

Three Aircraft Ground Icing Research Activities During the 2001-02 Winter

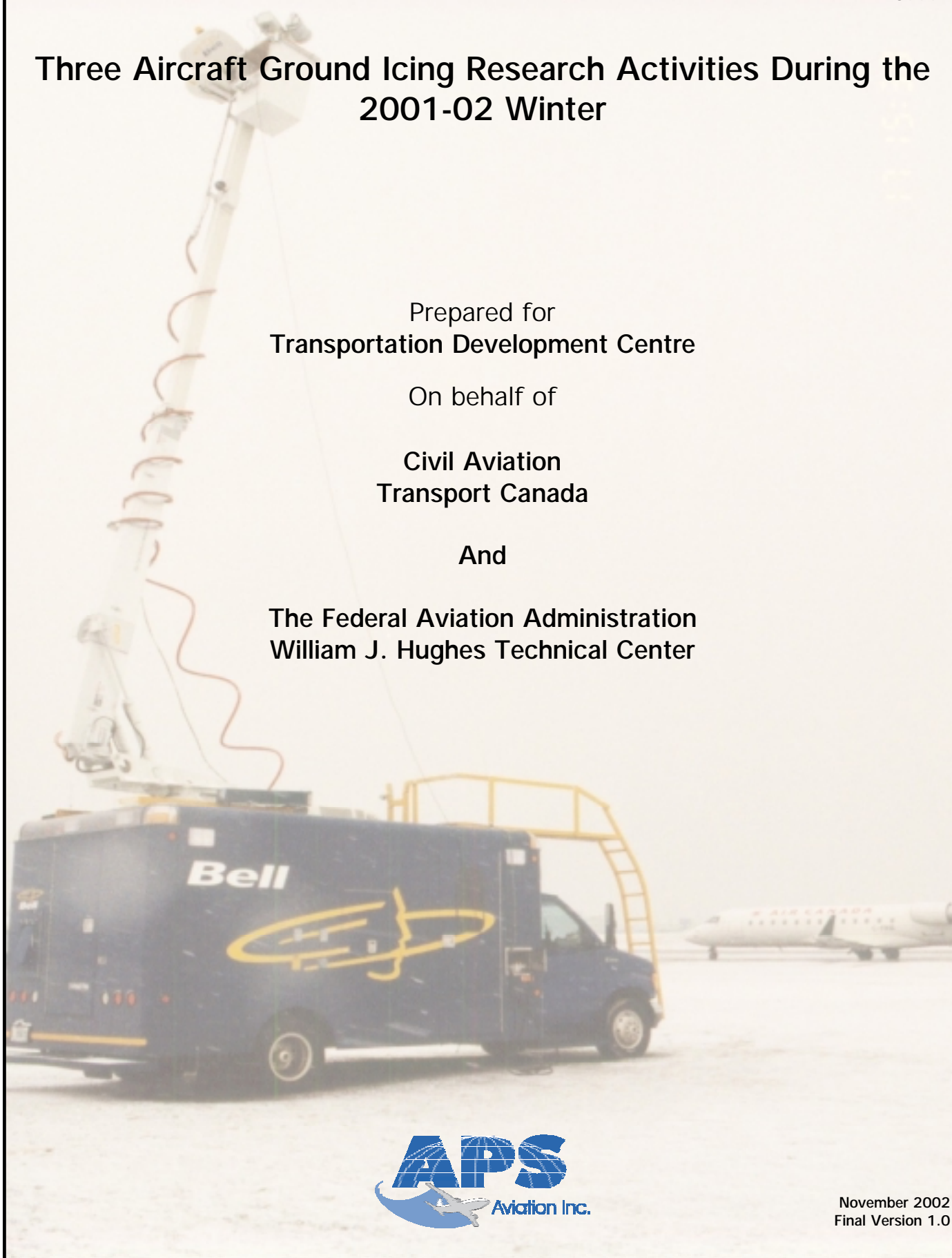
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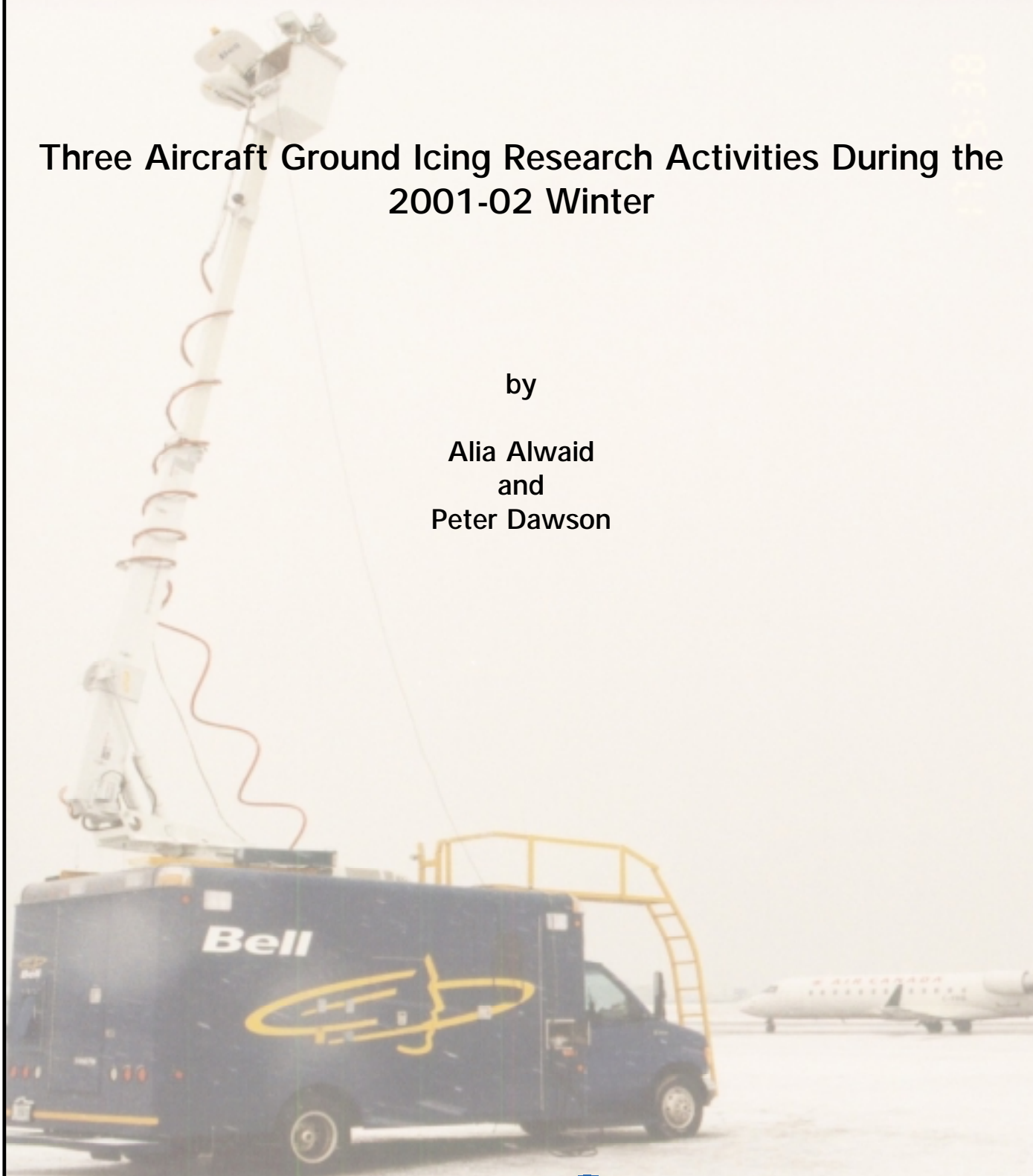
**The Federal Aviation Administration
William J. Hughes Technical Center**



