TP 14452E

Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681

Prepared for
Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

And

The Federal Aviation Administration
William J. Hughes Technical Center

Prepared by

APS Aviation Inc.

November 2007
Final Version 1.0

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by
George Balaban, Katrina Bell, John D'Avirro and Marco Ruggi

Prepared by
APS Aviation Inc.

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Final Version 1.0

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by: George Balaban, Katrina Bell, John D'Avirro and Marco Ruggi

Reviewed by:

Notarius

February 2, 2018

John D'Avirro
Program Manager

Date

Approved by: **

Jack Rigley, P. Eng
Vice President, Communications Engineering
ADGA Group

Date

Un sommaire français se trouve avant la table des matières.

***This report was prepared by George Balaban, Katrina Bell, John D'Avirro and Marco Ruggi, reviewed and signed by John D'Avirro, and approved and signed by Jack Rigley in November 2007 as part of the first submission to Transport Canada (Final Draft 1.0). A final Transport Canada technical and editorial review was completed in June 2012; Jack Rigley was not available to participate in the final review or to sign the current version of this report.*

PREFACE

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

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To evaluate whether holdover times should be developed for ice pellet conditions;
- To examine the effect of heated fluids on Type II/III/IV fluid endurance times;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To assist in the testing of flow of contaminated fluid from aircraft wings during takeoff;
- To assist in the testing of flow of contaminated fluid from simulated aircraft wings during takeoff;
- To validate the laboratory snow test protocol with Type II and IV fluids;
- To develop performance specifications for an integrated weather system that measures holdover time;
- To provide support for the development of a standard that evaluates remote on-ground ice detection systems;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests on non-aluminum plates;
- To conduct endurance time tests in frost on various test surfaces;
- To conduct preliminary wind tunnel endurance time tests in heavy snow;
- To compile historical data for calculation of holdover times based on a small number of inputs;
- To examine the use of non-glycol tempered steam technology to deice aircraft; and
- To assist DND Canada in evaluating the effects of slipstream on anti-icing fluid.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2006-07 are documented in eight reports. The titles of the reports are as follows:

- TP 14452E Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681;
- TP 14776E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2006-07 Winter;
- TP 14777E Winter Weather Impact on Holdover Time Table Format (1995-2007);
- TP 14778E Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report;
- TP 14779E Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets;

- TP 14780E Evaluation of Tempered Steam Technology (TST) for Aircraft Deicing Applications;
- TP 14781E Aircraft Ground Icing Research General Activities During the 2006-07 Winter; and
- TP 14782E Regression Coefficients Used to Develop the Winter 2007-08 Type I Generic and Dow UCAR Endurance EG106 Holdover Time Tables.

In addition, the following six interim reports are being prepared:

- *Preliminary Aircraft Deicing Research in Heavy Snow Conditions;*
- *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2006-07;*
- *Effect of Heat on Fluid Endurance Times Using Composite Surfaces;*
- *Effect of Heat on Endurance Times of Anti-Icing Fluids (Volume 1);*
- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions; and*
- *Regression Coefficients Used to Develop Aircraft Ground Deicing on Holdover Time Tables: Winter 2007-08.*

In addition, the following report was written for DND as part of this contract; this report does not have a TP number:

- Support for Testing to Ascertain the Effects of SAE Type IV De/Anti-Icing Fluids on CC-130 Hercules and CP-140 Aurora Aircraft Takeoff Handling.

This report, TP 14452E, has the following objective:

- To provide support for the development of a standard that evaluates remote on-ground ice detection systems;

This objective was met by holding a demonstration of the conditions required to conduct laboratory trials for evaluating the minimum operational performance requirements (proposed SAE AS5681) of Remote On-Ground Ice Detection Systems (ROGIDS).

PROGRAM ACKNOWLEDGEMENTS

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

APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: George Balaban, Katrina Bell, Stephanie Bendickson, Ryan Brydges, Michael Chaput, John D'Avirro, Peter Dawson, Dany Posteraro, Marco Ruggi, Joey Tiano, and David Youssef.

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

PROJECT ACKNOWLEDGEMENTS

Special thanks are extended to all the members of the ROGIDS Working Group, who have participated, contributed and provided guidance in the preparation of this document. This includes the following people: Katrina Bell, John D'Avirro, Frank Eyre, Cliff Fiscus, Dennis Gregoris, Douglas Ingold, Ed Pugacz, Mario Rosa, Clint Tanner, and Frank Teti.

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Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.
TP 14452E

2. Project No.
5498-5501 (a-d)

3. Recipient’s Catalogue No.

4. Title and Subtitle
Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681

5. Publication Date
November 2007

6. Performing Organization Document No.
CM2020.002

7. Author(s)
George Balaban, Katrina Bell, John D’Avirro and Marco Ruggi

8. Transport Canada File No.
2450-BP-1

9. Performing Organization Name and Address
APS Aviation Inc.
6700 Cote de Liesse, Suite 102
Montreal, (St-Laurent)
H4T 2B5
Canada

10. PWGSC File No.
MTB-5-21166

11. PWGSC or Transport Canada Contract No.
T8200-055516/001/MTB

12. Sponsoring Agency Name and Address
Transportation Development Centre (TDC)
800 René Lévesque Blvd. West, Suite 600
Montreal, Quebec
H3B 1X9
Canada

13. Type of Publication and Period Covered
Final

14. Project Officer
Antoine Lacroix for Barry B. Myers

15. Supplementary Notes (Funding programs, titles of related publications, etc.)
Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada. These are available from the Transportation Development Centre (TDC). Several reports were produced as part of this winter’s research program. Their subject matter is outlined in the preface. This project was co-sponsored by the Federal Aviation Administration.

16. Abstract

Human factor testing performed by Transport Canada (TC), the FAA and APS in recent years has indicated that ice detection systems can perform better than trained human observers in the determination of ice under de/anti-icing fluid during post-deicing tactile examinations. As a result of these tests, the SAE G-12 Ice Detection Subcommittee is writing a new minimum performance standard document, Aerospace Standard (AS) 5681, for testing and approval of a Ground Ice Detection System (GIDS) to supplant human observers for tactile inspections.

To ensure that the tests included in proposed AS 5681 are feasible, APS conducted the pertinent laboratory tests. A number of short comings were identified and revised test procedures were developed and recommended for inclusion in AS 5681.

17. Key Words
ROGIDS, Curtain Solution, Ice disks, Anti-icing, Deicing, Lighting conditions, Foam test, Ice detection, Human Factors, Tactile

18. Distribution Statement
Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)
Unclassified

20. Security Classification (of this page)
Unclassified

21. Declassification (date)
—

22. No. of Pages
xviii, 50 app.

23. Price
—

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. Nº de la publication de Transports Canada
TP 14452E

2. Nº de l'étude
5498-5501 (a-d)

3. Nº de catalogue du destinataire

4. Titre et sous-titre
Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681

5. Date de la publication
Novembre 2007

6. Nº de document de l'organisme exécutant
CM2020.002

7. Auteur(s)
George Balaban, Katrina Bell, John D'Avirro et Marco Ruggi

8. Nº de dossier - Transports Canada
2450-BP-1

9. Nom et adresse de l'organisme exécutant

APS Aviation Inc.
6700 Côte de Liesse, Suite 102
Montréal, (St-Laurent)
H4T 2B5
Canada

10. Nº de dossier - TPSGC
MTB-5-21166

11. Nº de contrat - TPSGC ou Transports Canada
T8200-055516/001/MTB

12. Nom et adresse de l'organisme parrain

Centre de développement des transports (CDT)
800, boul. René-Lévesque Ouest, Bureau 600
Montréal (Québec)
H3B 1X9
Canada

13. Genre de publication et période visée
Final

14. Agent de projet
Antoine Lacroix pour Barry B. Myers

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

Plusieurs comptes rendus de recherches sur les essais de technologies d'antigivrage et de dégivrage ont été produits pour le compte de Transports Canada pour les hivers précédents. Ils sont disponibles au Centre de développement des transports (CDT). Plusieurs comptes-rendus ont été produits dans le cadre du programme de recherches de cet hiver. Les grandes lignes de leurs éléments sont données dans l'introduction. Ce projet a été coparrainé par la *Federal Aviation Administration (FAA)*.

16. Résumé

Les essais sur les facteurs humains menés par Transports Canada (TC), la FAA et APS au cours des dernières années ont démontré, lors d'examens tactiles d'après dégivrage, que les systèmes de détection de la glace peuvent donner de meilleurs résultats que les observateurs humains qualifiés dans l'identification de la glace sous les liquides antigivre ou de dégivrage. Par suite de ces essais, le sous-comité du G-12 de la SAE sur la détection de la glace prépare un nouveau document sur la norme minimale de rendement, *l'Aerospace Standard (AS) 5681*, qui concerne les essais et l'approbation d'un Système de détection de givrage au sol (SDGS) pour remplacer les observateurs humains pour les inspections tactiles.

Afin d'assurer que les essais proposés dans l'AS 5681 soient réalisables, APS a mené des essais pertinents en laboratoire. Un certain nombre de lacunes ont été identifiées et des procédures d'essais modifiées ont été élaborées et leur inclusion dans l'AS 5681 a été recommandée.

17. Mots clés
ROGIDS, solutions de rideau liquide, disques de glace, antigivrage, dégivrage, luminosité, test de mousse, détection de la glace, facteurs humains, tactile.

18. Diffusion
Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)
Non classifiée

20. Classification de sécurité (de cette page)
Non classifiée

21. Déclassification (date)
—

22. Nombre de pages
xviii, 50 ann.

23. Prix
—

CDT/TDC 79-005
Rev. 96

EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC), with financial support from the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology.

Human factor testing performed by Transport Canada (TC), the FAA and APS in recent years has indicated that an ice detection system performed better than trained human observers in the determination of ice under de/anti-icing fluid in tests aimed to simulate post-deicing tactile examinations. As a result of these tests, the SAE G-12 Ice Detection Subcommittee is writing a new minimum performance standard document, Aerospace Standard (AS) 5681, for testing and approval of a Ground-based Ice Detection Sensor (GIDS) to supplant human observers for tactile inspections.

To ensure that the tests included in proposed AS5681 are feasible, APS held a demonstration of the conditions required to conduct laboratory tests. This report details the work conducted.

The general specification parameters and logistics that were investigated included:

- Ice disk stability verification;
- Daytime, night-time and shadow lighting conditions;
- Ice detection test simulation; and
- Laboratory foam test.

In addition, APS attempted to simulate the following conditions:

- Freezing rain between the plates and the sensor(s), and encompassing the sensor field of view;
- Freezing drizzle between the plates and the sensor(s), and encompassing the sensor field of view; and
- Rain between the plates and the sensor(s), and encompassing the sensor field of view.

The results of testing were analysed, and changes were made to the proposed SAE AS5681 where appropriate.

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En vertu d'un contrat avec le Centre de développement des transports (CDT) et avec le soutien financier de la Federal Aviation Administration (FAA), APS Aviation Inc. (APS) a entrepris des activités de recherche pour faire progresser la technologie en matière de dégivrage et d'antigivrage d'aéronefs au sol.

Les essais menés par Transports Canada (TC), la FAA et APS en matière de facteurs humains au cours des dernières années ont démontré, lors d'essais visant à simuler les examens tactiles d'après dégivrage, qu'un système de détection de la glace donne des meilleurs résultats que des observateurs humains qualifiés dans l'identification de la glace sous les liquides antigivre ou de dégivrage. Par suite de ces essais, le sous-comité du G-12 de la SAE sur la détection de la glace prépare un nouveau document sur la norme minimale de rendement, *l'Aerospace Standard (AS) 5681*, qui concerne les essais et l'approbation d'un SDGS pour remplacer les observateurs humains pour les inspections tactiles.

Afin d'assurer que les essais proposés dans l'AS5681 soient réalisables, APS a tenu une démonstration des conditions requises pour mener des essais en laboratoire. Le présent compte rendu donne les détails du travail effectué.

Les paramètres en matière de spécifications et les questions de logistique examinés comprennent :

- La vérification de la stabilité des disques de glace ;
- La luminosité de jour, de nuit et de zones d'ombre ;
- La simulation d'essais de détection de la glace ; et
- Un test de mousse en laboratoire.

De plus, APS a tenté de simuler les conditions suivantes :

- La pluie verglaçante entre les plaques et le(s) capteur(s), englobant le champ de vision du capteur ;
- La bruine verglaçante entre les plaques et le(s) capteur(s), englobant le champ de vision du capteur ; et
- La pluie entre les plaques et le(s) capteur(s), englobant le champ de vision du capteur.

Les résultats des essais ont été analysés et des changements ont été apportés à l'AS5681 de la SAE, le cas échéant.

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GLOSSARY

APS	APS Aviation Inc.
AS	Aerospace Standard
CARs	Canadian Air Regulations
FAA	Federal Aviation Administration
FARs	Federal Aviation Regulations (United States)
FFP	Fluid Freeze Point
GIDS	Ground-based Ice Detection System
JARs	Joint Aviation Regulations (European)
MSC	Meteorological Service of Canada
NRC	National Research Council (Canada)
PG	Propylene Glycol
ROGIDS	Remote On-Ground Ice Detection Systems
SAE	SAE International
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

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

Over the past several years, the Transportation Development Centre (TDC), Transport Canada (TC) has managed and conducted de/anti-icing related tests at various sites in Canada; it has also coordinated worldwide testing and evaluation of evolving technologies related to de/anti-icing operations with the co-operation of the US Federal Aviation Administration (FAA), the National Research Council (Canada) (NRC), Meteorological Service of Canada (MSC), several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

Under contract to the TDC, with financial support from the FAA, APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology. The work statement for this project is included in Appendix A. APS was requested to participate in the activities of the Society of Automotive Engineers (SAE International) G-12 Subcommittee for Ice Detection, the SAE Regulatory Approval Process Working Group, and the Transport Canada “Ground-based Ice Detection System (GIDS) Implementation Team”.

1.1 Background

Exposure to weather conditions on the ground that are conducive to clear ice formation can cause aircraft surfaces and components to adversely affect aircraft performance, stability, and control. Therefore, regulatory bodies provide regulations governing aircraft operations in icing conditions that must be followed. Specific rules for aircraft are set forth in Federal Aviation Regulations (United States) (FARs), Joint Aviation Regulations (European) (JARs), Canadian Air Regulations (CARs), and others. The intent of these regulations is to ensure that no one attempts to dispatch or operate an aircraft with frozen deposits adhering to any aircraft component critical to safe flight.

1.2 Current Status of Performance Standards

A Ground-based Ice Detection System (GIDS) is a system that performs remote measurements of a monitored aircraft surface to determine whether frozen contamination is present. Numerous GIDS have been developed and tested by the industry over the past decade.

The development of GIDS has remained stagnant in recent years, primarily due to issues of technology performance and lack of industry approvals for use of the systems. Perhaps the biggest obstacle to the regulatory approval of GIDS was the determination of a detection threshold, which defines the minimum amount of ice present on aircraft surfaces that the GIDS must be able to detect. A minimum detection threshold was eventually established and included within SAE Aerospace Standard (AS) 5116, which established the minimum performance standard for GIDS. While it was thought GIDS would be brought to market soon after the approval of AS 5116, no systems were produced that could meet the minimum performance criteria set out in the document. As a result, no GIDS have ever been commercially produced.

However, human factor testing performed by TC (see TC report, TP 14449E, *Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests* (1) and TC report, TP 14450E, *Comparison of Human Ice Detection Capabilities and Ground Ice Detection Performance Tests on Wing at PMG* (2)), the FAA (see FAA report, DOT/FAA/TC-06/21, *Human Visual and Tactile Ice Detection Capabilities under Aircraft Post Deicing Conditions*, (3) and FAA report, DOT/FAA/TC-06/20, *Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance Under Post Deicing Conditions*, (4)) and APS in recent years has indicated that an ice detection system performed better than trained human observers in the determination of ice under de/anti-icing fluid in tests aimed to simulate post-deicing tactile examinations. As a result of these tests, the SAE G-12 Ice Detection Subcommittee is writing a new minimum performance standard document, AS5681, for testing and approval of GIDS to supplant human observers for tactile inspections. The minimum performance criteria in this document will be less exacting than the criteria set in AS5116; in fact, it is expected some GIDS in development may already meet the AS5681 requirements.

As a result of the human factors studies, the SAE G-12 Ice Detection Subcommittee formed the Remote On-Ground Ice Detection Systems (ROGIDS) Working Group to develop AS5681.

1.3 Objective

In general, three sets of tests are described in the proposed AS5681 (see Appendix B): pre-deicing, post-deicing, and post-deicing with precipitation. The work conducted for this project focused predominantly on the post-deicing with precipitation tests.

The specific objective of the project was to hold a demonstration of the conditions required to conduct laboratory tests for evaluating the minimum operational performance requirements (given in proposed SAE AS5681) of ice detection sensors. The testing took place at the NRC from March 26-28, 2007, and encompassed two activities:

1. General specification parameters and logistics, including:
    - Ice disk stability verification;
    - Daytime, night-time and shadow lighting conditions;
    - Ice detection test simulation; and
    - Laboratory foam test.
2. Clear ice detection during precipitation (the “curtain solution”). The “curtain solution” was used to test and evaluate the following test conditions:
    - Freezing rain between the plates and the sensor(s), and encompassing the sensor field of view;
    - Freezing drizzle between the plates and the sensor(s), and encompassing the sensor field of view; and
    - Rain between the plates and the sensor(s), and encompassing the sensor field of view.

Two procedures on how to conduct these tests were written, and are included in Appendices C and D.

APS was asked to prepare and co-ordinate testing to demonstrate to the ROGIDS Working Group members whether the conditions and tests described in proposed standard SAE AS5681 were in fact feasible and realistic. The ROGIDS Working Group felt strongly that there was no point in producing a standard that was not usable.

The majority of Working Group members were present for the testing and had direct input in the testing and subsequent recommendations. All the results were later presented at the April 2007 ROGIDS Working Group meeting in

Toronto, Canada, and the recommended changes to the standard were agreed upon by the group.

It should be noted that in an attempt to keep costs to a minimum, freezing fog tests were not attempted, as the freezing fog condition has successfully been achieved at the NRC in the past. In addition, it was decided at the October 2006 ROGIDS Working Group meeting in Atlantic City that snow tests should be conducted outdoors; therefore, snow tests were not attempted.

1.4 Report Format

Each of the subsequent sections of this report presents a brief report on work conducted related to a specific test parameter:

- Section 2 discusses ice disk stability;
- Section 3 discusses lighting conditions;
- Section 4 discusses ice detection test simulation;
- Section 5 discusses the laboratory fluid foam test; and
- Section 6 discusses clear ice detection during precipitation.

1.5 Daily Test Reports

Daily test reports were produced at the end of each day of testing. These reports were used to document the test results and identify the problems that needed to be resolved.

The tests reports, written in memo format, documented the test logistics, investigation of ambient lighting conditions, ice detection test simulation and the foam tests. The reports are included in Appendix E.

1.6 Investigation of Aircraft Wing Surfaces

During the March 2007 NRC test session, Transport Canada and FAA representatives visited the Ottawa International Airport to observe the characteristics of aircraft wing surfaces and amend the proposed standard accordingly. In the original version of the standard, three surfaces were selected to simulate the aircraft wings in the ROGIDS tests:

- Highly polished and (other half) polished aluminum;

- White and red painted aluminum; and
- White and red painted composite.

Following the airport visit, the standard was amended and the selected test surfaces are:

- Polished aluminum and grey painted;
- White and red painted aluminum;
- White and red painted composite; and
- Rubber surface replicating aircraft deicing boot.

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2. ICE DISK STABILITY

2.1 Introduction

This section focuses on the feasibility of creating ice disks for use during the pre/post-deicing tests described in the proposed AS5681. Previous testing conducted by APS (in 2004-05) demonstrated the feasibility of manufacturing ice coupons (disks). A final procedure for creating ice disks was issued following these tests. A copy of this procedure is included in Appendix C.

The testing described in this section was required to demonstrate the feasibility of using ice disks prepared using the Appendix C procedure for use in the pre/post-deicing tests described in the proposed AS5681.

2.2 Objectives

The objective of this project was to evaluate the decay of ice disk samples following the application of de/anti-icing fluid. The following particulars were investigated:

- Test parameters less likely to cause ice to dissolve;
- Maximum allowable time following fluid application until ice disk thickness begins to decrease; and
- Feasibility of carrying out the test plan requiring ice disk samples as described in the proposed AS5681.

To minimize expenditures, preliminary testing was conducted in the APS refrigerated truck research chamber (APS Reefer Chamber). Procedural modifications and feasibility were demonstrated at the NRC chamber in March 2007.

2.3 Test Methodology

2.3.1 Preliminary Test Parameter Investigation (APS Reefer Chamber)

Testing was conducted to investigate which parameters were less likely to cause the ice disk to reduce in thickness following fluid application. It was recommended that fluid temperature and plate temperature be investigated. Testing was conducted with 0.5 mm thick ice disks with a maximum area of 315 cm². Variations of fluid and plate temperatures were investigated. The total time required to completely dissolve each ice sample was recorded. A detailed procedure is included in Appendix C.

2.3.2 Ice Thickness Reduction Tests (APS Reefer Chamber)

Testing was conducted to investigate the maximum allowable time following fluid application until ice disk thickness began to decrease. Following fluid application, the ice disk was carefully cleaned using a squeegee and the thickness of the ice was measured and recorded using a wet film thickness gauge. One-step application tests (with Type I and Type IV fluid), as well as two-step applications (Type I fluid followed by Type IV fluid) were conducted. Testing was conducted with 0.5 mm thick ice disks with a maximum area of 315 cm². The de/anti-icing fluid was cooled to the lowest attainable temperature (approximately -35°C was obtained with the APS freezer) to extend the time required to cause significant reduction in the ice disks. A pre-measured amount of fluid was poured around the ice disk and gently brushed over the ice disk using a paintbrush. For each dataset, the time it took to remove all of the de/anti-icing fluid varied between 15 seconds and 7 minutes; the data collected was plotted to generate an ice decay profile specific to the test conditions. A detailed procedure is included in Appendix C.

2.3.3 Test Logistics Validation (NRC Chamber)

Testing was conducted at the NRC in March 2007 to validate the procedural guidelines set forth as a result of the preliminary research conducted by APS in the reefer chamber. Testing was conducted to confirm the validity of the procedure for creating ice disks, specifically, to ensure that the thickness of the ice disks would not degrade within two minutes of application. Testing was conducted with 0.5 mm thick ice disks with a maximum area of 315 cm². Type I fluid was diluted to a standard mix and was cooled to the lowest attainable temperature (approximately -40°C); ice disks were developed on standard aluminum test plates inside the cold chamber, which was cooled to approximately -5°C. A detailed procedure is included in Appendix D.

2.4 Results

2.4.1 Preliminary Test Parameter Investigation (APS Reefer Chamber)

Results from the testing conducted demonstrated that the fluid temperature most significantly affected the melting time for the ice disks. Results showed that by cooling the de/anti-icing fluid to the lowest attainable temperature (approximately -35°C was obtained with the APS freezer), the time required to cause significant reduction in the ice disks was extended. This methodology was adopted by the proposed AS5681 for use with all pre/post-deicing tests to be conducted with ice disks.

2.4.2 Ice Thickness Reduction Tests (APS Reefer Chamber)

Results from the testing conducted demonstrated that the ice disk would begin to reduce in thickness approximately 2 minutes following fluid application for a one-step application test, and approximately 1 minute following fluid application for a two-step application test. It was also demonstrated that fluid application could be performed in a short period of time; approximately 17 seconds for a one-step application, and approximately 36 seconds for a two-step application. It was concluded that the ice disk samples would allow for sufficient time following fluid application to conduct the required series of ice detection tests described in AS5681. Details of the test results are included in Appendix F.

2.4.3 Test Logistics Validation (NRC Chamber)

Testing was conducted using a one-step Type I fluid application. Results from the testing conducted confirmed the results previously documented during the tests conducted in the APS reefer trailer; the ice disk would begin to reduce in thickness approximately 2 minutes following fluid application for a one-step application test. It was also confirmed that the ice disk samples would allow for sufficient time following fluid application to conduct the required series of ice detection tests described in AS5681. Details of the test results are included in the daily test reports found in Appendix E.

2.5 Conclusions and Recommendations

2.5.1 De/Anti-Icing Fluid Application to Ice Disks

Results demonstrated that de/anti-icing fluid should be applied to the ice disk at the lowest attainable temperature (-35°C to -40°C) to extend the time required to cause significant reduction in the ice disk thickness. Plate temperature and ice disk temperature were maintained at approximately -5°C; these parameters did not have a significant effect on the ice disk thickness reduction following fluid application.

2.5.2 Ice Disk Reduction Following Fluid Application

Results from the testing conducted demonstrated that the 0.5 mm thick ice disk with a maximum area of 315cm² would begin to reduce in thickness approximately 2 minutes following fluid application for a one-step application test, and approximately 1 minute following fluid application for a two-step application test. These results were documented during the testing conducted in the APS reefer trailer and were confirmed during the testing conducted at the NRC.

2.5.3 Feasibility of Using Ice Disk Samples for the Proposed AS5681 Test Plan

Results from the testing conducted at the APS reefer trailer and at the NRC demonstrated that the ice disk samples would allow for sufficient time following fluid application to conduct the required series of ice detection tests described in AS5681. Test results showed that multiple ice detection tests (as described in AS5681) could be conducted consecutively using the same ice disk sample.

These results were presented to the ROGIDS Working Group at the November 2006 meeting in Atlantic City. The presentation is included in Appendix G.

3. LIGHTING CONDITIONS

3.1 Introduction

The proposed Aerospace Standard AS5681 gives three lighting conditions under which tests must be conducted: daylight, daylight with shadows, and night-time. The daylight and night-time lighting conditions are specified based on illumination (in LUX) and colour temperature (in Kelvin).

Prior to testing, the illumination and colour specifications shown in Table 3.1 were included in AS5681.

Table 3.1: Initial AS5681 Lighting Requirements

	Illumination	Colour Temperature
Daylight	>25,000 lux	5,000 to 6,500 K
Night-time	100 to 500 lux	2,100 to 3,200 K

3.2 Objective

The objective of this testing was to ensure the lighting specifications given in the standard for each lighting condition could be produced in the NRC chamber.

3.3 Methodology

A test procedure was developed for this research (included in Appendix D) and testing was completed in April 2007 at the NRC chamber. Of note:

- Light illumination and colour temperature were measured using a Sper Scientific 840020 light meter and a Konica-Minolta Colormeter III;
- Various lighting conditions currently available in the chamber were tested;
- Different types of lighting available were investigated;
- Lighting was added as necessary to achieve the lighting specifications; and
- Plastic boards were positioned above plates to replicate shadows.

3.4 Data

The investigation of lighting requirements is detailed in the test reports included in Appendix E. Table 3.2 shows the lighting measurements obtained during the NRC test session.

Table 3.2: Lighting Characteristics Measurements

	Illumination	Colour Temperature
Daylight (halogen)	28,000 lux	2,700 K
Daylight (car light)	N/A	4,000 K
Daylight (metal halide)	28,000 lux	5,870 K
Night-time (chamber light)	140 lux	3,500 K

3.5 Conclusions and Recommendations

At the suggestion of the Working Group members present during the NRC test session, APS visited the AéroMag central deicing facility in Montreal to measure the lighting characteristics.

At the deicing pad, the intensity of light was measured to be around 20-30 lux in the lighted areas. While this is slightly below specifications, spotlights from the deicing vehicle would likely place the intensity within specifications.

The color temperature was measured to be 2,600 K, within specifications.

A presentation summarizing the test procedures and results was given at the ROGIDS Working Group meeting in Toronto in April 2007; this presentation is included in Appendix H.

3.5.1 Daylight

The daylight condition was successfully replicated using a metal halide bulb (see Photo 3.1) with the following characteristics:

- Sylvania Metalarc BT56;
- Metal Halide; and

- ANSI luminance code “S”.

Only one bulb, placed approximately 2 feet above the plates, was needed to provide the required illumination for the test area. Because the heat emitted by metal halide bulbs is moderate, it is recommended an additional bulb is used and the distance between the light source and the plates is increased. Alternatively, the plates can be placed on the test stand immediately prior to testing to minimize the time under the heat; another solution would be to place a shield between the light and the plates.

3.5.2 Night-time

The standard lighting conditions in the chamber fell within the illumination specification and just outside the colour temperature specification for the night-time lighting condition.

It was recommended to change the night-time colour temperature upper limit requirement from 3,200 K to 3,600 K.

3.5.3 Daylight with Shadows

To achieve the shadow condition, a wood board was positioned above the plates to cast a shadow on one half of each of the plates (see Photo 3.2). This proved that the shadow condition is easily achievable.

3.5.4 Lighting Requirements After Feasibility Tests

Table 3.3 shows the lighting requirements that were adopted by the Working Group based on these tests.

Table 3.3: Proposed Lighting Requirements

	Illumination	Colour Temperature
Daylight	>25,000 lux	5,000 to 6,500 K
Night-time	100 to 500 lux	2,100 to 3,600 K

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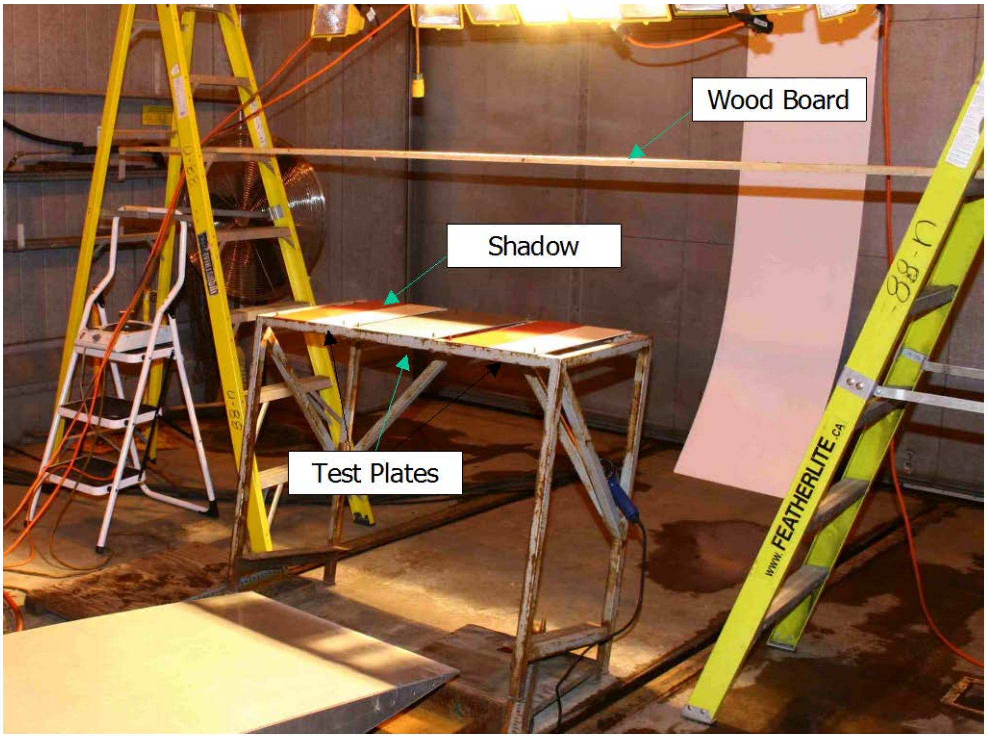
Photo 3.1: Setup for Lighting Condition - Daylight

Photo 3.2: Setup for Lighting Condition – Daylight with Shadow



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4. ICE DETECTION TESTS SIMULATION

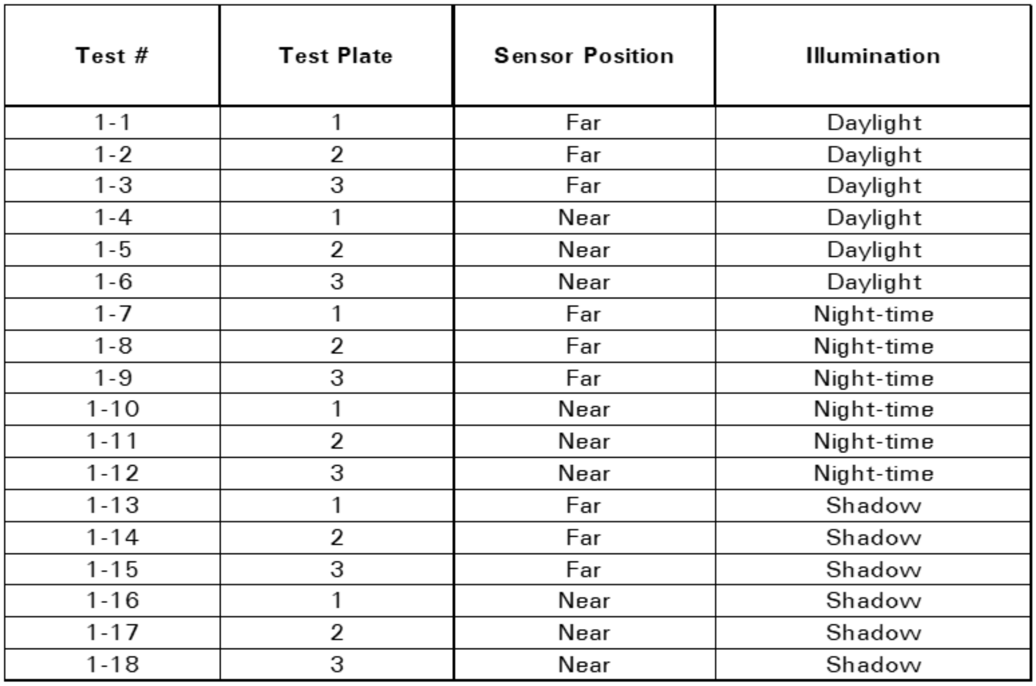
4.1 Introduction

Tests were conducted to investigate the feasibility of conducting the laboratory pre-deicing and post-deicing residual clear ice detection tests as described in AS5681 (see Appendix B).

4.2 Objective

The objective of the ice detection tests simulation was to illustrate that tests in the test plan can be conducted within a reasonable time frame. Two test sets, pre-deicing and post-deicing, were conducted. Table 4.1 (pre-deicing) and Table 4.2 (post-deicing) show the tests that were simulated during this demonstration. Note that these were the tests in the proposed standard at the time when the NRC testing was being carried out; the current proposal standard in Appendix B has been slightly modified to incorporate the new "deicing boot" test surface.

Table 4.1: Test Set 1 – Detection of Clear Ice Pre-Deicing



Test #	Test Plate	Sensor Position	Illumination
1-1	1	Far	Daylight
1-2	2	Far	Daylight
1-3	3	Far	Daylight
1-4	1	Near	Daylight
1-5	2	Near	Daylight
1-6	3	Near	Daylight
1-7	1	Far	Night-time
1-8	2	Far	Night-time
1-9	3	Far	Night-time
1-10	1	Near	Night-time
1-11	2	Near	Night-time
1-12	3	Near	Night-time
1-13	1	Far	Shadow
1-14	2	Far	Shadow
1-15	3	Far	Shadow
1-16	1	Near	Shadow
1-17	2	Near	Shadow
1-18	3	Near	Shadow

1. Sensor at Minimum Sight Angle and Maximum Distance (Far) and Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: ≤-5°C
4. Fluid Type Required: None
5. See Appendices B and C for definitions of parameters.

