type IV appliqués avec assistance pneumatique. Le but de cette vérification supplémentaire était de voir si une variante de l’application pneumatique, non couverte par la méthode d’essai, pouvait réduire l’endurance.

Pour répondre à cette question, des échantillons de liquides appliqués par la méthode pneumatique ont été obtenus d’exploitants de services de dégivrage, et soumis à des essais de viscosité et d’endurance. Les exploitants reconnus pour avoir essayé l’application de liquides de type II ou de type IV à l’aide de systèmes à air forcé, ou pour être intéressés à utiliser de tels systèmes, ont été contactés. Deux exploitants, FedEx et US Airways, ont accepté de fournir des échantillons de liquides.

Conclusions

Il a été conclu ce qui suit :

a) la méthode à air forcé dans laquelle la buse de vaporisation du liquide est placée au-dessus ou à côté de la buse à air forcé a peu d'effet sur la viscosité, le niveau d'aération et l'endurance du liquide, dans les conditions d'essai (système à air forcé et marque de liquide);

b) la méthode à air forcé dans laquelle le liquide est injecté dans la veine d'air à l'intérieur même de la buse à air est inacceptable, car elle entraîne une diminution importante de la viscosité du liquide, un niveau élevé d'aération et une diminution de l'endurance;

c) la mesure de la dégradation de la viscosité du liquide est une bonne indication que l'endurance du liquide s'est aussi dégradée, et qu'il n'est pas nécessaire d'intégrer à la méthode d'essai actuelle une mesure de l'endurance réelle pour ces configurations et ces liquides;

d) la méthode d'essai/approbation devrait être modifiée comme suit :

- les données d'essai soumises à la FAA et à TC pour l'obtention de l'autorisation d'utiliser les lignes directrices sur les durées d'efficacité doivent comprendre uniquement les résultats d'essais de viscosité des liquides (appliqués selon une méthode pneumatique et selon la méthode classique, et puisés dans la citerne du camion), assortis d'information détaillée concernant le système à air forcé utilisé et le liquide essayés;

- la viscosité du liquide doit être mesurée au site d'essai immédiatement après la vaporisation du liquide;

- le liquide d'essai doit être vaporisé sur une surface d'aile en vraie grandeur, et non sur une surface de substitution;

- les exploitants peuvent utiliser les données de la méthode d'essai concernant l'épaisseur et l'apparence de la couche de liquide sur l'aile, pour décider si cette méthode d'application est acceptable pour leurs programmes de dégivrage.

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GLOSSARY

APS	APS Aviation Inc.
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
NRC	National Research Council Canada
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers, Inc.
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), APS Aviation Inc. (APS) has undertaken research activities, co-sponsored by the U.S. Federal Aviation Administration (FAA), to further advance aircraft ground de/anti-icing technology.

1.1 Background

In response to deicing operator requests, deicing vehicle manufacturers have incorporated forced air deicing systems.

Operators are interested in forced air as an alternative approach to deicing, and foresee various ways of using forced air systems in the deicing process:

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

b) 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 (HOT) guidelines;

c) 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) 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) 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 HOT guidelines;

f) 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) 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.

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

1.2 Development of Test Methods for Forced Air-Assist Fluid Applications

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

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

The subcommittee requested the cooperation and assistance of TDC and the FAA Technical Centre 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.

Of the various potential applications, the working group gave priority to developing a test procedure to learn whether HOT guidelines can be used when Type II or Type IV fluid is either sprayed over or injected into the forced air stream. A test procedure, intended for use by interested operators, and an approval process were developed. The test procedure was reported in TC report TP 13999E, *Support Activities Related to Deicing Research for the 2001-02 Winter* (2), and is included as Appendix A.

The examination of whether Type I fluid, when sprayed over or injected into forced air, can be used as the first-step when followed by a second-step application of Type II or Type IV fluid was given second priority. A test procedure for this application was also developed. The goal is for operators to understand the implications of using forced air in conjunction with Type I fluid for first-step deicing, and to decide whether the procedure should be implemented. This decision does not require the approval of regulatory authorities.

Development of test procedures/approval processes for other potential uses of forced air systems has not yet been requested.

1.3 Approval to Use Holdover Time Guidelines for Forced Air-Assist Type II or Type IV Fluid Application

The main reason that operators are interested in this application of the forced air system lies in the possibility of achieving an increased spray distance and improved distribution of Type II or Type IV fluids over the aircraft wing. Photo 1.1 shows a typical configuration for an air-assist fluid application. In this photo, the air nozzle is the lower and larger pipe projecting forward from the operators cab. The Type II/IV fluid nozzle is placed on top of the air nozzle. Fluid is being sprayed over the air stream. The manufacturer has already found the best point of intersection of the two streams through testing, so the fluid stream converges with the air stream at about 1/3 of the distance from nozzle to wing.

The test procedure's goal was to provide an official process for examining whether SAE HOT guidelines can be used when SAE Type II or IV fluid is applied with the assistance of forced air.

Forced air-assist can be provided to Type II/IV fluid application in either of two ways:

a) The fluid nozzle is placed above the forced air nozzle, so that the fluid is carried on top of the air stream; or

b) The fluid nozzle is placed to inject fluid directly into the air stream, so that the fluid is mixed with and carried within the air stream.

1.3.1 Test and Approval Process

A standard test procedure, approved by the FAA, TC, and the Forced Air Working Group, was developed in October 2001. It intended for use by any operator interested in obtaining approval for SAE HOT guidelines when SAE Type II or IV fluid is applied with the assistance of forced air. The approval process requires that each combination of forced air deicing truck and Type II/IV fluid brand that interests an operator be tested individually. Below is a brief description of the approved test procedure (included in Appendix A):

a) Before testing, the operator develops forced air-assist spray techniques that satisfy the operator's goal, and verifies that forced air systems are operating within manufacturer specifications;

b) The operator then schedules a test session and invites observers from the FAA Technical Center and TDC;

c) The operator conducts tests on aircraft wings, examining results of fluid applications using both *forced air-assist* and *conventional* methods. Test conditions include spraying into the wind, and at the very least some tests are conducted with an outside air temperature (OAT) below freezing. Factors measured include:

- Fluid viscosity;
- Fluid density;
- Fluid thickness; and
- Graded appearance of fluid layer:
  - Ridged;
  - Patchy in colour;
  - Extent of aeration; and
  - Contaminated appearance.

d) If satisfied with the test results, the operator then submits the completed data forms and declaration of equipment conformity to FAA/TC, requesting approval to use HOT guidelines for that specific truck/fluid combination; and

e) FAA/TC approval depends on submitted results and applies solely to that specific truck/fluid combination.

The test and approval process is based on the principle that, if the quality of the fluid layer applied with forced air-assist is equivalent to that of fluid applied with conventional nozzles, and if the fluid viscosity is not degraded below the fluid manufacturer's stated lowest on-wing viscosity, then the fluid application is suitable for the use of HOT guidelines.

1.3.2 FAA Request to Examine Fluid Endurance Times for Forced Air-Assist Applications

In November 2002, the FAA requested an examination of endurance times for Type II/IV fluids applied with forced air-assist. The goal of this supplementary check was to see whether some aspect of the forced air-assist application not examined by the test procedure could degrade endurance times.

To find out, participation was sought from operators interested in this use of forced air systems. Operators who volunteered collected samples of fluids sprayed with forced air-assist and with the conventional method of application. The samples were subsequently measured for viscosity, density and endurance time.

This goal is reflected in the objectives outlined in the TDC work statement. An excerpt from the work statement is provided in Appendix B. Provision of support to the test activities as identified in the work statement depended on operator initiative. Support to the SAE Ground Equipment Subcommittee was provided at the annual subcommittee meeting.

Photo 1.1: Typical Application Type II/IV Over Forced Air

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2. METHODOLOGY

The test procedure is included as Appendix C. It consisted first of collecting fluid samples from field operators, and then testing them. These activities are described in this section.

2.1 Collecting Fluid Samples

Operators known to have tested or to have a potential interest in using forced air-assist Type II or Type IV fluid application were contacted and their participation sought in collecting and submitting fluid samples. Two operators, FedEx and US Airways, volunteered to participate.

Fluid collection data forms were provided to participants for completion, as shown in Figure 2.1. These are included in Appendix C.

Samples of fluid sprayed with forced air-assist and sprayed with conventional nozzles were requested. A quantity of 10 L was requested for each type of spray application, to enable several endurance tests to be conducted in both natural snow conditions outdoors and in freezing precipitation in the laboratory.

As well, a sample of unsprayed fluid from the truck tank was requested to serve as a base case for reference.

2.1.1 Forced Air Systems and Fluid Nozzles Used to Collect Fluid Samples

Both US Airways and FedEx used FMC LMD deicing vehicles. The installed forced air systems were identical, although the fluid nozzles were different. The manufacturer reported value for the system forced air pressure was 13 psi (90 kPa) and for the forced air flow rate, 100 lb/min (45 kg/min).

2.1.1.1 FedEx

Photo 2.1 shows a variety of nozzles available for use with the FMC forced air system, but points out the nozzle used by FedEx for anti-icing fluid carried by the air stream. This was a Task Force Tips #BER-HT 120HV nozzle rated at 20 to 25 gal/min (75 to 95 L/min) at 50 psi (345 kPa). The spray pattern is adjustable, from solid-stream to fan-shape, and is adjusted remotely via the fluid nozzle control box shown in the photo.

Photo 2.2 shows the nozzle used by FedEx for injecting fluid directly into the air stream. It produces a flow rate variable from 0 to 15 gal/min (0 to 57 L/min). This nozzle can be used to inject either deicing or anti-icing fluid.