Three Aircraft Ground Icing Research Activities During the 2001-02 Winter

by

Alia Alwaid
and
Peter Dawson



PREFACE

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

- To develop holdover time data for all newly qualified de/anti-icing fluids;
- To evaluate the parameters specified in Proposed Aerospace Standard 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 develop holdover times in snow using a more realistic protocol for Type I fluid endurance time testing;
- To further evaluate the flow of contaminated fluid from the wing of an aircraft during simulated takeoff runs;
- To examine the change in viscosity with the application process of Type IV fluids;
- To further evaluate hot water deicing;
- To compare endurance times in natural snow with those in artificial snow;
- To provide support for tactile tests at the Toronto Airport Central Deicing Facility;
- To utilize ice sensors for a pre-takeoff contamination check;
- To prepare the JetStar and Canadair RJ wings for thermodynamic tests; and
- To provide support services to Transport Canada.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2001-02 are documented in nine reports. The titles of the reports are as follows:

- TP 13991E Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Test Program for the 2001-02 Winter;
- TP 13992E Evaluation of Laboratory Test Parameters for Frost Endurance Time Tests;
- TP 13993E Impact of Winter Weather on Holdover Time Table Format;
- TP 13994E Generation of Holdover Times Using the New Type I Fluid Test Protocol;
- TP 13995E Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid;
- TP 13996E Influence of Application Procedure on Anti-icing Fluid Viscosity;

- TP 13997E Endurance Time Tests in Snow: Reconciliation of Indoor and Outdoor Data 2000-02;
- TP 13998E Exploratory Aircraft Ground Deicing Research for the 2001-02 Winter; and
- TP 13999E Three Aircraft Ground Icing Research Activities During the 2001-02 Winter.

This report, TP 13999E, has the following objective:

- To provide support to TDC and others on research activities carried out during the winter of 2001-02.

This report contains three studies:

- Replacement of tactile check with ground ice detection systems: Preliminary data collection and analysis.
- Development of test specifications for forced air deicing systems; and
- Cooperation in the development of ground minimum operational performance specification for ground ice detection systems.

This report also contains an account of the test procedures and presentations that were produced for the program activities conducted in 2001-02.

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 Directorate and the Transportation Development Centre of Transport Canada, the U.S. Federal Aviation Administration, National Research Council Canada, the Meteorological Service of Canada (formerly known as Atmospheric Environment Services Canada), and several fluid manufacturers. Special thanks are extended to US Airways Inc., Air Canada, American Eagle Airlines Inc., the National Center for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, Ottawa International Airport Authority, ATCO Airports, Aviation Boréale, 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: Nicolas Blais, Yagusha Bodnar, Alison Cairns, Robert Paris, Parimal Patel, Harvinder Rajwans, Ruth Tikkanen, Bob MacCallum, Trevor Leslie, Chris McCormack, and David Belisle.

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15. Supplementary Notes (Funding programs, titles of related publications, etc.) <p>Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.</p>					
16. Abstract <p>This report contains the results of three studies conducted by APS Aviation Inc. on activities related to aircraft deicing research.</p> <p>Replacement of Tactile Check with Ground Ice Detection Systems: Preliminary Data Collection and Analysis</p> <p>A tactile inspection of certain aircraft is necessary following deicing to ensure that the wing is free of ice. GlobeGround, the operator of the Central Deicing Facility at Toronto International Airport, wishes to examine whether ice detection systems could replace the tactile inspection. A test procedure was developed to assist GlobeGround in collecting data using an ice detection system in this application. The APS team logged and analyzed the data. Results of the analysis were submitted to GlobeGround in early April 2002.</p> <p>Development of Test Specifications for Forced Air Deicing Systems</p> <p>The SAE G-12 Aircraft Ground Deicing Equipment Subcommittee identified the need for an official process for operators to test the use of forced air to assist in certain deicing applications and, based on successful outcomes, request approval from authorities to use the forced air systems in their deicing operations. Test procedures and approval processes were developed for specific forced air deicing applications.</p> <p>Cooperation in the Development of Ground Minimum Operational Performance Specification for Ground Ice Detection Systems</p> <p>APS held a demonstration of the procedures required to conduct laboratory trials for evaluating the minimum operational performance requirements of ice detection sensors. In addition, APS prepared a test procedure in 2001-02 for a study funded separately by a sensor manufacturer wanting to certify its remote ground ice detection system. A number of challenges were noted in the methodology and in the procedures to be followed while conducting the tests specified in Aerospace Standard AS 5116A. As a result, APS presented these issues and proposed changes to AS 5116A at the SAE G-12 Ice Detection Subcommittee meeting in Frankfurt, Germany, on June 6, 2002.</p>					
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16. Résumé Ce rapport présente les résultats de trois études réalisées par APS Aviation Inc. (APS) concernant des activités entourant le dégivrage des aéronefs au sol. Remplacement de la vérification tactile par des systèmes de détection de givrage : collecte et analyse de données préliminaires Il est parfois nécessaire de procéder à une inspection tactile des aéronefs après dégivrage, pour s'assurer que l'aile est vraiment exempte de givrage. GlobeGround, l'exploitant de l'installation centrale de dégivrage à l'aéroport international de Toronto, souhaitait examiner la possibilité de remplacer l'inspection tactile par des systèmes de détection de givrage. Les chercheurs ont élaboré une procédure d'essai, dont GlobeGround s'est servi pour mettre en oeuvre un système de détection de givrage et en colliger les données. L'équipe d'APS a ensuite enregistré et analysé ces données. Les résultats de cette analyse ont été remis à GlobeGround au début d'avril 2002. Élaboration des spécifications d'essai de systèmes de dégivrage à air forcé 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 demander ensuite, forts de résultats concluants, l'autorisation des organismes de réglementation d'intégrer ces systèmes à leurs programmes de dégivrage. Une méthode d'essai et un processus d'approbation ont été élaborés pour des applications précises de dégivrage à air forcé. Coopération à l'élaboration de spécifications de performances opérationnelles minimales pour les systèmes de détection de givrage APS a organisé une démonstration des procédures devant encadrer les essais en laboratoire destinés à définir les performances opérationnelles minimales des détecteurs de givrage. Toujours en 2001-2002, APS a élaboré une procédure d'essai pour une étude financée séparément par un fabricant de détecteurs, qui voulait faire homologuer son système de détection de givrage à distance. Divers problèmes ont été notés dans la méthodologie et les procédures d'essai prescrites par la norme Aerospace Standard (AS 5116A). APS a donc fait état de ces problèmes et proposé des modifications à la norme AS 5116A à la réunion du sous-comité G-12 de la SAE sur la détection de givrage, qui a eu lieu à Francfort, en Allemagne, le 6 juin 2002.					
17. Mots clés Endurance, durée d'efficacité, liquides de dégivrage, caméra, vérification tactile, détection de givrage au sol, système à air forcé, infrarouge, spécification de performances opérationnelles minimales			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 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.