Table 4.2: Test Set 2 – Detection of Residual Clear Ice Post Deicing

Test #	Test Plate	Fluid Type Required	Sensor Position
2-1	1	Type I (E base) over ice	Far
2-2	2	Type I (E base) over ice	Far
2-3	3	Type I (E base) over ice	Far
2-4	1	Type I (P base) over ice	Far
2-5	2	Type I (P base) over ice	Far
2-6	3	Type I (P base) over ice	Far
2-7	1	Type II (P base) over ice	Far
2-8	2	Type II (P base) over ice	Far
2-9	3	Type II (P base) over ice	Far
2-10	1	Type III (P base) over ice	Far
2-11	2	Type III (P base) over ice	Far
2-12	3	Type III (P base) over ice	Far
2-13	1	Type IV (E base) over ice	Far
2-14	2	Type IV (E base) over ice	Far
2-15	3	Type IV (E base) over ice	Far
2-16	1	Type IV (P base) over ice	Far
2-17	2	Type IV (P base) over ice	Far
2-18	3	Type IV (P base) over ice	Far
2-19	1	Type I (P base) over thick ice	Far
2-20	2	Type I (P base) over thick ice	Far
2-21	3	Type I (P base) over thick ice	Far
2-22	1	Type I (E base) over ice	Near
2-23	2	Type I (E base) over ice	Near
2-24	3	Type I (E base) over ice	Near
2-25	1	Type I (P base) over ice	Near
2-26	2	Type I (P base) over ice	Near
2-27	3	Type I (P base) over ice	Near
2-28	1	Type II (P base) over ice	Near
2-29	2	Type II (P base) over ice	Near
2-30	3	Type II (P base) over ice	Near
2-31	1	Type III (P base) over ice	Near
2-32	2	Type III (P base) over ice	Near
2-33	3	Type III (P base) over ice	Near
2-34	1	Type IV (E base) over ice	Near
2-35	2	Type IV (E base) over ice	Near
2-36	3	Type IV (E base) over ice	Near
2-37	1	Type IV (P base) over ice	Near
2-38	2	Type IV (P base) over ice	Near
2-39	3	Type IV (P base) over ice	Near
2-40	1	Type I (P base) over thick ice	Near
2-41	2	Type I (P base) over thick ice	Near
2-42	3	Type I (P base) over thick ice	Near

1. Sensor at Minimum Sight Angle and Maximum Distance (Far) and Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: $\leq$-5°C
4. Illumination: Night-time
5. See Appendices B and C for definitions of parameters.

The purpose of the pre-deicing tests was to illustrate that all 18 tests given in the pre-deicing test set (Table 4.1) could be conducted within a reasonable time frame. Tests were required to be conducted at both far and near camera distances, on all test surfaces and in each lighting condition (daylight, night-time and shadow). No fluid was required for these tests.

The purpose of the post-deicing tests was to prove that 6 tests (Test Set 2, # 2-4 to 2-6 and # 2-25 to 2-27 in Table 4.2) could be conducted within the two-minute window that exists for ice disk thickness stability. The tests were meant to simulate testing on all surfaces (painted aluminum plate, painted composite plate and a polished/unpolished aluminum plate), in the night-time lighting condition from both near and far camera distances.

4.3 Methodology

A test procedure was developed for this research. It is included in Appendix D. Testing was carried out at the NRC chamber in March 2007.

4.3.1 Methodology for Pre-Deicing Tests

All 18 tests from Test Set 1 (Table A1 in AS5681) were carried out, including:

- Three test surfaces (concurrently);
- Daylight: far camera, near camera;
- Night-time: far camera, near camera; and
- Shadow: far camera, near camera.

4.3.2 Methodology for Post-Deicing Tests

The demonstrations of post-deicing tests were conducted for the night-time condition only. Six tests were simulated at this condition:

- Ice disks were developed on three test plates and initial thickness was measured;
- Type I fluid was applied to test plates;
- Simulated ROGIDS picture taken from far angle;
- Simulated ROGIDS picture taken from near angle; and
- Ice disk thickness measurements were taken at the end of the test.

4.4 Results

4.4.1 Pre-Deicing Tests

It took less than 30 seconds to conduct all 18 tests. This was done by setting up the three test surfaces on one test stand, setting up two simulated cameras (far and near) and then turning the lights off for the night-time condition, on for the daylight condition, and inserting a shield for the shadow condition.

4.4.2 Post-Deicing Tests

It took approximately 30 seconds to conduct all 6 tests. For each test, the thickness of the ice patch on each test was measured, fluid was applied to the test plate and a simulated ROGIDS photo was taken. At the end of the test set, the thickness of the ice on each test plate was measured. This was all done within 30 seconds, proving that it is feasible to conduct the 6 tests within the two-minute window that was previously established as the time that the ice disk thickness will not degrade following application of Type I fluid.

4.5 Conclusions and Recommendations

All pre-deicing tests were completed in approximately 30 seconds, confirming the validity of the test protocol.

All post-deicing tests were completed in approximately 30 seconds, confirming the validity of the test protocol. Tests can be conducted within the 2-minute window for ice disk stability.

A presentation summarizing the test procedures and results was given at the ROGIDS Working Group meeting in Toronto in April 2007; this presentation is included in Appendix H.

5. LABORATORY FLUID FOAM TEST

5.1 Introduction

Certain deicing fluids show foaming characteristics when applied to aircraft wings. A foam test has been included in AS5681 to ensure that ROGIDS performance is not affected by fluids that become foamy when applied.

Prior to this testing, the following formulation was given for the fluid to be used for the foaming test (proportion by percent weight).

- Sodium di (2-ethylhexyl) sulfosuccinate (0.5 percent) (surfactant);
- Water (11.5 percent); and
- Propylene glycol (PG) (88 percent).

The formulation was based on the historical fluid used for aerodynamic acceptance tests, MIL-A-8243. A majority of the fluid manufacturers were consulted and they agreed that this was a reasonable approach in an attempt to get a fluid that would provide foaming.

5.2 Objective

The objective of these tests was to investigate the suitability of the laboratory foam test being developed for inclusion in AS5681.

5.3 Methodology

The foaming fluid formulation described in Section 5.1 was the starting point. The formulation of the fluid was adjusted subsequently to provide the appropriate foaming effects and freeze point.

Photo 5.1 shows the laboratory blender in which the fluid was foamed, and Photo 5.2 shows the application of the foamed fluid.

The procedure used to conduct this work is included Appendix D.

5.4 Results

It was noted that the proposed foam formulation had two issues:

- It did not produce enough foam/bubbles; and
- PG fluid should have a fluid freeze point (FFP) of approximately -40°C.

Following further analysis, it was decided that a reasonable glycol dilution would be one mixed to a fluid freezing point of approximately -40°C. Different formulations were made, including one with 0.5 percent surfactant, one with 0.25 percent surfactant, heated applications and cold applications.

In the end, it was concluded by the test observers (including members of the Working Group) that the fluid formulation and application method that was most suitable for inclusion in AS5681 was as follows:

- Fluid formulation (to be blended);
    - sodium di (2-ethylhexyl) sulfosuccinate (0.5 percent);
    - water (38.5 percent); and
    - propylene glycol (61 percent);
- Fluid heated to 60°C;
- Test be conducted on a 1.0 m by 1.5 m aluminum long plate inclined at 10° to the horizontal; and
- 2 L of fluid applied by pouring to a wing surface with an ice patch of approximately 1 mm thickness.

Because this series of tests was conducted in the early phase of development, additional tests were carried out in July 2007 at the NRC chamber. The objective was to determine if the 1.0 mm thick ice patch used in the foam test consistently reduces to a 0.5 mm thickness after heated fluid is applied. The results of three tests confirmed that the heated fluid reduces the thickness of the ice patch from 1.0 mm to 0.5 mm.

5.5 Conclusions and Recommendations

The fluid formulation and application method that was most suitable for inclusion in AS5681 was as follows:

- Fluid formulation;

    - sodium di (2-ethylhexyl) sulfosuccinate (0.5 percent);
    - water (38.5 percent); and
    - propylene glycol (61 percent);
- Fluid heated to 60°C; and
- 2 L applied by pouring to a wing surface with an ice patch of approximately 1 mm thickness.

The final formulation was compared with a commercial Type I fluid and was found to have more foam and bubbles present. The test observers felt this formulation and application method produced a worst-case scenario for a foamy Type I fluid application. The final procedure that was developed together with the Working Group observers is included in SAE AS5681 (see Appendix B).

A presentation summarizing the test procedures and results was given at the ROGIDS Working Group meeting in Toronto in April 2007; this presentation is included in Appendix H.

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Photo 5.1: 1 L Waring Blender Used to Foam Fluid

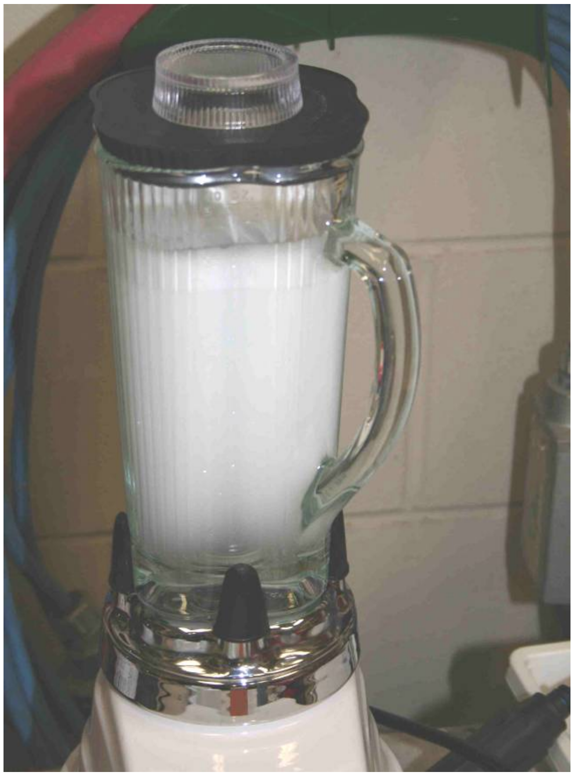

Photo 5.2: Application of Foamed Fluid at NRC in March 2007

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6. CLEAR ICE DETECTION DURING PRECIPITATION

6.1 Introduction

SAE AS5681 is being developed to test the minimum operational performance requirements of ice detection sensors. Three sets of tests were described in the proposed AS5681:

- Pre-deicing;
- Post-deicing; and
- Post-deicing with precipitation.

This section focuses on the third set of tests: post-deicing with precipitation. Preliminary characterization and calibration research and tests were conducted in the past (in 2002). Those attempts were successful in creating some of the parameters required for three of the five test conditions that were described at the time. Additional testing was required to demonstrate the feasibility of generating the current conditions described in the proposed AS5681.

6.2 Objective

The objective of this project was to demonstrate the feasibility of generating the precipitation conditions required to conduct laboratory tests for evaluating the minimum operational performance requirements (proposed SAE AS5681) of ice detection sensors.

The “curtain solution” was used to test and evaluate the following simulated precipitation conditions:

- Freezing rain between the plates and the sensor(s), and encompassing the sensor field of view;
- Freezing drizzle between the plates and the sensor(s), and encompassing the sensor field of view; and
- Rain between the plates and the sensor(s), and encompassing the sensor field of view.

It was decided at the October 2006 ROGIDS Working Group meeting in Atlantic City that snow tests should be conducted outdoors. Also, the freezing fog condition was successfully achieved at the NRC in 2002. Therefore, in an attempt to keep the costs at a minimum, these two conditions were not attempted.

6.3 Curtain Methodology

6.3.1 Procedure

The "curtain solution" was developed to simulate precipitation conditions by generating a "curtain" of high intensity precipitation, using one nozzle spraying along the short axis of the chamber (see Photo 6.1). The droplet diameters were verified using a "dye stain" technique. Rate pans, weighed before and after exposure to precipitation, were placed beneath the spray footprint. Photo 6.2 shows the chamber setup. The data collected using the rate pans was analysed to calculate the effective rate of precipitation over a defined distance along the long axis of chamber. The ROGIDS and the target were placed 12 m apart, as this was considered to be representative of the maximum distance. The number of nozzles required to generate the condition effectively was determined mathematically based on the results from the one spray nozzle. A detailed description of the procedure used is found in Appendix D.
The following three precipitation conditions were attempted in the NRC chamber:

a) Freezing Drizzle
Precipitation rate: 5-10 g/dm^2/h
Droplet size: 300μm±100
Temperature: <= -5 °C

b) Light Freezing Rain
Precipitation rate: 19-25 g/dm^2/h
Droplet size: 1000μm±100
Temperature: <= -5 °C

c) Rain
Precipitation rate: 65-75 g/dm^2/h
Droplet size: 1000μm±100
Temperature: <= +1 °C

The chamber was cooled to the target temperature, and then the cooling system was shut to get still air (turbulence caused by the cooling system caused variances in the precipitation rates produced). The calibration was conducted until the chamber temperature rose above freezing (or reached approximately 6°C in the case of rain), at which point the calibration was stopped, and the cooling system was restarted until the target temperature was attained once again.

6.3.2 Setup

To conduct the calibration tests, three nozzles were positioned along the walls of the long axis of the NRC chamber; these nozzles were installed and available from previous testing conducted in 2002. A plan view of the setup inside the NRC chamber is shown in Figure 6.1. Calibration was only conducted on one nozzle at a time. Figure 6.2 shows the rate pan layout used for conducting the calibration for each nozzle. During each of the calibration tests, two rate trays (which held 12 rate pans each) provided a large enough collection area to completely capture the nozzle footprint along the long axis of the chamber. This was necessary in order to accurately calculate the weighted average of the footprint along the long axis of the chamber (as described in detail in Section 6.3.3).

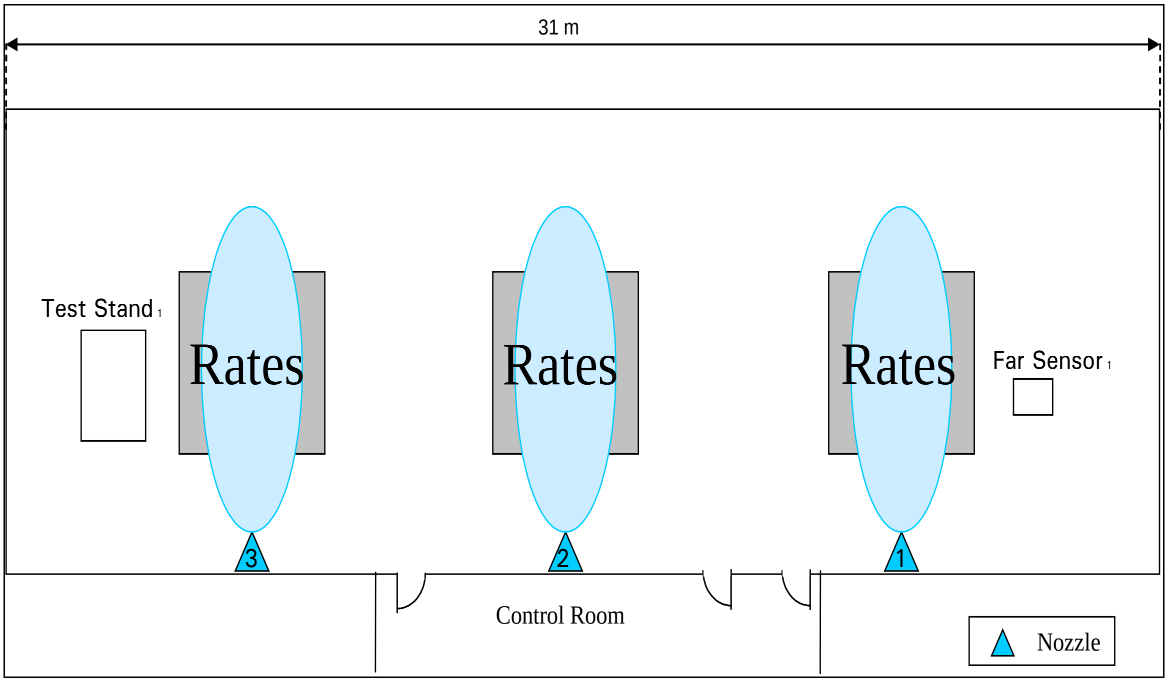


Figure 6.1: Plan View of NRC Chamber "Curtain" Setup

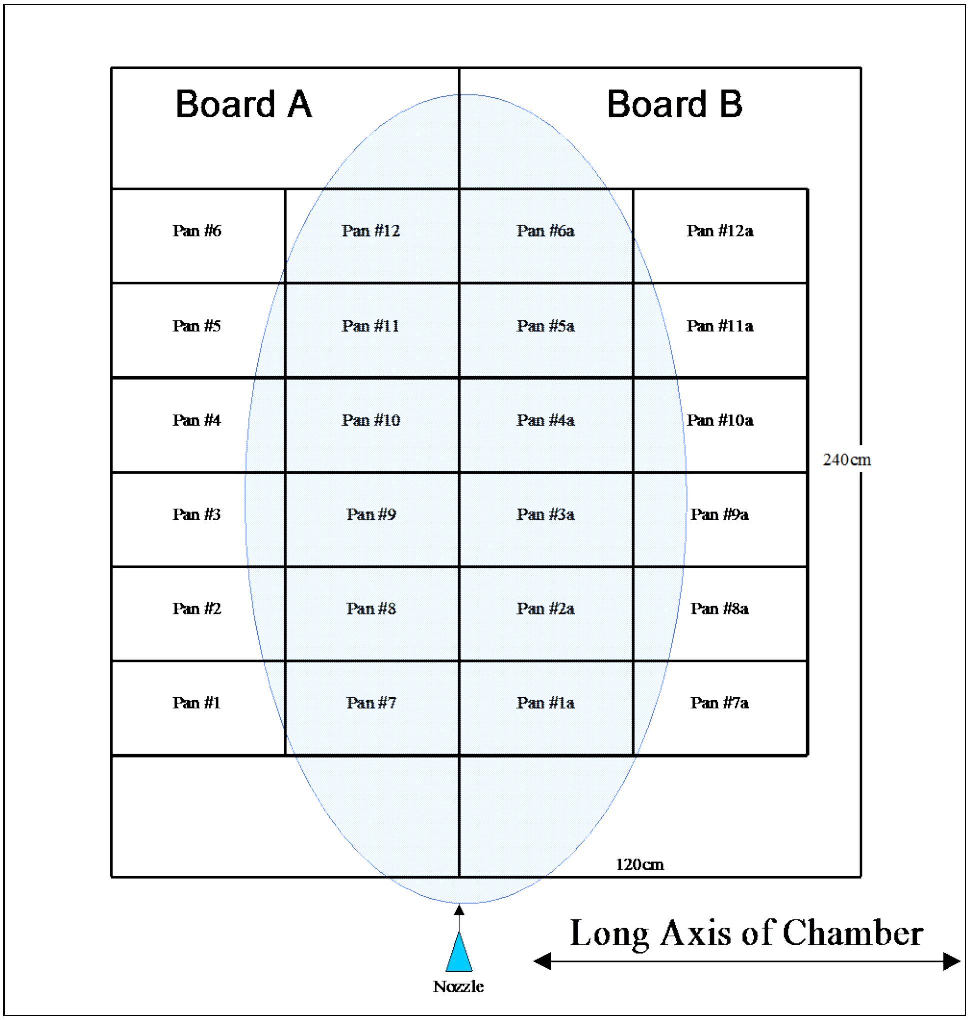


Figure 6.2: Rate Pan Layout for 1 Nozzle

6.3.3 Calculation of Effective Rate

6.3.3.1 Effective Rate Using One Nozzle

The effective rate of precipitation was calculated as the weighted average of the rate of precipitation between the ROGIDS sensor and the target. Calibration was conducted for one nozzle at a time. The following formula was used to calculate the effective rate of precipitation:

$$ER = AvgR \times \frac{LP}{DC}$$

Where:

ER = Effective Rate per Axis;

AvgR = Average rate of 4 pans;

LP = Length of 4 Pans; and

DC = Distance from Camera to Objective; 12 m was selected to represent maximum distance between ROGIDS system and target.

Figure 6.3 shows which rate pans were used in calculating the effective rate of precipitation along one axis of the chamber. The average rate of precipitation of the four rate pans along the selected axis was used to calculate the weighted average over the long axis of the chamber. Figure 6.4 demonstrates the effective precipitation rates measured using one nozzle during Run #3.

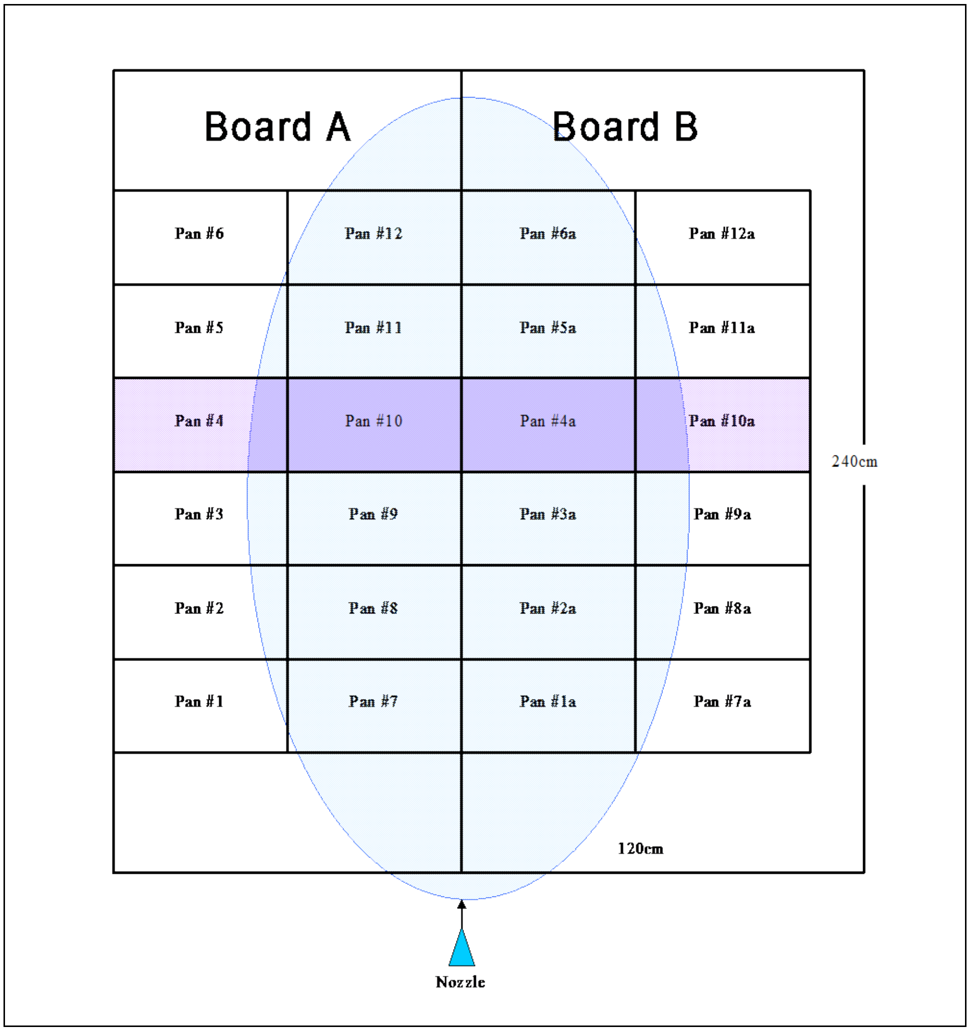
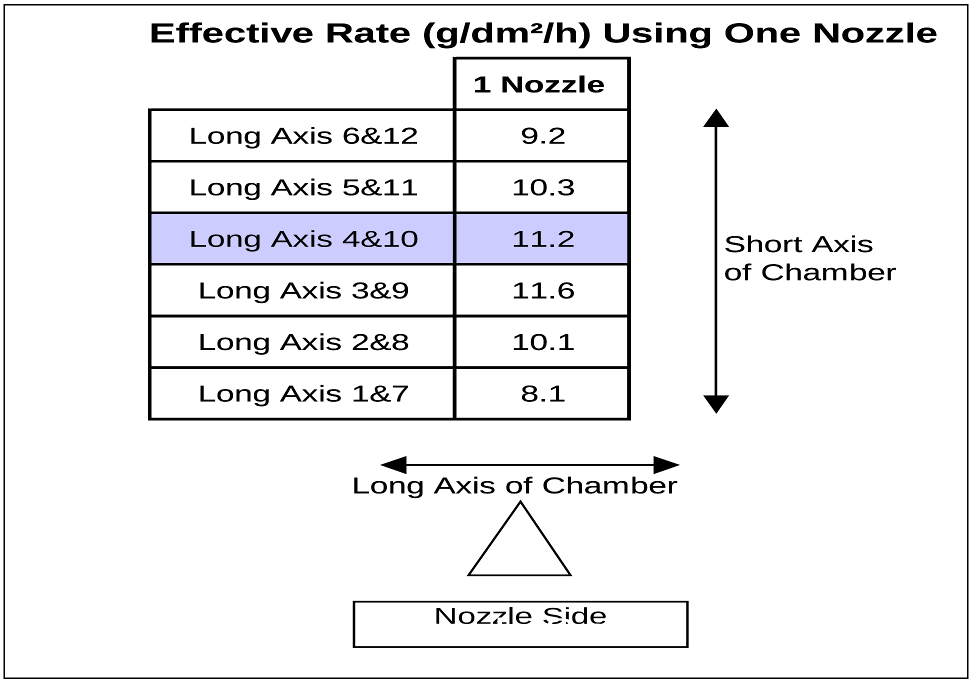


Figure 6.3: Rate Calculation Per Axis Using 1 Nozzle



Effective Rate (g/dm²/h) Using One Nozzle

	1 Nozzle
Long Axis 6&12	9.2
Long Axis 5&11	10.3
Long Axis 4&10	11.2
Long Axis 3&9	11.6
Long Axis 2&8	10.1
Long Axis 1&7	8.1

Figure 6.4: Effective Rate Measured Per Axis Using 1 Nozzle

6.3.3.2 Effective Rate Using Multiple Nozzles

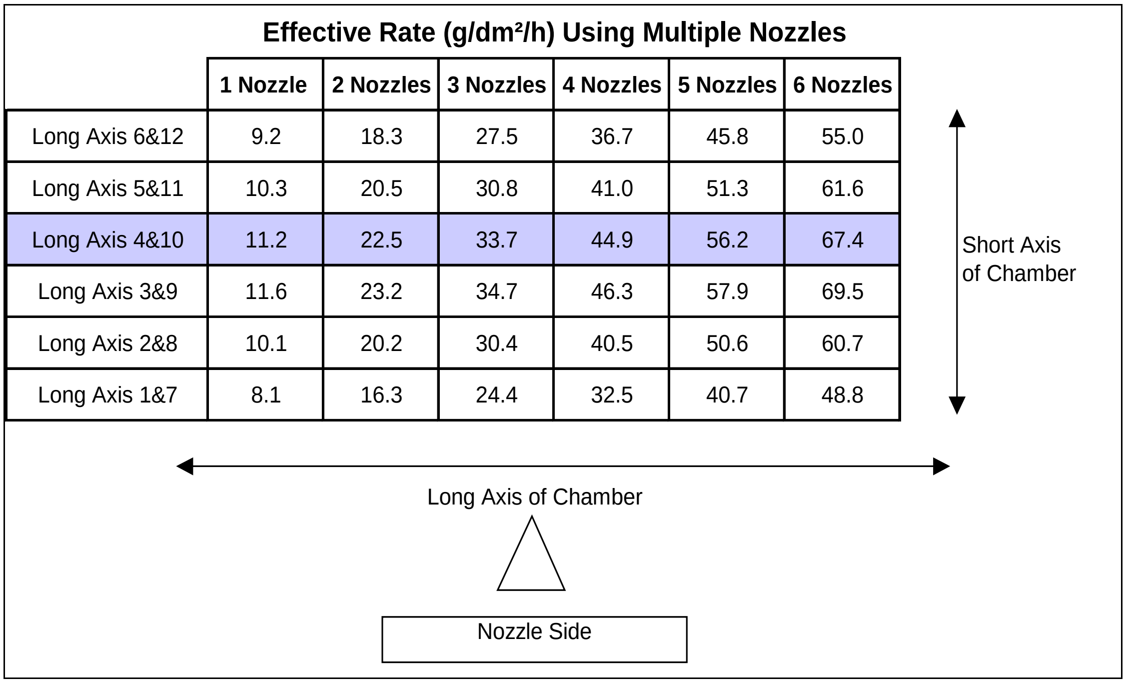
To estimate the effective rate using multiple spray nozzles, the following formula was used:

$$MR = ER \times Z$$

Where:

MR = Effective Rate of Precipitation using multiple nozzles (g/dm²/h);
ER = Effective Rate of Precipitation (see above) using one nozzle (g/dm²/h); and
Z = Number of nozzles (#).

Figure 6.5 demonstrates the effective precipitation rates for multiple nozzles calculated based on the one nozzle calibration data during Run #3. Results for each of the test runs conducted are found in Section 6.3.2. The feasibility of using multiple nozzles to generate higher intensities of precipitation was verified as a separate objective and is described in Section 6.3.4.



Effective Rate ($g/dm^2/h$) Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.2	18.3	27.5	36.7	45.8	55.0
Long Axis 5&11	10.3	20.5	30.8	41.0	51.3	61.6
Long Axis 4&10	11.2	22.5	33.7	44.9	56.2	67.4
Long Axis 3&9	11.6	23.2	34.7	46.3	57.9	69.5
Long Axis 2&8	10.1	20.2	30.4	40.5	50.6	60.7
Long Axis 1&7	8.1	16.3	24.4	32.5	40.7	48.8

Figure 6.5: Effective Rate Per Axis Calculated for Multiple Nozzles

6.3.4 Verification of Repeatability

Once the desired rate of precipitation was obtained, the feasibility of producing the same rate of precipitation was verified by undergoing the following procedure:

- Shut off the water supply;
- Wait 10 minutes (for the lines to drain);
- Turn on water supply and water flow using the flow meter to obtain desired rate of precipitation; and
- Repeat rate calibration.

The precipitation rate repeatability was also verified using the different nozzles located in the NRC chamber. Once a desired rate of precipitation was obtained with the first nozzle, the same flow rate settings were applied to a different nozzle and a precipitation rate verification was conducted. The feasibility of using multiple nozzles at the same time was also verified; a spot check was conducted with two pans (one per curtain) instead of the full twenty-four pans.

6.4 Test Log and Results

6.4.1 Test Log

To facilitate the accessibility of the data collected, a log was created for the series of tests conducted by APS at the NRC research facility. The log presented in Table 6.1 provides relevant information for each of the calibration test runs, as well as final values recorded. Each row contains data specific to one test. The following is a brief description of the column headings:

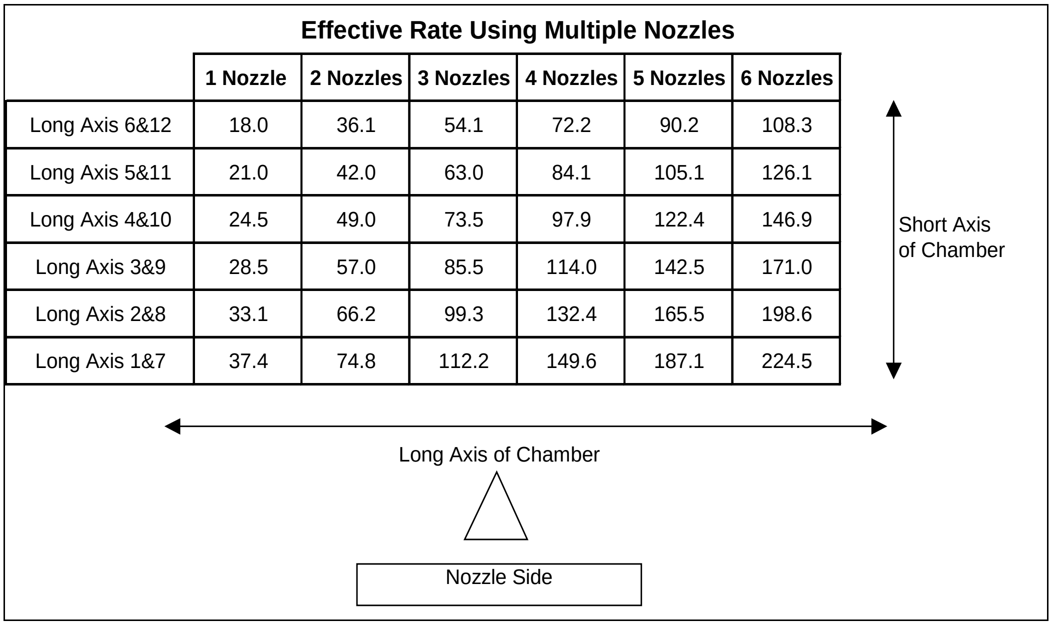
Run:	Exclusive number identifying each calibration test.
Sprayer Settings:	Sprayer system parameters modified during the tests.
Position of Wall Nozzle Used:	Location of the nozzle used for the specific test.
Nozzle # Used:	Teejet nozzle identification number (larger number relates to increased flow and droplet diameter).
Water Flow Rate:	Water flow rate setting used with the Alicat Scientific Flow Meter/Regulator.
Precip. Type:	Simulated precipitation type required to satisfy SAE AS5681 test plan.
Target Precip. Rate:	Target precipitation rate required to satisfy SAE AS5681 test plan.
# of Nozzles Required for Effective Rate:	Number of nozzles required to produce desired rate of precipitation calculated mathematically based on data collected from one nozzle.
# of Axis with Acceptable Rates:	Number of axis (measuring 27.5 cm wide) in which the measured rate of precipitation was within an acceptable tolerance of the target precipitation rate.
Effective Precip Rate:	Rate of precipitation calculated as the average of the axis with acceptable rates.
Approx Drop Size:	Droplet mean volume diameter estimated based on the Whatmans paper dye stain technique.
Comments:	Comments recorded by APS personnel during the test.

Table 6.1: Test Log

Run #	Sprayer Settings			Precip. Type	Target Precip. Rate (g/dm^2/h)	# of Nozzles Required for Effective Rate	# of Axis With Acceptable Rates	Effective Precip. Rate (g/dm^2/h)	Approx. Drop Size (mm)	Comments
	Position of Wall Nozzle Used (1,2, or 3)	Nozzle # Used	Water Flow Rate (L/min)							
1	2	2.0	2.00	ZR	19-25	1	4	23	0.5	Droplet Size to small, had to reduce flow rate.(distance from wall is 5'3")
2	2	2.0	0.70	ZR	19-25	2	2	23	1	Used flow meter to regulate
3	2	2.0	0.47	ZR	19-25	2	4	22	1	Reduced flow and had to bring boards 2' closer to wall (distance from wall is 3'3")
4	2	2.0	0.47	ZR	19-25	2	4	22	1	Good Duplicate of Run #3
5	2	2.0	0.47	ZR	19-25	2	4	21	1	Good Duplicate of Run #3
6	2	0.4	0.17	ZD	5-10	2	1-3	8	0.3	Large Variance in rates, axis rates slightly outside of target Rate
7	2	0.4	0.17	ZD	5-10	2	1-3	7	0.3	Large Variance in rates, axis rates slightly outside of target Rate
8	1	2.0	0.47	ZR	19-25	2	4	19	1	Rate slightly lower. Showed repeatability of Run #3 with different wall position on different day.
9	2	5.0	1.00	R	65-75	4	3-4	74	0.6-1.4	High Var in rates and droplet Size. Moved boards 1' further from wall (distance from wall is 4'3")
10	2	5.0	1.00	R	65-75	4	4	71	0.8-1.0	Good Rates, variablity in droplet size considred acceptable due to high rate.
11	2	5.0	1.00	R	65-75	4	4	73	0.8-1.0	Good Duplicate of Run #10
12	1 and 2	5.0, 6.5	1.00	R	65-75	4	N/A	Spot Check	N/A	Verify Feasability of multiple Nozzles. Spot Checked with 2 rate pans to verify that rate was similar to Run #10

6.4.2 Results

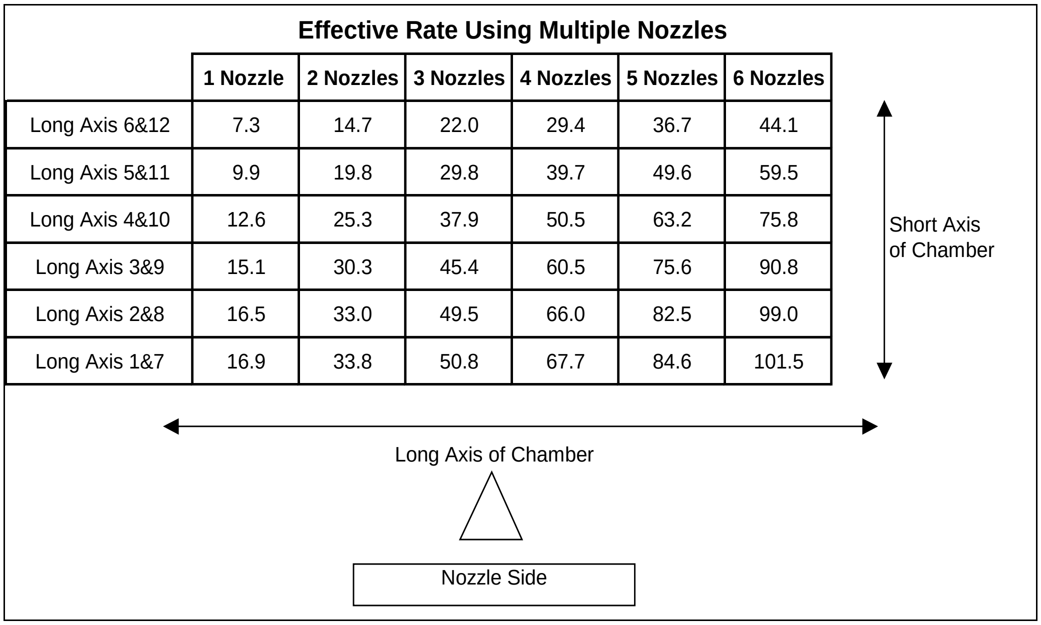
During each test run (with the exception of Run #12), the effective rate of precipitation per axis was measured using one nozzle and was calculated for multiple nozzles. The methodology used to calculate the effective rates of precipitation is described in Section 6.3.3. Figure 6.6 to Figure 6.16 demonstrate the results produced.