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: ____/____/____ (day/month/year) Time: ____:____

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. There should be some mention on the packing slip of the contents of the shipment (and possibly state that there is no commercial value to the samples).

SHIPPING ADDRESS:
APS Aviation Inc.
1100 René Lévesque Ouest, Suite 1340
Montréal (Québec) CANADA H3B 4N4
Phone: 514 878-4388

AFFILIATED CUSTOM BROKER:
Charles Higgerty Limited
Phone: 514 636-3926

Figure 2.1: SAE Type II/IV Fluid Sample Data Form

Photo 2.3 shows the actual configuration of the air and fluid nozzles on the FedEx deicing truck. The fluid nozzle was mounted beside the air nozzle, as opposed to above it. FedEx plans to change this configuration by mounting the fluid nozzle above the air nozzle thus conforming to manufacturers recommendations and to the practice of other operators.

2.1.1.2 US Airways

Photo 2.4 shows the variety of nozzles available for use with the FMC forced air system, but here points out the nozzle used by US Airways for anti-icing fluid carried by the air stream. This is a straight pipe nozzle, produced by FMC, and rated at 20 to 25 gal/min (75 to 95 L/min) at 50 psi (345 kPa). Its spray pattern is fixed as a solid stream.

Photos 2.5 and 2.6 show the actual nozzle configuration on the US Airways deicing truck. The Type IV nozzle is the narrow pipe mounted at the 1 o'clock position on the forced air nozzle, to the right (as seen from the front) and slightly behind the larger, adjustable Type I nozzle.

2.1.2 FedEx Fluid Collection

FedEx collected its fluid samples on February 10, 2003, at Rochester airport in New York. A FedEx representative oversaw the spraying and fluid collection. An FMC representative assisted.

The original FedEx plan for collecting fluid was to drape plastic over an aircraft wing, spray the fluid and by carefully folding the plastic, lift samples directly from the wing. However, as it was snowing when the team arrived in Rochester, the operation was moved inside a warehouse. Inside air temperature was about 7ºC (45ºF), but the deicing vehicle, along with the fluid in its tanks, was cold-soaked at -8ºC (17ºF).

A catch basin was constructed of wooden beams laid in a square on the concrete floor and overlaid with plastic sheeting.

The deicing vehicle was placed so that the operator and spray nozzle were at a distance from and at an angle to the catch-basin target typical of an actual operation. The fluid was sprayed onto the plastic, and then collected into sterile sample containers. New plastic sheeting was installed for each fluid sample collected. Each sample bottle was numbered and labelled to indicate the type of application.

FedEx collected samples for several variations on the fluid application method:

a) Fluid sprayed from a conventional Type IV fluid nozzle;
b) Fluid sprayed beside the air stream – air stream at full airflow;
c) Fluid sprayed beside the air stream – air stream at 1/2 airflow;
d) Fluid injected into the air stream – air stream at full airflow;
e) Fluid injected into the air stream – air stream at 1/2 airflow; and
f) Fluid injected into the air stream – air stream at 1/3 airflow.

As well, a fluid sample was taken from the truck tank.

The fluid was 100 percent strength in all cases.

2.1.3 US Airways Fluid Collection

US Airways collected fluid samples on February 12, 2003, at Boston's Logan International Airport.

Samples were collected for two variations on the fluid application method:

a) Fluid sprayed from a conventional Type IV fluid nozzle; and

b) Fluid sprayed over the air stream with the air stream at full airflow.

As well, a fluid sample was taken from the truck tank.

2.2 Fluid Sample Test Procedure

2.2.1 Test Sites and Personnel

When APS received the fluid samples, the fluid containers were inventoried and labelled for test control (Photo 2.7). As it happened, operators used the same SAE Type IV Fluid brand, Lyondell/Clariant Safewing MP IV 2001. The fluid was applied at full strength as delivered from the manufacturer.

An APS technician measured viscosity and density.

Two APS technicians conducted endurance tests.

Tests in natural snow outdoors were conducted at the APS test site at Montreal International Airport in Dorval (Photo 2.8).

Endurance times in selected conditions of freezing precipitation were measured at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa (Photo 2.9).

2.2.2 Test Procedures

2.2.2.1 Measuring fluid sample viscosity

The viscosity of the received samples was measured using a Brookfield Digital Viscometer Model DV-I + (Photo 2.10) in accordance with fluid manufacturers' guidelines. Both the centrifuged fluid and the fluid in an "as received" condition were measured.

The viscometer, along with other APS measurement instruments and test equipment, is calibrated/verified on an annual basis. This calibration is carried out according to a calibration plan based on approved ISO 9001 standards and developed internally by APS.

2.2.2.2 Measuring fluid sample density

Fluid density was measured to gauge the extent of aeration of the various samples. Density was calculated using the weight of a fixed volume of each fluid sample. Both centrifuged fluid and fluid in the "as received" condition were measured.

2.2.2.3 Measuring fluid endurance

Endurance times were measured in natural snow and in artificial freezing precipitation. Standard SAE Type II/IV test methodology was followed, using standard test equipment.

2.2.3 Test Plans

Figure 2.2 shows test plans for the fluid samples received from FedEx and Figure 2.3 shows the fluid samples received from US Airways.

Lyondell Safewing MP IV 2001 Type IV Fluid

Fluid Sample Bottle Numbers	Fluid Application Type	Fluid Flow Rate (L/min)
1	Tank	
2-10	Conventional nozzle	83
11-19	Over air, full airflow	83
20-28	Injected, ½ air flow	45
29-37	Over air, ½ airflow	83
38-46	Injected, full air flow	45
47-50	Injected, 1/3 air flow	45

	Density and Viscosity Tests	Endurance Test #'s					
Test Location	APS Office	APS Site	NRC				
		Natural Snow*	ZD -3ºC 13 g/dm²/h	ZD -10ºC 13 g/dm²/h	ZR -3ºC 25 g/dm²/h	ZR -10ºC 25 g/dm²/h	Fog -25ºC 5 g/dm²/h
Bottle Numbers	1	51			52		
	2	3,4,5	6	7	8	9	10
	11	12,13,14	15	16	17	18	19
	20	21,22,23	24	25, 28	26	27	
	29	30,31,32	33	34	35	36	37
	38	39,40,41	42	43, 46	44	45	
	47	48,49			50		

*Natural Snow: Run #1: Test 51, 3, 12, 21, 30, 39, and 48 simultaneously
Run #2: Test 4, 13, 22, 31, 40 and 49 simultaneously
Run #3: Test 5, 14, 23, 32, and 41 simultaneously

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Figure 2.2: Test Plan for FedEx Fluid Samples

Lyondell Safewing MP IV 2001 Type IV Fluid

Fluid Sample Bottle Numbers	**Fluid Application Type**	**Fluid Flow Rate (L/min)**
U1	Tank	75 - 95
U2-U11	Conventional nozzle	75 - 95
U12-U21	Over air, full airflow	75 - 95

	Density and Viscosity Tests	**Endurance Tests**					
Test Location	APS Office	APS Site	NRC				
		Natural Snow*	ZD -3ºC 13 $g/dm^2/h$	ZD -10ºC 13 $g/dm^2/h$	ZR -3ºC 25 $g/dm^2/h$	ZR -10ºC 25 $g/dm^2/h$	Fog -25ºC 5 $g/dm^2/h$
Bottle Numbers	U1						
Bottle Numbers	U2	U3,U4, U5,U6	U7	U8	U9	U10	U11
Bottle Numbers	U12	U13, U14, U15, U16	U17	U18	U19	U20	U21

CM1747/Reports/Forced Air/Figures/Figure 2.3.doc

*Natural Snow: Run #1: Test U3 and U13 simultaneously
Run #2: Test U4 and U14 simultaneously
Run #3: Test U5 and U15 simultaneously
Run #4: Test U6 and U16 simultaneously

Figure 2.3: Test Plan for US Airways Fluid Samples

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Photo 2.1: Fluid Nozzles Used by FedEx
(shown with a variety of nozzles available for FMC forced air system)