Several research reports for testing of de/anti-icing technologies have been produced for this winter test program 2001-02. The subject matter of these reports is described in the preface of this document. This report contains the documentation of the work conducted by APS on activities related to aircraft deicing research. Three studies are included in this report:

- a) Replacement of tactile check with ground ice detection systems (GIDS): Preliminary data collection and analysis;
- b) Development of test specifications for forced air deicing systems; and
- c) Cooperation in the development of ground minimum operational performance specification (GMOPS) for GIDS.

This report also contains the test procedures and presentations that were produced for the program activities conducted in 2001-02.

Replacement of Tactile Check with Ground Ice Detection Systems (GIDS): Preliminary Data Collection and Analysis

GlobeGround, the operator of the Central Deicing Facility at Toronto International Airport, wished to examine whether ice detection systems could replace the tactile inspection. The examination process and the outcome must meet the needs of the approving authority, TC, and be accepted by the airline industry. APS was asked to develop suitable procedures to be used by personnel at GlobeGround for data gathering, and to assist in the analysis of the collected data in order to document the effectiveness of specific ice detection systems proposed for use.

Procedures and data forms were developed by APS for use by GlobeGround during the winter of 2001-02.

It was agreed with GlobeGround that a typical data package for each deicing operation would include:

- a) Completed data forms;

- b) GlobeGround daily statistics sheets (OPS Reports); and
- c) JPEG ice detection images of the wing before and after deicing.

During the winter of 2001-02, GlobeGround collected a limited amount of data, using both the Cox and Company Inc. and Goodrich Corporation ice detection systems.

The completed data forms from the winter of 2001-02 were provided to APS, along with some data forms completed during the previous season. The APS team logged and analyzed the data. Results of the analysis were submitted to GlobeGround in early April 2002.

There was insufficient data collected to support a submission for sensor approval to TC. Additional data will be needed to have a substantial package suitable for submission for approval.

Development of Test Specifications for Forced Air Deicing Systems

The Society of Automotive Engineers (SAE) G-12 Aircraft Ground Deicing Equipment Subcommittee identified the need for an official process for requesting approval from authorities to use forced air deicing systems in operator deicing programs. Such a process would include an approved test procedure and a documented procedure for requesting approval.

Members of the subcommittee requested the cooperation and assistance of the FAA and TC to develop an official test procedure and to define an approval process for selected applications. The two authorities agreed to the request and assigned APS to work with the Forced Air Working Group of the SAE G-12 Equipment Subcommittee.

APS developed two test procedures addressing two specific applications of the forced air systems. One test procedure was for use by operators to examine whether published fluid holdover times can be used for forced air assist applications of Type II or Type IV fluid. Some operators have since conducted tests on specific forced air deicing truck/fluid combinations using the test procedure.

The second test procedure was to assist operators in understanding the acceptability of using forced air with Type I fluid in a first step of a two-step deicing operation. This procedure has also been provided for operator implementation. Test results will also indicate whether it is appropriate to examine the use of forced air with Type I fluid as a one-step process.

Cooperation in the Development of Ground Minimum Operational Performance Specification (GMOPS) for Ground Ice Detection Systems (GIDS)

As part of the activities and the overall test program for TC, APS held a demonstration of the procedures required to conduct laboratory trials for evaluating the minimum operational performance requirements of ice detection sensors.

In addition, APS prepared a test procedure in 2001-02 for a study funded separately by a sensor manufacturer wanting to certify its remote GIDS. A number of challenges were faced in the methodology and procedures to be followed when conducting the tests specified in SAE Aerospace Standard AS 5116A. APS presented these issues and proposed changes to AS 5116A at the SAE G-12 Ice Detection Subcommittee meeting in Frankfurt, Germany, on June 6, 2002.

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SOMMAIRE

À la demande du Centre de développement des transports 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 aéronefs au sol.

Plusieurs rapports traitant d'essais de technologies de dégivrage/antigivre ont été produits pour la saison hivernale 2001-2002. La préface du présent rapport donne un aperçu des sujets abordés dans ces rapports. Le rapport comme tel contient la documentation des travaux réalisés par APS en marge de projets touchant le dégivrage des aéronefs. Trois études sont visées :

- a) Remplacement de la vérification tactile par des systèmes de détection de givrage : collecte et analyse de données préliminaires
- b) Élaboration des spécifications d'essai de systèmes de dégivrage à air forcé
- c) Coopération à l'élaboration de spécifications de performances opérationnelles minimales pour les systèmes de détection de givrage

Le rapport contient également les procédures d'essai et présentations produites dans le cadre du programme de la saison 2001-2002.

Remplacement de la vérification tactile par des systèmes de détection de givrage : collecte et analyse de données préliminaires

GlobeGround, l'exploitant de l'installation centrale de dégivrage de l'aéroport international de Toronto, souhaitait déterminer si l'inspection tactile pouvait être remplacée par des systèmes de détection de givrage. Le plan et les résultats d'une telle étude devaient répondre aux exigences de l'autorité approbatrice, TC, et être acceptés par l'industrie aérienne. C'est ainsi qu'APS a été chargé d'élaborer les procédures qu'allaient utiliser les employés de GlobeGround pour la collecte des données, et d'analyser les données colligées afin de documenter l'efficacité des systèmes de détection de givrage proposés.

APS a élaboré des procédures et des formulaires d'enregistrement des données, dont s'est servi GlobeGround pour sa collecte de données au cours de l'hiver 2001-2002.

Il avait été convenu avec GlobeGround qu'un ensemble de données type devait être constitué pour chaque opération de dégivrage. Un tel ensemble devait comporter ce qui suit :

- a) formulaires d'enregistrement des données remplis;
- b) feuilles de données statistiques quotidiennes de GlobeGround (rapports d'opérations);
- c) photos JPEG de l'aile prises avant et après le dégivrage.

GlobeGround a colligé une quantité limitée de données au cours de l'hiver 2001-2002. Deux systèmes de détection ont été utilisés, soit celui de Cox and Company Inc. et celui de Goodrich Corporation.

Tous les formulaires d'enregistrement des données établis au cours de l'hiver 2001-2002 ont été transmis à APS, de même que d'autres formulaires établis au cours de la saison antérieure. L'équipe d'APS a enregistré et analysé les données. Les résultats de cette analyse ont été remis à GlobeGround au début d'avril 2002.