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	18.0	36.1	54.1	72.2	90.2	108.3
Long Axis 5&11	21.0	42.0	63.0	84.1	105.1	126.1
Long Axis 4&10	24.5	49.0	73.5	97.9	122.4	146.9
Long Axis 3&9	28.5	57.0	85.5	114.0	142.5	171.0
Long Axis 2&8	33.1	66.2	99.3	132.4	165.5	198.6
Long Axis 1&7	37.4	74.8	112.2	149.6	187.1	224.5

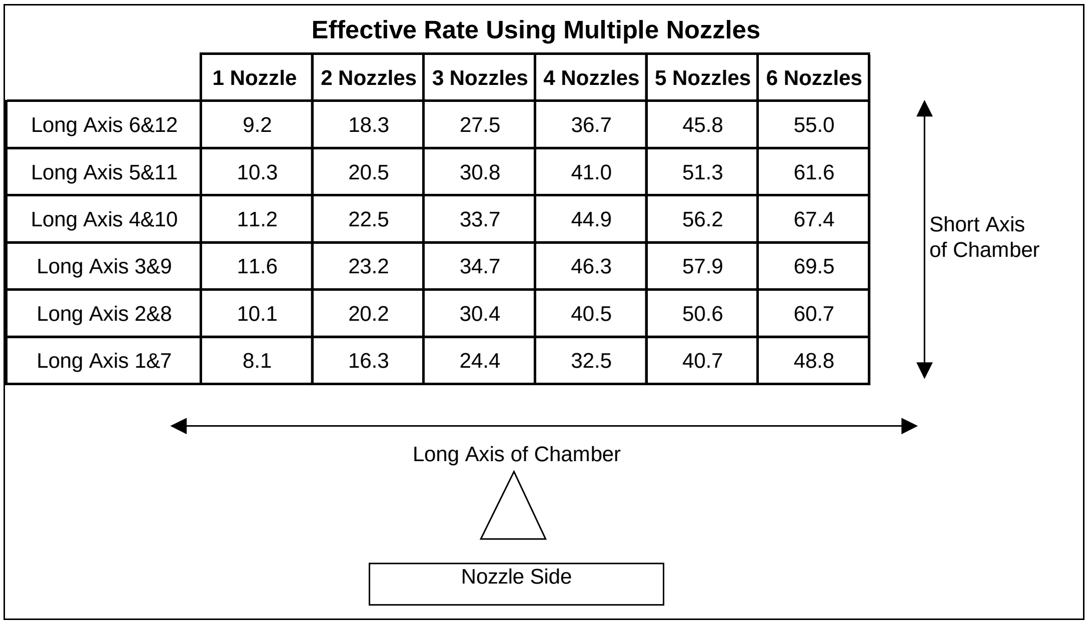
Figure 6.6: Effective Rate Per Axis – Run #1



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	7.3	14.7	22.0	29.4	36.7	44.1
Long Axis 5&11	9.9	19.8	29.8	39.7	49.6	59.5
Long Axis 4&10	12.6	25.3	37.9	50.5	63.2	75.8
Long Axis 3&9	15.1	30.3	45.4	60.5	75.6	90.8
Long Axis 2&8	16.5	33.0	49.5	66.0	82.5	99.0
Long Axis 1&7	16.9	33.8	50.8	67.7	84.6	101.5

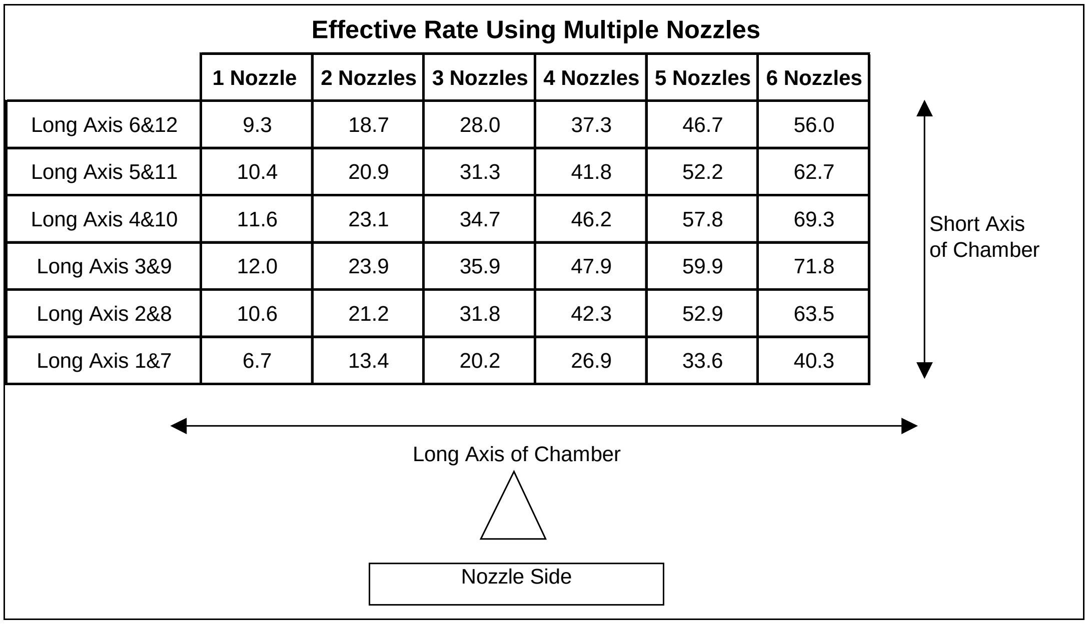
Figure 6.7: Effective Rate Per Axis – Run #2



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.2	18.3	27.5	36.7	45.8	55.0
Long Axis 5&11	10.3	20.5	30.8	41.0	51.3	61.6
Long Axis 4&10	11.2	22.5	33.7	44.9	56.2	67.4
Long Axis 3&9	11.6	23.2	34.7	46.3	57.9	69.5
Long Axis 2&8	10.1	20.2	30.4	40.5	50.6	60.7
Long Axis 1&7	8.1	16.3	24.4	32.5	40.7	48.8

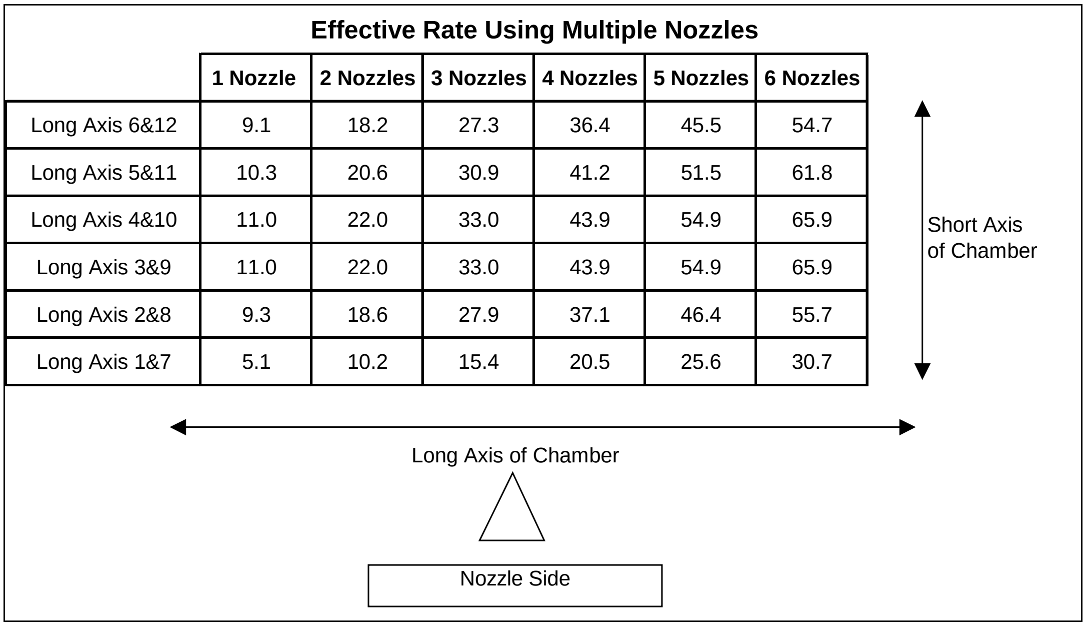
Figure 6.8: Effective Rate Per Axis – Run #3



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.3	18.7	28.0	37.3	46.7	56.0
Long Axis 5&11	10.4	20.9	31.3	41.8	52.2	62.7
Long Axis 4&10	11.6	23.1	34.7	46.2	57.8	69.3
Long Axis 3&9	12.0	23.9	35.9	47.9	59.9	71.8
Long Axis 2&8	10.6	21.2	31.8	42.3	52.9	63.5
Long Axis 1&7	6.7	13.4	20.2	26.9	33.6	40.3

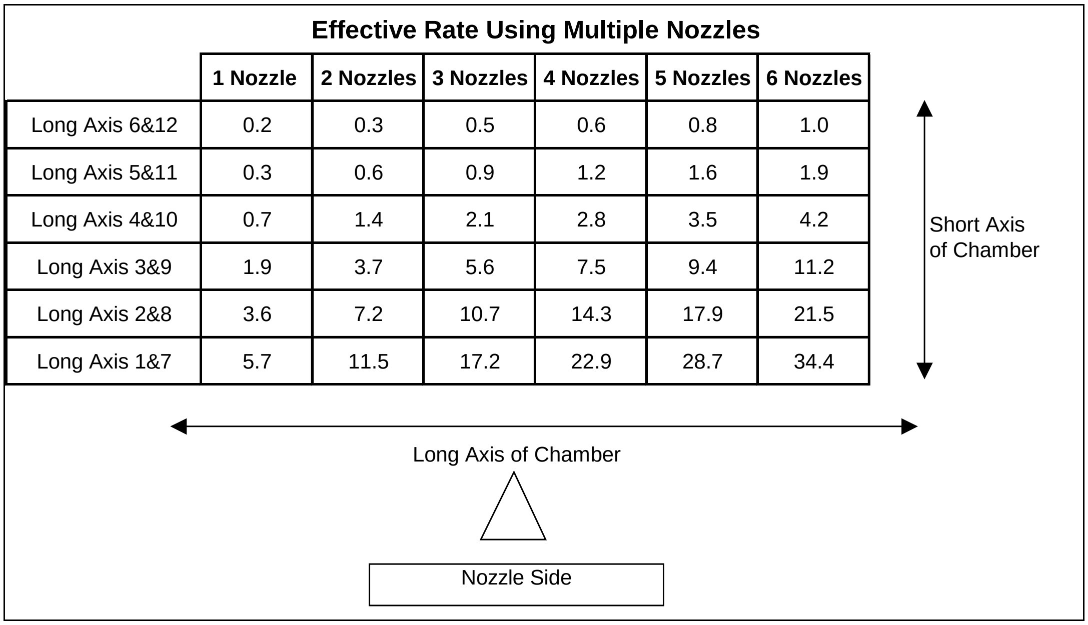
Figure 6.9: Effective Rate Per Axis – Run #4



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.1	18.2	27.3	36.4	45.5	54.7
Long Axis 5&11	10.3	20.6	30.9	41.2	51.5	61.8
Long Axis 4&10	11.0	22.0	33.0	43.9	54.9	65.9
Long Axis 3&9	11.0	22.0	33.0	43.9	54.9	65.9
Long Axis 2&8	9.3	18.6	27.9	37.1	46.4	55.7
Long Axis 1&7	5.1	10.2	15.4	20.5	25.6	30.7

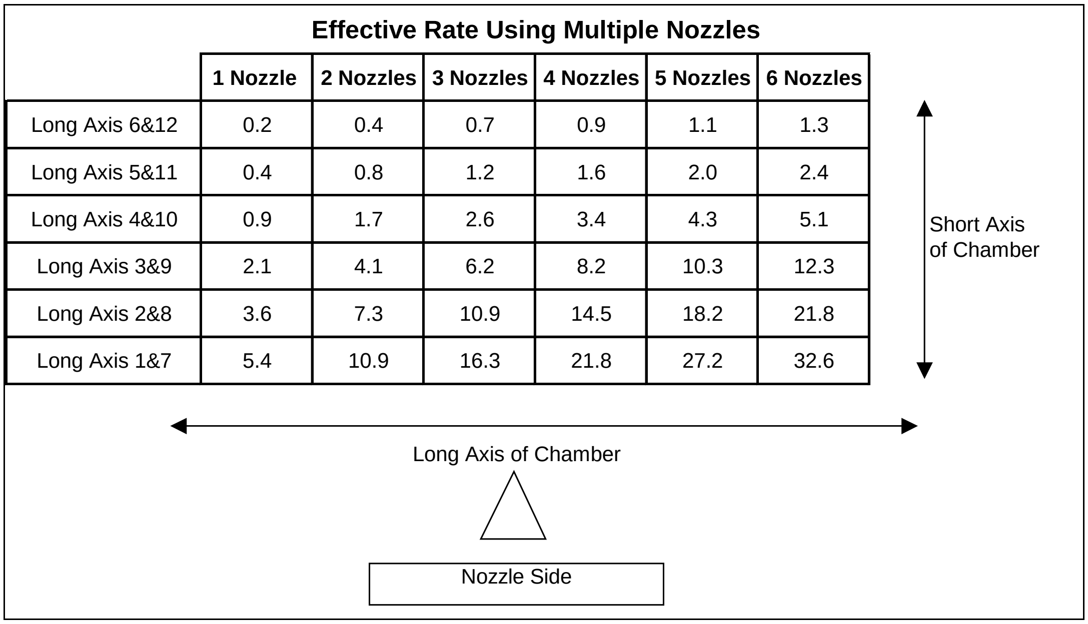
Figure 6.10: Effective Rate Per Axis – Run #5



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	0.2	0.3	0.5	0.6	0.8	1.0
Long Axis 5&11	0.3	0.6	0.9	1.2	1.6	1.9
Long Axis 4&10	0.7	1.4	2.1	2.8	3.5	4.2
Long Axis 3&9	1.9	3.7	5.6	7.5	9.4	11.2
Long Axis 2&8	3.6	7.2	10.7	14.3	17.9	21.5
Long Axis 1&7	5.7	11.5	17.2	22.9	28.7	34.4

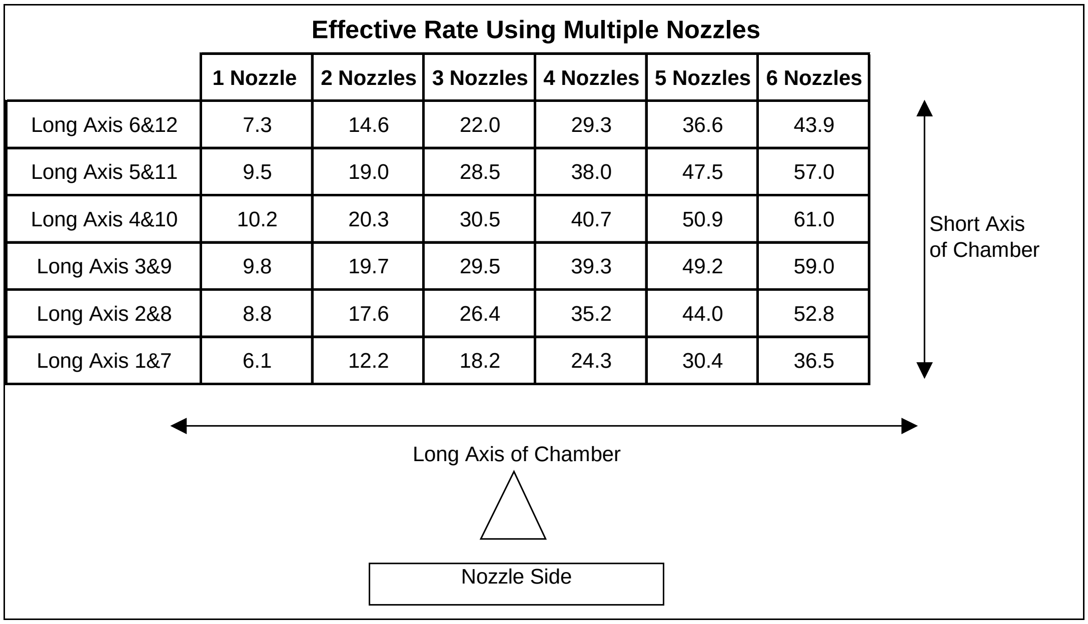
Figure 6.11: Effective Rate Per Axis – Run #6



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	0.2	0.4	0.7	0.9	1.1	1.3
Long Axis 5&11	0.4	0.8	1.2	1.6	2.0	2.4
Long Axis 4&10	0.9	1.7	2.6	3.4	4.3	5.1
Long Axis 3&9	2.1	4.1	6.2	8.2	10.3	12.3
Long Axis 2&8	3.6	7.3	10.9	14.5	18.2	21.8
Long Axis 1&7	5.4	10.9	16.3	21.8	27.2	32.6

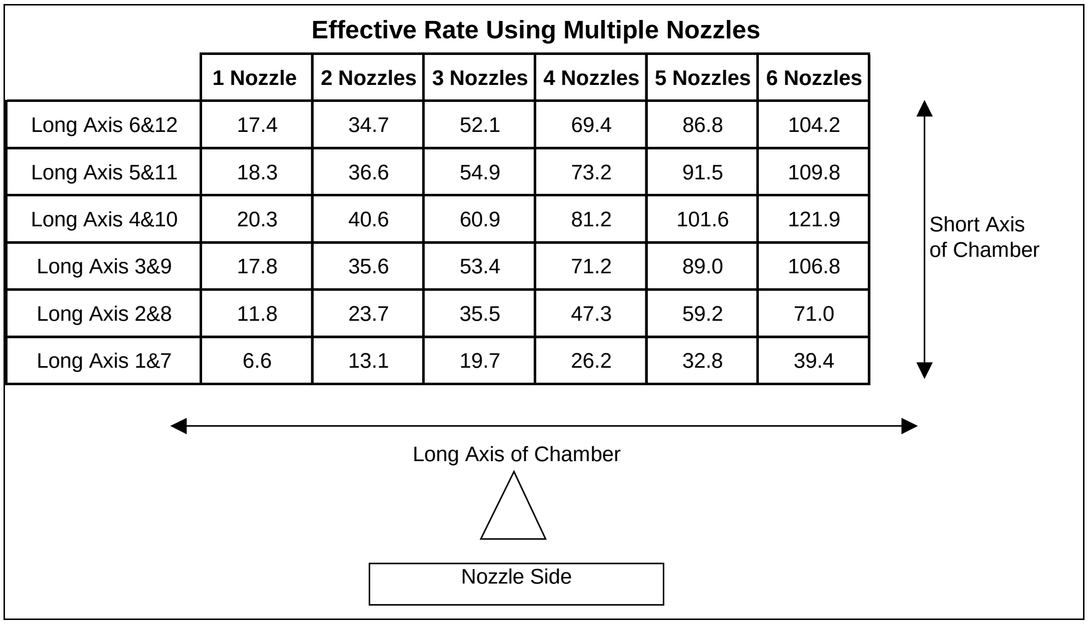
Figure 6.12: Effective Rate Per Axis – Run #7



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	7.3	14.6	22.0	29.3	36.6	43.9
Long Axis 5&11	9.5	19.0	28.5	38.0	47.5	57.0
Long Axis 4&10	10.2	20.3	30.5	40.7	50.9	61.0
Long Axis 3&9	9.8	19.7	29.5	39.3	49.2	59.0
Long Axis 2&8	8.8	17.6	26.4	35.2	44.0	52.8
Long Axis 1&7	6.1	12.2	18.2	24.3	30.4	36.5

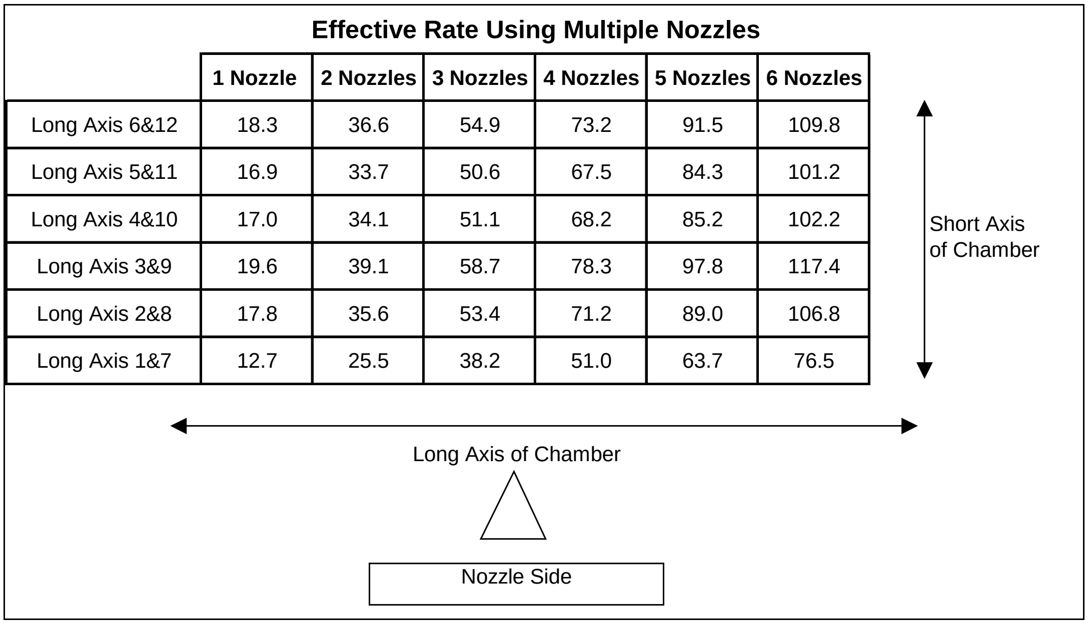
Figure 6.13: Effective Rate Per Axis – Run #8



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	17.4	34.7	52.1	69.4	86.8	104.2
Long Axis 5&11	18.3	36.6	54.9	73.2	91.5	109.8
Long Axis 4&10	20.3	40.6	60.9	81.2	101.6	121.9
Long Axis 3&9	17.8	35.6	53.4	71.2	89.0	106.8
Long Axis 2&8	11.8	23.7	35.5	47.3	59.2	71.0
Long Axis 1&7	6.6	13.1	19.7	26.2	32.8	39.4

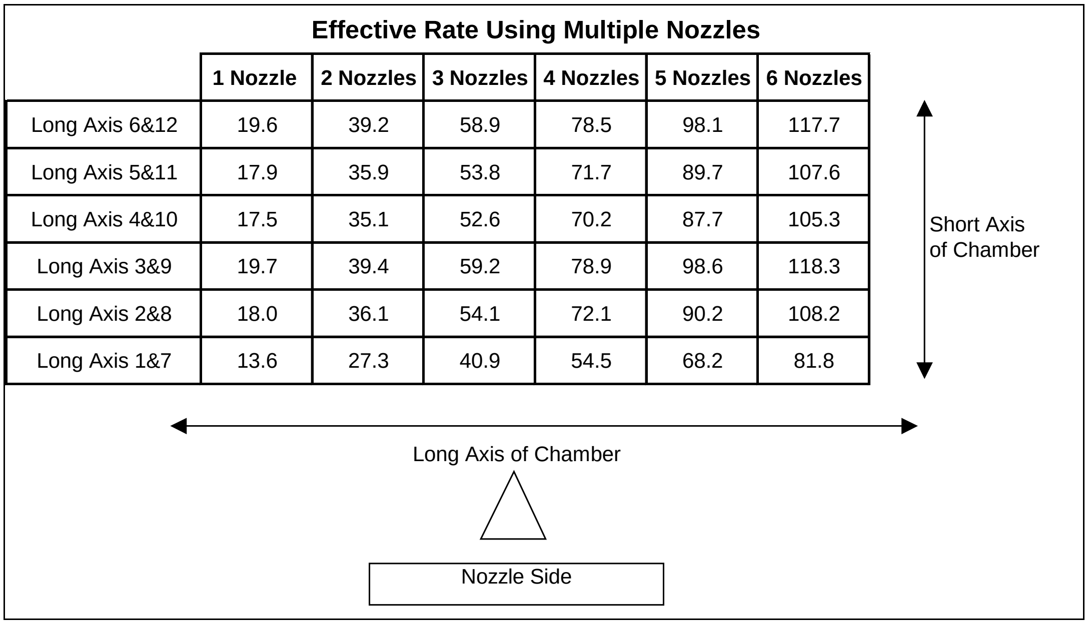
Figure 6.14: Effective Rate Per Axis – Run #9



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	18.3	36.6	54.9	73.2	91.5	109.8
Long Axis 5&11	16.9	33.7	50.6	67.5	84.3	101.2
Long Axis 4&10	17.0	34.1	51.1	68.2	85.2	102.2
Long Axis 3&9	19.6	39.1	58.7	78.3	97.8	117.4
Long Axis 2&8	17.8	35.6	53.4	71.2	89.0	106.8
Long Axis 1&7	12.7	25.5	38.2	51.0	63.7	76.5

Figure 6.15: Effective Rate Per Axis – Run #10



Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	19.6	39.2	58.9	78.5	98.1	117.7
Long Axis 5&11	17.9	35.9	53.8	71.7	89.7	107.6
Long Axis 4&10	17.5	35.1	52.6	70.2	87.7	105.3
Long Axis 3&9	19.7	39.4	59.2	78.9	98.6	118.3
Long Axis 2&8	18.0	36.1	54.1	72.1	90.2	108.2
Long Axis 1&7	13.6	27.3	40.9	54.5	68.2	81.8

Figure 6.16: Effective Rate Per Axis – Run #11

6.5 Test Results

6.5.1 Light Freezing Rain

Six tests were conducted to generate and calibrate the required light freezing rain conditions with rates of precipitation ranging from 19-25 g/dm²/h. Results showed that it was possible to achieve the required rate of precipitation using two nozzles and maintain droplet size diameters within 1000µm±100. Test Runs #3, #4, #5, and #8 demonstrated good repeatability of the results produced, even when using different nozzle locations.

It should be noted that using four nozzles at half the intensity was not possible. The nozzles on the market are typically designed for different applications such as agriculture where high flows are needed. The flow rates and quantities needed for these tests are much lower.

6.5.2 Freezing Drizzle

Two tests were conducted to generate and calibrate the required freezing drizzle conditions with rates of precipitation ranging from 5-10 g/dm²/h. Results showed that it was possible to maintain droplet size diameters within 300µm±100; however, it was difficult to produce consistent rates. The fine droplets produced for freezing drizzle were more susceptible to air turbulence, even with the cooling system turned off. The curtain produced for freezing drizzle was also smaller than the light freezing rain curtain; the smaller droplets were not projected as far as the larger light freezing rain droplets. Test Runs #6 and #7 demonstrated good repeatability of the results produced, but the variance in the rates collected minimized the number of acceptable axes for testing.

6.5.3 Rain

4 tests were conducted to generate and calibrate the required rain conditions with rates of precipitation ranging from 65-75 g/dm²/h. Results showed that it was possible to achieve the required rate of precipitation using four nozzles and maintain droplet size diameters within 1000μm±200. Test Runs #10, #11, and #12 demonstrated good repeatability of the results produced, even when using different nozzle locations. The rain condition generated was considered the worst-case scenario, with respect to visibility, in comparison to light freezing rain and freezing drizzle.

6.5.4 Chamber Temperature

The refrigeration system used at the NRC chamber generated air turbulence causing variability in the rate distribution produced by the wall-mounted nozzles. To minimize the air turbulence, the refrigeration was stopped once the target temperature was reached, and the rate calibration was conducted. Conducting the calibration without active refrigeration caused large fluctuations in temperature; the temperature in the chamber often rose above freezing.

6.6 Recommendations

The majority of ROGIDS Working Group members were present for the testing and had direct input into the subsequent recommendations.

6.6.1 Light Freezing Rain and Freezing Drizzle

It is recommended that light freezing rain and freezing drizzle conditions be removed from the Proposed SAE AS5681. The conditions generated by the rain curtain were deemed as the worst-case scenario with respect to visibility. In addition, the requirement of four nozzles to achieve the appropriate rain rates provided a more even distribution, which was more representative of nature.

Therefore, to avoid redundancy in the test requirements, it was suggested that only rain be tested resulting in the most conservative results.

6.6.2 Rain

It is recommended that precipitation requirements for rain be expanded from 65-75 g/dm²/h to 65-80 g/dm²/h. Increasing the upper precipitation rate limit would allow for greater ease of testing while remaining conservative. It was also recommended that the droplet diameter requirements be expanded from 1000µm±100 to 1000µm±200; due to the high rate of precipitation it was difficult to control size distribution.

6.6.3 Chamber Temperature

It is recommended that the chamber temperature requirements be changed to greater than or equal to -5°C. Chamber temperature did not have a significant effect on the visibility of the precipitation curtain generated, therefore, removing the upper limit would facilitate future testing.

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Photo 6.1: Nozzle Used for ‘Curtain Solution”

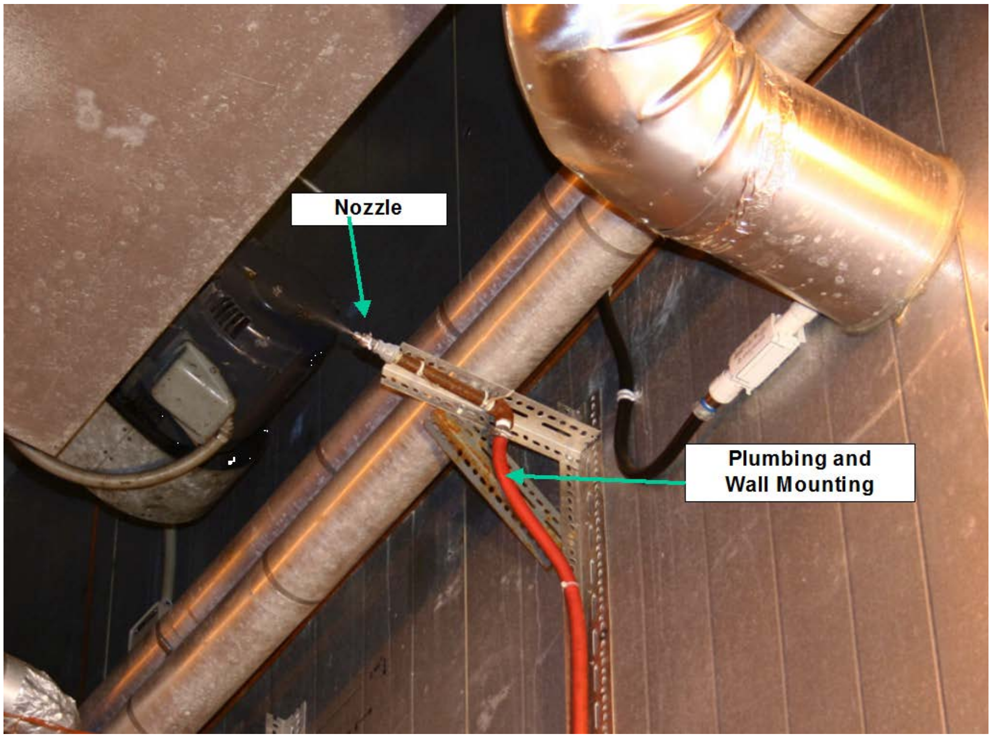
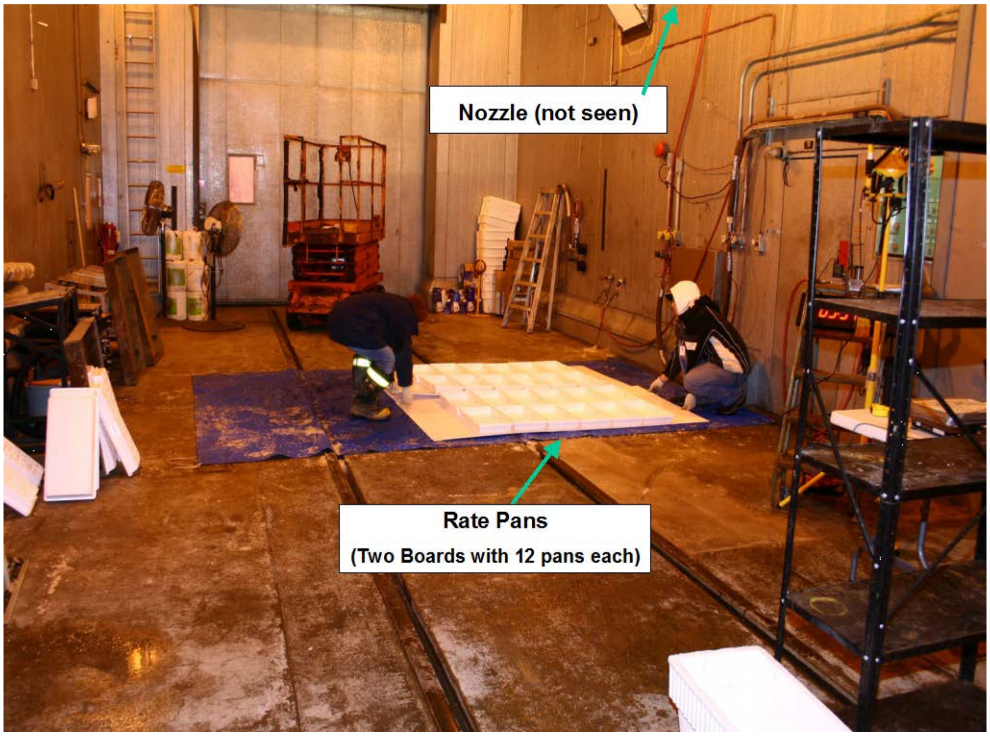


Photo 6.2: Chamber Setup for “Curtain Solution”



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7. CONCLUSIONS AND RECOMMENDATIONS

APS successfully demonstrated to the ROGIDS Working Group members and test participants that with the changes identified during conduct of the tests it is possible to create the conditions required by SAE AS5681 for evaluating the minimum operational performance requirements. The testing also showed that the test parameters were mostly satisfactory.