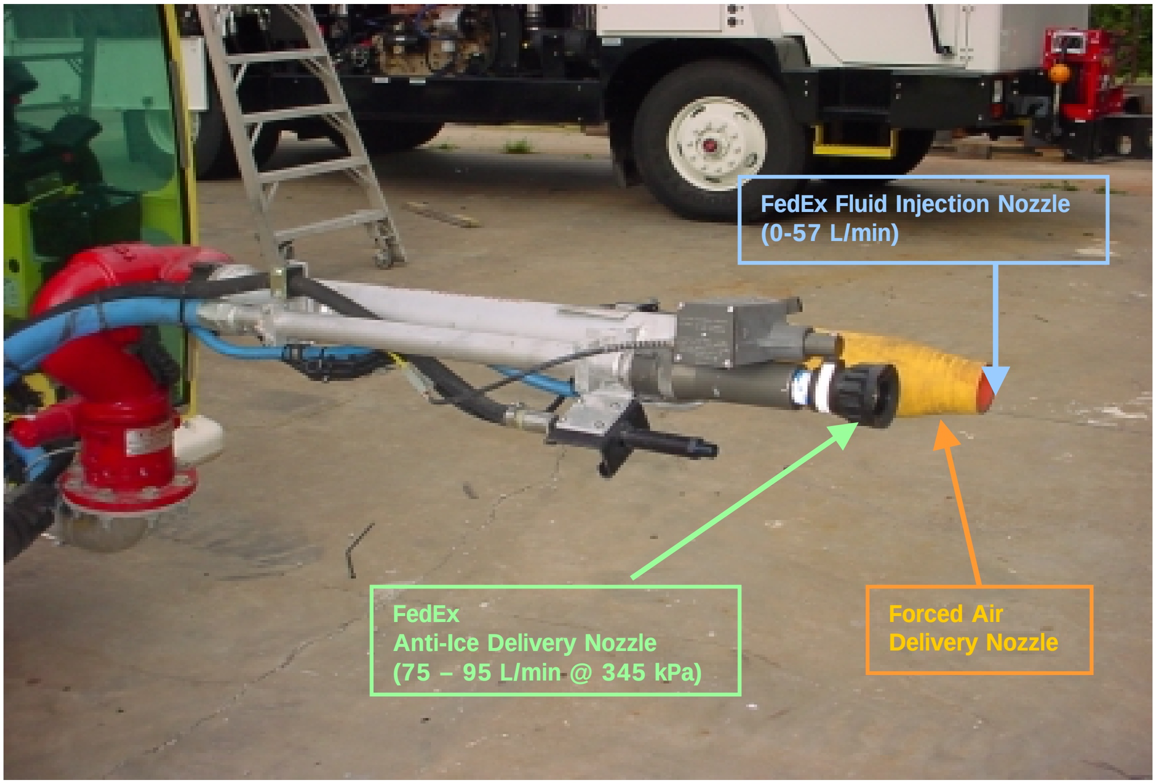
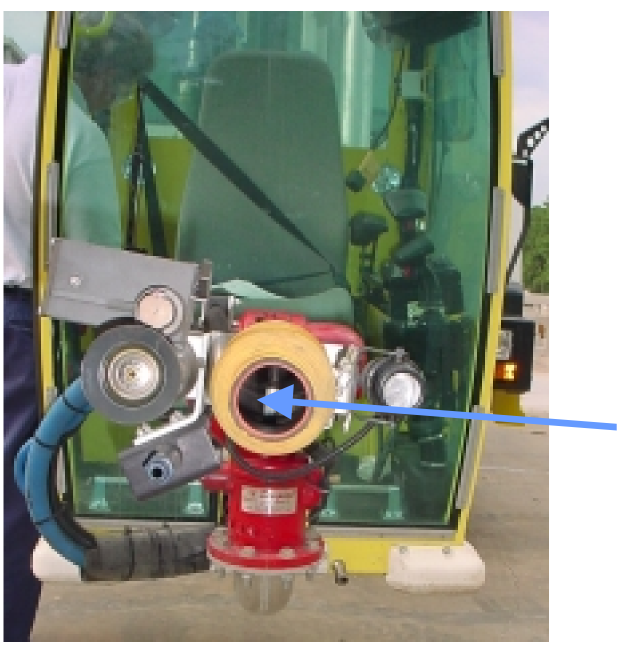


Photo 2.2: Detail of Fluid Injection Nozzle used by FedEx
(shown with a variety of nozzles available for FMC forced air system)



Forced Air Delivery Nozzle with Fluid Injection Nozzle Inside (0 – 57 L/min) Deice/Anti-Ice Selectable

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Photo 2.3: FedEx Forced Air Configuration

Photo 2.4: Fluid Nozzle Used by US Airways
(shown with a variety of nozzles available for FMC forced air system)

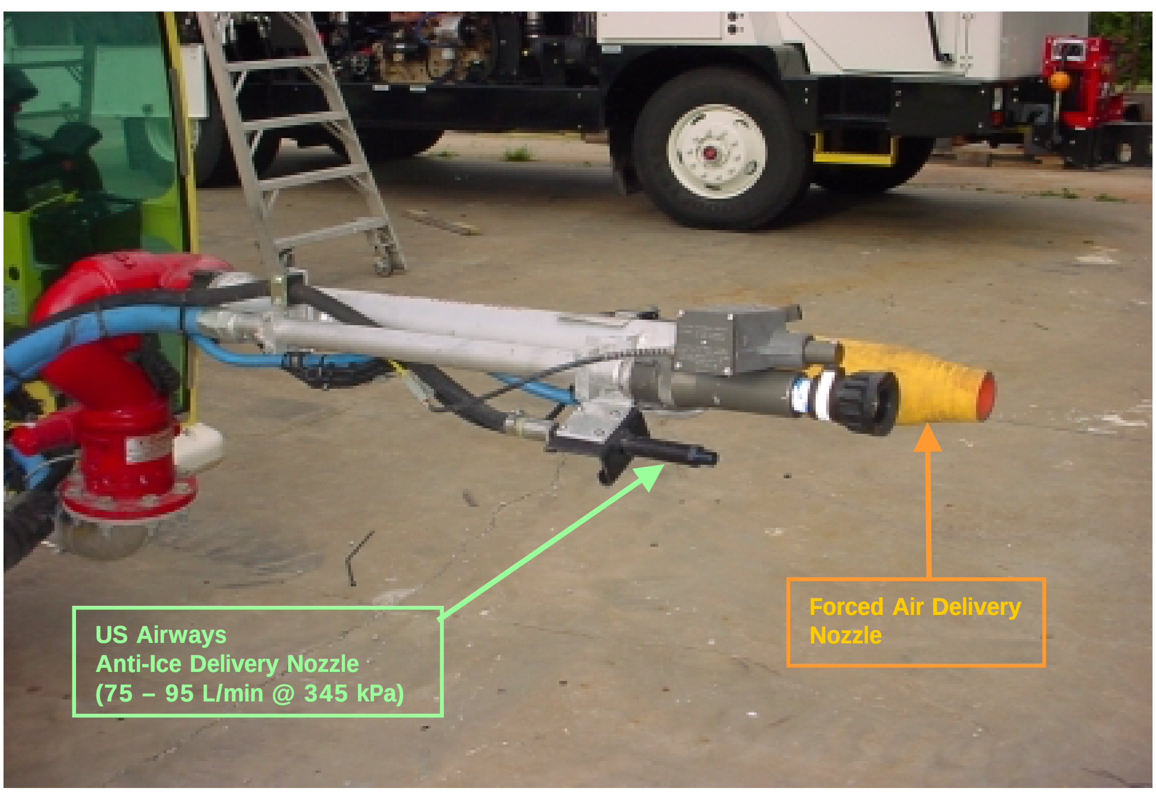

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Photo 2.5: US Airways – Forced Air Configuration – View 1

Photo 2.6: US Airways – Forced Air Configuration – View 2

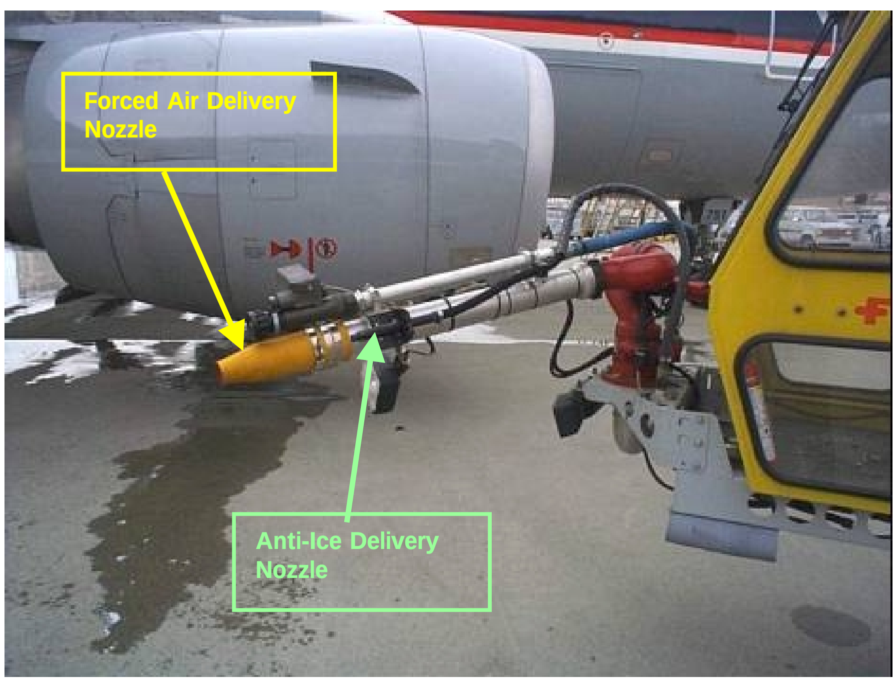

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Photo 2.7: Fluid Containers Labelled for Test Control

Photo 2.8: APS Test Site at Dorval Airport

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Photo 2.9: Outdoor View of National Research Council Canada Facility

Photo 2.10: Brookfield Digital Viscometer Model DV-I +

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3. DESCRIPTION AND PROCESSING OF DATA

3.1 Viscosity and Density Measurement Data

Table 3.1 shows results of viscosity and density measurement. In Section 4, bar charts based on this data are provided and the results discussed. Values in the columns labelled *standardized* are percentages of the absolute value reported for the conventional nozzle. US Airways data is compared to the US Airways conventional nozzle value, and FedEx data is compared to the FedEx conventional nozzle value.

3.2 Fluid Endurance Data

Table 3.2 shows the endurance times measured for various precipitation conditions tested. Four test runs in natural snow were conducted, with ambient temperatures and precipitation rates as shown. Tests in artificial freezing precipitation were conducted as planned, and the test temperatures and precipitation rates are shown. The table also reports values for fluid sample viscosity measured when the fluid samples were received.