Les données colligées étaient insuffisantes pour appuyer le dépôt d'une soumission pour l'approbation d'un détecteur auprès de TC. Il faudra obtenir des données additionnelles pour étayer correctement le dossier de demande d'approbation.

Élaboration des spécifications d'essai de systèmes de dégivrage à air forcé

Le sous-comité G-12 de la SAE (Society of Automotive Engineers) sur les systèmes de dégivrage au sol a reconnu la nécessité d'établir un processus formel auquel les exploitants pourraient recourir pour demander aux autorités compétentes l'autorisation d'intégrer l'utilisation de systèmes à air forcé à leurs programmes de dégivrage. Un tel processus doit comporter une méthode d'essai et une procédure documentée de demande d'autorisation.

Les membres du sous-comité ont fait appel à la coopération et à l'aide de la FAA et de TC pour élaborer une méthode d'essai formelle et définir un processus d'approbation aux fins de certaines applications. La FAA et TC ont tous deux accepté de prêter leur concours et ont demandé à APS de collaborer avec le groupe de travail sur les systèmes à air forcé du sous-comité G-12 de la SAE sur les systèmes de dégivrage.

APS a élaboré deux méthodes d'essai, pour deux applications bien précises des systèmes à air forcé. L'une devait permettre aux exploitants de déterminer si les durées d'efficacité publiées pour les liquides de type II et de type IV demeurent

valables lorsque ces liquides sont appliqués à l'aide de systèmes à air forcé. Certains exploitants ont depuis utilisé cette méthode pour mettre à l'essai des combinaisons précises de système de dégivrage à air forcé et de liquide.

L'autre méthode d'essai devait aider les exploitants à déterminer dans quelle mesure un système à air forcé peut servir à l'application de liquide de type I en tant que première étape d'une procédure de dégivrage à deux étapes. Cette méthode a aussi été prévue pour être mise en oeuvre par les exploitants. Les résultats de ces essais indiqueront également s'il est opportun d'étudier l'utilisation d'un système à air forcé pour l'application de liquide de type I, à titre d'opération de dégivrage à une seule étape.

Coopération à l'élaboration de spécifications de performances opérationnelles minimales pour les systèmes de détection de givrage

En marge des activités et essais menés pour le compte de TC, APS a organisé une démonstration des procédures devant encadrer les essais en laboratoire destinés à définir les performances opérationnelles minimales des détecteurs de givrage.

Toujours en 2001-2002, APS a élaboré une procédure d'essai pour une étude financée séparément par un fabricant de détecteurs, qui voulait faire homologuer son système de détection de givrage à distance. Divers problèmes ont été notés dans la méthodologie et les procédures d'essai prescrites par la norme Aerospace Standard (AS 5116A). APS a donc fait état de ces problèmes et proposé des modifications à la norme AS 5116A à la réunion du sous-comité G-12 de la SAE sur la détection de givrage, qui a eu lieu à Francfort, en Allemagne, le 6 juin 2002.

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GLOSSARY

APS	APS Aviation Inc.
AS	Aerospace Standard
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration (U.S.)
GIDS	Ground Ice Detection System
GMOPS	Ground Minimum Operational Performance Specification
HOT	Holdover Time
MOPS	Minimum Operational Performance Specification
NRC	National Research Council Canada
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

Under contract to the Transportation Development Centre 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 Overview

Several research reports for testing of de/anti-icing technologies have been produced for the winter 2001-02 test program. The subject matter of these reports is described in the preface of this document. This report contains the documentation of the work conducted by APS on activities related to aircraft deicing research. Three studies are included in this report:

- a) Replacement of tactile check with ground ice detection systems (GIDS): Preliminary data collection and analysis;
- b) Development of test specifications for forced air deicing systems; and
- c) Cooperation in the development of ground minimum operational performance specification for GIDS.

This report also contains the test procedures and presentations that were produced for the program activities conducted in 2001-02, as well as the list of the reports provided to the various manufacturers whose fluids were tested for the development of endurance times during this winter season.

The following subsections contain the background for each of the activities listed above.

1.2 Replacement of Tactile Check with Ground Ice Detection Systems: Preliminary Data Collection and Analysis

In some countries, ground deicing operators must comply with a regulated requirement to perform tactile inspections of wings of specified aircraft following deicing to ensure that no ice has adhered to the wing under the applied fluid.

GlobeGround North America (operator of the Central Deicing Facility at Toronto airport) examined the use of remote ice detection sensors during the deicing process to replace the human tactile inspection. During the winter of 2001-02, members of the APS research team developed a test procedure to be used by

the operator to evaluate the effectiveness of sensors in this application, and assisted in the analysis of collected data.

Sections from the work statement that relate to this activity are provided in Appendix A.

This activity is documented in Section 2 of this report.

1.3 Development of Test Specifications for Forced Air Deicing Systems

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

In theory, forced air can be used in several ways in a deicing operation:

- a) To remove most of the contamination prior to standard deicing with heated fluid;
- b) As the first step of a two-step procedure, either alone or with Type I fluid;
- c) With Type I fluid as a one-step procedure; and
- d) To assist in the delivery of a second-step application of Type II or Type IV fluid to achieve better reach and coverage, and to reduce fluid amounts dispensed.

The Society of Automotive Engineers (SAE) G-12 Aircraft Ground Deicing Equipment Subcommittee identified the need 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 authorities to use the forced air deicing systems in operator deicing programs.

Members of the subcommittee requested the cooperation and assistance of the FAA and TC to develop an official test procedure and to define an approval process for selected applications. The two authorities agreed to the request and assigned APS to work with the Forced Air Working Group to achieve these aims.

APS has developed a test procedure for use by operators to examine whether published fluid holdover times can be used for forced air assist applications of Type II or Type IV fluid. Some operators plan to conduct tests on specific truck/fluid combinations.

A test procedure to assist operators in understanding the feasibility of using forced air with Type I fluid in a first step deicing operation has also been provided for operator implementation. Test results will indicate whether it is appropriate to examine the use of forced air with Type I fluid as a one-step process. It was concluded from previous trials in a laboratory environment on one manufacturer's system that this was not a safe application. Other systems may need to be examined. Such a study would examine the heat transfer to the wing as well as the initial fluid coverage and fluid endurance times in precipitation, and would require the involvement of experienced testers.

The work is described in Appendix A and was conducted in response to a request from the SAE G-12 Aircraft Ground Deicing Equipment Subcommittee and was approved by the FAA and TC.

This activity is documented in Section 3 of this report.

1.4 Cooperation in the Development of Ground Minimum Operational Performance Specification for Ground Ice Detection Systems

A test procedure was prepared, and tests were conducted, for a sensor manufacturer in order to evaluate compliance of its sensor with the requirements of SAE AS5116. The manufacturer funded the work, and the findings are outside the scope of this report. However a number of difficulties were experienced in the conduct of these tests. This experience provided the basis for recommendations for changes to upgrade the Standard.