Based on the results of the tests, changes were incorporated into AS5681 where necessary. These conclusions and recommendations are described in detail in Sections 2 to 6 of this report.

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REFERENCES

1. Moc, M., *Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests*, APS Aviation Inc., Transportation Development Centre, Montreal, September 2005, TP 14449E, 46.

2. Narlis, C., *Comparison of Human Ice Detection Capabilities and Ground Ice Detection Performance Tests on Wing at PMG*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2005, TP 14450E, 54.

3. Bender, K., D’Avirro, J., Eyre, F., Marcil, I., Pugacz, E., Sierra Jr., E. A., *Human Visual and Tactile Ice Detection Capabilities under Aircraft Post Deicing Conditions*, FAA, February 2006, DOT/FAA/TC-06/21, 113.

4. Bender, K., Sierra Jr., E. A., Terrace, S. M., Marcil, I., D’Avirro, J., Pugacz, E., Eyre, F., *Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance Under Post Deicing Conditions*, FAA, February 2006, DOT/FAA/TC-06/20, 182. Retrieved from http://www.tc.faa.gov/its/worldpac/techrpt/tc06-20.pdf

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2006-07

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2006-07

6.5.1 Support for Development of Performance Specifications for ROGIDS

a) Participate in the activities of the SAE G-12 Subcommittee for Ice Detection, the SAE Regulatory Approval Process Working Group, and the Transport Canada "Ground Ice Detection System (GIDS) Implementation Team" (Ref: RDIMS 554519v5) including:

   i) Address the issue of the visual threshold for detection of frozen contamination on aircraft surfaces;

   ii) Review Remote GIDS reliability issues including implications of Transport Canada Hardware and Software Issue papers;

   iii) Chair the SAE Ice Detection Subcommittee Working Group to develop a Standard for Remote On-Ground Ground Ice Detection Sensors (RGIDS);

   iv) Prepare and coordinate an updated draft Standard for On-Board Aircraft Point and Remote Ground Ice Detection Systems (OGIDS). Coordinate with EUROCAE activities;

   v) Evaluate the feasibility of preparing ice disk samples for testing in conjunction with Aerospace Standard AS5681. Examine the decay of ice disk samples following the application of de/anti-icing fluid. The following particulars will be investigated:

      i. Test parameters less likely to cause the ice disk to dissolve; and

      ii. Maximum allowable time following fluid application until ice disk thickness begins to decrease.

   vi) Perform an internal review of previous work conducted for full-scale ROGIDS testing and prepare an internal document summarizing previous results, conclusions, and recommendations; and

   vii) Provide support for preparation and development of AS 5681 document.

6.5.2 Demonstration of Laboratory Trial Conditions for ROGIDS

a) Plan a demonstration of the conditions required to conduct laboratory trials for evaluating the minimum operational performance requirements (Proposed AS5681) of ice detection sensors;

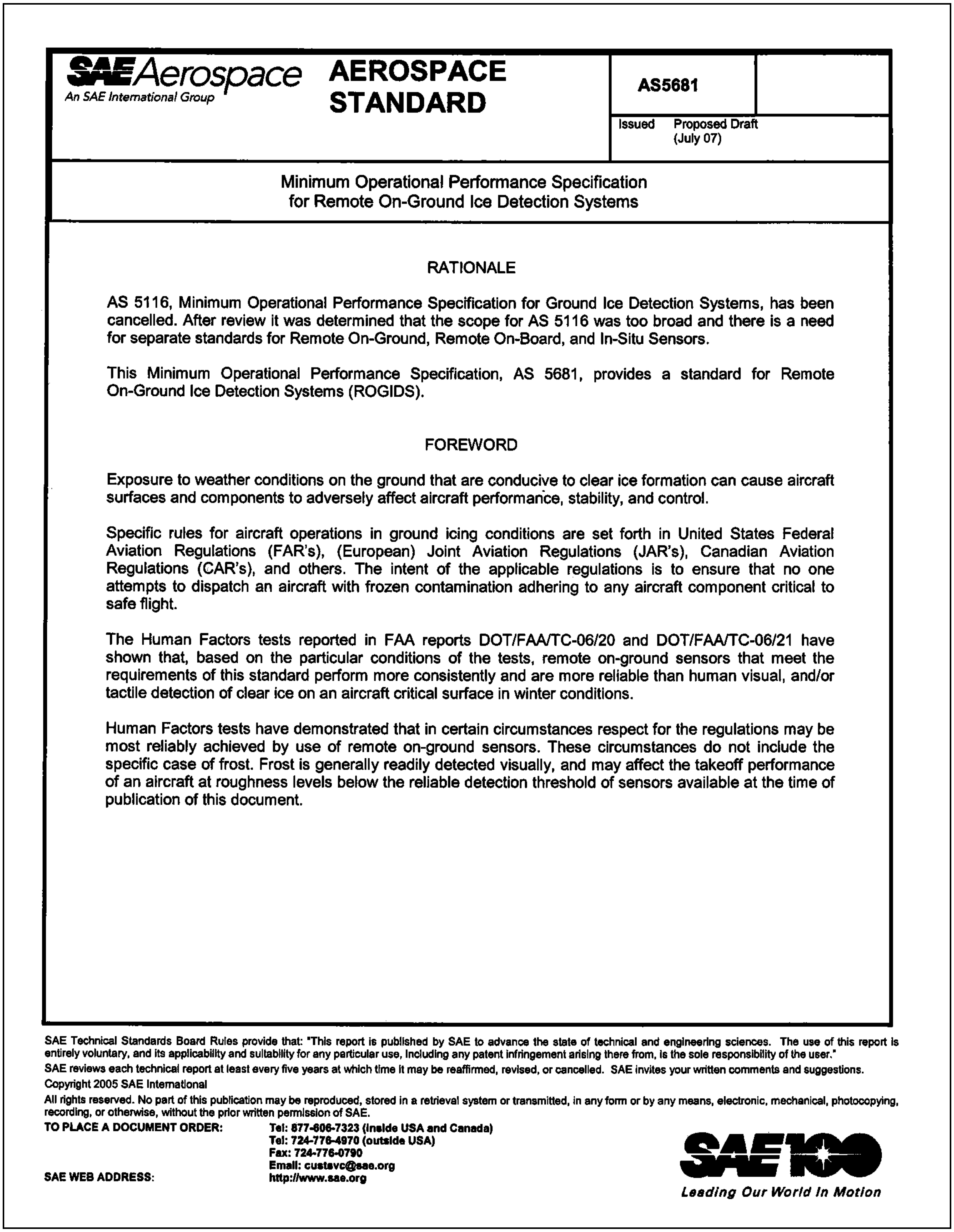
  - i) Freezing rain between the plates and the sensor(s), and encompassing the sensor field of view;
  - ii) Freezing drizzle between the plates and the sensor(s), and encompassing the sensor field of view; and
  - iii) Rain between the plates and the sensor(s), and encompassing the sensor field of view.

- b) Prepare a test plan and procedure for testing;
- c) Coordinate, with NRC, the piping and installations of the spray nozzles;
- d) Coordinate other activities (obtain ROGIDS system, photometer, nozzles, etc.); and
- e) Conduct tests at NRC (1 day setup, 4 days testing).
  - i) Characterization and feasibility of creating conditions; and
    - i. Measure the intensities produced for each condition using rate pans to determine if the intensities in the proposed specifications are appropriate; and
    - ii. Obtain ZR, ZD, and R droplet size distributions.
  - ii) Procedural feasibility.
    - i. Measure and control light intensity inside the chamber;
    - ii. Produce appropriate light intensity shadows on test plates;
    - iii. Survey the chamber for positioning of ROGIDS (far and near);
    - iv. Evaluate logistics for testing; and
    - v. Dry run using actual ROGIDS system.

APPENDIX B

PROPOSED AEROSPACE STANDARD 5681
MINIMUM OPERATIONAL PERFORMANCE SPECIFICATION FOR REMOTE ON-GROUND ICE DETECTION SYSTEMS

JULY 2007



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AEROSPACE STANDARD

AS5681

Issued Proposed Draft
(July 07)

Minimum Operational Performance Specification for Remote On-Ground Ice Detection Systems

RATIONALE

AS 5116, Minimum Operational Performance Specification for Ground Ice Detection Systems, has been cancelled. After review it was determined that the scope for AS 5116 was too broad and there is a need for separate standards for Remote On-Ground, Remote On-Board, and In-Situ Sensors.

This Minimum Operational Performance Specification, AS 5681, provides a standard for Remote On-Ground Ice Detection Systems (ROGIDS).

FOREWORD

Exposure to weather conditions on the ground that are conducive to clear ice formation can cause aircraft surfaces and components to adversely affect aircraft performance, stability, and control.

Specific rules for aircraft operations in ground icing conditions are set forth in United States Federal Aviation Regulations (FAR's), (European) Joint Aviation Regulations (JAR's), Canadian Aviation Regulations (CAR's), and others. The intent of the applicable regulations is to ensure that no one attempts to dispatch an aircraft with frozen contamination adhering to any aircraft component critical to safe flight.

The Human Factors tests reported in FAA reports DOT/FAA/TC-06/20 and DOT/FAA/TC-06/21 have shown that, based on the particular conditions of the tests, remote on-ground sensors that meet the requirements of this standard perform more consistently and are more reliable than human visual, and/or tactile detection of clear ice on an aircraft critical surface in winter conditions.

Human Factors tests have demonstrated that in certain circumstances respect for the regulations may be most reliably achieved by use of remote on-ground sensors. These circumstances do not include the specific case of frost. Frost is generally readily detected visually, and may affect the takeoff performance of an aircraft at roughness levels below the reliable detection threshold of sensors available at the time of publication of this document.

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SAE AS5681 Draft

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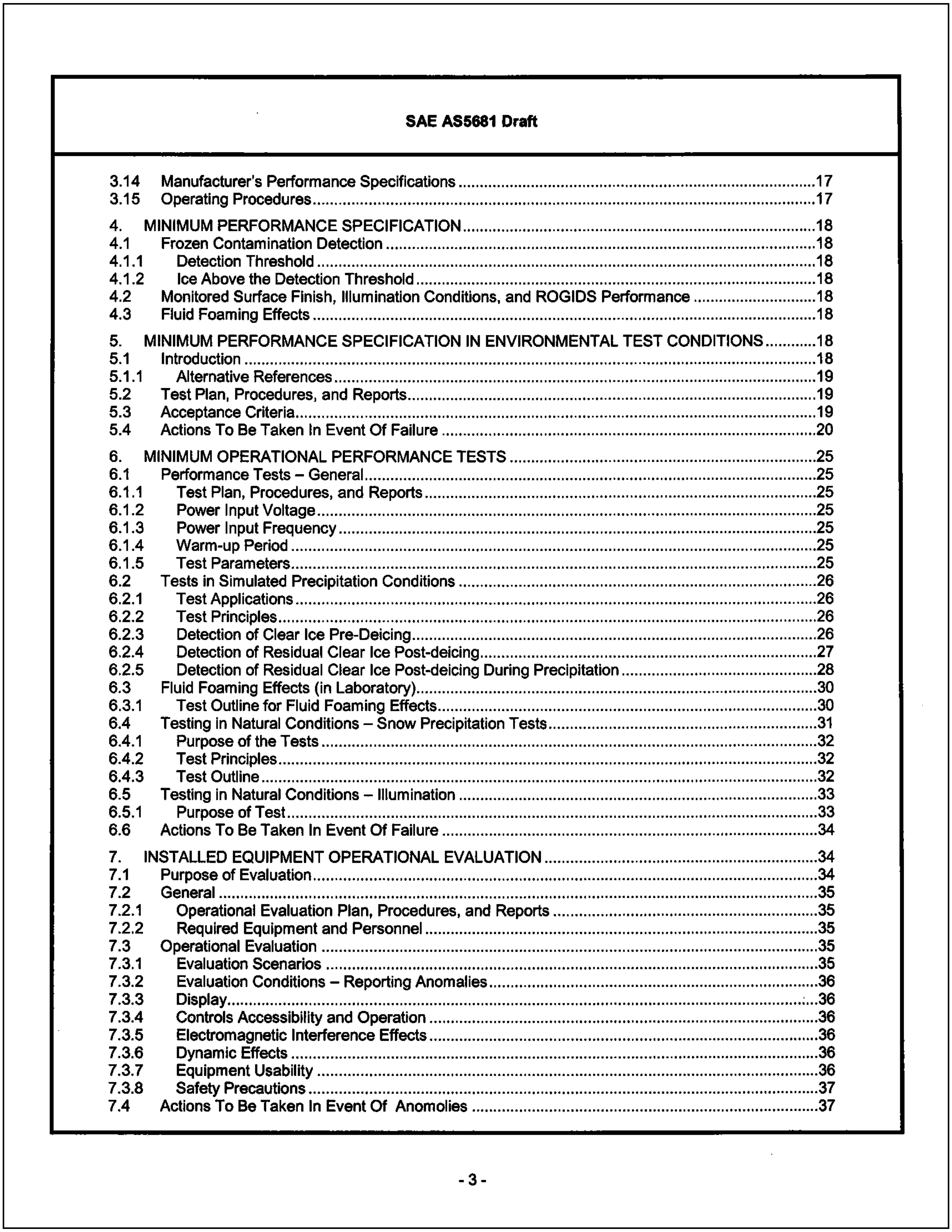

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1. SCOPE

This SAE Aerospace Standard (AS)/Minimum Operational Performance Specification (MOPS) specifies the minimum performance requirements of Remote On-Ground Ice Detection Systems (ROGIDS). These systems are ground-based. They provide information that indicates whether frozen contamination is present on aircraft surfaces.

Chapter 1 provides information required to understand the need for the ROGIDS, ROGIDS characteristics, and tests that are defined in subsequent chapters. It describes typical ROGIDS applications and operational objectives and is the basis for the performance criteria stated in Chapter 3 through Chapter 5.

Chapter 2 provides reference information, including related documents, abbreviations and definitions.

Chapter 3 contains general design requirements for the ROGIDS.

Chapter 4 contains the Minimum Operational Performance Requirements for the ROGIDS, which define performance in icing conditions likely to be encountered during ground operations.

Chapter 5 describes environmental test conditions that provide laboratory means of testing the overall performance characteristics of the ROGIDS in conditions that may be encountered in actual operations.

Chapter 6 describes recommended test procedures for demonstrating compliance with Chapters 3 and 4.

Chapter 7 contains the operational evaluation requirements for verifying the performance of the ROGIDS when installed for in-service use.

1.1 Applications of This Document:

Compliance with this AS/MOPS ensures that the ROGIDS will satisfactorily perform its intended functions.

Compliance with this AS/MOPS does not necessarily constitute compliance with regulatory requirements. Any application of this document in whole or in part is the sole responsibility of the appropriate regulatory agencies. It is recommended to seek guidance from the regulatory agencies before developing any test plans or test procedures. The manufacturer should confer with the regulatory agencies to determine those tests that need to be witnessed or performed by the regulatory agencies or other acceptable entity(s) and any associated reporting requirements.

The measured values of the ROGIDS performance characteristics may be a function of the method of measurement. Therefore, controlled test conditions and methods of testing are recommended in this document.

Mandating and Recommendation Phrases:

a. "Shall"

The use of the word "shall" indicates a mandated criterion; i.e., compliance with the particular procedure or specification is mandatory and no alternative may be applied.

b. "Should"

The use of the word "should" (and phrases such as, "it is recommended that...", etc.) indicates that although the procedure or criterion is regarded as the preferred option, alternative procedures, specifications or criteria may be applied, provided that the manufacturer, installer or tester can provide information or data to adequately support and justify the alternative.

1.2 Safety

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

1.3 Functional Description of System

The function of ROGIDS is to detect clear ice on aircraft surfaces.

ROGIDS are intended to be used during aircraft ground operations to inform the ground crew and/or the flight crew and/or a relevant system about the condition of monitored aircraft surfaces.

ROGIDS make a remote measurement of a monitored surface, and may be hand held, pedestal or vehicle mounted.

The ROGIDS may provide an alternative to the visual and tactile post-deicing checks required by aviation regulatory agencies, including the European Aviation Safety Agency (EASA), the United States Federal Aviation Administration (FAA) and Transport Canada Civil Aviation (TCCA), to determine the condition of aircraft critical surfaces in operating conditions involving freezing contamination. Approval for the use of ROGIDS as an advisory or primary means of performing post-deicing checks rests with the appropriate regulatory agency.

In addition, the ROGIDS may also supplement visual and tactile pre-deicing checks for clear ice. Approval for the use of ROGIDS as an advisory means of performing pre-deicing checks rests with the appropriate regulatory agency.

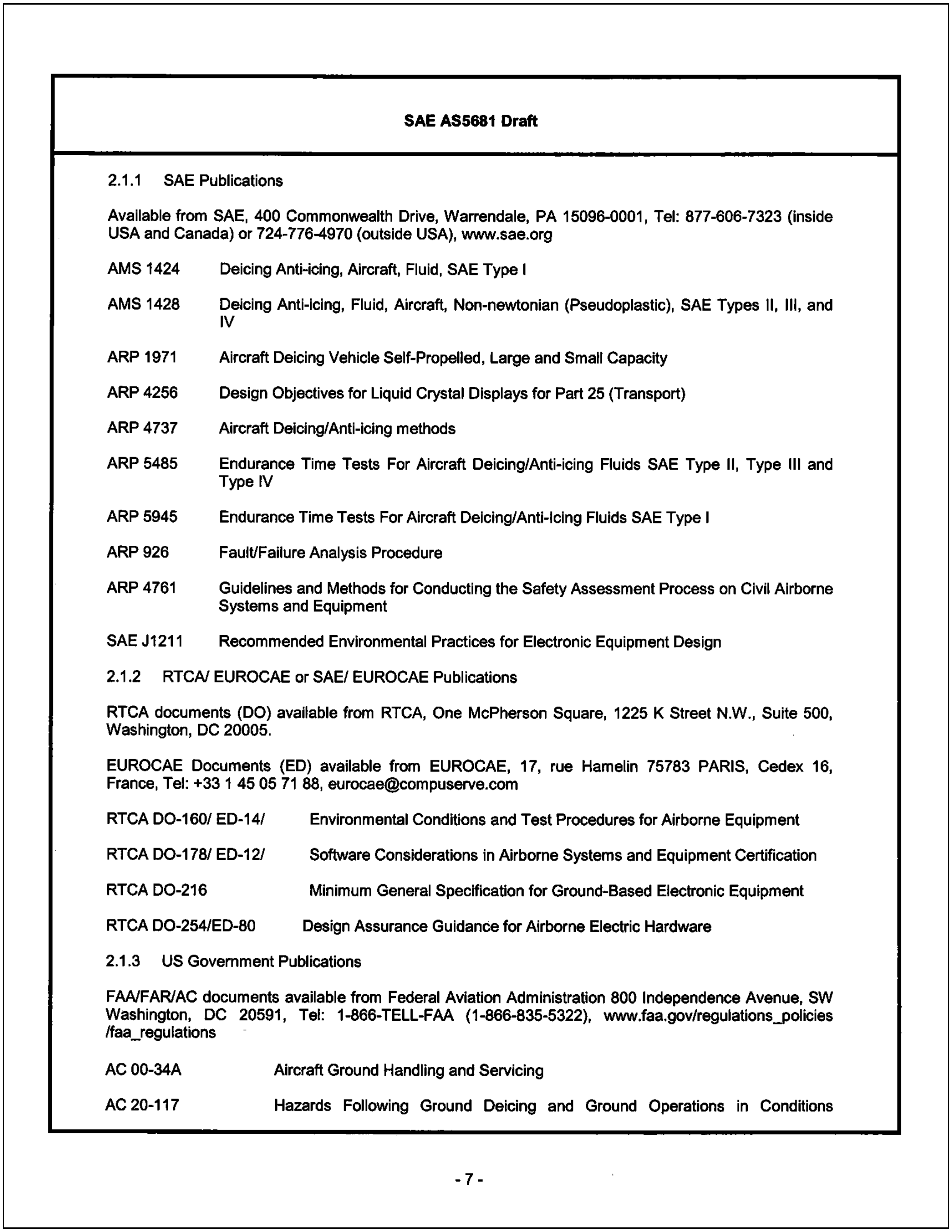
1.4 The ROGIDS should typically include:

a. At least one sensor that is directly or indirectly sensitive to the physical phenomena of aircraft icing during weather conditions consistent with ground icing operations.
b. A processing unit to perform signal processing. The unit may either be integrated with or separate from the sensor(s).
c. A device to provide information to the flight and/or ground crew.

2. REFERENCES

2.1 Applicable Documents

Unless otherwise specified, the current versions of the following publications form a part of this document. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.



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2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org

AMS 1424	Deicing Anti-icing, Aircraft, Fluid, SAE Type I
AMS 1428	Deicing Anti-icing, Fluid, Aircraft, Non-newtonian (Pseudoplastic), SAE Types II, III, and IV
ARP 1971	Aircraft Deicing Vehicle Self-Propelled, Large and Small Capacity
ARP 4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport)
ARP 4737	Aircraft Deicing/Anti-icing methods
ARP 5485	Endurance Time Tests For Aircraft Deicing/Anti-icing Fluids SAE Type II, Type III and Type IV
ARP 5945	Endurance Time Tests For Aircraft Deicing/Anti-Icing Fluids SAE Type I
ARP 926	Fault/Failure Analysis Procedure
ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
SAE J1211	Recommended Environmental Practices for Electronic Equipment Design

2.1.2 RTCA/ EUROCAE or SAE/ EUROCAE Publications

RTCA documents (DO) available from RTCA, One McPherson Square, 1225 K Street N.W., Suite 500, Washington, DC 20005.

EUROCAE Documents (ED) available from EUROCAE, 17, rue Hamelin 75783 PARIS, Cedex 16, France, Tel: +33 1 45 05 71 88, eurocae@compuserve.com

RTCA DO-160/ ED-14/	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA DO-178/ ED-12/	Software Considerations in Airborne Systems and Equipment Certification
RTCA DO-216	Minimum General Specification for Ground-Based Electronic Equipment
RTCA DO-254/ED-80	Design Assurance Guidance for Airborne Electric Hardware

2.1.3 US Government Publications

FAA/FAR/AC documents available from Federal Aviation Administration 800 Independence Avenue, SW Washington, DC 20591, Tel: 1-866-TELL-FAA (1-866-835-5322), www.faa.gov/regulations_policies /faa_regulations

AC 00-34A	Aircraft Ground Handling and Servicing
AC 20-117	Hazards Following Ground Deicing and Ground Operations in Conditions

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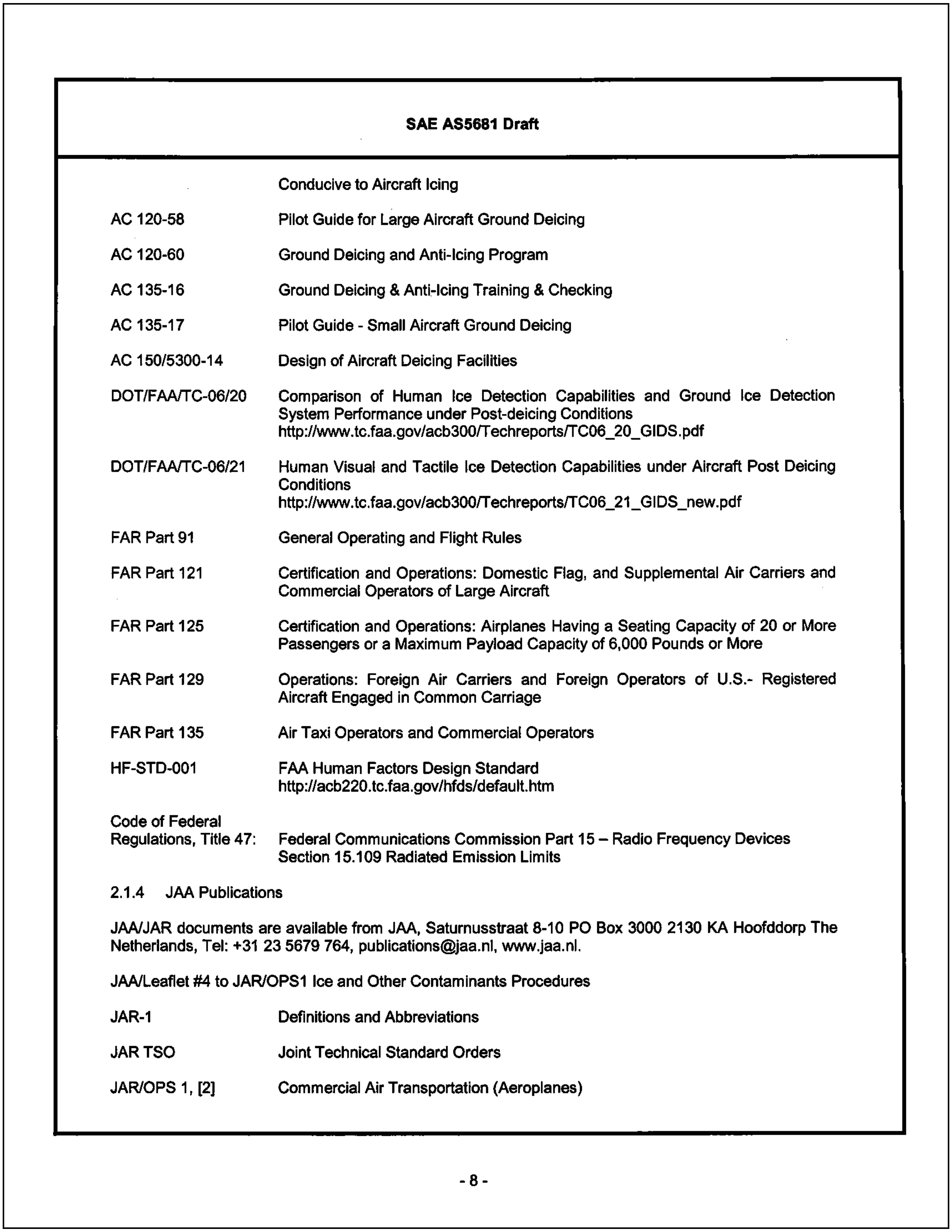

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	Conducive to Aircraft Icing
AC 120-58	Pilot Guide for Large Aircraft Ground Deicing
AC 120-60	Ground Deicing and Anti-Icing Program
AC 135-16	Ground Deicing & Anti-Icing Training & Checking
AC 135-17	Pilot Guide - Small Aircraft Ground Deicing
AC 150/5300-14	Design of Aircraft Deicing Facilities
DOT/FAA/TC-06/20	Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance under Post-deicing Conditions http://www.tc.faa.gov/acb300/Techreports/TC06_20_GIDS.pdf
DOT/FAA/TC-06/21	Human Visual and Tactile Ice Detection Capabilities under Aircraft Post Deicing Conditions http://www.tc.faa.gov/acb300/Techreports/TC06_21_GIDS_new.pdf
FAR Part 91	General Operating and Flight Rules
FAR Part 121	Certification and Operations: Domestic Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft
FAR Part 125	Certification and Operations: Airplanes Having a Seating Capacity of 20 or More Passengers or a Maximum Payload Capacity of 6,000 Pounds or More
FAR Part 129	Operations: Foreign Air Carriers and Foreign Operators of U.S.- Registered Aircraft Engaged in Common Carriage
FAR Part 135	Air Taxi Operators and Commercial Operators
HF-STD-001	FAA Human Factors Design Standard http://acb220.tc.faa.gov/hfds/default.htm
Code of Federal Regulations, Title 47:	Federal Communications Commission Part 15 – Radio Frequency Devices Section 15.109 Radiated Emission Limits

2.1.4 JAA Publications

JAA/JAR documents are available from JAA, Saturnusstraat 8-10 PO Box 3000 2130 KA Hoofddorp The Netherlands, Tel: +31 23 5679 764, publications@jaa.nl, www.jaa.nl.

JAA/Leaflet #4 to JAR/OPS1 Ice and Other Contaminants Procedures

JAR-1	Definitions and Abbreviations
JAR TSO	Joint Technical Standard Orders
JAR/OPS 1, [2]	Commercial Air Transportation (Aeroplanes)

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2.1.5 Transport Canada Publications

Transport Canada documents are available fom Transport Canada, Tower C, Place de Ville, 330 Sparks Street Ottawa, Ontario K1A 0N5, Tel: 1-800-305-2059, www.tc.gc.ca.

TP 14449	Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests
TP 14450	Development of Ice Samples for Comparison Study of Human and Sensor Capability to Detect Ice on Aircraft
TP 14452	Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681 (not yet published)
TC-CASS 622.11	Commercial Air Service Standard - Ground Icing Operations Standard
TC CAR 602.11	Canadian Aviation Regulation - Aircraft Icing

2.1.6 CEN/IEC/ISO Publications

CEN/EN documents available from CEN, 36, rue de Stassart B-1050 Brussels, Tel: +32 2 550 0811, infodesk@cenorm.be.

CEN 50081-2	Electromagnetic compatibility - Generic emission standard - Part 2: Industrial environment
CEN 50082-2	Electromagnetic compatibility - Generic immunity standard - Part 2: Industrial environment

2.1.7 ARINC Publications

Available from ARINC, 2551 Riva Road, Annapolis, MD 21401, www.arinc.com.

ARINC-415	Operational and Technical Guidelines on Failure Warning and Functional Test
ARINC-604	Guidance for Design and Use of Built-in Test Equipment (BITE)

2.1.8 Weather Related Publications

WMO documents are available from World Meteorological Organization, P.O. Box 2300, CH-1211, Geneva 2, Switzerland, Tel: 617 227 2425, wmopubs@ametsoc.org.

World Meteorological Organization Aerodrome Reports and Forecasts – Doc No. 782, revised 1 Jan 1996

2.2 Definitions and Abbreviations

2.2.1 Definitions

ANTI-ICING: A precautionary procedure that provides protection of an aircraft against the formation of frost or ice and accumulation of snow or slush on treated surfaces of the aircraft for a limited period of time.

CLEAR ICE: Clear ice forms at temperatures at or below 0°C, often associated with a high concentration of large supercooled water droplets. It can also be a residual product of an incomplete deicing process.

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Clear ice is hard, and appears as a smooth and glassy coating that can be very difficult to detect without a tactile inspection. Clear ice may not be seen during a walkaround, particularly if the wing is wet or during night-time operations. Clear ice can occur inflight or on the ground. Clear ice adheres firmly to surfaces, is difficult to remove, and requires special care during deicing/anti-icing.

DEICING: A procedure by which frost, ice, snow or slush is removed from the aircraft in order to provide aerodynamically clean surfaces. This is typically performed using heated (at least 60^0C) deicing fluid.

DEICING EVENT: A deicing event is the series of action required to deice and inspect one aircraft, culminating with the release of that aircraft in what is considered to be a state compliant with the ground icing regulatory requirements.

DEICING (and ANTI-ICING) FLUIDS: The fluids used for conduct of the deicing (and anti-icing) procedures. These are typically ethylene or propylene glycol based.

FALSE NEGATIVE: An indication of the absence of frozen contamination when frozen contamination is present on the reference surface.

FALSE POSITIVE: An indication of the presence of frozen contamination when no frozen contamination is present on the reference surface.

DEICING/ANTI-ICING FLUID FAILURE: When the deicing/anti-icing fluid can no longer absorb incoming precipitation and provide protection from the adherence of frozen contamination on treated surfaces. Characteristics of fluid failure can be surface freezing or snow accumulation, random snow accumulation and/or dulling of surface reflectivity caused by the gradual deterioration of the deicing/anti-icing fluid, possibly indicated by the presence of frozen contamination in or on the de/anti-icing fluid.

FROZEN CONTAMINATION/CONTAMINANTS: For the purpose of this AS/MOPS: frost, ice, snow, slush.

ILLUMINANCE: The amount of visible light power incident per unit area of a surface; measured in lux (lumens/meter^2) or foot-candles (Lumens/foot^2)

LATENT FAILURE: A latent failure is one that is inherently undetected when it occurs.

MAXIMUM DETECTION ANGLE: The maximum angle with respect to the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MAXIMUM DETECTION DISTANCE: The furthest the ROGIDS sensor can be from the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MINIMUM DETECTION ANGLE: The minimum angle with respect to the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MINIMUM DETECTION DISTANCE: The closest the ROGIDS sensor can be to the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MONITORED SURFACE: The surface of concern regarding ice hazard.

PRE-DEICING CHECK: An examination of an aircraft's wings and/or other critical surfaces to check for

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the presence of frozen contamination. Usually performed to determine the need for deicing.

POST-DEICING CHECK: An examination of an aircraft's wings and/or other critical surfaces after a deicing has been performed to determine the presence of any remaining frozen contamination.

Ra: Average surface roughness.

ROGIDS: A system that makes a remote measurement of a monitored surface to determine whether frozen contamination is present.

SYSTEM: A combination of components which are inter-connected to perform one or more functions.

2.2.2 Abbreviations

AC	Advisory Circular (FAA)
AMJ	Advisory Material Joint (JAA)
ARINC	Aeronautical Radio, Inc.
ARP	Aerospace Recommended Practice
AS	Aerospace Standard
BIT	Built In Test
BITE	Built In Test Equipment
CEN	Comité Européen de Normalisation. European Committee for Standardisation. Europäisches Komitee für Normung.
EASA	European Aviation Safety Agency
EN	Norme Européenne. European Standard. Europäische Norm.
EUROCAE	The European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration (USA)
FAR	Federal Aviation Regulations (USA)
FOD	Foreign Object Damage
FPD	Freezing Point Depressant; used to qualify the nature of deicing/anti-icing fluids
FTA	Fault Tree Analysis
GIDS	Ground Ice Detection System
IEC	International Electricity Committee
ISO	International Organization for Standardization

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JAA	Joint Aviation Authorities (Europe)
JAR	Joint Aviation Requirements (Europe)
min	Minute
MOPS	Minimum Operational Performance Specification
MTBF	Mean Time Between Failure
OAT	Outside Air Temperature
ROGIDS	Remote On-Ground Ice Detection System(s)
RTCA	Radio Technical Commission for Aeronautics
TC - CAR	Transport Canada - Civil Aviation Requirements
TC	Transport Canada (Canadian Civil Aviation Authority)

3. GENERAL DESIGN REQUIREMENTS

3.1 Introduction

This chapter identifies general design considerations for ROGIDS.

3.2 Complex Hardware and Software Design

The design of complex hardware such as large scale integrated circuits shall follow the guidelines specified in document RTCA DO-254/EUROCAE ED-80. The hardware criticality level will depend on the particular ROGIDS function and application.

3.2.1 Software design

Software design shall follow the guidelines specified in document RTCA DO-178/EUROCAE ED-12. The software criticality level will depend on the particular ROGIDS function and application.

3.3 Technical Requirements

3.3.1 Materials

Materials should be of a quality which experience and/or tests have demonstrated to be suitable and dependable for use in the ROGIDS.

3.3.2 Workmanship

All components shall be fitted properly and firmly in their appropriate positions. All electrical connections shall be mechanically secured and electrically sound. Care shall be given to neatness and thoroughness of soldering, wiring, welding, brazing, surface treatments, painting, screwed and bolted assemblies, marking of parts and assemblies, and elimination of burrs and sharp edges.

3.3.3 Mean Time Between Failure (MTBF)

The manufacturer shall report the MTBF.

3.3.4 Electrical Bonding and Grounding

The ROGIDS grounding system should provide for separation of AC power, DC power, chassis ground and signal ground(s). Optionally, signal ground(s) may be "referenced" to chassis ground. Wire shields shall not be used as a signal return.

On non-conductive enclosures, controls or metal parts which may be touched shall be bonded to ground. Case ground shall not be used for electrical power returns. Materials, surface preparation and finishes for electric bonding surfaces shall be compatible with preservation of adequate electrical conductivity over the life of the ROGIDS. The maximum resistance across any bonding or grounding junction shall be 0.25 Ω, as manufactured.