Table 3.3 presents endurance times for forced air-assist and injected fluid application samples normalized against the conventional fluid application sample. It can be quickly seen that times from the *forced air-assist* samples are similar to those from the conventional application, whereas times from the *injected* samples are much lower. This table also compares sample fluid viscosities with the conventional application sample and with the tank sample. The comparison is similar to that of endurance times.

Bar charts based on this data are provided and results discussed in Chapter 4.

The production range for the Clariant Type IV 2001 fluid is typically between 20,000 mPa.s to 30,000 mPa.s.

Table 3.1: Fluid Sample Viscosity and Density

	Viscosity When Received (mPa.s)		Percentage of Conventional Nozzle (%)	Viscosity of Fluid After Two Months (Centrifuged) (mPa.s)	Percentage of Conventional Nozzle (%)	Density When Received (kg/m^3)		Percentage of Conventional Nozzle (%)
Sample	Not Centrifuged	Centrifuged	Centrifuged	Centrifuged	Centrifuged	Not Centrifuged	Centrifuged	Not Centrifuged
Tank (U)	31,000	30,600	105%	27,200	93%	1,008	1,032	106%
Conventional Nozzle (U)	30,400	29,200	100%	26,800	92%	950	1,035	100%
Air Assist (U)	28,400	26600	91%	23,000	79%	939	1,035	99%
Tank (F)	32,600	29,600	116%	25,800	101%	1,004	1,033	106%
Conventional Nozzle (F)	28,600	25,600	100%	21,400	84%	945	1,033	100%
Over Air, Full Airflow (F)	27,800	26,400	103%	18,800	73%	904	1,036	96%
Over Air, 1/2 Airflow (F)	28,200	26,400	103%	21,200	83%	971	1,035	103%
Injected, Full Airflow (F)	15,400	13,000	51%			877	1,036	93%
Injected, 1/2 Airflow (F)	16,400	15,400	60%			755	1,036	80%
Injected, 1/3 Airflow (F)	16,900	19,100	75%			858	1,032	91%

Note: Injected, 1/3 originally run twice, avg shown
Injected, 1/3 run 1 17,400 20,000
Injected, 1/3 run 2 16,400 18,200
Viscosity procedure in accordance with manufacturer guidelines

Table 3.2: Endurance Times for Type IV Fluid Applied with Forced Air

Weather			Operator	Endurance Time (minutes)						
						Air Assist		Inject		
Type	Temp (ºC)	Rate ($g/dm^2/h$)		Tank Sample	Conv'l Nozzle	Full Airflow	1/2 Airflow	Full Airflow	1/2 Airflow	1/3 Airflow
Snow	-6	13	FedEx	75	63	58	62	45	50	55
			USAirways		78	74				
	0	19	FedEx		62	50	60	33	34	48
			USAirways		64	60				
	-8	6	FedEx		116	115	110		75	
			USAirways		116	114				
	-8	5	FedEx							
			USAirways		113	96				
ZR	-3	25	FedEx	60	40	34	40	23	27	31
			USAirways		47	45				
	-10	25	FedEx		23	23	25	17	21	
			USAirways		30	30				
ZD	-3	13	FedEx		57	42	55	33	35	
			USAirways		62	58				
	-10	13	FedEx		41	40	42	29	33	
			USAirways		55	56				
Freezing fog	-25	5	FedEx		28	30	31			
			USAirways		36	35				
Fluid viscosity (mPa.s)			FedEx	29600	25600	26400	26400	13000	15400	19100
			USAirways	30600	29200	26600				

CM1747/Reports/Forced Air/Tables/Forced Air Endurance Times vs. Hot.xls
AT: Results wo Hot

Table 3.3: Endurance Times for Forced Air Applications Compared to Conventional Nozzle

Weather			Operator	Tank Sample	Conv'l Nozzle	Air Assist		Inject		
Type	**Temp (ºC)**	**Rate ($g/dm^2/h$)**				**Full Airflow**	**1/2 Airflow**	**Full Airflow**	**1/2 Airflow**	**1/3 Airflow**
Snow	-6	13	FedEx		1.00	0.92	0.98	0.71	0.79	0.87
			USAirways		1.00	0.95				
	0	19	FedEx		1.00	0.81	0.97	0.53	0.55	0.77
			USAirways		1.00	0.94				
	-8	6	FedEx		1.00	0.99	0.95		0.65	
			USAirways		1.00	0.98				
	-8	5	FedEx							
			USAirways		1.00	0.85				
ZR	-3	25	FedEx		1.00	0.85	1.02	0.57	0.67	0.77
			USAirways		1.00	0.95				
	-10	25	FedEx		1.00	1.00	1.11	0.75	0.93	
			USAirways		1.00	0.98				
ZD	-3	13	FedEx		1.00	0.74	0.98	0.58	0.61	
			USAirways		1.00	0.94				
	-10	13	FedEx		1.00	0.97	1.01	0.71	0.79	
			USAirways		1.00	1.02				
Freezing fog	-25	5	FedEx		1.00	1.06	1.12			
			USAirways		1.00	0.97				
Fluid viscosity compared to conventional nozzle			FedEx		1.00	1.03	1.03	0.51	0.60	0.75
			USAirways		1.00	0.91				
Fluid viscosity compared to tank sample			FedEx	1.00	0.86	0.89	0.89	0.44	0.52	0.65
			USAirways	1.00	0.95	0.87				

CM1747/Reports/Forced Air/Tables/Forced Air Endurance Times vs. Hot.xls
AT: Results wo Hot

4. ANALYSIS AND OBSERVATIONS

Results of the various tests are charted and discussed in this section.

4.1 Fluid Viscosity

Fluid viscosity was recorded when the samples were first received and again following the tests in artificial freezing precipitation.

4.1.1 Fluid Viscosity of Samples in "As Received" Condition

Figure 4.1 charts the fluid viscosity values measured for the various fluid samples when they were first received (mid-February 2003). Viscosity was measured with centrifuged fluid, in accordance with standard procedures, and also non-centrifuged fluid in an "as received" condition. Both values are shown in the chart, although the values for centrifuged fluid are more significant than those of non-centrifuged fluid.

The sources of fluid samples are shown on the x-axis, with operators identified by the letter *U* for US Airways and *F* for FedEx. Viscosity values (in mPa.s units) are indicated on the y-axis. For reference purposes, the lowest on-wing viscosity indicated on the HOT guideline for the tested fluid (18,000 mPa.s) is also shown. The tank samples from both FedEx and from US Airways had viscosities at the upper end of the production range.

The reduction in viscosity for fluids injected into the air stream is evident, being much below the forced air-assist sample values and also below the lowest on-wing viscosity value for the fluid.

Viscosity values for fluid applied over the air stream (or for FedEx, beside the air stream) are similar to those for the conventional nozzle.

Figure 4.2 presents viscosity values as a percentage of the viscosity for the conventional nozzle fluid sample. This presentation provides a clearer picture of the similarity of the *over-air* fluid sample viscosities to the conventional. It also points out a drop in viscosity from the tank sample to the conventional application.

4.1.2 Fluid Viscosity Reduction over Time

In mid-April 2003, following the fluid endurance tests in artificial freezing precipitation, fluid sample viscosities (centrifuged only) were again measured.