Subsequently, and at the request of TC, APS conducted a demonstration for SAE/EuroCAE Working Group members of the procedures required to perform laboratory tests in accordance with SAE AS5116/ED104 Minimum Operational Performance Specification for GIDS. This demonstration, carried out at National Research Council Canada's (NRC) Climatic Engineering Facility (CEF), was undertaken to provide the participants with a better appreciation of the practicality and potential limitations of the specified tests.

APS presented a record of its experience, and recommended changes to SAE AS5116/ED104 at the SAE G-12 Ice Detection Subcommittee meeting in

Frankfurt, Germany, on June 6, 2002. The majority of the recommended changes were adopted, and the specifications have been upgraded.

A number of challenges were faced in the methodology and procedures to be followed when conducting the tests. APS also presented these issues and proposed changes to AS 5116A at the SAE G-12 Ice Detection Subcommittee meeting in Frankfurt, Germany on June 6, 2002.

This activity is documented in Section 4 of this report.

2. REPLACEMENT OF TACTILE CHECK WITH GROUND ICE DETECTION SYSTEMS: PRELIMINARY DATA COLLECTION AND ANALYSIS

This section discusses the activities related to developing operational and test data examining the possible replacement of hands-on tactile checks with GIDS.

2.1 Introduction

With the development of centralized deicing pads at airports, operators are now using radio and electronic communication methods to position aircraft, thereby eliminating personnel on the tarmac area. In addition, new truck designs with enclosed baskets have restricted the ability of the deicing operator to physically perform tactile inspections. This has led to the need for additional manpower to perform the post-deicing inspection.

GlobeGround, the operator of the Central Deicing Facility at Toronto International Airport, wished to examine the performance of remote ice detection systems with the intent of replacing the present hands-on tactile inspection. The examination process and outcome needed to demonstrate the suitability of sensors to replace tactile inspection to the satisfaction of TC, and be acceptable to the airline industry.

At the start of the winter of 2001-02, APS was asked to develop suitable procedures to be used by GlobeGround for data gathering, and to assist in the analysis of the collected data.

2.2 Methodology

In discussions between TC and GlobeGround, some guiding principles regarding data collection for this examination were agreed upon:

- a) Use the remote sensors for as many deicing events as possible;
- b) Record the application details and inspection findings of all aircraft deicing events (indicating whether sensors were used and whether tactile checks were conducted);
- c) Maintain a paper trail back to each event so that notes on the deicing can be credited. At the end of the winter it must be possible to go back and review all aspects of an individual deicing event, including weather, prior

condition of aircraft (type of contamination), aircraft type, operator identification, deicing equipment, visual findings, need to re-deice or do significant touch-ups, sensor results (as applicable), and any other comments or factors; and

- d) Report the results of the observations using detailed documentation to address such issues as: Did the sensor “see” ice when it was detected by the inspector?; Were there cases when the sensor identified ice and the inspector did not?; Did the sensor see ice when in fact there was none present?

These guidelines were recognized in the developed procedures, and are included in Appendix B. Because the number of occasions that clear ice actually forms is very small, and the number of times that the deicing operation fails to clean away any clear ice is even smaller, there are very few operations where tactile inspections and ice detector systems would actually be examining ice. To compensate, the procedure included examination of the wing prior to deicing, in order to provide comparative data of how actual contamination on the wing was discerned by tactile inspection, visual inspection, and/or the ice detection system.

It was agreed with GlobeGround that a typical data package for each deicing operation would include the following:

- a) Completed data forms from the test procedure;
- b) GlobeGround daily statistics sheets (OPS Reports); and
- c) JPEG ice detection images of the wing before and after deicing.

2.3 Activities – Winter 2001-02

During the winter of 2001-02, GlobeGround collected a limited amount of data using the supplied procedure and data forms on a number of operations. Both the Cox and Goodrich ice detection systems were employed in these trials.

The data forms completed for these operations were provided to APS, and the data were then logged and analyzed. Some data collected on GlobeGround data forms from the previous winter were also submitted and included in the analysis.

Results of the analysis were submitted to GlobeGround in early April 2002 and were presented by GlobeGround at the SAE G-12 Ice Detection Subcommittee meeting in Frankfurt in June 2002.

2.4 Conclusions and Recommendations

There were insufficient data collected to support a submission to TC. It will be necessary to collect additional data in order to have a substantial package suitable for submission for approval. To obtain more data, GlobeGround should assign a dedicated coordinator for this activity to ensure that data is collected at every opportunity.

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3. DEVELOPMENT OF TEST SPECIFICATIONS FOR FORCED AIR DEICING SYSTEMS

3.1 Introduction

During the winter of 1999-2000, APS examined safety implications of forced air deicing systems in a series of tests conducted at the NRC CEF. A Vestergaard Elephant μ deicing vehicle equipped with a forced air deicing system was used to remove various types and thicknesses of contamination from the JetStar test wing in three modes of operation: with forced air alone; with a forced air/fluid combination; and with heated fluid alone.

Test results indicated that the forced air deicing system provided neither risk of injury to personnel nor damage to aircraft any greater than current deicing methods; however, some performance shortcomings were noted. These included the failure to produce a clean wing with forced air only, and a much reduced time interval between the end of cleaning and the initial occurrence of refreezing when a forced air / Type I fluid combination was used.

At the 2001 annual SAE G-12 meeting, the Aircraft Ground Deicing Equipment Subcommittee identified the need for an official process for operators to test the use of forced air to assist in certain deicing applications and, based on successful outcomes, request approval from authorities to use the forced air deicing systems in their deicing operations. A Forced Air Working Group was nominated to work on this project on behalf of the Aircraft Ground Deicing Equipment Subcommittee.

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

3.2 Potential Forced Air Applications

The use of forced air to assist in the deicing process has several potential applications:

- a) Forced air used alone to remove most of the snow before conventional heated fluid deicing;
- b) Type II or Type IV fluid either sprayed over or injected into the forced air system in a manner that allows the use of holdover time guidelines;

- c) Type I fluid either sprayed over or injected into the forced air system in a manner 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) Type I fluid either sprayed over or injected into the forced air system in a manner that allows it to be used as the first step followed by Type I fluid application in the second step;
- e) Type I fluid either sprayed over or injected into the forced air system in a one-step de/anti-icing process that allows the use of the holdover time guidelines;
- f) Type I fluid either sprayed over or injected into the forced air system to remove frost in a non-active condition; and
- g) Forced air delivered alone to deice an aircraft during non-active precipitation.

Of the various potential applications, the working group gave priority to item (b).

Item (c) was given second priority.

Other potential applications have yet to be considered for the development of test procedures and the definition of the approval process.

3.3 Use of Holdover Time Guidelines for Air-Assist Type II or Type IV Fluid Application

The primary interest in this application of the forced air system lies in the possibility of an increased spray distance and improved distribution of Type II or Type IV fluids over the aircraft wing. The objective was to provide an official process for examining whether SAE Holdover Time (HOT) Guidelines could be used when SAE Type II or IV fluid is applied with the assistance of forced air.