3.3.5 Interchangeability

All major components having the same part number shall be interchangeable with each other physically and functionally.

3.3.6 Marking

Permanently and legibly mark each major component with the following information:

1. Name and address of the manufacturer.
2. The name, type, part number or model designation of the component.
3. The serial number and the date of manufacture of the component.

If the component includes software, the part number shall either include hardware and software identification, or use separate part numbers for hardware and software identification. The part number shall uniquely identify the hardware and software design, including modification status.

3.4 Exposure During Normal Operations

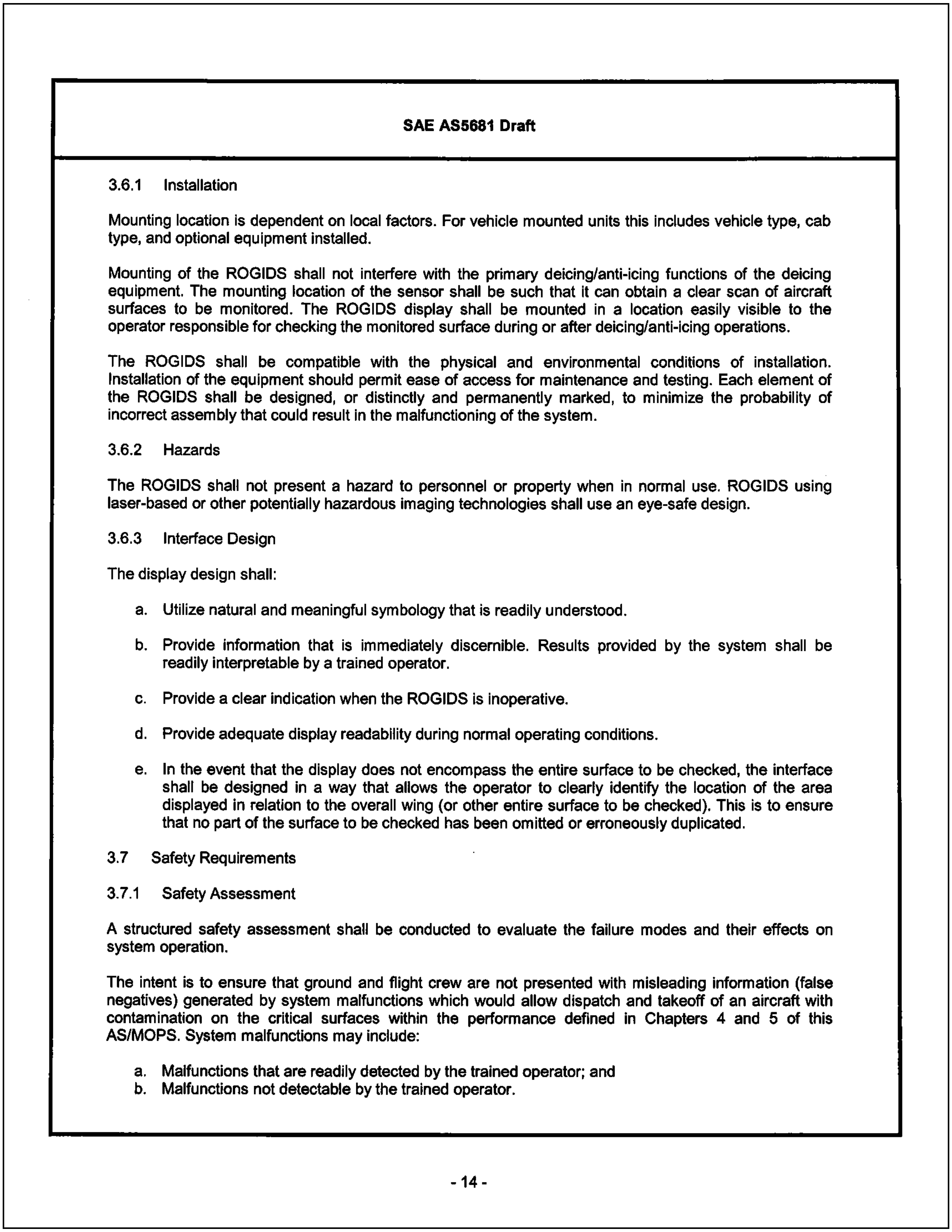
ROGIDS parts exposed to the external environment should be designed to withstand the temperature, pressure, chemical and/or radiation environment associated with deicing/anti-icing conditions. ROGIDS parts exposed to the external environment should be designed to withstand impact from ice particles shed from the aircraft and remain functional.

3.5 Foreign Object Damage (FOD)

The ROGIDS should be constructed so that in the normal operating environment parts do not become loose in service and create a FOD hazard.

3.6 Human Factors

Design of any ROGIDS should include consideration of the applicable human factors enumerated in FAA Human Factors Design Standard HF-STD-001. As a minimum, each design shall consider the following factors:



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3.6.1 Installation

Mounting location is dependent on local factors. For vehicle mounted units this includes vehicle type, cab type, and optional equipment installed.

Mounting of the ROGIDS shall not interfere with the primary deicing/anti-icing functions of the deicing equipment. The mounting location of the sensor shall be such that it can obtain a clear scan of aircraft surfaces to be monitored. The ROGIDS display shall be mounted in a location easily visible to the operator responsible for checking the monitored surface during or after deicing/anti-icing operations.

The ROGIDS shall be compatible with the physical and environmental conditions of installation. Installation of the equipment should permit ease of access for maintenance and testing. Each element of the ROGIDS shall be designed, or distinctly and permanently marked, to minimize the probability of incorrect assembly that could result in the malfunctioning of the system.

3.6.2 Hazards

The ROGIDS shall not present a hazard to personnel or property when in normal use. ROGIDS using laser-based or other potentially hazardous imaging technologies shall use an eye-safe design.

3.6.3 Interface Design

The display design shall:

a. Utilize natural and meaningful symbology that is readily understood.

b. Provide information that is immediately discernible. Results provided by the system shall be readily interpretable by a trained operator.

c. Provide a clear indication when the ROGIDS is inoperative.

d. Provide adequate display readability during normal operating conditions.

e. In the event that the display does not encompass the entire surface to be checked, the interface shall be designed in a way that allows the operator to clearly identify the location of the area displayed in relation to the overall wing (or other entire surface to be checked). This is to ensure that no part of the surface to be checked has been omitted or erroneously duplicated.

3.7 Safety Requirements

3.7.1 Safety Assessment

A structured safety assessment shall be conducted to evaluate the failure modes and their effects on system operation.

The intent is to ensure that ground and flight crew are not presented with misleading information (false negatives) generated by system malfunctions which would allow dispatch and takeoff of an aircraft with contamination on the critical surfaces within the performance defined in Chapters 4 and 5 of this AS/MOPS. System malfunctions may include:

a. Malfunctions that are readily detected by the trained operator; and
b. Malfunctions not detectable by the trained operator.

Acceptable structured assessment procedures include but are not limited to:

a. System Safety Assessment;
b. Functional Hazard Assessment;
c. Failure Modes and Effects Analysis; and
d. Fault Tree Analysis.

Appropriate software and hardware design assurance levels shall be selected based on a structured safety assessment process.

ROGIDS shall be designed, installed, operated, and maintained according to applicable safety standards defined by the authority having jurisdiction.

Overall equipment failure rate, including active failures, shall be provided by the ROGIDS manufacturer.

3.7.2 Latent Failure Rate

Appendix D contains background material and rationale for the determination of the acceptable latent failure rate.

The acceptable rate for latent failures that lead to false negatives shall be on the order of 1 in 10,000 deicing events (10^{-4} per deicing events).

Fault Tree Analysis and Failure Modes and Effects Analysis shall be conducted and documented to establish that the equipment false negative rate due to malfunction is less than the acceptable rate as defined above.

3.8 ROGIDS Operation

3.8.1 ROGIDS Controls

The operation of ROGIDS controls in all possible positions, combinations and sequences, shall not be detrimental to the continued normal operation of the ROGIDS.

ROGIDS controls that are not intended to be adjusted in normal operation shall not be readily accessible to the ground crew.

3.8.2 Data Processing

Following acquisition, the processing and interpretation of data by the ROGIDS shall be automatic.

The system shall be designed in such a manner as to preclude the display of invalid output data.

3.8.3 Built In Test Equipment (BITE)

The ROGIDS shall include a confidence (BITE) test. The test function shall be automatic during operation.

The BITE shall support the safety objectives and the reliability requirements of this document. BITE shall provide a clear indication of detected ROGIDS failures to the operator.

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3.8.4 Nuisance Alarms

Nuisance alarms should be minimized.

3.8.5 Operating Weather Conditions

The ROGIDS shall perform its intended function during weather conditions consistent with ground icing operations.

3.9 Qualification Tests

3.9.1 Responsibility for Testing

The manufacturer of the product shall be responsible for the performance and documentation of all required tests specified in Chapters 5, 6 and 7 to demonstrate compliance with this AS/MOPS.

3.9.2 Test Article

The tests shall be conducted with one or more ROGIDS that are in full conformity with production build.

3.10 Test Plan(s)

The manufacturer shall prepare a test plan or test plans detailing at a minimum the following:

a. Purpose of Test;
b. Scope;
c. Test article configuration (the test shall be conducted with one or more ROGIDS that are in full conformity with the production build);
d. Applicable and reference documents;
e. Test administration:
    1. Test activities and Responsibilities; and
    2. Quality assurance.
f. Test Documentation and data recording/capture;
g. Pass/Fail Criteria;
h. Pass/Fail Reporting;
i. Actions to be taken in event of failure;
j. Test Equipment:
    1. Calibration;
    2. Safety and Hazards; and
    3. Material and handling.
k. Test Procedures to be prepared; and
l. Test Reports to be prepared.

3.11 Test Procedures

The manufacturer shall prepare test procedures detailing at a minimum the following:

a. Purpose;
b. Scope;

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c. Test article configuration (the test shall be conducted with one or more ROGIDS that are in full conformity with the production build);
d. Applicable and reference documents;
e. General Instructions:
    1. Test activities and Responsibilities;
    2. Quality Assurance and Inspection;
    3. Standard Test Conditions;
    4. Test Equipment Calibration; and
    5. Test Documentation.
f. Test Equipment Hardware and Software;
g. Test Configuration;
h. Test Sequence;
i. Test Procedures
j. Pass/Fail Criteria;
k. Pass/Fail Reporting; and
l. Actions to be taken in event of failure.

3.12 Test Report

The ROGIDS manufacturer shall prepare a test report detailing the following:

a. The part number and serial number, which identifies the ROGIDS as tested, and hardware/software revision numbers as applicable;

b. A description of the test facility and test procedures used; and

c. Results of all tests and technical data that substantiate the manufacturer's performance specifications.

The foregoing information shall be cross referenced to the appropriate sections of this AS/MOPS.

3.13 Compliance checklist

The manufacturer shall provide a declaration that design, verification, validation, testing and analysis confirms that the equipment complies with all the requirements of this document. A compliance checklist shall be provided to facilitate this task. It is acceptable for the compliance check to provide a cross reference between requirements in this document and manufacturer documents demonstrating compliance.

3.14 Manufacturer's Performance Specifications

The manufacturer shall provide performance specifications for the ROGIDS. These shall incude the maximum and minimum detection distances and angles.

3.15 Operating Procedures

A set of operating procedures for each specific ROGIDS shall be developed.

The manufacturer shall clearly identify all operational limitations.

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4. MINIMUM PERFORMANCE SPECIFICATION

This chapter defines the minimum performance criteria that shall be used for the design of ROGIDS.

4.1 Frozen Contamination Detection

ROGIDS shall be able to detect and communicate the presence of:

a. Clear Ice Pre-Deicing;
b. Residual Clear Ice Post-deicing; and
c. Residual Clear Ice Post-deicing During Precipitation.

ROGIDS performance standards for detection of frost, snow and slush on a critical surface have not been defined.

ROGIDS performance related to the detection of frost, snow and/or slush may be addressed in future versions of this document.

4.1.1 Detection Threshold

The ROGIDS detection threshold shall ensure the detection of clear ice of 0.5 mm thickness or less, continuously distributed over an area of 315 cm^2, or less.

4.1.2 Ice Above the Detection Threshold

The ROGIDS shall detect and indicate the presence of ice on the monitored surface in excess of the detection threshold.

4.2 Monitored Surface Finish, Illumination Conditions, and ROGIDS Performance

The material, the surface finish and/or the surface treatment of the monitored surface shall not adversely affect the ROGIDS performance.

The ROGIDS shall not be adversely affected by the transition between two or more surface finishes and/or illumination conditions.

4.3 Fluid Foaming Effects

The ROGIDS performance shall not be affected by foaming in applied deicing/anti-icing fluids.

5. MINIMUM PERFORMANCE SPECIFICATION IN ENVIRONMENTAL TEST CONDITIONS

5.1 Introduction

a. The environmental tests described in this section will determine the ROGIDS ability to operate in conditions representative of those that may be encountered in actual operation.

b. Tests 1-7 in Table 1, Required Tests, are mandatory. All seven tests shall be completed in full and passed.

c. Unless otherwise specified, the tests shall be conducted using ALL components of the ROGIDS.

d. Tests 1-6 specified in Table 1 have been adapted from RTCA DO-160E: *Environmental Conditions and Test Procedures for Airborne Equipment.* Guidance for adapting the specified DO-160E tests to ROGIDS testing is provided in the comments section for each test.

e. For Test 4 in Table 1 (Fluids Susceptibility - ROGIDS External Components), it is permissible to remove the internal components of the ROGIDS for the duration of the test. However, Test 5 in Table 1 (Fluids Susceptibility - ROGIDS System) shall be performed using a fully functioning ROGIDS.

f. Table 2 provides a series of recommended tests. While these tests are optional, it is strongly recommended that tests from this list that apply to the operational environment in which the ROGIDS will be used be performed, and that the test results be reported.

5.1.1 Alternative References

In addition to recommended tests 9 and 16 in Table 2, SAE Surface Vehicle Recommended Practice J1211 is a good source of information on the environmental challenges electronic equipment face in the automotive environment, and contains useful optional additional test recommendations and procedures.

5.2 Test Plan, Procedures, and Reports

A test plan and test procedures shall be prepared in accordance with Subsections 3.10 and 3.11.

A report of test results shall be prepared in accordance with Subsection 3.12.

All test procedures shall be documented. Where physical facility limitations exist which influence the set-up and conduct of the tests, these limitations shall be noted.

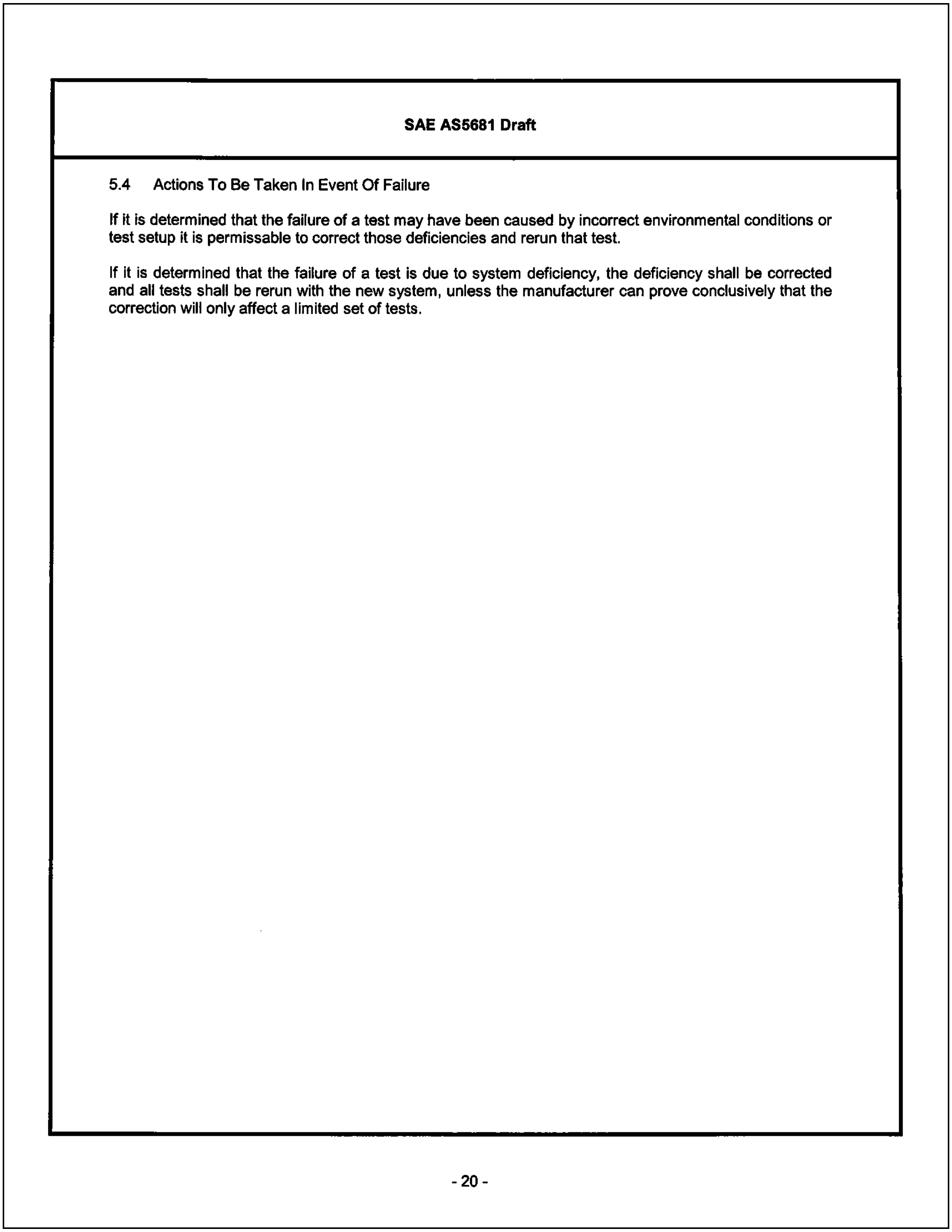
5.3 Acceptance Criteria

In some of the tests specified in Tables 1 and 2, an ice detection test is called for in the comments column. The purpose of this test is to determine whether the ROGIDS has survived the environmental test and can still detect ice.

When "Perform an ice detection test" is called for in the comments column of the tests in Tables 1 and 2, at a minimum the following shall be done:

Using the four test plates described in Appendix B (Table B1 – Test Plates), develop a patch of clear ice of 0.5 mm thickness and a circular area of 315 cm^2 on each plate. A method for development of the ice patch is described in Transport Canada publications TP 14449 and TP 14450. There is no need for deicing/anti-icing fluid during this test; therefore the test plates may be mounted vertically, perpendicular to the ROGIDS. Place the ROGIDS at the manufacturer's specified minimum operational distance from the test samples. Take an individual image of each of the four ice patches. Place the ROGIDS at the manufacturer's specified maximum operational distance from the test samples. Take an individual image of each of the four ice patches. If the ROGIDS correctly detects all four patches at both the minimum and maximum operational distances (a total of 8 correct images), the test is passed. If the ROGIDS does not correctly detect all four ice patches at both the minimum and maximum operational distances, the test is failed.

The ice detection test described above shall also be used when DO 160E states DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.



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5.4 Actions To Be Taken In Event Of Failure

If it is determined that the failure of a test may have been caused by incorrect environmental conditions or test setup it is permissable to correct those deficiencies and rerun that test.

If it is determined that the failure of a test is due to system deficiency, the deficiency shall be corrected and all tests shall be rerun with the new system, unless the manufacturer can prove conclusively that the correction will only affect a limited set of tests.

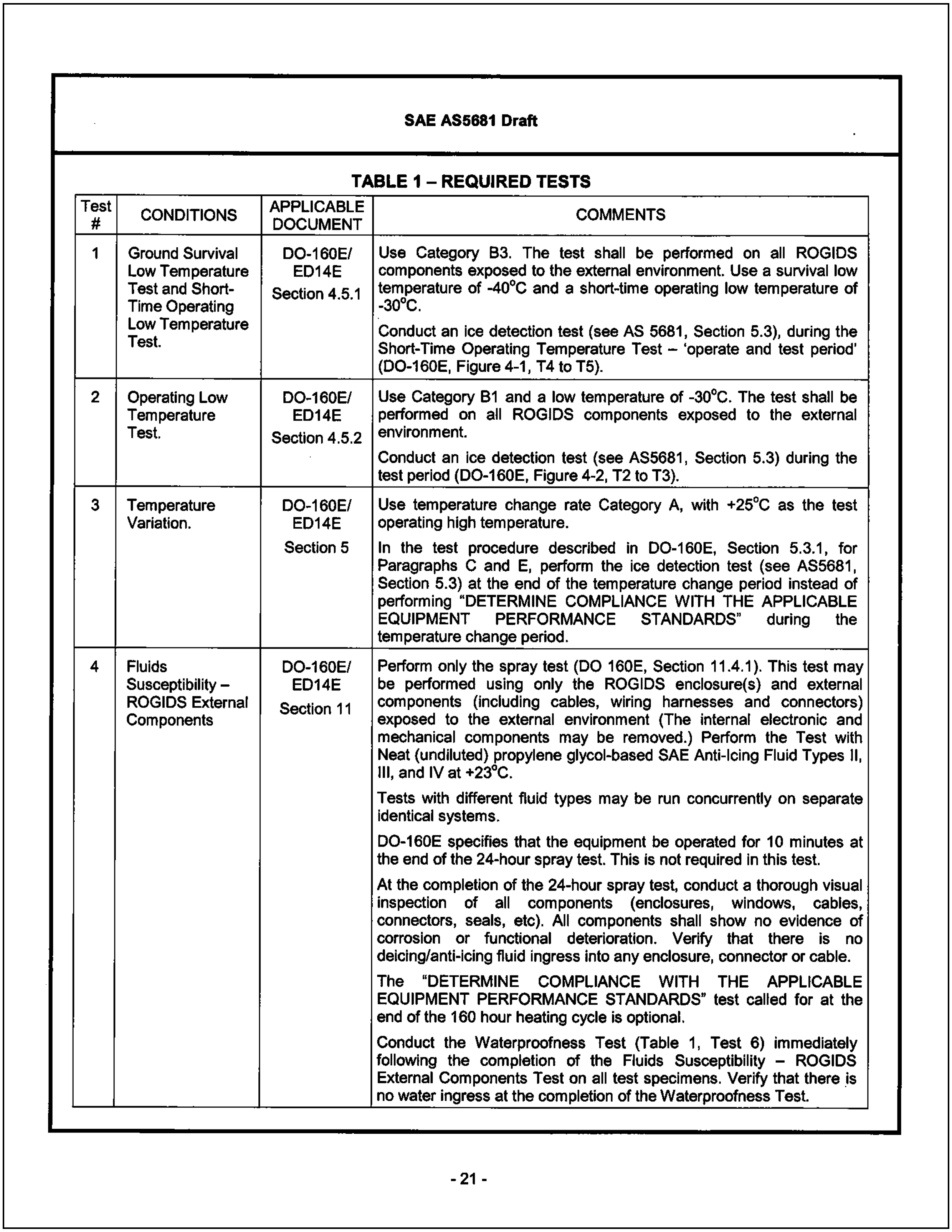

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TABLE 1 – REQUIRED TESTS

Test #	CONDITIONS	APPLICABLE DOCUMENT	COMMENTS
1	Ground Survival Low Temperature Test and Short-Time Operating Low Temperature Test.	DO-160E/ ED14E Section 4.5.1	Use Category B3. The test shall be performed on all ROGIDS components exposed to the external environment. Use a survival low temperature of -40°C and a short-time operating low temperature of -30°C. Conduct an ice detection test (see AS 5681, Section 5.3), during the Short-Time Operating Temperature Test – 'operate and test period' (DO-160E, Figure 4-1, T4 to T5).
2	Operating Low Temperature Test.	DO-160E/ ED14E Section 4.5.2	Use Category B1 and a low temperature of -30°C. The test shall be performed on all ROGIDS components exposed to the external environment. Conduct an ice detection test (see AS5681, Section 5.3) during the test period (DO-160E, Figure 4-2, T2 to T3).
3	Temperature Variation.	DO-160E/ ED14E Section 5	Use temperature change rate Category A, with +25°C as the test operating high temperature. In the test procedure described in DO-160E, Section 5.3.1, for Paragraphs C and E, perform the ice detection test (see AS5681, Section 5.3) at the end of the temperature change period instead of performing "DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS" during the temperature change period.
4	Fluids Susceptibility – ROGIDS External Components	DO-160E/ ED14E Section 11	Perform only the spray test (DO 160E, Section 11.4.1). This test may be performed using only the ROGIDS enclosure(s) and external components (including cables, wiring harnesses and connectors) exposed to the external environment (The internal electronic and mechanical components may be removed.) Perform the Test with Neat (undiluted) propylene glycol-based SAE Anti-Icing Fluid Types II, III, and IV at +23°C. Tests with different fluid types may be run concurrently on separate identical systems. DO-160E specifies that the equipment be operated for 10 minutes at the end of the 24-hour spray test. This is not required in this test. At the completion of the 24-hour spray test, conduct a thorough visual inspection of all components (enclosures, windows, cables, connectors, seals, etc). All components shall show no evidence of corrosion or functional deterioration. Verify that there is no deicing/anti-icing fluid ingress into any enclosure, connector or cable. The "DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS" test called for at the end of the 160 hour heating cycle is optional. Conduct the Waterproofness Test (Table 1, Test 6) immediately following the completion of the Fluids Susceptibility – ROGIDS External Components Test on all test specimens. Verify that there is no water ingress at the completion of the Waterproofness Test.

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TABLE 1 (cont'd) – REQUIRED TESTS

Test #	CONDITIONS	APPLICABLE DOCUMENT	COMMENTS
5	Fluids Susceptibility - ROGIDS System	DO-160E/ ED14E Section 11	Perform only the Spray Test (DO-160E, Section 11.4.1). The test shall be performed on all ROGIDS components exposed to the external environment. Perform the test using a Neat propylene glycol-based SAE Type I Deicing Fluid, diluted to a 50% concentration with water, and heated to +50°C. This test shall be performed using a fully functional ROGIDS system. For the 160 hour heating cycle, the test shall be run at the manufacturer's specified maximum survival temperature. Conduct the 'Waterproofness Test' (Table 1, Test 6) immediately following the completion of the 'Fluids Susceptibility – ROGIDS System Test' on all components. Verify that there is no water ingress at the completion of the 'Waterproofness Test'.
6	Waterproofness	DO-160E/ ED14E Section 10	Note: This test is performed at the end of Tests 4 and 5. It does not need to be repeated separately. Use Category R. The test shall be performed on all ROGIDS components exposed to the external environment.
7	Radio Frequency Emission	FCC 15.109(B)	Category FCC Class A

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TABLE 2 – RECOMMENDED TESTS

Test #	CONDITIONS	DOCUMENTS SECTION	COMMENTS
1	Ground Survival High Temperature Test and Short-Time Operating High Temperature Test	DO-160E/ ED14E Section 4.5.3	Use a ground survival high temperature of +60°C. For the Short-Time Operating High Temperature Test, use the manufacturer's specified short-time operating high temperature.
2	Operating High Temperature	DO-160E/ ED14E Section 4.5.4	Perform the test using an operating high temperature of at least +25 °C.
3	Operational Shock	DO-160E/ ED14E Section 7 And/Or SAE J1211 Section 4.8	Categories A and D (DO-160E)
4	Vibration	DO-160E/ ED14E Section 8 And/Or SAE J1211 Section 4.7	Category S (DO-160E)
5	Sand and Dust	DO-160E/ ED14E Section 12 And/Or SAE J1211 Section 4.5	Category S (DO-160E).
6	Fungus Resistance	DO-160E/ ED14E Section 13.0	
7	Salt Fog	DO-160E/ ED14E Section 14	This test is required if the ROGIDS is to be used in a salt atmosphere or exposed to salt fog.
8	Magnetic Effect	DO-160E/ ED14E Section 15	

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TABLE 2 (cont'd) – RECOMMENDED TESTS

Test #	CONDITIONS	DOCUMENTS SECTION	COMMENTS
9	Power input	SAE J1211 Sections 4.9, 4.10, 4.11	
10	Voltage spike	DO-160E/ ED14E Section 17 And/Or ISO 7637-2	Category B (DO-160E)
11	Icing	DO-160E/ ED14E Section 24	Category C
12	Electrostatic Discharge	DO-160E/ ED14E Section 25	
13	Audio Frequency Susceptibility	DO-160E/ ED14E Section 18	
14	Induced Signal Susceptibility/EMI	DO-160E/ ED14E Section 19	
15	Radio Frequency Susceptibility (ISO 7637)	EN 50082-2 Or DO160E Section 20	
16	Humidity	DO160E/ ED14E Section 6.0	Category C

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6. MINIMUM OPERATIONAL PERFORMANCE TESTS

6.1 Performance Tests – General

The purpose of the performance capability tests is to demonstrate that the ROGIDS complies with the Minimum Performance Specification.

Appendix A lists the tests to be performed. Appendices B and C give the test parameters.

Conduct tests for the detection of clear ice:

a. In a controlled (laboratory) environment with and/or without deicing/anti-icing fluids, and in visibility conditions associated with rain and with freezing fog;

b. Under foamed fluid in a controlled (laboratory) environment;

c. In natural conditions with deicing/anti-icing fluids, and in visibility conditions associated with snow; and

d. On a wing surface in natural light conditions.

6.1.1 Test Plan, Procedures, and Reports

Detailed test plans, test procedures, and a report of test results shall be prepared.
The test procedures, ice thickness and area measurements, combined fluid thickness, fluid names, sensor sight angle and distance, visibility conditions, precipitation characteristics, and detection results for each test conducted shall be documented.

All test procedures, including the test set-up, and any deviations, and/or non-conformances to the test procedures shall be documented. Where physical facility limitations exist which influence the set-up and conduct of the tests, these limitations shall be noted.

6.1.2 Power Input Voltage

Unless otherwise specified, all tests shall be conducted at the designed power input voltage. The input voltage shall be measured at the equipment input terminals.

6.1.3 Power Input Frequency

In the case of equipment designed for operation from an AC power source of essentially constant frequency, tests shall be conducted at the designed input frequency.

6.1.4 Warm-up Period

All tests shall be conducted after the warm-up period specified by the manufacturer.

6.1.5 Test Parameters

Conduct tests using:

a. Flat test plates representative of aircraft surface materials and finishes (Appendix B, Table B1 and Figure B1); and

b. Deicing and anti-icing fluids meeting SAE specifications (AMS 1424 and AMS 1428).

For test purposes, the following surfaces have been selected: bare aluminum; grey, white and red painted aluminum; white and red painted fiber reinforced composite; and deicing boot material.

6.2 Tests in Simulated Precipitation Conditions

The test conditions listed below were designed for testing in simulated precipitation conditions. These tests may be performed in equivalent natural conditions.

6.2.1 Test Applications

The tests for ROGIDS in a controlled environment address three applications:

a. Detection of Clear Ice Pre-Deicing;
b. Detection of Residual Clear Ice Post-deicing; and
c. Detection of Residual Clear Ice Post-deicing During Precipitation.

6.2.2 Test Principles

To demonstrate the capability to identify clear ice, the artificial precipitation conditions created in a temperature-controlled climatic chamber are considered to be consistent with natural icing conditions.

The tests have been adapted from and use similar principles as laboratory test procedures used to establish endurance times for aircraft deicing/anti-icing fluids (SAE Types I, II, III, and IV). These test procedures are described in SAE ARP 5485 and SAE ARP 5945.

6.2.3 Detection of Clear Ice Pre-Deicing

6.2.3.1 Test Outline

Conduct tests in Appendix A, Table A1, to demonstrate the capability of a ROGIDS to identify clear ice on an untreated surface.

a. Ensure the plates are clean and dry. The ambient air temperature is recommended to be less than or equal to -5°C.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm².

c. Take an image of the test plate with the ROGIDS.

d. Measure and record the ice thickness. Record any false positive indication on the area of the plate not covered by clear ice.

e. Complete for all the illumination conditions defined in Appendix C. The illumination conditions that will be considered include daylight, night-time illumination and a condition with shadows on the test plate.

f. Tests shall be completed with the ROGIDS placed at two locations:

   1. Far - A ROGIDS at manufacturer's specified minimum operational sight angle and maximum distance.

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2. Near - A ROGIDS at manufacturer's specified minimum distance and maximum operational sight angle.

g. False Positive Tests: Once each clear ice test is complete, a plate without clear ice will be placed above the original plate and tests shall be carried out with the ROGIDS in the far and near locations for each illumination condition.

6.2.3.2 Pass/Fail Criteria

a. False negatives

For each test in test set 1 (pre-deicing) the ROGIDS shall always correctly detect and indicate the presence of clear ice on each half or quadrant of the clear ice sample irrespective of:

1. The plate finish under the clear ice;
2. Illumination of clear ice sample;
3. Sensor location (near, far); and
4. Ambient Air Temperature.

b. False positives

For each clean plate test in test set 1 the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish;
2. Illumination of plate;
3. Sensor location (near, far); and
4. Ambient Air Temperature.

6.2.4 Detection of Residual Clear Ice Post-deicing

6.2.4.1 Test Outline

Conduct the tests in Appendix A, Table A2, to demonstrate the capability of a ROGIDS to identify residual clear ice beneath a deicing/anti-icing fluid layer. For these tests commercially available ethylene and propylene glycol based Type I, II, III and IV deicing/anti-icing fluids shall be used. If the ROGIDS is intended to be used with other glycol based fluids (e.g. diethylene) or non-glycol based fluids, then additional tests with these fluids will be required.

a. Ensure the plates are clean and dry. The ambient air temperature is recommended to be less than or equal to -5°C.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm^2 after the deicing/anti-icing fluid has been applied. For the thick ice test the ice thickness shall be 10 mm ± 1mm. For these tests the plates shall be horizontal in order to ensure a consistent and representative deicing/anti-icing fluid thickness over the ice.

c. Prior to application of the fluid, ensure that the ROGIDS is capable of detecting the ice. Measure and record the ice thickness.

d. Apply the appropriate fluid tempered and prepared in accordance with Appendix B, B.2. A retainer placed on the plate may be used to ensure that the required thickness is achieved. The procedure for the application of the fluid is as follows:

1. Apply Type I fluid to produce an average fluid thickness of 0.1 mm ± 0.05 mm.
2. Apply Type II fluid to produce an average fluid thickness of 3.0 mm ± 0.5 mm.
3. Apply Type III fluid to produce an average fluid thickness of 1.0 mm ± 0.02 mm.
4. Apply Type IV fluid to produce an average fluid thickness of 3.0 mm ± 0.5 mm.

e. Perform the test.

f. One clear ice sample may be used for more than one test.

NOTE: The fluid will dissolve the clear ice; therefore minimize the time between the fluid application and the performance of the test.

g. Complete under the night-time illumination conditions.

h. Complete with the ROGIDS placed at two locations:

1. Far - A ROGIDS at manufacturers specified minimum operational sight angle and maximum distance.
2. Near - A ROGIDS at manufacturers specified minimum distance and maximum operational sight angle.

i. False positive tests: Perform the tests with all fluids. Once each of the tests using 0.5 mm ice samples are completed, plates without ice shall be placed above the original plates and tests with fluid only shall be carried out with the ROGIDS in the far and near locations.