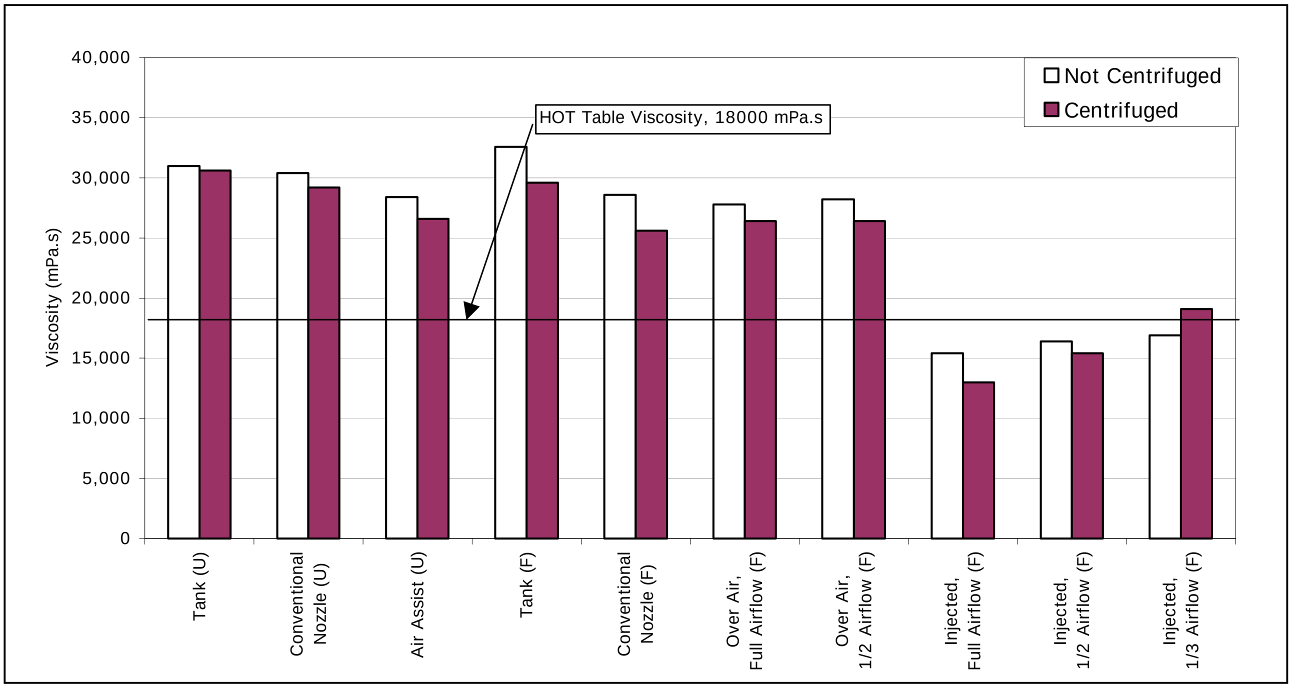

Figure 4.1: Fluid Sample Viscosity when Received, FedEx and US Airways

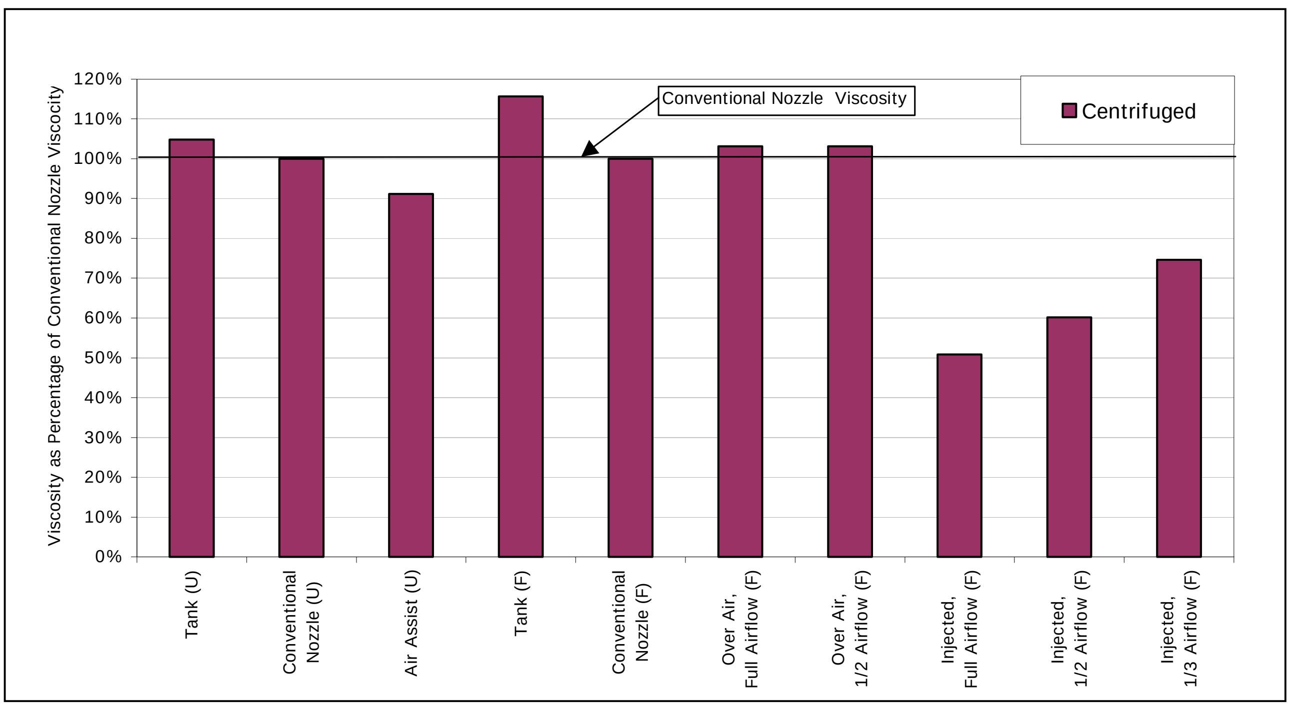

Figure 4.2: Fluid Sample Viscosity when Received Relative to Conventional Application

Figure 4.3 shows the results. Fluid samples for injected fluids were not measured again as it was evident that this method of application was not acceptable.

In all cases, including that of the unsprayed fluid samples taken from the truck tanks, the results showed a notable decrease in viscosity from the original values.

Similar temporal reduction of fluid viscosity was observed in a separate study, documented in TC report TP 13996E, *Influence of Application Procedure on anti-icing Viscosity* (3). That study compared viscosity measurements of three fluid brands over a 16-month period. The data showed that the extent of reduction in viscosity varied by fluid brand. The viscosity dropped by 67 percent for Fluid A, by 43 percent for Fluid B1, and by 16 percent for Fluid C1 over the period from week two to month sixteen.

4.2 Fluid Density

The purpose of measuring fluid density was to gauge the extent of fluid aeration resulting from the various methods of application.

Figure 4.4 charts the density values for all fluid samples as measured when the samples arrived. Centrifuged and non-centrifuged fluids were measured. The results for centrifuged fluids are identical, indicating that the method of centrifuging was successful in removing all entrained air.

Figure 4.5, the reporting on non-centrifuged fluid samples, compares the density of the various samples with that of the conventional application. Fluid applied over or beside the air stream had density values similar to those of conventional applications indicating similar levels of aeration.

The extent of aeration was greatest with the injected fluid, where fluid density was as much as 20 percent lower than the conventional application.

All fluid samples showed a drop in density as compared to the fluid taken from the tank, indicating some degree of aeration from all application methods. Relative to the tank fluid, all variations on application method generated at least a 5 percent drop in density due to aeration.