In this application, forced air assistance can take either of two forms:

- a) The fluid nozzle can be positioned above the forced air nozzle so that the fluid stream is carried on top of the air stream; or
- b) The fluid nozzle can be positioned to inject fluid into the air stream so that the fluid is mixed with and carried within the air stream.

APS developed a draft test procedure and approval process that evolved through several document versions based on discussions between the Forced Air Working Group and the FAA and TC, which was finally approved.

3.3.1 Approval Process

A standard test procedure, approved by the FAA, TC, and the Forced Air Working Group, was developed to be followed by those operators interested in obtaining approval for this application. Each combination of forced air deicing truck and Type II or Type IV fluid brand requires individual testing and approval. The approved test procedure is included in Appendix D and is described briefly as follows:

- a) Prior to testing the operator develops in-house air-assist spray techniques and verifies that forced air systems are operating within manufacturer specifications;
- b) Operator schedules a test session and invites observers from the FAA and TC.
- c) Tests are conducted on aircraft wings to measure results of fluid application using both air-assist and conventional methods. Tests include spraying into the wind and at least some tests with an outside air temperature (OAT) below freezing. Parameters tested include:
 - Fluid viscosity
 - Fluid thickness
 - Appearance of fluid layer
 - Ridged
 - Patchy
 - Aerated
 - Contaminated
- d) If the operator is satisfied with the test results, completed data forms and declaration of conformity are submitted by the operator to FAA/TC for approval on that specific truck/fluid combination; and
- e) FAA/TC decision to approve is then made based on the submitted results.

3.3.2 Tests Conducted to Date

To date, the test procedures have been applied by three operators:

- a) American Airlines at Chicago O'Hare International Airport, Oct. 31, 2001;
- b) US Airways at Boston Logan International Airport, Nov. 15, 2001; and
- c) Air Canada at Ottawa International Airport, Feb. 6, 2002.

APS participated in these tests by advising the operators about the test procedures and assisting in the data collection. The collected data remained the property of the operators involved.

Of these operators, US Airways has developed the most data and intends to complete the tests required in cold weather during the winter of 2002-03. Results of its initial tests have been documented on the SAE G-12 Aircraft Ground Deicing Equipment Subcommittee website (1). Results of tests conducted thus far indicate that application of Type II or Type IV fluid where the fluid nozzle is positioned above the forced air nozzle so that the fluid stream is carried on top of the air stream provides results similar to the conventional method of fluid application.

American Airlines has not indicated whether it will continue with testing. Results of its initial tests have not been circulated.

Air Canada has indicated that it intends to discontinue use of forced air in this specific application, as the benefits do not appear to justify the additional expense and training required.

Other operators (United Airlines, FedEx) have conducted unofficial tests, and may test with the official test procedure next winter.

3.4 Type I Fluid Application with Forced Air as the First Step in a Two-Step Procedure

The objective was to provide a test procedure to assist operators in examining whether Type I fluid applied with air-assist can be used safely as the first step of a two-step process when followed with an application of Type II or Type IV anti-icing fluid.

In a two-step deicing operation, it is a safety requirement that the wing surfaces (or other critical surfaces) remain free of contamination after deicing, until the second step anti-icing fluid is applied. SAE ARP4737 (2) gives a 3-minute guideline as the time that the surface might be expected to remain uncontaminated. However, this is only a guideline, and the deicing operator is

always responsible for ensuring that the surfaces are still uncontaminated when the anti-icing fluid is applied.

Two factors control the time to refreeze: the freeze point of the fluid on the wing and the wing surface temperature.

The fluid freeze point is influenced by:

- a) Initial freeze point of the fluid (limit of OAT + 3°C);
- b) Initial thickness of the fluid layer on the wing;
- c) The rate of precipitation; and
- d) The local geometry of the wing surface (which affects the rate of run-off and fluid feed from other areas).

The wing surface temperature is influenced by:

- a) Initial wing temperature;
- b) Fluid temperature;
- c) Quantity of fluid applied;
- d) Operator technique;
- e) OAT;
- f) Wind;
- g) Cooling from precipitation; and
- h) Fuel quantity and temperature.

3.4.1 Approval Process

As mentioned above, the requirement to maintain a clean wing until the second step anti-icing fluid was applied was a fundamental responsibility of the deicing operator, regardless of the method of cleaning the aircraft surface. Because the fluid endurance time was irrelevant in this application, it was concluded that approval of the two authorities (FAA and TC) was not needed, but that the operator should decide whether the proposed use of the forced air system was satisfactory. The following requirements would have to be met:

- a) A clean surface is produced;
- b) The surface remains uncontaminated long enough to allow the second step to be accomplished before the first step can freeze;
- c) Slush is not pushed into wing cavities by the air stream; and
- d) There is no danger of the flying snow and ice being ingested into the aircraft engines.

If, after testing, the operator was satisfied that the forced air-assist deicing procedure met the requirements, then the operator could decide to use it as a standard procedure. To support operator decision-making, it was suggested that the results of independent operator tests be shared among the various interested operators.

3.4.2 Test Procedure

The approved test procedure is included in Appendix E. The following is a summary of the test requirements:

- a) Each combination of forced air deicing truck and Type I fluid brand requires individual testing;
- b) When sufficient information has been gathered for a range of conditions, then an operator decision can be made; and
- c) Results of tests conducted in mild conditions are not applicable in more severe conditions.

Procedures and training for operators to follow would include:

- a) The definition of acceptable weather limits for this application of the forced air deicing system (based on test experience); and
- b) An emphasis on deicing operator responsibility for ensuring that the deiced surfaces are still uncontaminated when the anti-icing fluid is applied.

3.4.3 Tests to Date

No tests using the test procedure have been conducted yet. US Airways has expressed an interest in conducting tests next winter.

4. COOPERATION IN THE DEVELOPMENT OF GMOPS FOR GIDS

4.1 Demonstration of Ice Detection Trials

4.1.1 Introduction

A test procedure was prepared and tests were conducted for a sensor manufacturer in order to evaluate compliance of its sensor with the requirements of SAE AS5116. The manufacturer funded the work, and the findings are outside the scope of this report; however, a number of difficulties were experienced in conduct of the tests. This experience provided the basis for recommendations for changes to upgrade the Standard.

Subsequently, and at the request of TC, APS conducted a demonstration for SAE/EUROCAE Working Group members of the procedures required to perform laboratory tests in accordance with SAE AS5116/ED104 Minimum Operational Performance Specification for GIDS. This demonstration, carried out in the NRC CEF, was undertaken to facilitate an appreciation of the practicality and potential limitations of the specified tests.

APS presented a record of its experience, and recommended changes to SAE AS5116/ED104 at the SAE G-12 Ice Detection Subcommittee meeting in Frankfurt, Germany, on June 6, 2002. The majority of the recommended changes were adopted, and the specifications have been upgraded.