6.2.4.2 Pass/Fail Criteria

a. False negatives

For each test in test set 2 (post-deicing), the ROGIDS shall detect and indicate the presence of clear ice on each half or quadrant of the clear ice sample irrespective of:

1. The plate finish under the clear ice
2. Illumination of clear ice sample
3. Sensor location (near, far)
4. Ice thickness
5. Fluid type

b. False positives

For each of the clean plate tests in test set 2, excluding Tests 2-25, 2-26, 2-27, 2-28, 2-53, 2-54, 2-55 and 2-56, the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish
2. Fluid type
3. Sensor location (near, far)

6.2.5 Detection of Residual Clear Ice Post-deicing During Precipitation

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6.2.5.1 Test Outline

Conduct the tests in Appendix A, Table A3 to demonstrate the capability of a ROGIDS to identify residual clear ice beneath a deicing/anti-icing fluid layer in the obscured visibility conditions specified in Appendix B. For these tests, propylene glycol based Type I and IV deicing/anti-icing fluids shall be used.

a. Ensure the plates are clean. The recommended ambient air temperature for each test is specified in Table A3.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm² after the deicing/anti-icing fluid has been applied. For this test the plates shall be horizontal in order to ensure a consistent and representative deicing/anti-icing fluid thickness over the clear ice.

c. Create the specified precipitation conditions encompassing the ROGIDS field of view.

d. Prior to application of the fluid, ensure that the ROGIDS is capable of detecting the clear ice. Measure and record the ice thickness.

e. Apply the appropriate fluid tempered and prepared in accordance with Appendix B, B.2. A retainer placed on the plate may be used to ensure that the required thickness is achieved. The procedure for the application of the fluid is as follows:

   1. Apply Type I fluid to produce an average fluid thickness of 0.1 mm ± 0.05 mm.
   2. Immediately following the Type I fluid application, apply the Type IV fluid over the Type I fluid to produce an average combined fluid thickness of 3 mm ± 0.5 mm.

f. Perform the test.

g. One clear ice sample may be used for more than one test.

NOTE: The fluid will slowly dissolve the clear ice; therefore minimize the time between the fluid application and the performance of the test.

h. Complete tests for all the illumination conditions listed in the test matrix in Appendix A, Table A3, and defined in Appendix C. The illumination conditions that shall be considered include daylight, night-time illumination and a condition with shadows on the test plate.

i. Complete tests with the ROGIDS placed at the far location (the manufacturer's specified minimum operational sight angle and maximum distance).

j. False positive tests: Repeat the tests on plates without ice. Once each ice test is complete, a plate without ice will be placed above the original plate and tests with fluid only shall be performed with the ROGIDS at the far location.

6.2.5.2 Pass/Fail Criteria

a. False negatives

For each test in test set 3 (post-deicing with precipitation) the ROGIDS shall detect and indicate the presence of clear ice on each half or quadrant of the clear ice sample irrespective of:

1. The plate finish under the clear ice;

2. Illumination of clear ice sample;
3. Sensor location (far);
4. Fluid types;
5. Ambient Air Temperature; and
6. Precipitation.

b. False positives

For each designated clean plate test in test set 3 the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish;
2. Illumination of plate;
3. Sensor location (far);
4. Fluid types;
5. Ambient Air Temperature; and
6. Precipitation.

6.3 Fluid Foaming Effects (in Laboratory)

Verify that the ROGIDS performance is not affected by foaming of applied deicing fluids. A specially formulated fluid (described below) shall be applied as specified in the following test procedure.

The test surface shall be a flat aircraft type 2024 aluminum alloy plate painted with grey polyurethane (as described in Appendix B, Table B1, Note 1), 1 m x 1.5 m long with the long edge inclined at 10° to the horizontal.

6.3.1 Test Outline for Fluid Foaming Effects

Conduct the test with a 315 cm^2 circular ice patch centered laterally 125 cm from the top of the plate. As the fluid is warm, the ice will melt. Thus the initial ice patch thickness will, by necessity, be greater than 0.5 mm. Ensure the resulting ice patch thickness for the test is not more than 0.5 mm.

The environmental conditions for the test shall be as follows:

1. No precipitation; and
2. The ambient air temperature shall be -10°C or lower.

6.3.1.1 Fluid Preparation

a. Fluid Composition

The fluid used shall be a specially formulated fluid that replicates the foaming characteristics of certain deicing fluids. The formulation of the fluid shall consist of the components given in Table 3.

CAUTION: This fluid is for testing purposes only, and not for use in aircraft deicing procedures.

b. Equipment for Fluid Foaming

Use a laboratory blender (Waring model number 7012G, or equivalent) with a 1 L glass mixing container.

Table 3: Formulation for Foaming Test Deicing Fluid*

COMPONENT	PERCENT BY WEIGHT
Propylene Glycol	61.0
Water	38.5
Dioctyl sulfosuccinate docusate sodium	0.5

* This mixture shall result in a fluid with a Brix of approximately 38°. The fluid shall be homogeneous and completely miscible with water.

c. Modification and Calibration of Equipment

In order to measure the speed of the blender, the following modification is recommended: Place the blender on a stand and elongate the rotating shaft at the base. Use a non-contact optical tachometer to measure the rotation speed with the mixing container in place. Place 700 mL of the test fluid in the 1 L glass container and determine the dial setting in order to get a mix speed of 3400 rpm ±200 rpm.

d. Heating of Fluid

Heat 2000 mL of the test fluid to +60°C ±5°C (140°F ±9°F).

e. Foaming of Fluid

Separate the fluid into three equal batches. Pour the fluid into the blender glass container and mix each batch for 15 seconds at a speed of 3,400 rpm ± 200 rpm.

6.3.1.2 Fluid Application

Apply the 2000 mL of fluid to the plate immediately below the upper edge in a uniform back-and-forth motion to distribute the fluid as evenly as possible. Apply the fluid within 90 seconds of blending the first batch of fluid. Ensure that the ice patch is covered with the foamed fluid.

6.3.1.3 Conduct of Test

Conduct the test with the ROGIDS placed at the far location (at manufacturer's specified minimum operational sight angle and maximum distance) in the night-time illumination condition.

Photographs of the foamed fluid and the ice sample shall be taken at the end of the test and shall be included in the test report.

6.3.1.4 Pass/Fail Criteria

a. The ROGIDS shall not indicate the presence of ice where none is present; and
b. The ROGIDS shall indicate the presence of ice where ice is present.

6.4 Testing in Natural Conditions – Snow Precipitation Tests

There is no practical method available for generation of artificial snow that has all of the important characteristics of natural snow for testing of ROGIDS over the necessary distances. Therefore, the snow tests shall be conducted outdoors in natural snow conditions.

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6.4.1 Purpose of the Tests

The purpose of the tests is to demonstrate that the ROGIDS complies with the minimum performance specifications for the detection of clear residual ice covered with deicing/anti-icing fluids in obscured visibility conditions associated with natural snow.

6.4.2 Test Principles

The tests have been adapted from and use the same principles as laboratory test procedures to establish Endurance Times for aircraft deicing/anti-icing fluids (SAE Types I, II, III, and IV). These test procedures are described in SAE ARP5485 and SAE ARP5945.

6.4.3 Test Outline

Conduct the tests in Appendix A, Table A4 to demonstrate the capability of a ROGIDS to identify residual clear ice beneath a deicing/anti-icing fluid layer in the precipitation conditions specified in Appendix B. For these tests, propylene glycol based Type I and IV deicing/anti-icing fluids shall be used.

Conduct tests with snow precipitation between the plates and the sensor(s), and encompassing the sensor field of view. Protect the plates from precipitation until the start of the test.

a. Ensure the plates as defined in Appendix B are clean; the ambient air temperature is recommended to be less than or equal to 0°C.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm^2 after the deicing/anti-icing fluid has been applied. For this test the plates shall be horizontal in order to ensure a consistent and representative deicing/anti-icing fluid thickness over the clear ice.

c. Prior to application of the fluid, ensure that the ROGIDS is capable of detecting the clear ice. Measure and record the ice thickness.

d. Apply the appropriate fluid tempered and prepared in accordance with Appendix B, B.2. A retainer placed on the plate may be used to ensure that the required thickness is achieved. The procedure for the application of the fluid is as follows:

    1. Apply Type I fluid to produce an average fluid thickness of 0.1 mm ± 0.05 mm.

    2. Immediately following the Type I fluid application, apply the Type IV fluid over the Type I fluid to produce an average combined fluid thickness of 3 mm ± 0.5 mm.

e. Remove the plate protection and immediately perform the test.

f. One clear ice sample may be used for more than one test.

NOTE: The fluid will dissolve the ice; therefore minimize the time between the fluid application and the performance of the test.

g. Conduct tests in both daylight and night-time natural conditions.

The maximum level of night-time illumination shall not exceed the level specified in Appendix C, Paragraph C2, 'Night-time illumination'.

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h. Conduct tests with the ROGIDS placed at the far location (the manufacturer's specified minimum operational sight angle, and maximum distance).

i. False positive tests: Repeat the tests on plates without ice. Once each ice test is complete, a plate without ice will be placed above the original plate and tests with fluid only shall be performed with the ROGIDS at the far location.

6.4.3.1 Pass/Fail Criteria

a. False negatives

For each test the ROGIDS shall detect and indicate the presence of clear ice on each half of the clear ice sample irrespective of:

1. The plate finish under the clear ice;
2. Illumination of ice sample;
3. Sensor location (far);
4. Fluid types;
5. Temperature; and
6. Precipitation.

b. False positives

For each designated clean plate test in test set 4, the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish;
2. Illumination of plate;
3. Sensor location (far);
4. Fluid types;
5. Temperature; and
6. Precipitation.

6.5 Testing in Natural Conditions – Illumination

6.5.1 Purpose of Test

The purpose of this test is to verify that the ROGIDS performance is not adversely affected by natural and artificial visible and non-visible light typically found at deicing facilities.

6.5.1.1 Test Outline for Illumination Condition Effects

a. Conduct tests on a wing surface of at least 10 m^2 in two configurations: (a) wing clean and dry, and (b) wing treated with Type I fluid diluted per Appendix B.

b. Conduct tests at an operational deicing facility with typical lighting.

c. The environmental conditions for the test shall be:

1. No precipitation;
2. Conduct one test in daylight under clear sky conditions;
3. Conduct one test at night-time;
4. Conduct 2 twilight tests. One morning twilight test (between half an hour before sunrise and

sunrise) and one evening twilight test (between sunset and half an hour after sunset); and

5. An ambient air temperature of -10°C or lower is recommended to ensure that ice samples do not degrade.

A summary matrix of tests is given in Appendix A, Table A5.

d. Conduct tests with no ice present, and tests with ice patches ≤0.5mm thick ice over a circular area ≤315cm^2 at leading edge (LE), mid-chord, and trailing edge (TE) locations.

e. Apply Type I ethylene glycol or propylene glycol fluid to the section of the wing to be tested. The section of the wing that is treated shall include the ice patches, shall be greater than 10 m^2, and shall extend over the full chord.

f. Perform the test within a short period of time following fluid application to minimize ice patch degradation.

g. Complete with the ROGIDS placed at two locations:

   1. Far - A ROGIDS at manufacturers specified minimum operational sight angle and maximum distance.
   2. Near - A ROGIDS at manufacturers specified minimum distance and maximum operational sight angle.

6.5.1.2 Pass/Fail Criteria

a. The ROGIDS shall not indicate the presence of ice where none is present.
b. The ROGIDS shall indicate the presence of ice where ice is present.

6.6 Actions To Be Taken In Event Of Failure

If it is determined that the failure of a test may have been caused by incorrect environmental conditions or test setup it is permissable to correct those deficiencies and rerun that test.

If it is determined that the failure of a test is due to system deficiency, the deficiency shall be corrected and all tests shall be rerun with the new system, unless the manufacturer can prove conclusively that the correction will only affect a limited set of tests.

7. INSTALLED EQUIPMENT OPERATIONAL EVALUATION

Certain ROGIDS performance parameters may be affected by the end-user's physical installation and shall be verified after installation. This chapter specifies the operational evaluation that shall be performed to verify the performance of the ROGIDS when installed for in-service use.

7.1 Purpose of Evaluation

The purpose of the operational evaluation is to perform a qualitative assessment to verify that the ROGIDS performance is not adversely affected by normal operating conditions and environment.

The following are conditions or events that may adversely affect the operation of the ROGIDS:

a. Illumination effects;
b. Fluid foaming effects;

c. Compatibility with monitored surface (e.g., the ROGIDS shall not produce false positives due to the material, the surface finish and/or surface treatment of the monitored aircraft surface);
d. Effects of precipitation; and
e. Effects of non-frozen contaminants (e.g., grease, dirt, fuel) on the monitored surface.

7.2 General

The installed equipment operational evaluation addresses conditions arising during in-service operations that are not covered by the minimum operational performance tests of Chapter 6. Although ROGIDS may be hand-held, pedestal or vehicle mounted in-service, the evaluations specified in this chapter are based on a vehicle-mounted operation. Hand-held or pedestal mounted installations may warrant adaptation of this chapter, as appropriate.

The evaluation will be performed during actual aircraft deicing operations.

Prior to starting this evaluation, conduct a conformity inspection to ensure that the ROGIDS has been installed in accordance with the manufacturer's instructions.

The ROGIDS shall be operated in accordance with the manufacturer's operating procedures. During this evaluation the equipment shall not be subject to environmental conditions that exceed the manufacturer's specified operating environment.

Any ground-based electrical and mechanical equipment likely to be operated in proximity of the ROGIDS during normal operations shall be activated during this evaluation.

7.2.1 Operational Evaluation Plan, Procedures, and Reports

Detailed test plans, test procedures, and a report of test results shall be prepared in accordance with Section 3. Where physical facility limitations exist which influence the set-up and conduct of the operational evaluation, these limitations shall be noted.

7.2.2 Required Equipment and Personnel

At a minimum, conduct the evaluation using:

a. A ROGIDS installed on the vehicle in accordance with the manufacturer's installation instructions;
b. Operational aircraft when specified herein;
c. Deicing and anti-icing fluids meeting SAE specifications (AMS 1424 and AMS 1428); and
d. Operator(s) trained to use all equipment being used in the conduct of these tests.

7.3 Operational Evaluation

7.3.1 Evaluation Scenarios

The total number of deicing operations that will be evaluated will be provided in separate regulatory guidance material for the initial evaluation and follow-on evaluations. The evaluations shall include as wide a variety of the aircraft types and sizes expected to be deiced at the airport as possible. Table 4 provides guidance on the distribution of the various evaluation conditions.

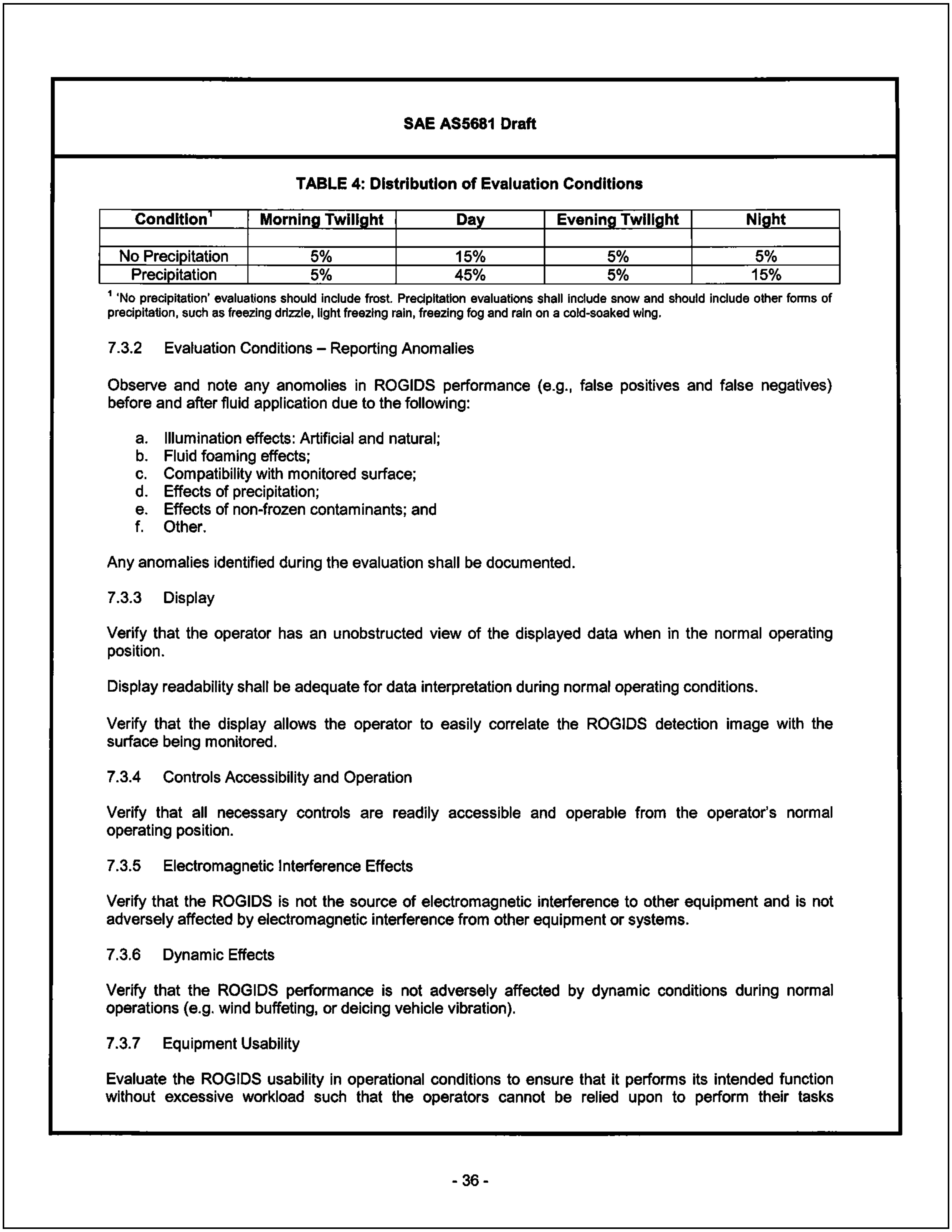

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TABLE 4: Distribution of Evaluation Conditions

Condition[1]	Morning Twilight	Day	Evening Twilight	Night
No Precipitation	5%	15%	5%	5%
Precipitation	5%	45%	5%	15%

[1] 'No precipitation' evaluations should include frost. Precipitation evaluations shall include snow and should include other forms of precipitation, such as freezing drizzle, light freezing rain, freezing fog and rain on a cold-soaked wing.

7.3.2 Evaluation Conditions – Reporting Anomalies

Observe and note any anomolies in ROGIDS performance (e.g., false positives and false negatives) before and after fluid application due to the following:

a. Illumination effects: Artificial and natural;
b. Fluid foaming effects;
c. Compatibility with monitored surface;
d. Effects of precipitation;
e. Effects of non-frozen contaminants; and
f. Other.

Any anomalies identified during the evaluation shall be documented.

7.3.3 Display

Verify that the operator has an unobstructed view of the displayed data when in the normal operating position.

Display readability shall be adequate for data interpretation during normal operating conditions.

Verify that the display allows the operator to easily correlate the ROGIDS detection image with the surface being monitored.

7.3.4 Controls Accessibility and Operation

Verify that all necessary controls are readily accessible and operable from the operator's normal operating position.

7.3.5 Electromagnetic Interference Effects

Verify that the ROGIDS is not the source of electromagnetic interference to other equipment and is not adversely affected by electromagnetic interference from other equipment or systems.

7.3.6 Dynamic Effects

Verify that the ROGIDS performance is not adversely affected by dynamic conditions during normal operations (e.g. wind buffeting, or deicing vehicle vibration).

7.3.7 Equipment Usability

Evaluate the ROGIDS usability in operational conditions to ensure that it performs its intended function without excessive workload such that the operators cannot be relied upon to perform their tasks

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accurately or completely.

7.3.8 Safety Precautions

Verify that there are no unusual characteristics or hazards to personnel or property (e.g., laser radiation, etc.) resulting from operation of the ROGIDS.

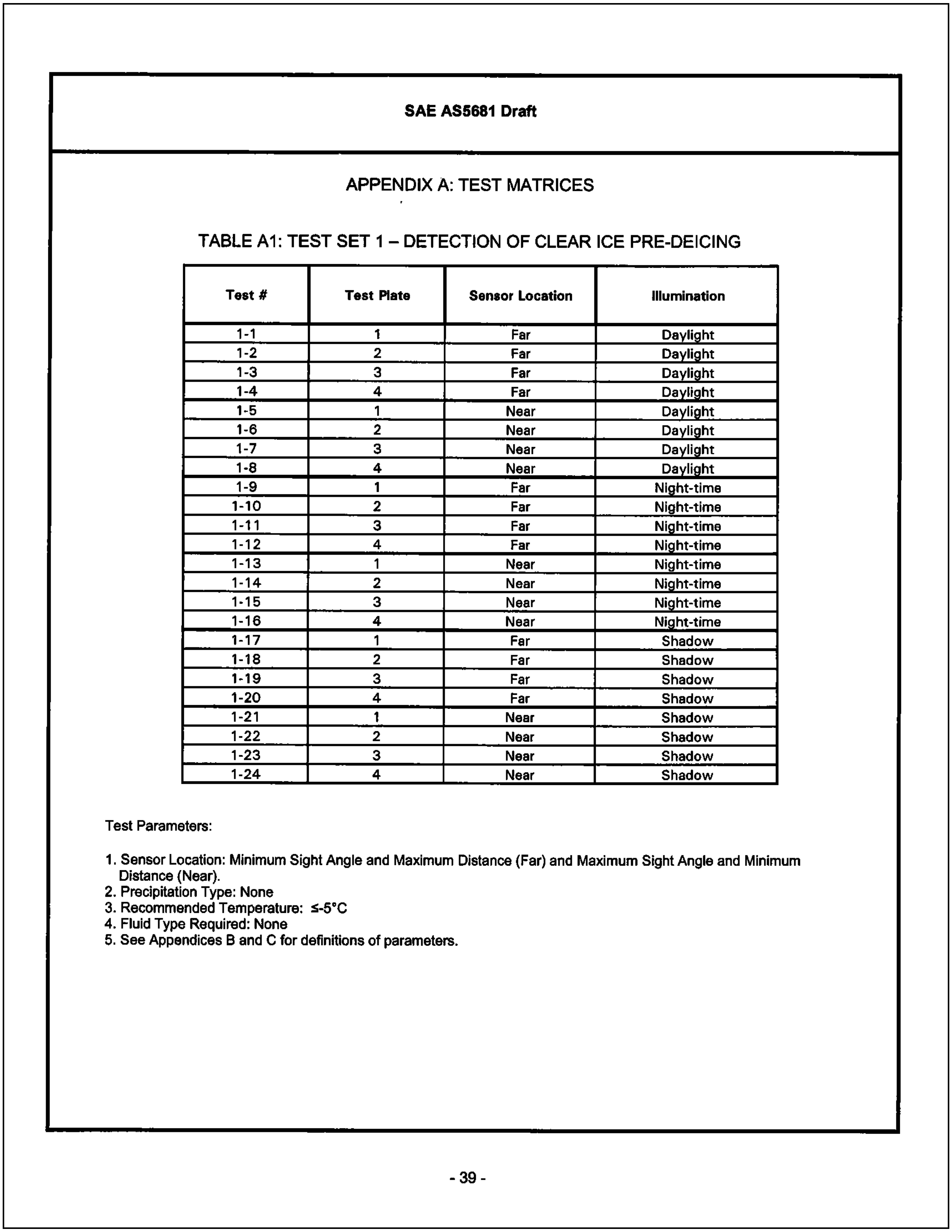
While the materials, methods, applications, and processes described or referenced in this procedure may involve the use of hazardous materials, this procedure does not address the hazards that may be involved in such use. It is the sole responsibility of the operator to ensure familiarity with the safe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

7.4 Actions To Be Taken In Event Of Anomolies

Anomolies shall be investigated to determine the cause.

If it is determined that an anomoly is due to system (operator and/or equipment) deficiency, the deficiency shall be identified, corrected, and all tests shall be rerun with the new system, unless the manufacturer can prove conclusively that the correction will only affect a limited set of tests.

PREPARED BY SAE SUBCOMMITTEE G-12ID, ICE DETECTION OF
COMMITTEE G-12, AIRCRAFT GROUND DEICING



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APPENDIX A: TEST MATRICES

TABLE A1: TEST SET 1 – DETECTION OF CLEAR ICE PRE-DEICING

Test #	Test Plate	Sensor Location	Illumination
1-1	1	Far	Daylight
1-2	2	Far	Daylight
1-3	3	Far	Daylight
1-4	4	Far	Daylight
1-5	1	Near	Daylight
1-6	2	Near	Daylight
1-7	3	Near	Daylight
1-8	4	Near	Daylight
1-9	1	Far	Night-time
1-10	2	Far	Night-time
1-11	3	Far	Night-time
1-12	4	Far	Night-time
1-13	1	Near	Night-time
1-14	2	Near	Night-time
1-15	3	Near	Night-time
1-16	4	Near	Night-time
1-17	1	Far	Shadow
1-18	2	Far	Shadow
1-19	3	Far	Shadow
1-20	4	Far	Shadow
1-21	1	Near	Shadow
1-22	2	Near	Shadow
1-23	3	Near	Shadow
1-24	4	Near	Shadow

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far) and Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: ≤-5°C
4. Fluid Type Required: None
5. See Appendices B and C for definitions of parameters.

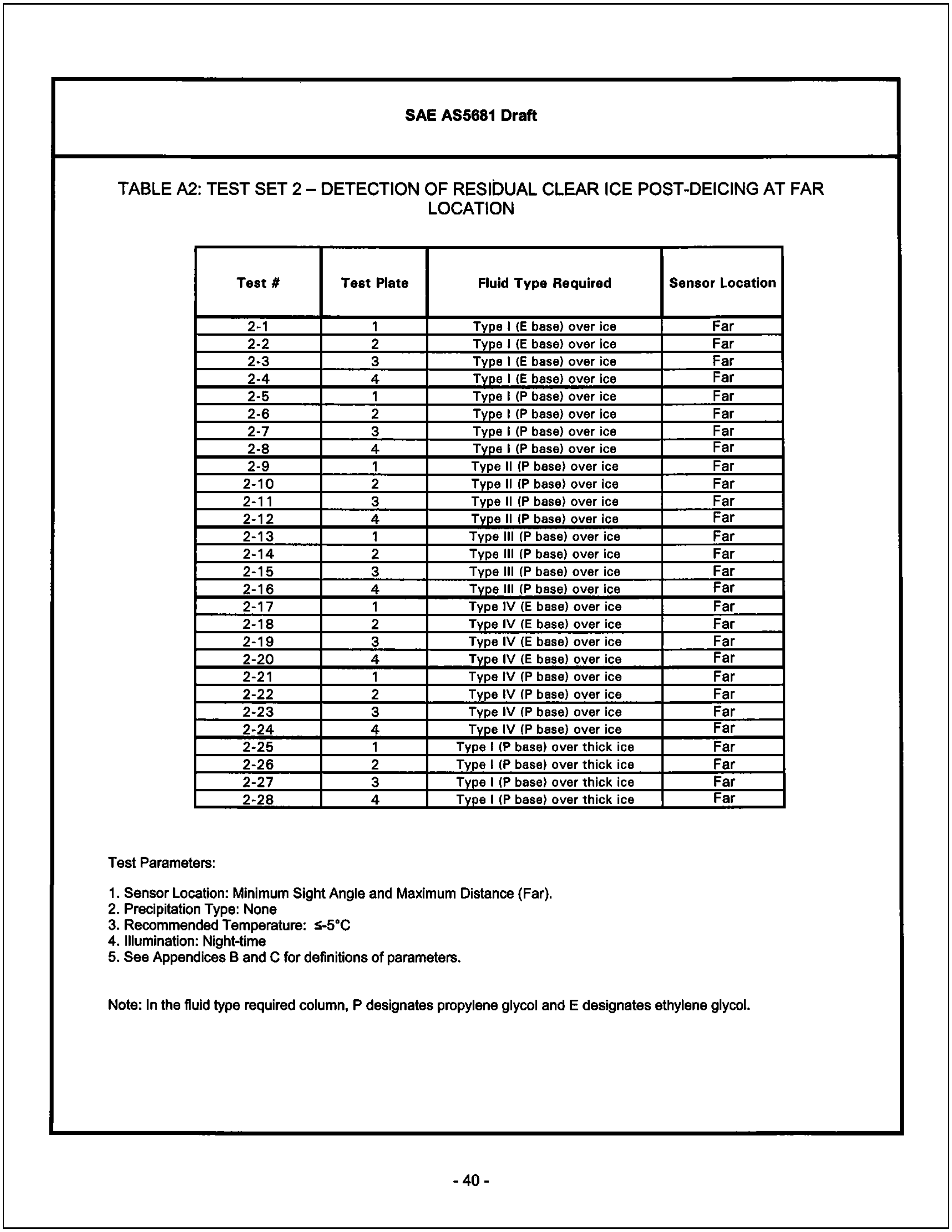

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TABLE A2: TEST SET 2 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING AT FAR LOCATION

Test #	**Test Plate**	**Fluid Type Required**	**Sensor Location**
2-1	1	Type I (E base) over ice	Far
2-2	2	Type I (E base) over ice	Far
2-3	3	Type I (E base) over ice	Far
2-4	4	Type I (E base) over ice	Far
2-5	1	Type I (P base) over ice	Far
2-6	2	Type I (P base) over ice	Far
2-7	3	Type I (P base) over ice	Far
2-8	4	Type I (P base) over ice	Far
2-9	1	Type II (P base) over ice	Far
2-10	2	Type II (P base) over ice	Far
2-11	3	Type II (P base) over ice	Far
2-12	4	Type II (P base) over ice	Far
2-13	1	Type III (P base) over ice	Far
2-14	2	Type III (P base) over ice	Far
2-15	3	Type III (P base) over ice	Far
2-16	4	Type III (P base) over ice	Far
2-17	1	Type IV (E base) over ice	Far
2-18	2	Type IV (E base) over ice	Far
2-19	3	Type IV (E base) over ice	Far
2-20	4	Type IV (E base) over ice	Far
2-21	1	Type IV (P base) over ice	Far
2-22	2	Type IV (P base) over ice	Far
2-23	3	Type IV (P base) over ice	Far
2-24	4	Type IV (P base) over ice	Far
2-25	1	Type I (P base) over thick ice	Far
2-26	2	Type I (P base) over thick ice	Far
2-27	3	Type I (P base) over thick ice	Far
2-28	4	Type I (P base) over thick ice	Far

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far).
2. Precipitation Type: None
3. Recommended Temperature: ≤-5°C
4. Illumination: Night-time
5. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol and E designates ethylene glycol.

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TABLE A2 CONTINUED: TEST SET 2 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING AT NEAR LOCATION

Test #	Test Plate	Fluid Type Required	Sensor Location
2-29	1	Type I (E base) over ice	Near
2-30	2	Type I (E base) over ice	Near
2-31	3	Type I (E base) over ice	Near
2-32	4	Type I (E base) over ice	Near
2-33	1	Type I (P base) over ice	Near
2-34	2	Type I (P base) over ice	Near
2-35	3	Type I (P base) over ice	Near
2-36	4	Type I (P base) over ice	Near
2-37	1	Type II (P base) over ice	Near
2-38	2	Type II (P base) over ice	Near
2-39	3	Type II (P base) over ice	Near
2-40	4	Type II (P base) over ice	Near
2-41	1	Type III (P base) over ice	Near
2-42	2	Type III (P base) over ice	Near
2-43	3	Type III (P base) over ice	Near
2-44	4	Type III (P base) over ice	Near
2-45	1	Type IV (E base) over ice	Near
2-46	2	Type IV (E base) over ice	Near
2-47	3	Type IV (E base) over ice	Near
2-48	4	Type IV (E base) over ice	Near
2-49	1	Type IV (P base) over ice	Near
2-50	2	Type IV (P base) over ice	Near
2-51	3	Type IV (P base) over ice	Near
2-52	4	Type IV (P base) over ice	Near
2-53	1	Type I (P base) over thick ice	Near
2-54	2	Type I (P base) over thick ice	Near
2-55	3	Type I (P base) over thick ice	Near
2-56	4	Type I (P base) over thick ice	Near

Test Parameters:

1. Sensor Location: Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: ≤-5°C
4. Illumination: Night-time
5. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol and E designates ethylene glycol.