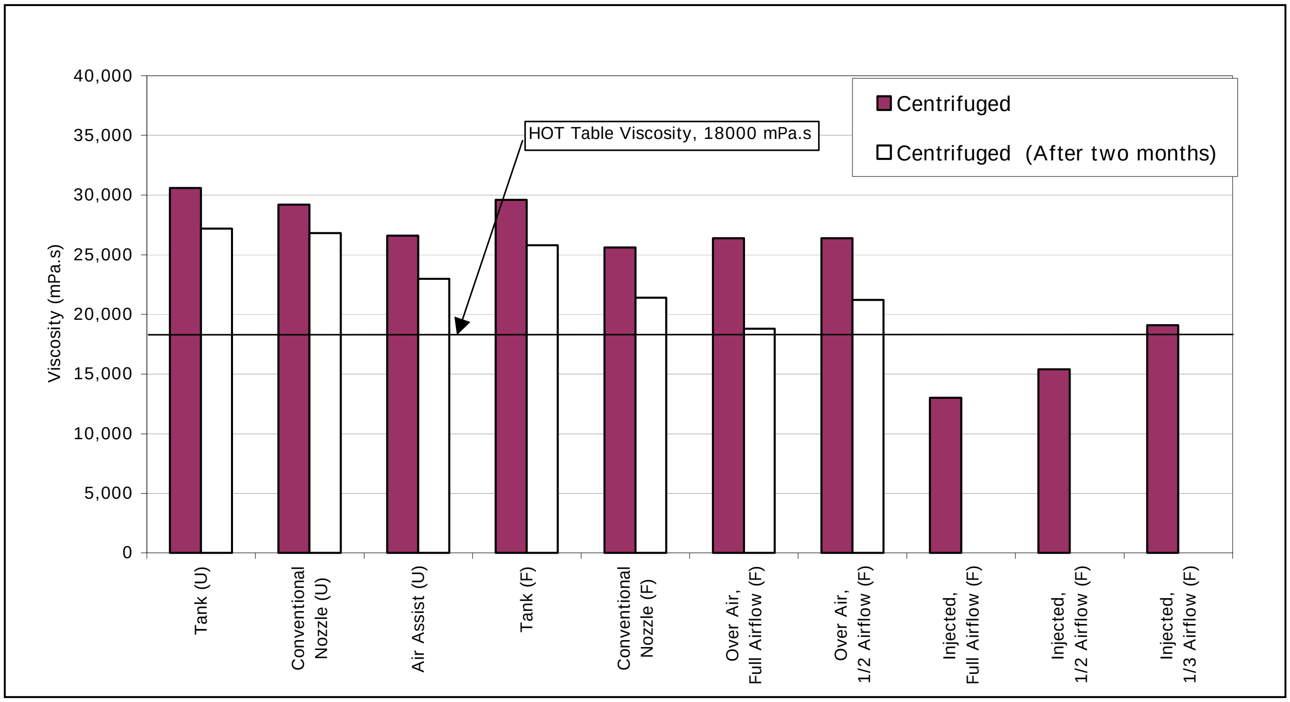

Figure 4.3: Fluid Sample Viscosity Reduction After Two Months

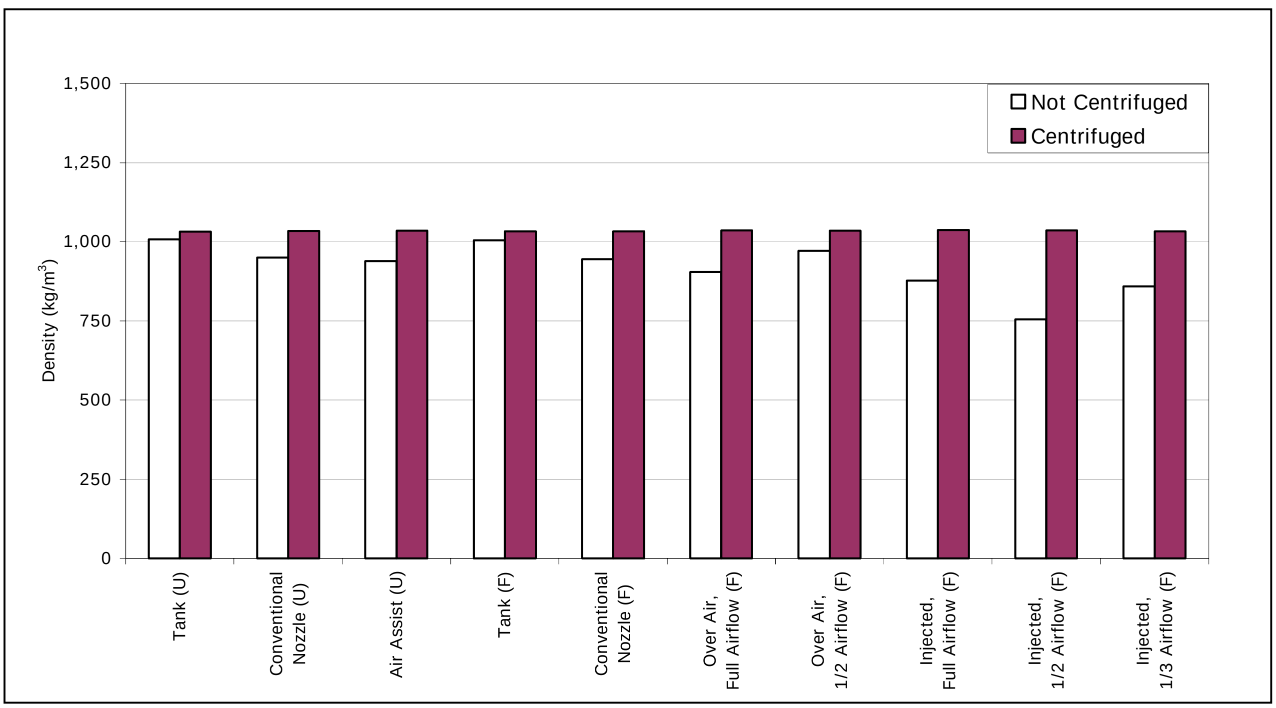

Figure 4.4: Fluid Sample Density when Received, FedEx and US Airways

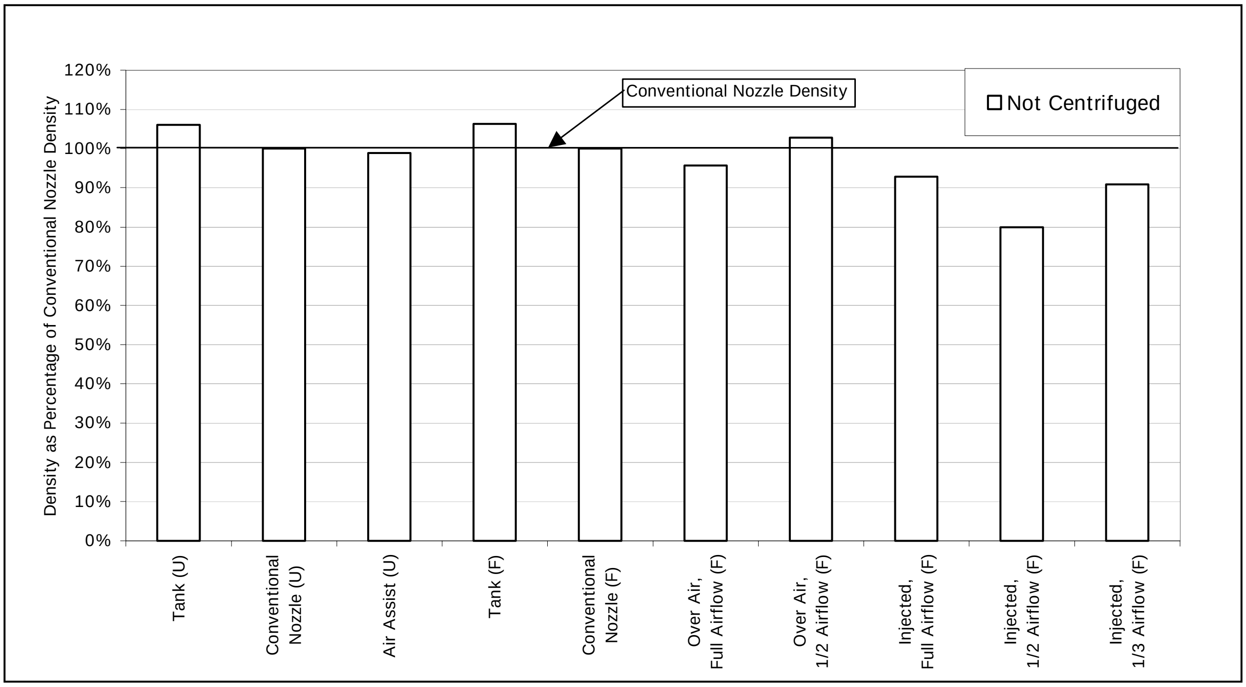

Figure 4.5: Fluid Sample Density when Received Relative to Conventional Application

4.3 Fluid Endurance Times

The results of fluid endurance tests in natural snow and in artificial freezing precipitation are discussed in this section.

4.3.1 Fluid Endurance Times in Natural Snow

Figure 4.6 is a bar chart of the endurance times measured in natural snow fluid endurance tests for the various fluid samples. Four test sessions were conducted. In one test session, the only samples that remained for testing were from US Airways. The chart format is similar to that used for examining viscosity and density values.

Figure 4.7 was developed to facilitate comparison of endurance times for forced air-assist fluid samples to times produced from fluid applied conventionally. Here endurance time values are shown as a percentage of those for the conventional nozzle fluid sample. This results in values of 100 percent for fluid applied conventionally, and different calculated percentage values for other samples. This chart illustrates that endurance times for fluids where the fluid nozzles were located over or beside the air nozzle were only slightly lower than those of conventional application. Endurance times for injected fluids were much less than for the other samples.