A number of challenges were faced in the methodology and procedures to be followed when conducting the tests. APS also presented these issues and proposed changes to AS 5116A at the SAE G-12 Ice Detection Subcommittee in Frankfurt, Germany, on June 6, 2002.

4.1.2 List of Demonstrations

The members of the working group were first given a tour of NRC. Following is a list of the demonstrations presented by APS to the working group over the two-day period:

- a) Ice disc making;
- b) Frost making;
- c) Precipitation rate measurement;

- d) Fluid failure call for freezing drizzle;
- e) Fluid failure call for snow using the NCAR snowmaker; and
- f) Freezing fog visibility.

A copy of the demonstration schedule and the details of the demonstration are contained in Appendix F.

4.1.3 Publication of GMOPS Document

The GMOPS document was accepted by the Council of EUROCAE in November 2001 as ED 104 and by SAE in February 2002 as GMOPS AS 5116A (3).

4.2 Revisions to GMOPS AS5116A

4.2.1 Introduction

During 2001, an agreed standard procedure was prepared for a sensor manufacturer to test its remote GIDS. AS 5116A was used as a guideline for preparing the test procedure. A number of challenges were faced in the methodology and procedures to be followed when conducting the tests. These challenges led APS to present the issues and propose changes to AS 5116A first in a document entitled "Proposed Revisions to AS 5116A", dated May 2, 2002. This document was posted for members of the SAE G-12 Ice Detection Subcommittee to review prior to the June 2002 meeting in Frankfurt, Germany. Comments and questions were received and addressed by APS.

During the meeting, the proposed changes were presented. After extended discussions and with the consensus of the members of the subcommittee that were present, changes were made to the document.

4.2.2 Presentation

A copy of the presentation to the Ice Detection Subcommittee of the proposed changes to AS 5116A is provided in Appendix G. Appendix G also contains a list of all the presentations that were made by APS during the SAE G-12 meetings in Frankfurt, Germany, in June 2002.

Due to the nature of the tests required by the sensor manufacturer, the changes proposed by APS involved several issues in the following domains:

- a) Section 5 of AS 5116A;
- b) Frozen contamination detection and visibility tests; and
- c) Remote ground ice detection.

Following is a brief list of the tests that presented procedural and methodological challenges and the associated changes proposed by APS. These items were addressed by APS and were discussed during the meetings in Frankfurt (Appendix G contains the details):

1. Contaminated surface treated with fluid after deicing
 - This was a technical and a procedural challenge. Tolerances were added to parameters and text that further elaborated the procedure was added.
2. Frozen contamination above the detection threshold
 - Text that further elaborated the procedure was added.
3. Fog visibility tests
 - The temperature of the water supply of the spray equipment was modified.
4. Snow visibility tests
 - The air temperature requirement was modified.
5. Freezing drizzle and light freezing rain visibility tests
 - The precipitation rate tolerances for both conditions were modified, and a new designation was created for each of the two conditions.
6. Angle of test plate
 - APS proposed that the angle requirement of the test plate be modified. All tests are to be conducted while plates are placed at a 10° angle to the horizontal. Tests conducted on the GIDS whose maximum distance and minimum angle are such that the physical limitations of the test chamber will not accommodate the distances and heights may require that the test plates be placed at varying angles. This also holds true for tests conducted outdoors where physical limitations dictate

that the test plates be placed at angles greater than 10°. The members of the subcommittee that were present did not accept this proposed change; they indicated that the sensor manufacturer can still carry out tests at different angles and report those angles.

4.2.3 Publication of Upgraded AS5116

SAE AS 5116 and ED 104 were revised to include the recommended changes.

A document entitled "Explanation of Revisions to AS 5116A" was provided by APS to explain the changes. This document contains a list of the changes proposed during the meeting, and which pertain to items raised by APS, as well as the justification related to those changes. The changes listed also reflect the recommendations and approval of the members of the subcommittee that were present. A copy of this document is contained in Appendix F.

5. PROCEDURES, PRESENTATIONS, AND FLUID MANUFACTURER REPORTS

5.1 Procedures

Several procedures were developed to guide and support the research team in the methodology for conducting trials. Table 5.1 provides a list of the procedures developed to address specific projects, which are also identified in the table. The actual procedures have been included in respective reports of the overall research program.

5.2 Presentations

During the course of a research program, subcommittees of the SAE G-12 Committee hold several meetings. During these meetings, APS presents the findings of the work that has been completed. Much of the research presented at these meetings is eventually documented in various reports.

In 2001-02, four meetings were held:

1. SAE G-12 HOT Subcommittee Meeting, Montreal, November 2001;
2. SAE G-12 HOT Subcommittee Working Group Meeting, Montreal, May 2002;
3. SAE G-12 Committee, Aircraft Ground Deicing Meetings, Frankfurt, June 2002; and
4. Summer Winter Integrated Field Technologies (SWIFT) Conference, Calgary, September 2002.

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

5.2.1 SAE G-12 Holdover Time Subcommittee Meeting, Montreal, November 2001

Two presentations were prepared for the SAE G-12 HOT Subcommittee meeting held in Montreal November 29-30, 2001:

Table 5.1: List of Procedures for Winter 2001-02

	Contract Task	Name of Procedures	Date of Latest Version	Versions submitted to TDC	Status
1.1	HOLDOVER TIME TESTING AND EVALUATION OF DE/ANTI-ICING FLUIDS	Experimental Program for Dorval Natural Precipitation Flat Plate Testing	09-Oct-01	1.0	TDC
1.1	HOLDOVER TIME TESTING AND EVALUATION OF DE/ANTI-ICING FLUIDS	Detailed Plan of NRC Cold Chamber Testing	03-Apr-02	1.0	TDC
1.3	HOT TESTS IN FROST	Phase I Evaluation of Frost Accretion Rates in Natural Condition	13-Nov-01	1.0	TDC
1.3	HOT TESTS IN FROST	Phase II Validation Tests in Conjunction with Aircraft Wings	13-Nov-01	1.0	TDC
1.3	HOT TESTS IN FROST	Phase III Evaluation of Wing-To-Air Temperature Differential	13-Feb-02	1.0	TDC
1.3	HOT TESTS IN FROST	Phase IV Experimental Procedure for Holdover Time Testing in Simulated Frost Conditions	13-Feb-02	1.0	TDC
1.6	EVALUATION OF WINTER WEATHER DATA	Experimental Procedure for the Collection of Fog Rates of Deposition in Natural Conditions	09-Nov-00	1.0	TDC
1.7	DOCUMENTATION OF FLUID FAILURE CHARACTERISTICS	Procedure for the Documentation of the Appearance of Failed Fluids for Outdoor Tests	09-Nov-01	1.0	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	ET Tests on Cold-Soak Boxes at Quebec City Airport	23-Jan-02	n/a	APS files
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Examination of Fluid Quantities for SAE Type I Fluid Endurance Laboratory Test Procedure	07-Sep-01	1.0	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Field Trials for Type I HOT Test Protocol	21-Nov-01	1.0	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Determination of Outdoor Endurance Times of Type I Fluids Using the New Test Protocol	09-Jan-02	1.1 & 2.0	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Potential Use of Protocol for Type II and IV Fluid Dilutions	09-Jan-02	1.0	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Examine Use of 60° C Fluid and a Cold-Soak Box as Test Surface for SAE Type I Fluid Endurance Laboratory Tests	22-Nov-01	1.0	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Determination of Indoor Endurance Times of Type I Fluids Using the New Test Protocol	10-Dec-01	1.0 & 1.1	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Determination of Indoor Endurance Times of Type I Fluids Using the New Test Protocol and an Adjusted Air Temperature	19-Feb-02	1.0	TDC
2	DEVELOPMENT OF PROTOCOL FOR TYPE I TESTING	Addendum One ET Times of Dilute Heated Type II/IV Fluids Measured by the New Test Protocol and an Adjusted Air Temperature	04-Mar-02	1.0	TDC
3	FLOW OF CONTAMINATED FLUID	Field Trials to Examine Removal of Diluted Fluid from Aircraft Wings During Takeoff Run	28-Feb-02	1.0	TDC
3	FLOW OF CONTAMINATED FLUID	Field Trials to Examine Removal of Diluted Fluid from Aircraft Wings During Takeoff Run	04-Mar-02	2.0	TDC
4	MEASURE OF ON-WING VISCOSITY	Viscosity Measurements of Fluids	03-Apr-02	1.0	TDC
6	NCAR SNOWMAKER	Trials to Determine the Differences between Natural Snow and the NCAR Snow Generation System - Outdoor	08-Jan-02	1.0	TDC
6	NCAR SNOWMAKER	Trials to Assess the Performance of the NCAR Snow Generation System	03-Apr-02	1.0	TDC
6	NCAR SNOWMAKER	Trials to Measure the Uniformity of Outdoor Snow Precipitation Rates	26-Oct-01	1.0	TDC
7.1	REPLACEMENT OF TACTILE CHECK WITH GIDS	Evaluation of GIDS Sensors to Replace Tactile Inspections	06-Dec-01	1.0	e-mailed to Frank Eyre
7.1	REPLACEMENT OF TACTILE CHECK WITH GIDS	Meteo Data Form	16-Mar-01	1.0	e-mailed to TC, GG & MFG
8	CONTAMINATION OF WINGS AT END-OF -RUNWAY	Field Trials to Determine the Extent of Contamination on Departing Aircraft	28-Feb-02	1.0	TDC
10	SUPPORT SERVICES	Overall Program of Tests at NRC - April, 2002	03-Apr-02	1.0	TDC
10	SUPPORT SERVICES	Experimental Program to Establish Film Thickness Profiles for Deicing and Anti-icing Fluids on Flat Plates - NRC CEF	03-Apr-02	1.0	TDC
10	SUPPORT SERVICES	Preliminary Evaluation of IR Thermometers to Assist in Identifying Ice on Wings after Deicing	10-Sep-01	1.0	TDC
10	SUPPORT SERVICES	Type II / IV Fluid Applied into Forced Air Stream	These procedures were created in 2000-01. The testing may continue in 2001-02.		
10	SUPPORT SERVICES	Type I Fluid Applied or Injected into Forced Air Stream			

M:\Groups\Cm1680 (01-02)\Reports\Support Services\Working Documents\Table 5.1 List of Procedures

1. Holdover Times for Forced Air Applications; and
2. Effect of Fluid Strength and Dilution Rates on SAE Type I Fluid Endurance Times.

5.2.2 SAE G-12 Holdover Time Subcommittee Working Group Meeting, Montreal, May 2002

Two presentations were prepared for the SAE G-12 HOT working group meeting in Montreal in May 2002:

1. Type I Fluid Endurance Time Tests Using New Protocol; and
2. Type I Fluid Endurance Time Tests at -3°C.

5.2.3 SAE G-12 Committee, Aircraft Ground Deicing Meetings, Frankfurt, June 2002

Eight presentations were prepared for the SAE G-12 meetings in Frankfurt from June 2-7, 2002, as follows:

1. Aircraft De/Anti-Icing Fluid Endurance Time Results from 2001-02 Tests (for HOT Subcommittee); Type I Fluid Endurance Time Tests Using New Protocol (for HOT Subcommittee); Frost Contamination – Countermeasure Development Opportunities (for Future Technologies Subcommittee);
4. Test Program - Forced Air Systems Type II or Type IV Fluid Applied Over or Injected into the Forced Air Stream (for HOT Subcommittee);
5. Test Program - Forced Air Systems Type II or Type IV Fluid Applied Over or Injected into the Forced Air Stream (for Equipment Subcommittee);
6. Test Program - Forced Air Systems Type I Fluid Applied Over or Injected into the Forced Air Stream (for Equipment Subcommittee);
7. Operational Guidelines for On-Wing Thickness of SAE Type II or Type IV Fluids (for HOT and Methods Subcommittee); and
8. Proposed Revisions to AS 5116A (for Ice Detection Subcommittee).

A presentation was prepared for the SWIFT conference at Calgary, Alberta in September 2002:

- Aircraft Deicing with Forced Air.

5.3 Fluid Manufacturer Reports

As part of the research program, several fluids are tested for holdover time performance every year. Some of this data is then published for holdover time use in the industry, while some of the data for some fluids that are tested is maintained by the fluid manufacturer for research purposes. During the winter of 2001-02, a total of 10 fluids were tested. Fluid manufacturer reports containing the test results were published for all 10 fluids. In addition, endurance time data for four of these fluids are being published in TC report TP 13991E, *Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter*, (4). Following is a list of all fluids tested:

1. Clariant Safewing MPIV 2001 (Degraded);
2. Clariant Safewing MP II 2025 LITE;
3. Kilfrost ABC 2000 Type II (also published in TC report TP 13991E (4));
4. Kilfrost P1064 Type IV;
5. Octagon E MAX II (also published in TC report TP 13991E (4));
6. DOW (UCAR) T4 Type IV;
7. DOW (UCAR) 20-MJM-66;
8. DOW (UCAR) PG ADF Type I (also published in TC report TP 13991E (4));
9. HOC Safetemp Type I; and
10. SPCA DE-950 Type I (also published in TC report TP 13991E (4)).

REFERENCES

1. <http://www.sae.org/servlets/index>, Society of Automotive Engineers (SAE).
2. Society of Automotive Engineers (SAE) Aerospace Recommended Practice ARP4737 (Rev. E), *Aircraft Deicing/Anti-icing Methods with Fluids*, Warrendale, PA, December 2001, 30.
3. Society of Automotive Engineers (SAE) Aerospace Standard AS 5116, *Aerospace Standard / Minimum Operational Performance Specification for Ground Ice Detection Systems*, Warrendale, PA, May 2001, 45.
4. Chaput, M., Campbell, R., *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Test Program for the 2001-02 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13991E (to be published).