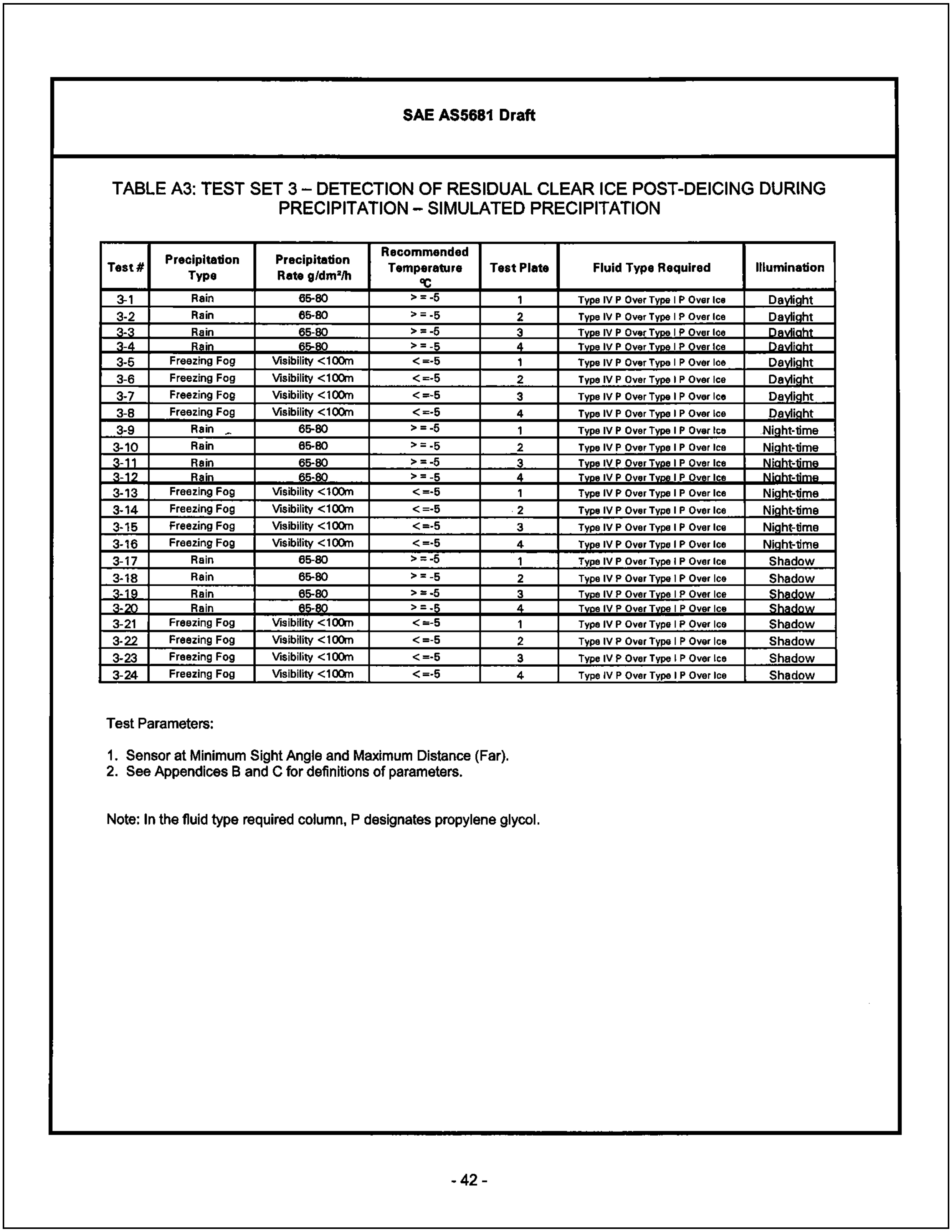

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TABLE A3: TEST SET 3 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING DURING PRECIPITATION – SIMULATED PRECIPITATION

Test #	Precipitation Type	Precipitation Rate g/dm²/h	Recommended Temperature °C	Test Plate	Fluid Type Required	Illumination
3-1	Rain	65-80	> = -5	1	Type IV P Over Type I P Over Ice	Daylight
3-2	Rain	65-80	> = -5	2	Type IV P Over Type I P Over Ice	Daylight
3-3	Rain	65-80	> = -5	3	Type IV P Over Type I P Over Ice	Daylight
3-4	Rain	65-80	> = -5	4	Type IV P Over Type I P Over Ice	Daylight
3-5	Freezing Fog	Visibility <100m	< =-5	1	Type IV P Over Type I P Over Ice	Daylight
3-6	Freezing Fog	Visibility <100m	< =-5	2	Type IV P Over Type I P Over Ice	Daylight
3-7	Freezing Fog	Visibility <100m	< =-5	3	Type IV P Over Type I P Over Ice	Daylight
3-8	Freezing Fog	Visibility <100m	< =-5	4	Type IV P Over Type I P Over Ice	Daylight
3-9	Rain	65-80	> = -5	1	Type IV P Over Type I P Over Ice	Night-time
3-10	Rain	65-80	> = -5	2	Type IV P Over Type I P Over Ice	Night-time
3-11	Rain	65-80	> = -5	3	Type IV P Over Type I P Over Ice	Night-time
3-12	Rain	65-80	> = -5	4	Type IV P Over Type I P Over Ice	Night-time
3-13	Freezing Fog	Visibility <100m	< =-5	1	Type IV P Over Type I P Over Ice	Night-time
3-14	Freezing Fog	Visibility <100m	< =-5	2	Type IV P Over Type I P Over Ice	Night-time
3-15	Freezing Fog	Visibility <100m	< =-5	3	Type IV P Over Type I P Over Ice	Night-time
3-16	Freezing Fog	Visibility <100m	< =-5	4	Type IV P Over Type I P Over Ice	Night-time
3-17	Rain	65-80	> = -5	1	Type IV P Over Type I P Over Ice	Shadow
3-18	Rain	65-80	> = -5	2	Type IV P Over Type I P Over Ice	Shadow
3-19	Rain	65-80	> = -5	3	Type IV P Over Type I P Over Ice	Shadow
3-20	Rain	65-80	> = -5	4	Type IV P Over Type I P Over Ice	Shadow
3-21	Freezing Fog	Visibility <100m	< =-5	1	Type IV P Over Type I P Over Ice	Shadow
3-22	Freezing Fog	Visibility <100m	< =-5	2	Type IV P Over Type I P Over Ice	Shadow
3-23	Freezing Fog	Visibility <100m	< =-5	3	Type IV P Over Type I P Over Ice	Shadow
3-24	Freezing Fog	Visibility <100m	< =-5	4	Type IV P Over Type I P Over Ice	Shadow

Test Parameters:

1. Sensor at Minimum Sight Angle and Maximum Distance (Far).
2. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol.

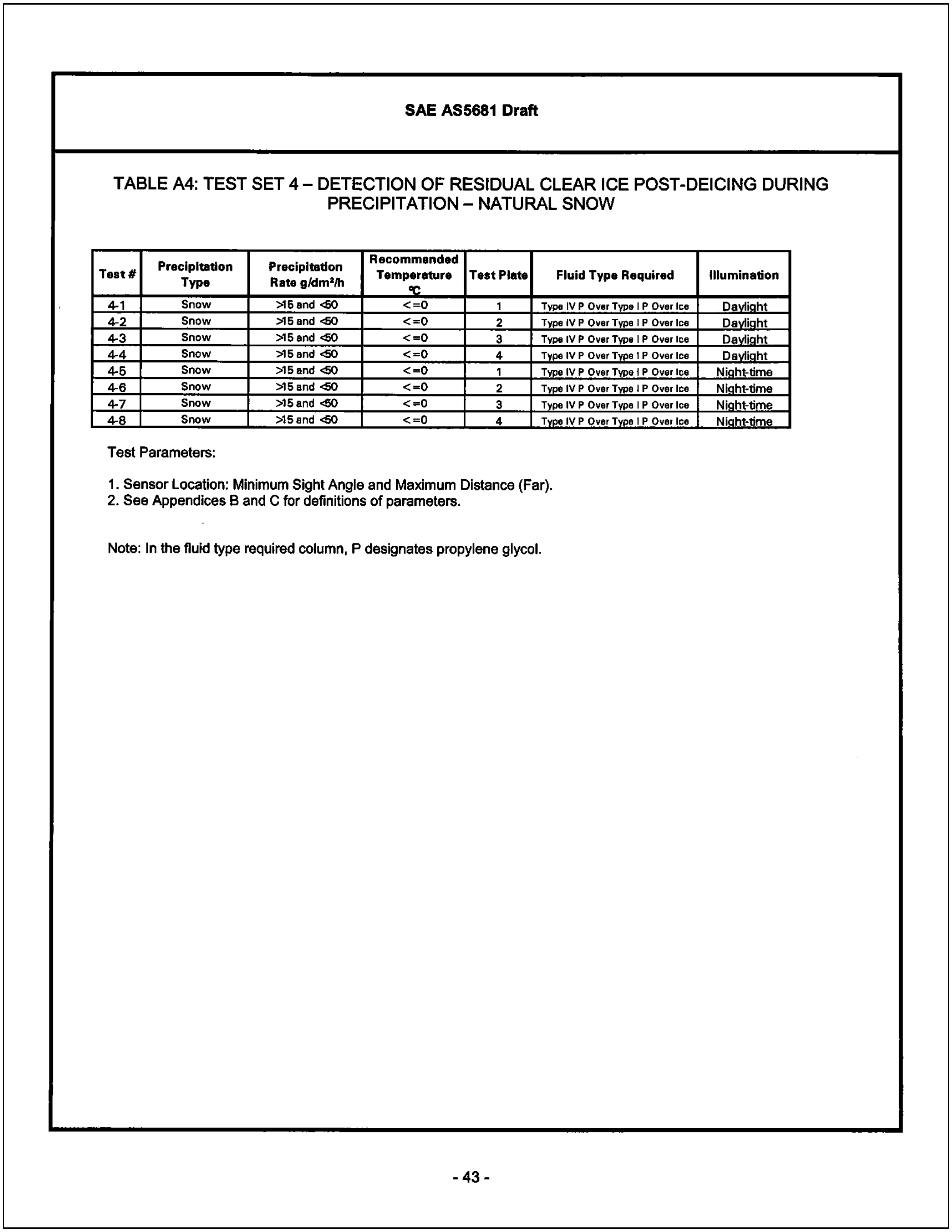

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TABLE A4: TEST SET 4 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING DURING PRECIPITATION – NATURAL SNOW

Test #	Precipitation Type	Precipitation Rate g/dm²/h	Recommended Temperature °C	Test Plate	Fluid Type Required	Illumination
4-1	Snow	>15 and <50	<=0	1	Type IV P Over Type I P Over Ice	Daylight
4-2	Snow	>15 and <50	<=0	2	Type IV P Over Type I P Over Ice	Daylight
4-3	Snow	>15 and <50	<=0	3	Type IV P Over Type I P Over Ice	Daylight
4-4	Snow	>15 and <50	<=0	4	Type IV P Over Type I P Over Ice	Daylight
4-5	Snow	>15 and <50	<=0	1	Type IV P Over Type I P Over Ice	Night-time
4-6	Snow	>15 and <50	<=0	2	Type IV P Over Type I P Over Ice	Night-time
4-7	Snow	>15 and <50	<=0	3	Type IV P Over Type I P Over Ice	Night-time
4-8	Snow	>15 and <50	<=0	4	Type IV P Over Type I P Over Ice	Night-time

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far).
2. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol.

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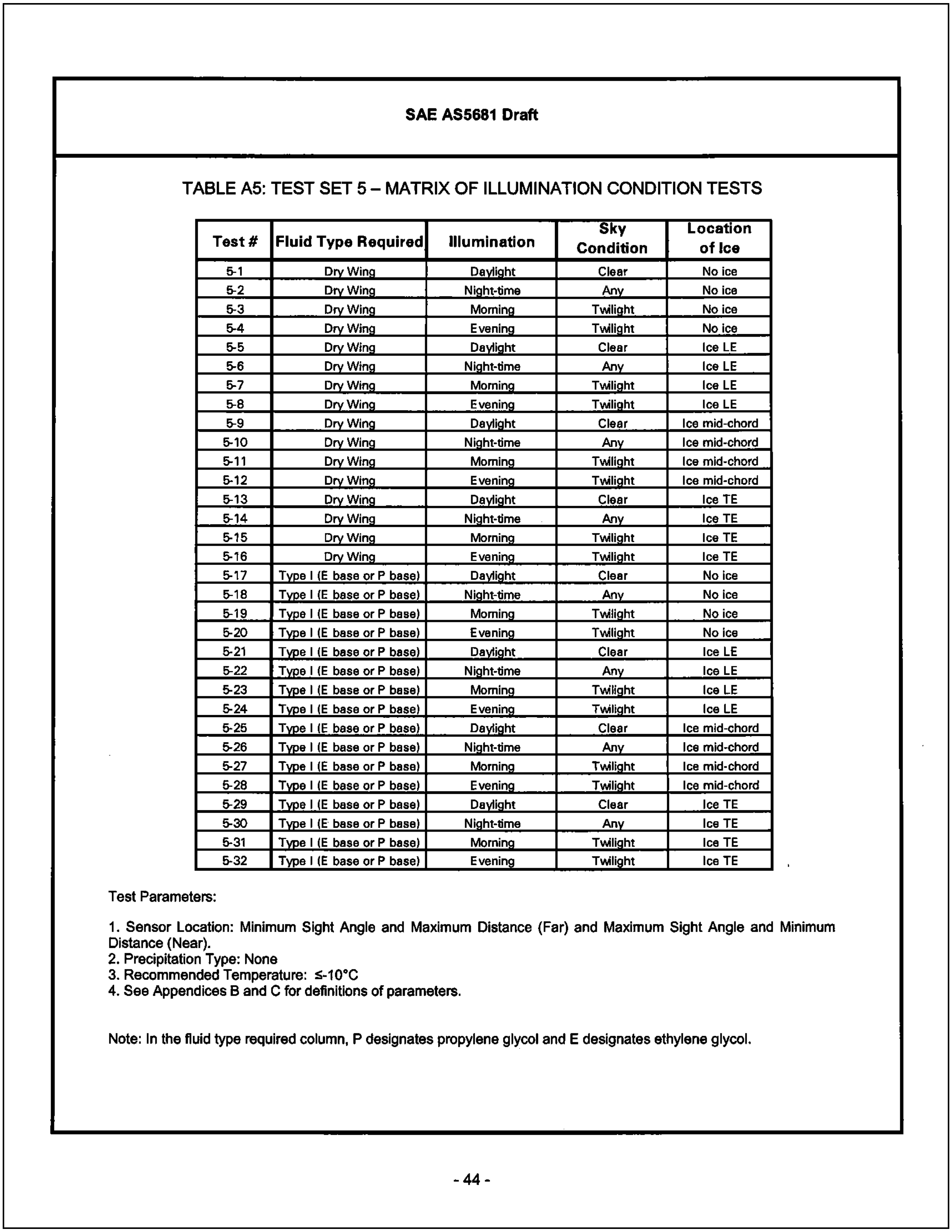

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TABLE A5: TEST SET 5 – MATRIX OF ILLUMINATION CONDITION TESTS

Test #	Fluid Type Required	Illumination	Sky Condition	Location of Ice
5-1	Dry Wing	Daylight	Clear	No ice
5-2	Dry Wing	Night-time	Any	No ice
5-3	Dry Wing	Morning	Twilight	No ice
5-4	Dry Wing	Evening	Twilight	No ice
5-5	Dry Wing	Daylight	Clear	Ice LE
5-6	Dry Wing	Night-time	Any	Ice LE
5-7	Dry Wing	Morning	Twilight	Ice LE
5-8	Dry Wing	Evening	Twilight	Ice LE
5-9	Dry Wing	Daylight	Clear	Ice mid-chord
5-10	Dry Wing	Night-time	Any	Ice mid-chord
5-11	Dry Wing	Morning	Twilight	Ice mid-chord
5-12	Dry Wing	Evening	Twilight	Ice mid-chord
5-13	Dry Wing	Daylight	Clear	Ice TE
5-14	Dry Wing	Night-time	Any	Ice TE
5-15	Dry Wing	Morning	Twilight	Ice TE
5-16	Dry Wing	Evening	Twilight	Ice TE
5-17	Type I (E base or P base)	Daylight	Clear	No ice
5-18	Type I (E base or P base)	Night-time	Any	No ice
5-19	Type I (E base or P base)	Morning	Twilight	No ice
5-20	Type I (E base or P base)	Evening	Twilight	No ice
5-21	Type I (E base or P base)	Daylight	Clear	Ice LE
5-22	Type I (E base or P base)	Night-time	Any	Ice LE
5-23	Type I (E base or P base)	Morning	Twilight	Ice LE
5-24	Type I (E base or P base)	Evening	Twilight	Ice LE
5-25	Type I (E base or P base)	Daylight	Clear	Ice mid-chord
5-26	Type I (E base or P base)	Night-time	Any	Ice mid-chord
5-27	Type I (E base or P base)	Morning	Twilight	Ice mid-chord
5-28	Type I (E base or P base)	Evening	Twilight	Ice mid-chord
5-29	Type I (E base or P base)	Daylight	Clear	Ice TE
5-30	Type I (E base or P base)	Night-time	Any	Ice TE
5-31	Type I (E base or P base)	Morning	Twilight	Ice TE
5-32	Type I (E base or P base)	Evening	Twilight	Ice TE

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far) and Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: ≤-10°C
4. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol and E designates ethylene glycol.

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APPENDIX B: DETAILED TEST PARAMETERS

B.1 SCOPE

The test conditions required to demonstrate the ability of the ROGIDS to comply with the performance specifications of Chapters 3 and 4 use the same principles as laboratory test procedures to establish endurance times for aircraft deicing/anti-icing fluids (SAE Types I, II, III, and IV). These test procedures are described in SAE ARP5485 and SAE ARP5945.

B.1.1 Safety

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

B.2 FLUID SAMPLE SELECTION PROCEDURE FOR SAE TYPE I FLUIDS

B.2.1 Requirements

B.2.1.1 Production Batch: The sample shall be a fluid taken from a manufacturer's production batch.

B.2.1.2 Fluid Selection: Fluid selection for Type I shall include ethylene glycol or propylene glycol based fluids as listed in Appendix A, Tables A2 and A3.

B.2.1.3 Fluid Concentration: All Type I fluid tests shall be performed using a fluid with a freezing point between -28°C and -43°C.

B.2.1.4 Manufacturer's Documentation:

(a) Fluid name, fluid type and batch number.
(b) The freezing point versus refraction at 20°C data for the fluid.

B.2.2 Condition of the Sample to be Used for Test:

To minimize dissolving of the ice sample, it is strongly recommended that the fluid be applied as cold as possible, at a minimum, it should be applied 3°C above the freezing point of the fluid. The sample's refractive index shall be measured and recorded. Research has shown (Transport Canada publication *Feasibility of ROGIDS Test Conditions Stipulated in AS5681*) that lower levels of ice sample degradation occur when the temperature of the fluid is close to its freeze point.

B.3 FLUID SAMPLE SELECTION PROCEDURE FOR SAE TYPE II, III, AND IV FLUIDS:

B.3.1 Requirements

B.3.1.1 Production Batch

The sample shall be a neat sample taken from a manufacturer's production batch.

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B.3.1.2 Viscosity

The viscosity shall be equal to or greater than the lowest on-wing viscosity specified for the fluid in the specific holdover time (HOT) guidelines available from FAA or TC.

B.3.1.3 Fluid Selection

Fluid selection for Type II, Type III and Type IV shall include ethylene glycol or propylene glycol based fluids as listed in Appendix A, Tables A2 and A3.

B.3.1.4 Fluid Concentration: All tests shall be performed with neat 100% fluids.

B.3.1.5 Fluid Manufacturer's Documentation

a. Fluid name, fluid type and batch number.
b. The freezing point versus refraction at 20°C data for the fluid.

B.3.2 Condition of the Sample

To minimize dissolving of the ice sample, it is recommended that the fluid be applied as cold as possible; at a minimum, it should be applied above the freezing point of the fluid. The sample's refractive index shall be measured and recorded.

B.4 TEST PROCEDURE - GENERAL

B.4.1 Purpose

This section establishes the minimum requirements for test equipment and test procedures used to demonstrate the ability of the ROGIDS to comply with the performance specifications of Chapters 4 and 5.

Section B.4 covers requirements that are common to many or all conditions (except where otherwise noted). Section B.5 establishes the specific requirements for each precipitation condition.

B.4.2 ROGIDS Sensor and Plate Test Set-up

The size and surface finishes of the test plates shall be as described in Table B1 and are illustrated in Figure B1.

Develop the ice sample on each plate over a circular area of 315 cm². The ice sample shall be positioned so that it is equally distributed over both surface finishes of the pertinent test plates, where applicable. If the ice sample cannot be formed on the test surface the area where the ice sample is to be formed may be minimally roughened.

For the tests involving shadow illumination, the shadow shall be created to cover either the top or the bottom half of the ice sample, thereby creating four equal and distinct quadrants (two surface finishes, each with two illumination conditions on the sample).

Tests shall be performed with the ROGIDS placed at two locations unless otherwise noted:

a. Far: One ROGIDS at manufacturers specified minimum operational sight angle and maximum distance.
b. Near: One ROGIDS at manufacturers specified minimum distance and maximum operational sight angle.

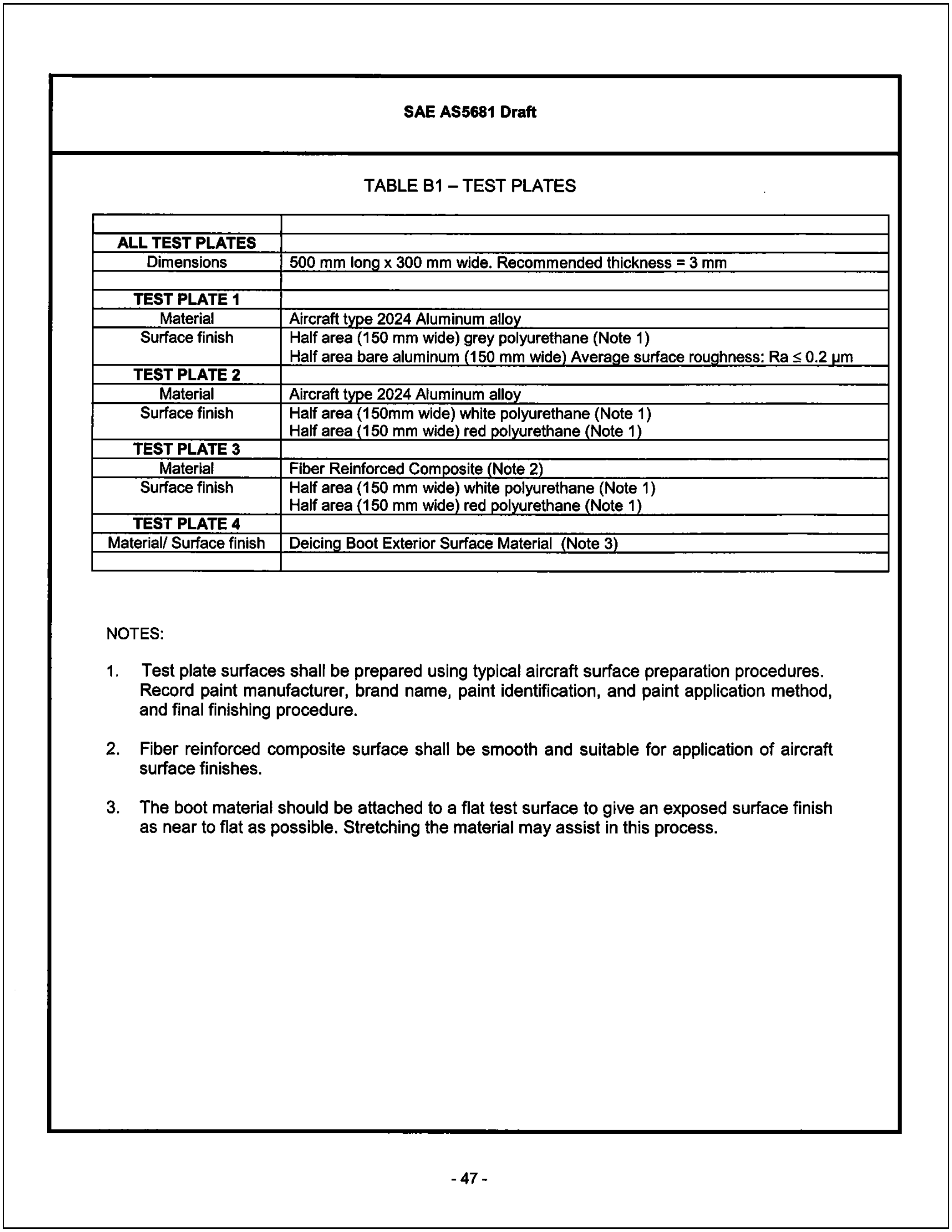

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TABLE B1 – TEST PLATES

ALL TEST PLATES	
Dimensions	500 mm long x 300 mm wide. Recommended thickness = 3 mm
TEST PLATE 1	
Material	Aircraft type 2024 Aluminum alloy
Surface finish	Half area (150 mm wide) grey polyurethane (Note 1) Half area bare aluminum (150 mm wide) Average surface roughness: Ra ≤ 0.2 µm
TEST PLATE 2	
Material	Aircraft type 2024 Aluminum alloy
Surface finish	Half area (150mm wide) white polyurethane (Note 1) Half area (150 mm wide) red polyurethane (Note 1)
TEST PLATE 3	
Material	Fiber Reinforced Composite (Note 2)
Surface finish	Half area (150 mm wide) white polyurethane (Note 1) Half area (150 mm wide) red polyurethane (Note 1)
TEST PLATE 4	
Material/ Surface finish	Deicing Boot Exterior Surface Material (Note 3)

NOTES:

1. Test plate surfaces shall be prepared using typical aircraft surface preparation procedures. Record paint manufacturer, brand name, paint identification, and paint application method, and final finishing procedure.
2. Fiber reinforced composite surface shall be smooth and suitable for application of aircraft surface finishes.
3. The boot material should be attached to a flat test surface to give an exposed surface finish as near to flat as possible. Stretching the material may assist in this process.

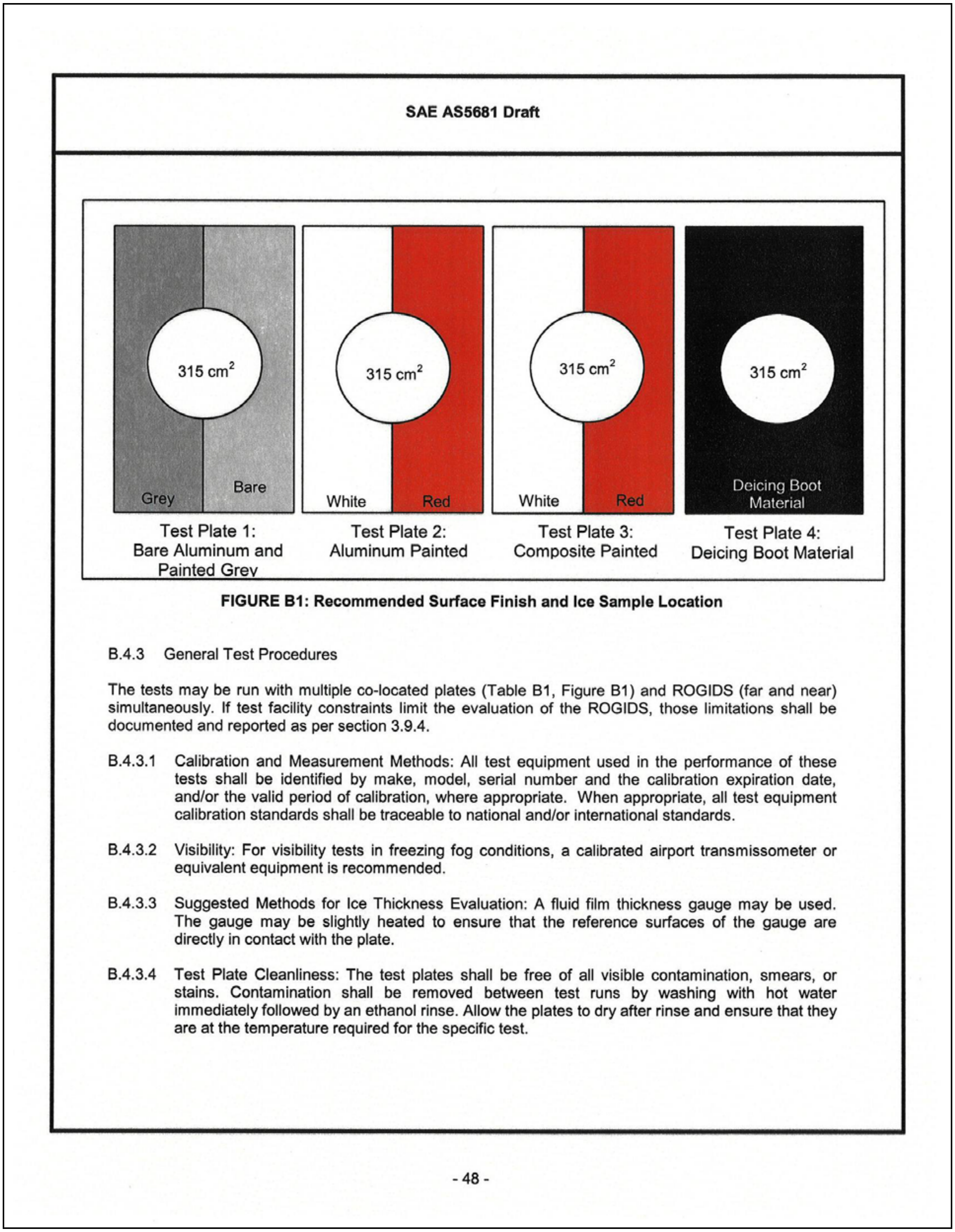

FIGURE B1: Recommended Surface Finish and Ice Sample Location

B.4.3 General Test Procedures

The tests may be run with multiple co-located plates (Table B1, Figure B1) and ROGIDS (far and near) simultaneously. If test facility constraints limit the evaluation of the ROGIDS, those limitations shall be documented and reported as per section 3.9.4.

B.4.3.1 Calibration and Measurement Methods: All test equipment used in the performance of these tests shall be identified by make, model, serial number and the calibration expiration date, and/or the valid period of calibration, where appropriate. When appropriate, all test equipment calibration standards shall be traceable to national and/or international standards.

B.4.3.2 Visibility: For visibility tests in freezing fog conditions, a calibrated airport transmissometer or equivalent equipment is recommended.

B.4.3.3 Suggested Methods for Ice Thickness Evaluation: A fluid film thickness gauge may be used. The gauge may be slightly heated to ensure that the reference surfaces of the gauge are directly in contact with the plate.

B.4.3.4 Test Plate Cleanliness: The test plates shall be free of all visible contamination, smears, or stains. Contamination shall be removed between test runs by washing with hot water immediately followed by an ethanol rinse. Allow the plates to dry after rinse and ensure that they are at the temperature required for the specific test.

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B.5 PRECIPITATION PARAMETERS FOR TESTING OF ROGIDS

B.5.1 Freezing Fog Test Equipment and Test Parameters

The environmental chamber and associated equipment shall be such that active precipitation is present between the ROGIDS and the test surface that is being detected. The spray equipment producing the precipitation shall provide a droplet median volume diameter of 22 µm ± 5 µm. The combination of precipitation rate and range shall be adjusted to give conditions equivalent to a field visibility of 100 m or less with the ROGIDS operating at its maximum range when in service. The ambient air temperature is recommended to be less than or equal to -5°C.

B.5.2 Rain Test Equipment and Test Parameters

The environmental chamber and associated equipment shall be such that active precipitation is present between the ROGIDS and the test surface that is being detected. The spray equipment producing the precipitation shall provide a droplet median volume diameter of 1000 µm ± 200 µm. The intensity shall be between 65 and 80 $g/dm^2/h$ and the ambient air temperature is recommended to be ≥ -5^0C.

B.5.3 Snow Test Equipment and Test Parameters:

Tests shall be conducted in natural snow conditions with a precipitation rate ≥ 15 $g/dm^2/h$ and ≤ 50 $g/dm^2/h$. Actual precipitation rate, wind speed, and temperature during the tests shall be recorded.

At the time of the publication of this document, no known technology exists to produce sufficient quantities of artificial snow, of an acceptable quality, in an environmental chamber. Therefore, until such equipment becomes available, the snow test shall be performed outdoors in natural conditions.

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APPENDIX C: ILLUMINATION REQUIREMENTS

C.1 PURPOSE

The purpose of this appendix is to define the illumination test requirements for daylight, night-time and shadow conditions.

Night-time illumination test conditions simulate the light levels during night-time or twilight deicing operations. Daylight illumination test conditions simulate the case of daylight deicing in full sunlight. Shadow test conditions simulate strong shadows on the inspected aircraft surface caused by sunlight being partially blocked by structures such as the aircraft fuselage or a deicing truck.

C.2 ILLUMINATION REQUIREMENTS

The test plate illumination may be provided by natural light or, when the ROGIDS clear ice detection performance tests occur in a climatic chamber, by artificial sources located at an appropriate distance from the surface and oriented to eliminate direct (specular) reflections into the ROGIDS.

a. Night-time illumination

The average illumination on the test plate shall be between 100-500 lux (9-46 footcandles) [1] and color temperature of approximately 2100-3500K.

Artificial illumination used in a climatic chamber can be provided by diffused 150 watt high pressure sodium bulbs with a color temperature of 2,100 K [2].

Night-time illumination may be a combination of natural light and deicing pad illumination.

b. Daylight illumination

The illuminance on the test plate shall be greater than 25,000 lux (2,300 footcandles) and have a color temperature between 5500-6500^{0}K.

If testing in a climatic chamber, it is recommended to use 1000 watt metal halide bulbs with a color temperature between 5500 – 6500^{0}K. The light source should be placed directly above the test plates.

NOTE: High intensity lighting can cause premature melting of the ice samples.

Light bulb intensity and color temperature vary with the age of the bulb. The luminance and color temperature of the selected artificial lighting shall be verified via measurements at the test plate(s).

c. Shadow illumination

The illuminance on the test plate shall be greater than 25,000 lux (2,300 footcandles) and have a color temperature between 5500-6500^{0}K.

If testing in a climatic chamber, it is recommended to use 1000 watt metal halide bulbs with a color temperature between 5500 – 6500^{0}K. The light source should be placed directly above the test plates to provide a relatively sharp transition from direct light to shadow.

The shadow is created by fixing flat plates with straight edges in the path of the light source such that the shadow covers approximately half of the ice patch without obscuring the ROGIDS line of sight

CAUTION: High intensity lighting can cause premature melting of the ice samples.

Light bulb intensity and color temperature vary with the age of the bulb. The luminance and color temperature of the selected artificial lighting shall be verified via measurements at the test plate(s).

References

1. Bond, D.S. and Henderson, F.P. The Conquest of Darkness, AD 346297, Defense Documentation Center, Alexandria, VA., 1963.
2. Kimberlea Bender, Edmundo A. Sierra, Jr., Isabelle Marcil, John D'Avirro, Edward Pugacz, and Frank Eyre, "Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance Under Post Deicing Conditions", DOT/FAA/TC- 06/20 February 2006.

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APPENDIX D: DETERMINATION OF ROGIDS ACCEPTABLE LATENT FAILURE RATE

D.1 PURPOSE

This appendix describes the methodology and assessment used to determine an acceptable in-service rate of latent false negative output (i.e. misleading guidance to the operator) from a ROGIDS as a consequence of ROGIDS equipment malfunction. The appendix also contains background material and substantiation of numerical data used in making this assessment.

Active failures are not considered in the analysis because they will be annunciated by system BITE or detected by the operator. The ROGIDS is a ground-based system and any "active" failures will result in the failed equipment being removed from service and replaced with a fully functional ROGIDS, or by reversion to standard visual/tactile inspections.

D.2 BACKGROUND

Human Factors testing demonstrated that a ROGIDS could perform as well as, or better than, a human inspector for clear ice detection. This finding has allowed ROGIDS to be considered as a suitable candidate system for post-deicing inspection/detection on aircraft. To ensure consistent operational performance, the ROGIDS shall be shown to have acceptable false negative rates that could be caused by system malfunction. A false negative is defined as an indication by the ROGIDS of absence of frozen contamination when frozen contamination is present on the inspected surface. This is considered as misleading guidance to the end-user.

One method that could be used to determine an acceptable false negative rate is the Fault Tree Analysis (FTA) method. FTA was developed in 1962 for the U.S. Air Force by Bell Telephone Laboratories and was later adopted and extensively applied by The Boeing Company. FTA is a graphical technique that provides a systematic description of the combinations of possible occurrences (failures) in a system linked by "AND" and "OR" logic gates, which can result in an undesirable "top event" outcome. The FTA is a standard system safety analysis technique, commonly used to identify the failures that have the greatest influence on bringing about the top event.

A fault tree is constructed by relating the sequences of events using standard logic symbols, which individually or in combination, could lead to the top event.

FTA is a standard method used to determine and analyze the critical failure modes for aircraft design and certification. The analyses are usually conducted using failure rates expressed in "failures/flight hour".

For on-aircraft systems, a single failure is not acceptable if it can lead to a catastrophic event. If it is determined that the criticality of the top event is catastrophic then the probability of the occurrence of the top event shall be equal to or lower than $1\text{x}10^{-9}$ /flight hour. The probability of $1\text{x}10^{-9}$ /flight hour as an acceptable occurrence rate associated with a catastrophic event has its origins in the early 1960s during the development of the first auto land systems. At that time a need arose to state the acceptable level of risk in the form of the probability of a fatal accident due to system failure.[1]

New designs of large civil transport aircraft should be able to achieve a fatal accident rate of better than one in 10 million hours for all system causes. Individual features of individual systems can only contribute a small portion to this target; if one has ten systems with ten critical failures in each, this puts the allowable share to each feature at about one in 1,000 million hours, which implies not only very high

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[1] System Safety, E.Llyod & W.Tye, CAA London 1982

levels of reliability, which can only be achieved by fail safe features in some form, but also a very intense scrutiny to obtain reasonable assurance that the target is likely to be achieved.[1]

The above discussion is relevant for on-aircraft systems, specifically those that have an impact on the safe operation of aircraft.

ROGIDS is not an on-aircraft system, it is a ground-based device, which is intended to enhance and replace current post de-icing visual and tactile inspection methods.

Nevertheless, it is conceivable that certain failure conditions of ROGIDS equipment could contribute to a catastrophic event.

For the purpose of this discussion, the ROGIDS is considered as an inspection tool only for post-deicing use.

In the discussion and assessment that follows, failure rates are based on "failures/de-icing event" instead of "failures/flight hour", which is more commonly used in on-aircraft systems design and analysis. This is necessary because the operating "mission profile" for a de-icing vehicle is different than that of an aircraft.

D.3 DISCUSSION

This section will provide discussion on:

1. Reviewing historical data to determine the current probability (failure rate) of encountering a catastrophic event post-deicing due to residual undetected contamination on the aircraft critical surfaces;
2. Using statistical data obtained from ROGIDS human factors testing to determine relative merit of using ROGIDS versus human inspectors; and
3. Postulating a latent failure rate for ROGIDS that will provide an increased level of safety when using ROGIDS as a post-deicing inspection tool.

D.3.1 Review of Historical Data

The present-day probability of aircraft loss due to undetected ice contamination can be estimated from the number of worldwide reported aircraft accidents and the total estimated number of worldwide deicing procedures performed.

The analysis utilizes worldwide data for the 20-year period 1985-2005. The period was selected because:

a. The events and their causes are generally well documented;
b. Modern deicing practices were in effect; and
c. The 20-year period provides a reasonable time period to estimate statistical averages.