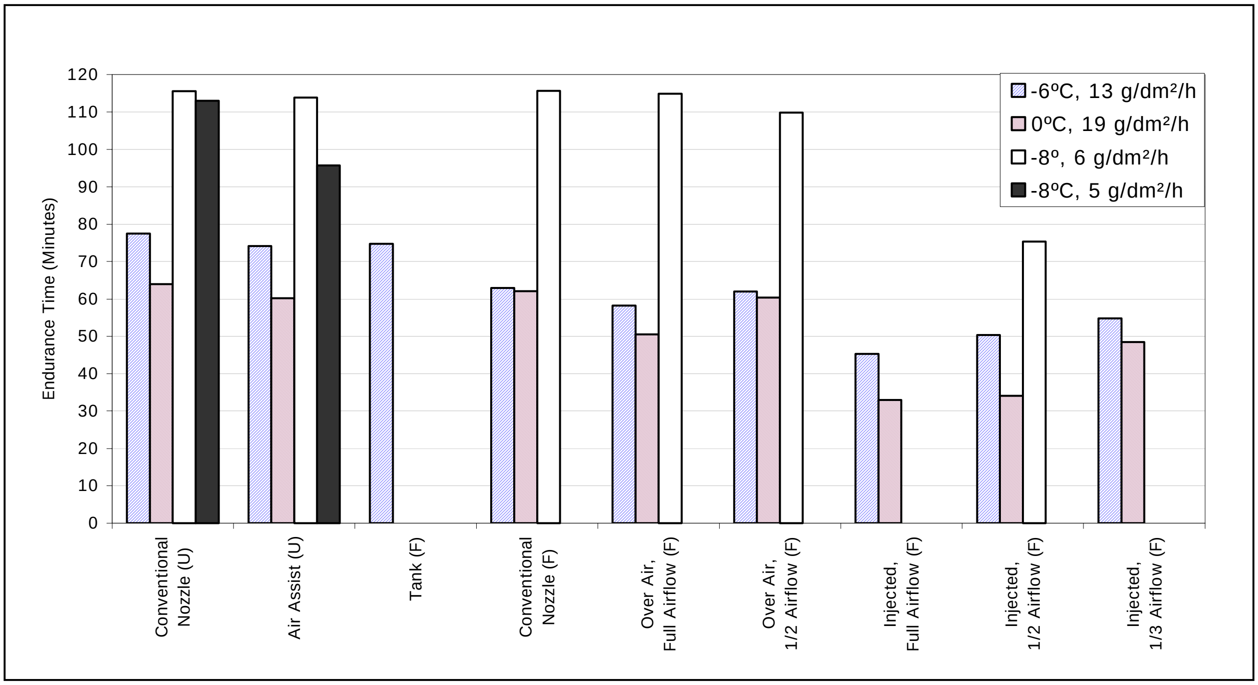

Figure 4.6: Forced Air Tests – Endurance Times in Snow

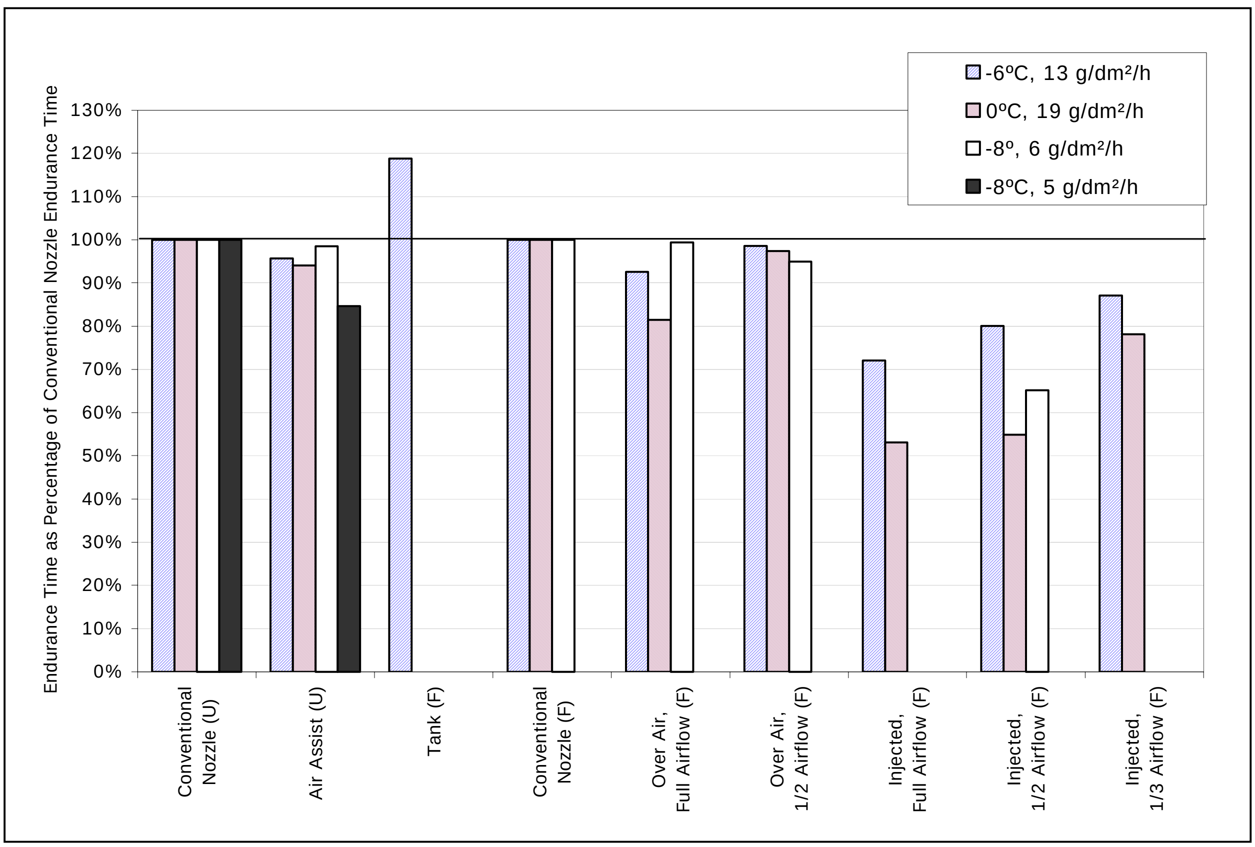

Figure 4.7: Forced Air Tests – Endurance Times in Snow – Relative to Conventional Nozzle Endurance Times

4.3.2 Fluid Endurance Times in Artificial Precipitation

Figure 4.8 is a bar chart of the endurance times measured in artificial precipitation fluid endurance tests for the various fluid samples.

Figure 4.9 compares endurance times for forced air-assist fluid samples to times produced from fluid applied conventionally. Here endurance time values are shown as a percentage of those for the conventional nozzle fluid sample. This results in values of 100 percent for fluid applied conventionally, and different calculated percentage values for other samples.

Endurance times for fluids from nozzles located over or beside the air nozzle, for the US Airways sample and the FedEx fluid sample at ½ airflow, were very close to those produced from the conventional application fluids. The FedEx fluid sample at full airflow was slightly lower than the conventional case.

Endurance times for injected fluids were much lower than all other samples.

4.3.3 Effect of Reduced Viscosity on Fluid Endurance Times

The objective of these tests was to examine whether measurement of any reduction to fluid viscosity resulting from the various modes of the forced air-assist fluid application is an adequate indicator of reduced fluid endurance times.

The most extreme cases examined were those in which fluid was injected into the air stream (FedEx samples) wherein the fluid experienced a large reduction in viscosity. For these cases, viscosity values for the three modes of fluid injection were 51 percent (Full Airflow), 60 percent (1/2 Airflow) and 75 percent (1/3 Airflow) of the viscosity resulting from a conventional application (Table 3.3 and Figure 4.2). When tested for fluid endurance, these fluid samples produced times, shown here as a percentage of the times for a conventional application, as follows: at Full Airflow, times ranged from 53 to 75 percent; at 1/2 Airflow, times ranged from 55 to 93 percent; and at 1/3 Airflow, times ranged from 77 to 87 percent. At least for these extreme cases, measurement of viscosity alone would appear to be an adequate indicator of reduced endurance times.

The cases where fluid was applied over (or beside) the air stream did not have such striking results. For the FedEx application, fluid viscosity from this method of application was slightly higher (103%) than that for the conventional application. However, the US Airways forced air-assist application exhibited a decrease in viscosity, with a value of 91 percent of that of the conventional application, and is examined here separately in Figure 4.10.

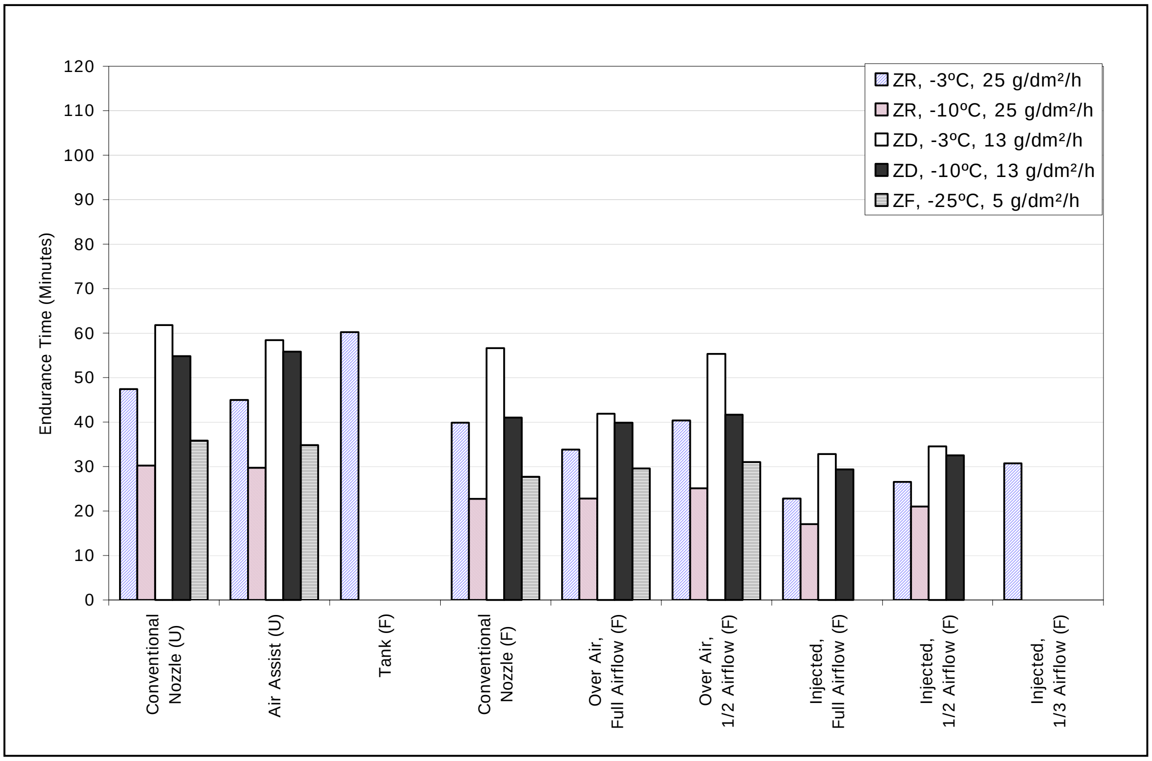

Figure 4.8: Forced Air Tests – Endurance Times in Freezing Precipitation

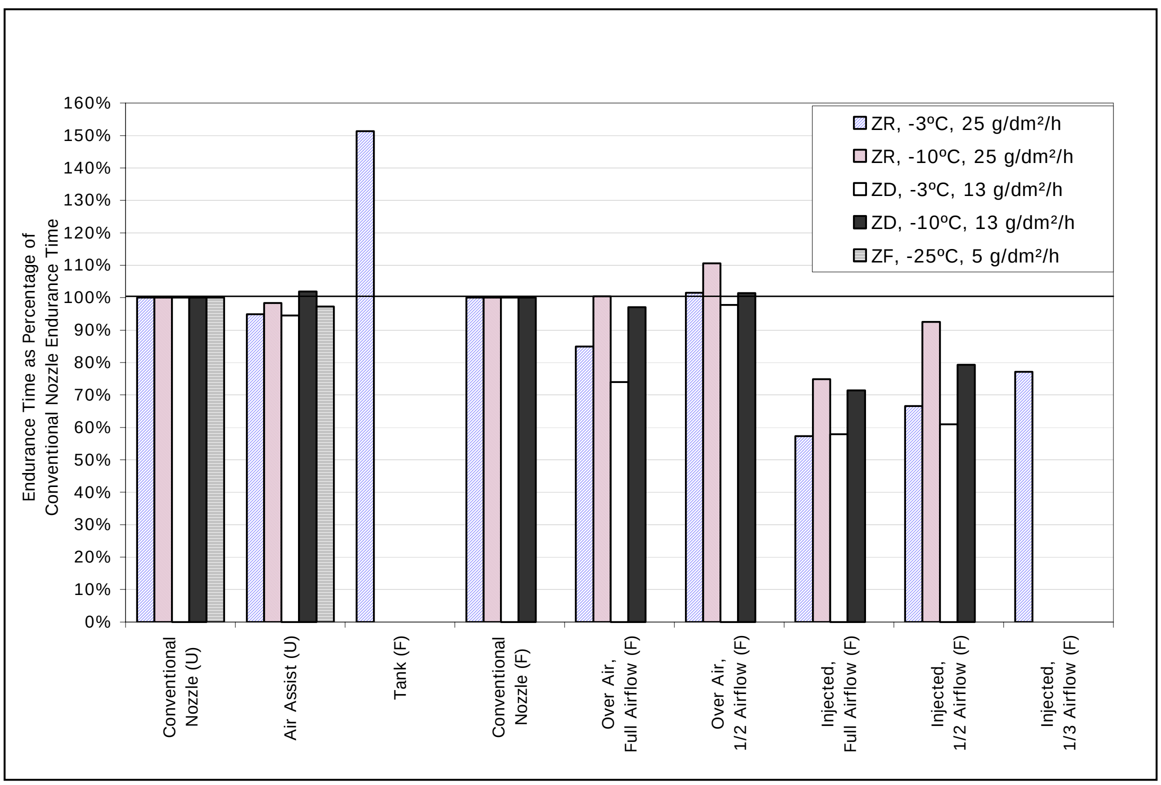

Figure 4.9: Forced Air Tests – Endurance Times in Freezing Precipitation – Relative to Conventional Nozzle Endurance Times

Figure 4.10 shows endurance times measured for each weather condition, for conventional and forced air-assist applications. This chart shows that, for the degree of viscosity reduction experienced and for this particular fluid, there is very little reduction in endurance times. This is especially true for those weather conditions where short endurance times are expected (at the left side of the chart). For those weather conditions lying at the right side of the chart, where longer endurance times are expected, the reduced viscosity appears to cause some reduction in endurance times.

Based on these data, the use of measured viscosity reduction as an indicator of expected endurance time reduction would be a conservative and safe approach.

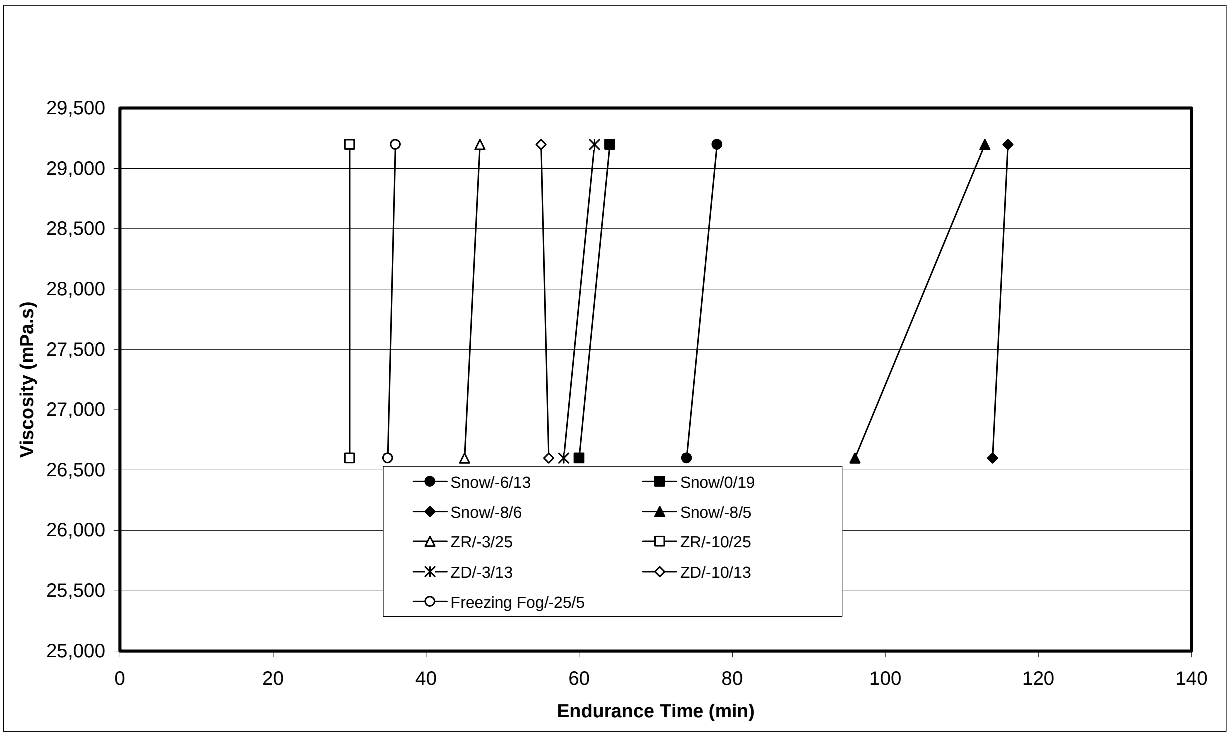

Figure 4.10: Viscosity vs. Endurance Time for Different Weather Conditions, US Airways Tests

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5. CONCLUSIONS

It was concluded that:

a) The forced air-assist method in which the fluid nozzle is positioned over or beside the forced air nozzle has little effect on fluid viscosity, level of aeration, or fluid endurance times for the forced air system, the deicing truck, the fluid brand tested, and the particular set of test conditions;

b) The air-assist method in which the fluid is injected into the forced air stream within the air nozzle is unacceptable, as it results in a large reduction in fluid viscosity, a high level of aeration, and reduced endurance times;

c) Measurement of fluid viscosity degradation provides an adequate indication that fluid endurance time has also been degraded, and that the current test method need not be augmented by measuring actual endurance times for these configurations and fluid; and

d) The test/approval process is to be modified as follows:

- Test data submitted to the FAA and TC for approval to employ HOT guidelines need include only the fluid viscosity test results (from air-assist and conventional applications, and from the truck tank), along with detailed information that identifies the specific forced air system and fluid tested;

- Fluid viscosity is to be measured at the test site immediately following fluid spray. This test is to be performed in cold conditions (OAT below 0ºC);

- Test fluid must be sprayed on an actual wing surface, not a substitute surface; and

- Operators can use the test procedure data on thickness and appearance of the fluid layer on the wing to decide whether this method of application is acceptable for deicing.

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6. RECOMMENDATIONS

It is recommended that:

a) The procedure for testing whether SAE HOT Time Guidelines can be employed when SAE Type II or IV fluid is sprayed with the assistance of forced air be modified as noted in the conclusion; and

b) The test procedure be formalized by the SAE G-12 Equipment Subcommittee as an SAE standard.

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REFERENCES

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., Alwaid, A., *Support Activities Related to Deicing Research for the 2001-02 Winter,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2002, TP 13999E (to be published).

3. Chebil, S., Alwaid, A., *Influence of Application Procedure on Anti-Icing Fluid Viscosity***,** APS Aviation Inc., Transportation Development Centre, Montreal, November 2002, TP 13996E (to be published).

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APPENDIX A

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

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: Peter Dawson

Reviewed by: John D'Avirro

Version 1.4
05 June 2002

APS AVIATION INC.

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 1X9Canada 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 A-1a) is to be submitted for each forced air deicing vehicle used in the tests. A sample completed form (Attachment A-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 A-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 0ºC)
5b	Standard	

3.2.6 Test Equipment

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

3.3 Data Forms

Two data forms are used for these tests as follows.

3.3.1 General Form (Figure A-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 A-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 A-III 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 sq. ft.) 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.

M:\Groups\Cm1680 (01-02)\Procedures\Forced Air\Type IV\Version 1.4\Final Test Procedure Type IV Vers 1.4.doc

Attachment A-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 A-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 A-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 A-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 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.
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 A-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 A-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 __________________

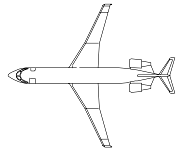
TYPE OF APPLICATION Over Air Stream ____ Injected In Air Stream ____ Standard Application ___________

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

Minimum distance from nozzle ____ ft

Estimated angle of stream to horizontal _____ º

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:

Label on Fluid Sample ______ **Aeration** ____ %

Sample Viscosity _________ **Brix** __________

Recorded by: ________________________________

AT MAXIMUM EFFECTIVE DISTANCE

Maximum distance from nozzle _____ ft

Estimated angle of stream to horizontal _____ º

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:

Label on Fluid Sample ______ **Aeration** ____ %

Sample Viscosity _________ **Brix** __________

Recorded by: ________________________________

APPENDIX B

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING
2002-03

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2002-03

5.20 Forced Air System Evaluation

5.20.1 Phase I

a) Analyse and report on the results of the endurance trials on Type II/IV fluids applied with forced air-assisted systems; and

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

5.20.2 Phase II

c) Monitor and participate in some operator field trials of air-assisted Type II/IV fluids, and report on observations;

d) Monitor and participate in some operator field trials of air-assisted Type I fluid as a first-step procedure to ascertain and recommend whether observed times to freezing are supportive of further study of potential use as a one-step application; and

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

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APPENDIX C

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

Editorial Revision
June 28, 2005
Version 1.1

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 the Federal Aviation Administration (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 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 C-I.

Samples of fluid sprayed with air-assist and sprayed with conventional nozzles will be requested. A quantity of 5 L 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 C-I Fluid Sample Data Form
- Attachment C-II End Condition Data Form
- Attachment C-III Meteo/Plate Pan Data Form

CM 1747/Procedures/Forced Air/Version 1.0.doc

ATTACHMENT C-I

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: _____/_____/_____ (day/month/year) Time: _____:_____ am/pm

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

ATTACHMENT C-II

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):

____

____

____

____

____

____

____

FAILURES CALLED BY : PRINT ________________ SIGN ________________

Cm1747\Procedures\Forced Air\Attachment B

ATTACHMENT C-III

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/dm²/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 :	________	________