The events and data sources used in the analysis are listed at the end of this appendix.

During this period there were 37 reported aircraft events caused by undetected frozen contamination on the aircraft either after inspection where no deicing was performed, or after deicing.[2]

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[2] http://aircrafticing.grc.nasa.gov/resources/related02.html

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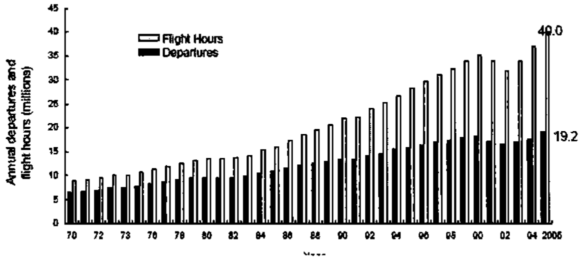
To estimate the total number of worldwide deicing events during the 1985-2005 period it was assumed that the number of worldwide deicings increased linearly from the early 1960s when commercial airlines accepted the use of deicing solutions[3]. Given that the worldwide number of deicings for 2002 is estimated to be 600,000[4], the total number of deicings in the period 1985-2005 is approximately 10 million. The number of deicings is estimated using the following data and assumptions:

a. Approximately 600,000 deicings worldwide in 2002; and
b. Linear approximation using 2% growth rate based on Boeing statistics on worldwide departures for seven aircraft manufacturers and 35 significant aircraft (14 Boeing) types over the period 1970-2005.[5]



- 492.2 million cumulative departures (406.2 million on Boeing airplanes)
- 846.9 million cumulative flight hours (706.5 million on Boeing airplanes)
- 7 manufacturers – 35 significant types (14 Boeing) in service as of 12/31/2005

FIGURE D1: Boeing Data On Worldwide Annual Aircraft Departures and Flight Hours 1970-2005[5]

Aircraft accidents with the following characteristics were selected for the analysis:

a. Worldwide accidents caused by ground icing events; and
b. Events were sorted according to:
    1. Events caused by undetected frozen contamination without deicing performed. These events were excluded from the analysis;
    2. Events caused by detected, but ignored, frozen contamination with no deicing performed. These events were excluded from the analysis; and
    3. Events caused by undetected residual frozen contamination after deicing but excluding fluid failure are the only ones considered here because this analysis deals with post-deicing only. At this time ROGIDS is only considered for post-deicing inspections.

The data for a 20-year period 1985-2005 were used. There were 3 catastrophic accidents due to residual undetected ice after deicing was performed. The total number of deicings during this period was approximately 10 million or 10^7. The probability of an accident is estimated to be the ratio of the number of events and the total number of deicing events, which is 3 in 10 million or 3 x10^{-7}.

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[3] Report On Federal Aviation Administration Deicing Program Report, Number: E5-FA-7-001 Date: October 2, 1996 Office of the Inspector General
[4] APS Aviation estimate for 2002
[5] Statistical Summary of Commercial Jet Airplane Accidents 1955-2005, Boeing presentation, May 2006

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D.3.2 Calculation of the ROGIDS Latent Failure Rate

The proposed ROGIDS Latent Failure Rate is calculated by using the historical data supplied in Section D.3.1 and applying a FTA to the ROGIDS performance and post-deicing aircraft inspection. In the analysis, it is assumed that the ROGIDS is used to detect ice that cannot be found by current visual and/or tactile processes: In the post-deicing scenario, the deicing operation has been completed to the best of the deicer's ability (i.e. the deicer believes that all the ice has been removed), and the deiced surface is inspected by the ROGIDS.

The Fault Tree is composed of two independent events whose occurrences may lead to the probability of an aircraft loss at takeoff due to ground ice contamination on the aircraft surfaces (see Figure D2). The fault tree is applicable to the post-deicing scenarios.

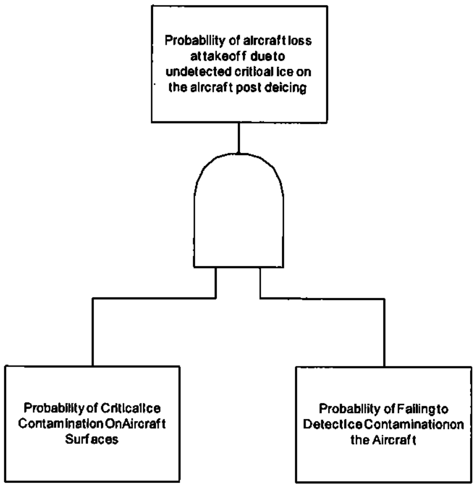

FIGURE D2: FTA of Aircraft Loss Due To Ground Ice

The presence of Critical Ice Contamination is the first factor that contributes to the loss of an aircraft at takeoff. Critical Ice Contamination is defined as ice contamination which leaves little or no aerodynamic lift or control margin and results in an aircraft accident. The amount, type (e.g. frost, clear ice) and spatial distribution of the contamination that is classified as critical is dependent on several variables including aircraft type and aircraft conditions at takeoff.

The second event is the probability that ice contamination on the critical aircraft surfaces is undetected. In the post-deicing scenario, the ice removal operation is completed and the deicer mistakenly believes that all of the ice has been removed. The probability that ice remains undetected is higher for the post-deicing scenario for a number of reasons: if performed incorrectly, the deicing process could create a thin and smooth layer of ice that is more difficult to see and the deicing/anti-icing fluid reduces the contrast of the ice on the aircraft surface.

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Assuming the two events are independent, the probability of a catastrophic loss of the aircraft at takeoff is the product of the probabilities of the two events. This means that a catastrophic accident will occur when undetected critical ice is present at takeoff.

Section D.3.1 shows the historical probability of a catastrophic accident due to undetected ice post-deicing is 3x10^{-7} accidents per deicing event. The probability of undetected ice post-deicing can be estimated from the series of human factor tests.[6]. In the Human Capability Test, ice below 0.8 mm thickness could not be visually detected beneath Type I fluid if the surface was painted white or if the ice covered the entire surface. In the comparison between ROGIDS and humans, only 15-60% of the thin ice patches on a test wing were visually detected and 30-80% were detected by tactile inspections.

In the case of light frozen contamination, e.g. frost or light adhering snow, the heat from the deicing fluid removes all of the frozen contamination. However, in the case of heavier frozen contamination, and based upon the Human Factors tests, the probability of undetected clear ice post-deicing is estimated to be 10^{-1}.

Therefore the probability of Critical Ice Contamination post-deicing is 3x10^{-7}/10^{-1} = 3x10^{-6} events/deicing or approximately once in every 330,000 deicing events.

The use of ROGIDS should improve the safety of the overall deicing process in the post-deicing scenarios. An acceptable safety target of one catastrophic event every 1 billion deicing events is proposed. This is in line with airborne applications[7].

Keeping in mind that the probability of Critical Ice Contamination remains the same whether a ROGIDS or human inspection is performed, the required maximum probability of ROGIDS detection failure is 10^{-9}/3x10^{-6} = 3.3x10^{-4} latent failures per deicing event for the post-deicing scenario (see Table D1). This is two orders of magnitude better than current practices. Conservatively no credit is given for the human post-deicing inspection.

TABLE D1: Maximum probability of ROGIDS detection failure

	Target top event (per deicing event)	Probability of critical ice contamination (per deicing event)	Maximum probability of ROGIDS detection failure (per deicing event)
Residual ice leading to a catastrophic accident	1 x10^{-9}	3 x10^{-6}	3.3 x10^{-4}

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[6]

a) Bender K., Sierra, Jr., E. A., Terrace S. M., Marcil I., D'Avirro J., Pugacz, E., Eyre F., Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance Under Post Deicing Conditions, FAA, December 2005, DOT/FAA/TC-06/20

b) Sierra, Jr., E. A., Bender K., Marcil I., D'Avirro J., Pugacz E., Eyre F., Human Visual and Tactile Ice Detection Capabilities Under Aircraft Post-Deicing Conditions, FAA, November 2005, DOT/FAA/TC-06/21.

c) Moc, M., Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests, APS Aviation Inc., Transportation Development Centre, Montreal, September 2005, TP 14449E, 46.

d) Narlis, C., Development of Ice Samples for Comparison Study of Human and Sensor Capability to Detect Ice on Aircraft, APS Aviation Inc., Transportation Development Centre, Montreal, January 2006, TP 14450E, 54.

[7] See for example DO-178 or DO-254 aerospace standards.

D.3.3 Sample Applications of ROGIDS Failure Rate to Equipment Design

In Section D.3.2 the maximum probability of ROGIDS detection failure was estimated as $3.3x10^{-4}$ per deicing event. Equipment failure rates are usually calculated on a per hour basis. This section provides two sample applications to calculate the ROGIDS latent failure rates on a per hour basis. The per hour rate is calculated using the time the ROGIDS is used for aircraft inspection during a deicing event.

A ROGIDS may have latent failure modes that are caused by hardware or software malfunctions. The ROGIDS may also incorporate a Built-in-test (BIT) device and/or software that can monitor the ROGIDS performance and detect any latent failures and annunciate them to the Operator. Consequently, a latent failure of the ROGIDS will remain undetected when the BIT system also malfunctions. The following analysis estimates the required maximum ROGIDS system and BIT failure rates:

The contamination detection failure probability, p, is calculated as the number of failures divided by the total number of deicing events or, equivalently, the total number of inspections. Inspection time is defined as the time the ROGIDS is performing contamination detection measurements and displaying information to the operator. It excludes activities such as system warm up time and standby time.

Case 1: ROGIDS without latent failure detection BIT capability

This case calculates the require ROGIDS latent failure rate assuming there is no BIT to detect and annunciate the latent failure to the operator.

Assuming an exponential probability function, the probability of contamination detection failure is given by

$p=e^{-\lambda \cdot T}$,
where

p is the probability of contamination detection failure caused by a latent failure of the ROGIDS hardware and/or software.

λ is the ROGIDS latent failure rate (latent failures per inspection hour)
T is the ROGIDS latency period (hours between camera maintenance)

If $\lambda \cdot T<<1$ then the probability can be simplified to

$p \approx \lambda \cdot T$

or

$\lambda = p / T$

As an example, given the post-deicing scenario $p=3.3x10^{-4}$ from Table D1 and assuming T=100 hours of inspection time between maintenance checks then the maximum required failure rate is $\lambda = 3.3x10^{-6}$ latent failures per inspection hour.

Case 2: ROGIDS with a BIT latent failure detection system

This case calculates the required ROGIDS latent failure rate assuming there is a BIT to detect and annunciate the ROGIDS latent hardware/software failure to the operator.

The ROGIDS probability of a contamination detection failure is composed of the ROGIDS probability of latent system failure and the probability of a failure to detect and annunciate a latent failure (BIT failure).

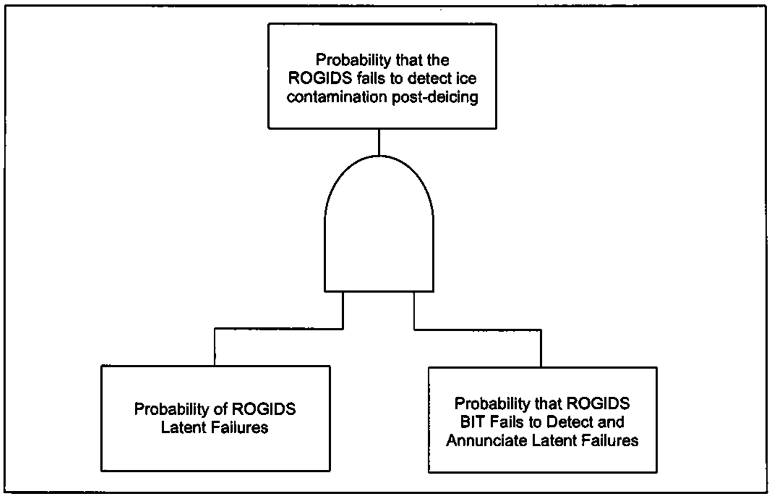

FIGURE D3: FTA for ROGIDS Latent Failure Cases

The probability of the ROGIDS contamination detection failure, p, is equal to the product of the combined latent failure of the ROGIDS system (failure rate λ System) and the failure of the BIT latent failure detection system (failure rate λ BIT) are related by the equation[8]:

$p= \lambda\ System \cdot T\ System \cdot \lambda\ BIT \cdot TBIT$

where

p is the probability of contamination detection failure caused by a latent failure of the ROGIDS hardware and/or software.

λ_{System} is the camera latent failure rate (latent failures per inspection hour)
T_{System} is the camera latency period (hours between camera maintenance)

λ_{BIT} is the BIT failure rate (BIT failures per inspection hour)
T_{BIT} is the BIT latency period (hours between BIT maintenance intervals)

If $T_{System} = T_{BIT} = T$ then

$\lambda_{System} \cdot \lambda_{BIT} = p / T^2$

Given $p=3.3x10^{-4}$ from Table D1 and assuming T=100 hrs then the combined ROGIDS failure rate is $\lambda_{System} \cdot \lambda_{BIT}=3.3x10^{-8}$ per inspection $hour^2$. If, for example, the ROGIDS $\lambda_{System} = 10^{-3}$ latent failures per

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[8] C. Tanner, "ROGIDS Fault Tree Analysis (FTA) –ROGIDS for Pre and Post deicing operation", Discussion Paper, October, 2006.

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inspection hour, then the required BIT failure rate shall be less than λ_{BIT}=3.3x10^{-5} failures per inspection hour.

D.4 SUMMARY AND RECOMMENDATIONS

D.4.1 Summary

On average, there has been a catastrophic accident every 3 million deicing events due to undetected critical contamination post-deicing.

Based upon the Human Factors tests, the probability of undetected clear ice post-deicing is estimated to be 10^{-1}.

The probability of Critical Ice Contamination post-deicing is 3.3x10^{-6} events/deicing or approximately once in every 330,000 deicing events.

D.4.2 Recommendations

Current deicing methods and inspection procedures have been in place for about 20 years. These are proven, reliable methods. However, accidents still occur which can be traced back to undetected contamination post-deicing on critical surfaces.

One method to improve the safety record associated with aircraft deicing is the use of properly designed, tested, implemented and reliable inspection tools such as ROGIDS. Therefore, the following are recommended:

a. The maximum acceptable rate for the ROGIDS providing false negatives due to latent malfunctions shall be less than 3 in every 10,000 deicing events (3x10^{-4} per deicing event);

b. The ROGIDS manufacturer shall conduct a thorough and systematic safety assessment to determine, classify, and document equipment failure modes and their effects;

c. Formal Fault Tree Analyses and Failure Modes and Effects Analyses shall be conducted to establish that the equipment false negative rate due to latent malfunctions is less than the maximum acceptable rate in (a) above.

D.5 HISTORICAL DATA ON AIRCRAFT GROUND-ICING ACCIDENTS

A. Undetected ice with no deicing (4)

Events (2)
- December 6, 2003 Reading Regional Airport in Reading Socata TBM-700
- March 14, 1997 Detroit, MI, USA - DC-9 Undetected clear ice on the wing

Catastrophic events (2)
- February 5, 1985 Philadelphia, PA, USA - DC-9 Undetected ice.
- March 10, 1989 Dryden Ontario F-28 Snow on wing undetected/ignored? by pilots

B. Residual ice after deicing (7)

Events (4)
- February 23, 2005 Aberdeen Scotland Jestream 4100 Residual ice after deicing

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- December 6, 2003 Reading Regional Airport in Reading Socata TBM-700
- November 4, 2003 Ottawa DHC-8-102 Residual ice after deicing
- February 16, 2002 Torino Italy Fokker F-70 Clear ice after deicing not detected

Catastrophic events (3)

- October 10 2001, Dillingham, AK, USA C-208 Residual ice after deicing
- December 27, 1991 Stockholm SAS MD-80 Clear ice not detected after two deicings
- November 25, 1989 Kimpo Korea Fokker 28 Residual ice after deicing

C. Detected ice that was ignored (2)

Catastrophic events (2)

- November 28, 2004 Canadair, Ltd., CL-600-2A12, N873G, Montrose, CO, NTSB/AAB-06/03
- January 17, 2004 Georgian Express Pelee Island C-208B

D. Accidents due to other/undetermined ground ice related causes (24)

Events (18)

- April 26, 2001White post VA Stinson-108
- January 19, 2001 Chillicothe OH PA-46
- February 7, 1999 Medina OH PA-32
- March 22, 1992, Flushing, NY
- February 17, 1991 Cleveland Ohio DC-9
- January 29, 1990 Williston, VT C-208
- January 10, 1988 Honshu Japan YS-11
- November 15, 1987 Denver CO DC-9
- January 6, 1987 Stockholm Caravelle
- January 18, 1985 Lubbock Tx C-208
- February 5, 1985 Philadelphia PA DC-9
- April 2, 1985 Johnson City NY C-421
- December 27, 1985 Spokane WA C-401
- January 31, 1985 Huntington W VA BE-18
- January 13, 1984 Jamaica NY Fokker F27
- March 19, 1984 Morrisonville NY BE-18
- December 12, 1985 Gander Newfoundland DC-8
- January 16, 1983 Anchorage AK C-206

Catastrophic events (6)

- January 4, 2002 Birmingham, England, Challenger 604
- November 24, 1994 Glenburn ME PA-18
- March 5, 1993 Skopje Macedonia Fokker F-100
- January 13, 1982 Washington DC B737
- February 18, 1980 Boston, MA
- November 27, 1978 Newark, NJ

D.5.1 References for historical data on aircraft ground-icing accidents

1. http://aircrafticing.grc.nasa.gov/resources/related02.html
2. http://www.caa.co.uk/default.aspx?categoryid=978&pagetype=90&pageid=6281

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3. Report on FAA deicing program Report Number: E5-FA-7-001 October 2, 1996 Office of the Inspector General: http://www.oig.dot.gov/StreamFile?file=/data/pdfdocs/e5fa7001.pdf
4. http://www.aopa.org/asf/ntsb/searchResults.cfm?tss=16
5. Swedish Civil Aviation Administration, Report C 1993:57: Air Traffic Accident, 27th December 1991, at Gottröra, AB County, 601 79 Norrköping

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APPENDIX C

EXPERIMENTAL PROGRAM:
EVALUATION OF ICE DISK SAMPLE DECAY FOLLOWING APPLICATION OF DE/ANTI-ICING FLUID

CM2020 (06-07)

EVALUATION OF ICE DISK SAMPLE DECAY FOLLOWING APPLICATION OF DE/ANTI-ICING FLUID

Fall 2006

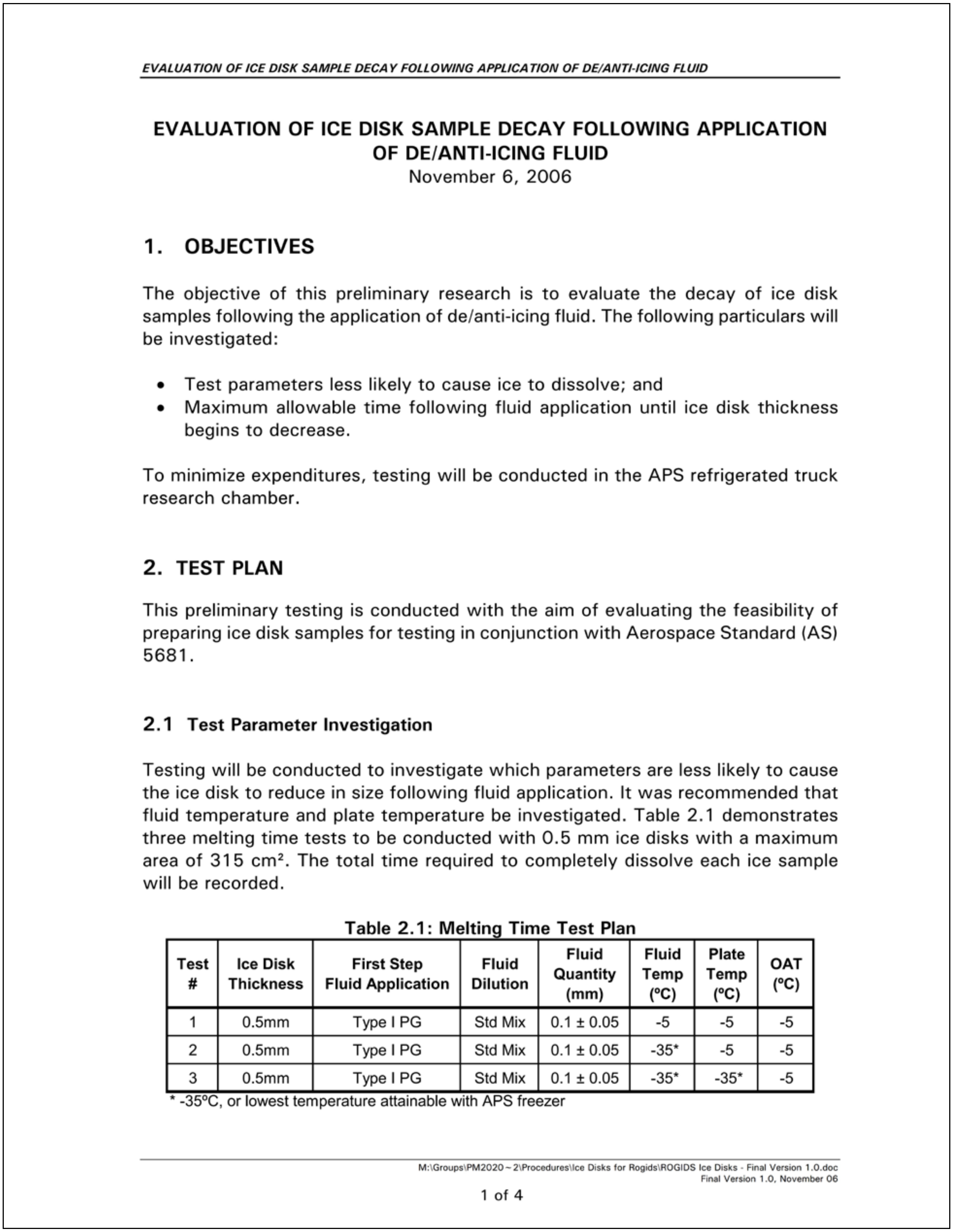
Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

November 6, 2006
Final Version 1.0



EVALUATION OF ICE DISK SAMPLE DECAY FOLLOWING APPLICATION OF DE/ANTI-ICING FLUID

November 6, 2006

1. OBJECTIVES

The objective of this preliminary research is to evaluate the decay of ice disk samples following the application of de/anti-icing fluid. The following particulars will be investigated:

- Test parameters less likely to cause ice to dissolve; and
- Maximum allowable time following fluid application until ice disk thickness begins to decrease.

To minimize expenditures, testing will be conducted in the APS refrigerated truck research chamber.

2. TEST PLAN

This preliminary testing is conducted with the aim of evaluating the feasibility of preparing ice disk samples for testing in conjunction with Aerospace Standard (AS) 5681.

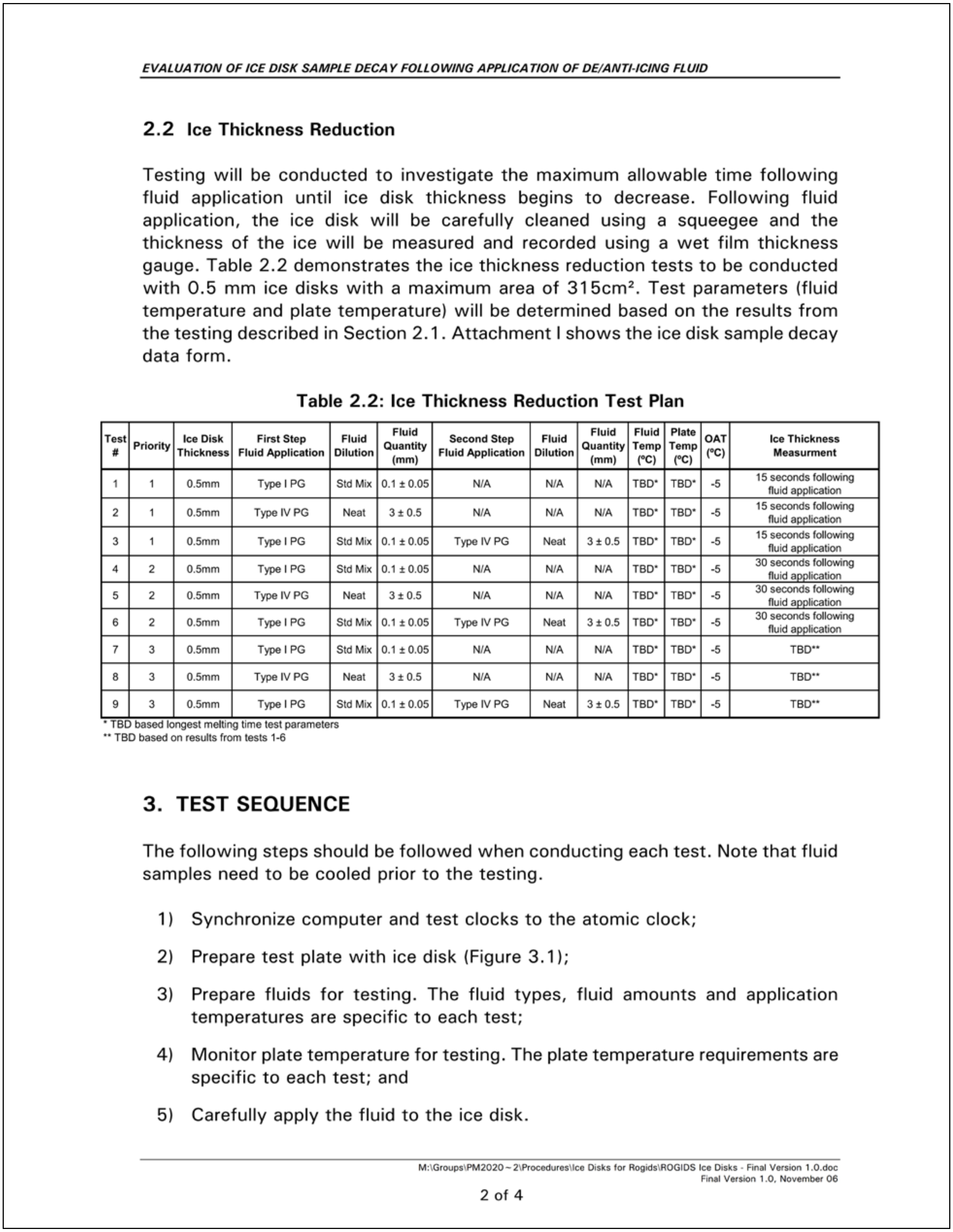
2.1 Test Parameter Investigation

Testing will be conducted to investigate which parameters are less likely to cause the ice disk to reduce in size following fluid application. It was recommended that fluid temperature and plate temperature be investigated. Table 2.1 demonstrates three melting time tests to be conducted with 0.5 mm ice disks with a maximum area of 315 cm². The total time required to completely dissolve each ice sample will be recorded.

Table 2.1: Melting Time Test Plan

Test #	Ice Disk Thickness	First Step Fluid Application	Fluid Dilution	Fluid Quantity (mm)	Fluid Temp (ºC)	Plate Temp (ºC)	OAT (ºC)
1	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	-5	-5	-5
2	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	-35*	-5	-5
3	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	-35*	-35*	-5

* -35ºC, or lowest temperature attainable with APS freezer



2.2 Ice Thickness Reduction

Testing will be conducted to investigate the maximum allowable time following fluid application until ice disk thickness begins to decrease. Following fluid application, the ice disk will be carefully cleaned using a squeegee and the thickness of the ice will be measured and recorded using a wet film thickness gauge. Table 2.2 demonstrates the ice thickness reduction tests to be conducted with 0.5 mm ice disks with a maximum area of 315cm². Test parameters (fluid temperature and plate temperature) will be determined based on the results from the testing described in Section 2.1. Attachment I shows the ice disk sample decay data form.

Table 2.2: Ice Thickness Reduction Test Plan

Test #	Priority	Ice Disk Thickness	First Step Fluid Application	Fluid Dilution	Fluid Quantity (mm)	Second Step Fluid Application	Fluid Dilution	Fluid Quantity (mm)	Fluid Temp (ºC)	Plate Temp (ºC)	OAT (ºC)	Ice Thickness Measurment
1	1	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	N/A	N/A	N/A	TBD*	TBD*	-5	15 seconds following fluid application
2	1	0.5mm	Type IV PG	Neat	3 ± 0.5	N/A	N/A	N/A	TBD*	TBD*	-5	15 seconds following fluid application
3	1	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	Type IV PG	Neat	3 ± 0.5	TBD*	TBD*	-5	15 seconds following fluid application
4	2	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	N/A	N/A	N/A	TBD*	TBD*	-5	30 seconds following fluid application
5	2	0.5mm	Type IV PG	Neat	3 ± 0.5	N/A	N/A	N/A	TBD*	TBD*	-5	30 seconds following fluid application
6	2	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	Type IV PG	Neat	3 ± 0.5	TBD*	TBD*	-5	30 seconds following fluid application
7	3	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	N/A	N/A	N/A	TBD*	TBD*	-5	TBD**
8	3	0.5mm	Type IV PG	Neat	3 ± 0.5	N/A	N/A	N/A	TBD*	TBD*	-5	TBD**
9	3	0.5mm	Type I PG	Std Mix	0.1 ± 0.05	Type IV PG	Neat	3 ± 0.5	TBD*	TBD*	-5	TBD**

* TBD based longest melting time test parameters

** TBD based on results from tests 1-6

3. TEST SEQUENCE

The following steps should be followed when conducting each test. Note that fluid samples need to be cooled prior to the testing.

1) Synchronize computer and test clocks to the atomic clock;
2) Prepare test plate with ice disk (Figure 3.1);
3) Prepare fluids for testing. The fluid types, fluid amounts and application temperatures are specific to each test;
4) Monitor plate temperature for testing. The plate temperature requirements are specific to each test; and
5) Carefully apply the fluid to the ice disk.

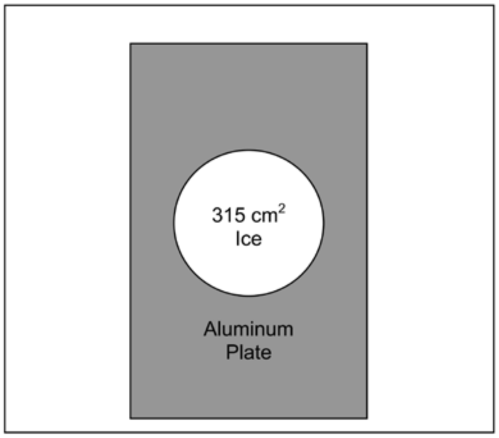


Figure 3.1: Test Plate with Ice Disk

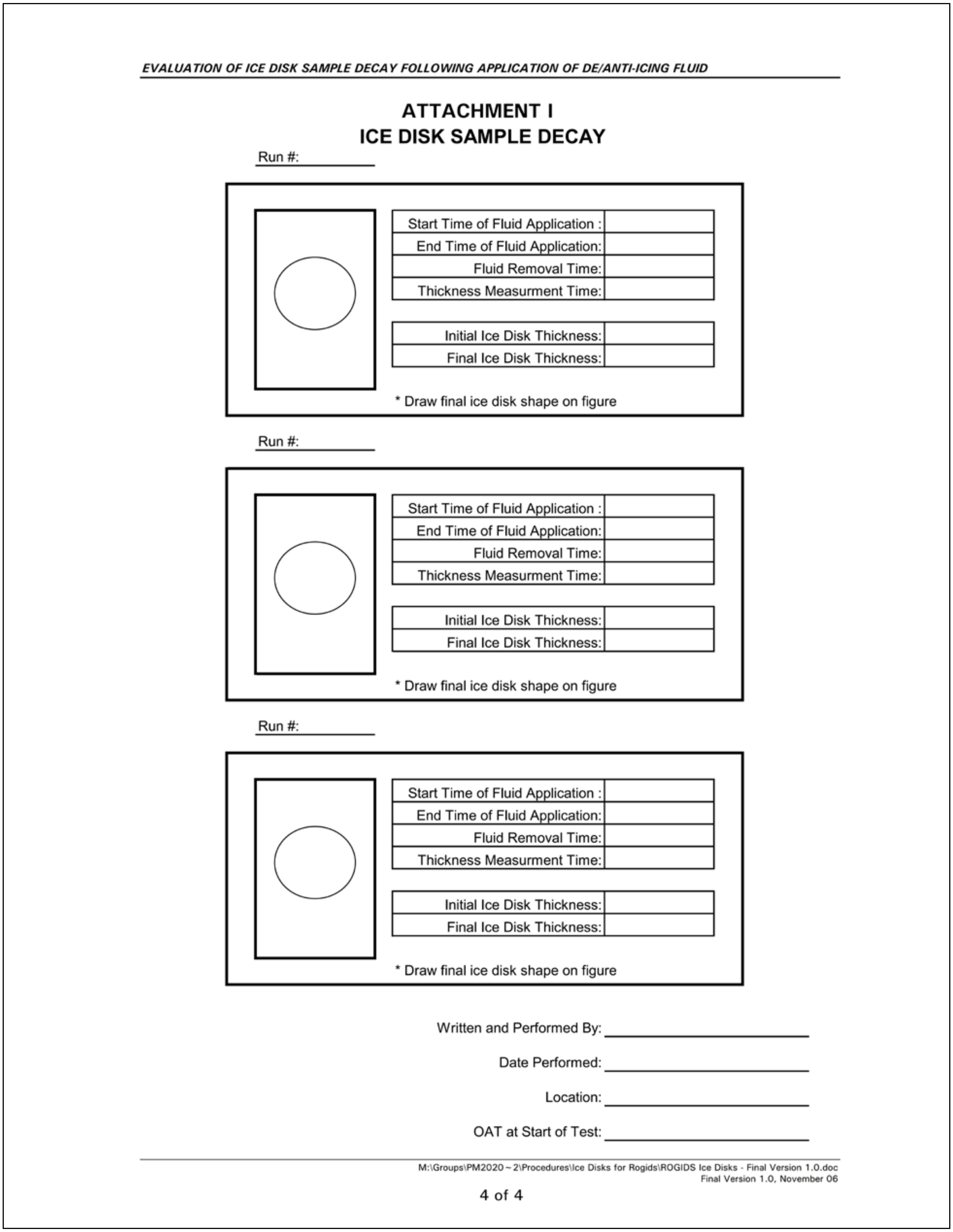
4. EQUIPMENT

- Test plates and test stand;
- SmartReader Eight-Channel temperature logger and thermistor probes will be used for logging test surface temperatures; and
- Wet film thickness gauges.

5. PERSONNEL

Two technicians are needed to conduct the tests:

- Technician one prepares ice disks and documents results obtained and procedural observations; and
- Technician two pours fluid and monitors fluid thickness.



EVALUATION OF ICE DISK SAMPLE DECAY FOLLOWING APPLICATION OF DE/ANTI-ICING FLUID

ATTACHMENT I
ICE DISK SAMPLE DECAY

Run #: __________

Start Time of Fluid Application :	
End Time of Fluid Application:	
Fluid Removal Time:	
Thickness Measurment Time:	

Initial Ice Disk Thickness:	
Final Ice Disk Thickness:	

* Draw final ice disk shape on figure

Run #: __________

Start Time of Fluid Application :	
End Time of Fluid Application:	
Fluid Removal Time:	
Thickness Measurment Time:	

Initial Ice Disk Thickness:	
Final Ice Disk Thickness:	

* Draw final ice disk shape on figure

Run #: __________

Start Time of Fluid Application :	
End Time of Fluid Application:	
Fluid Removal Time:	
Thickness Measurment Time:	

Initial Ice Disk Thickness:	
Final Ice Disk Thickness:	

* Draw final ice disk shape on figure

Written and Performed By: ____________________

Date Performed: ____________________

Location: ____________________

OAT at Start of Test: ____________________

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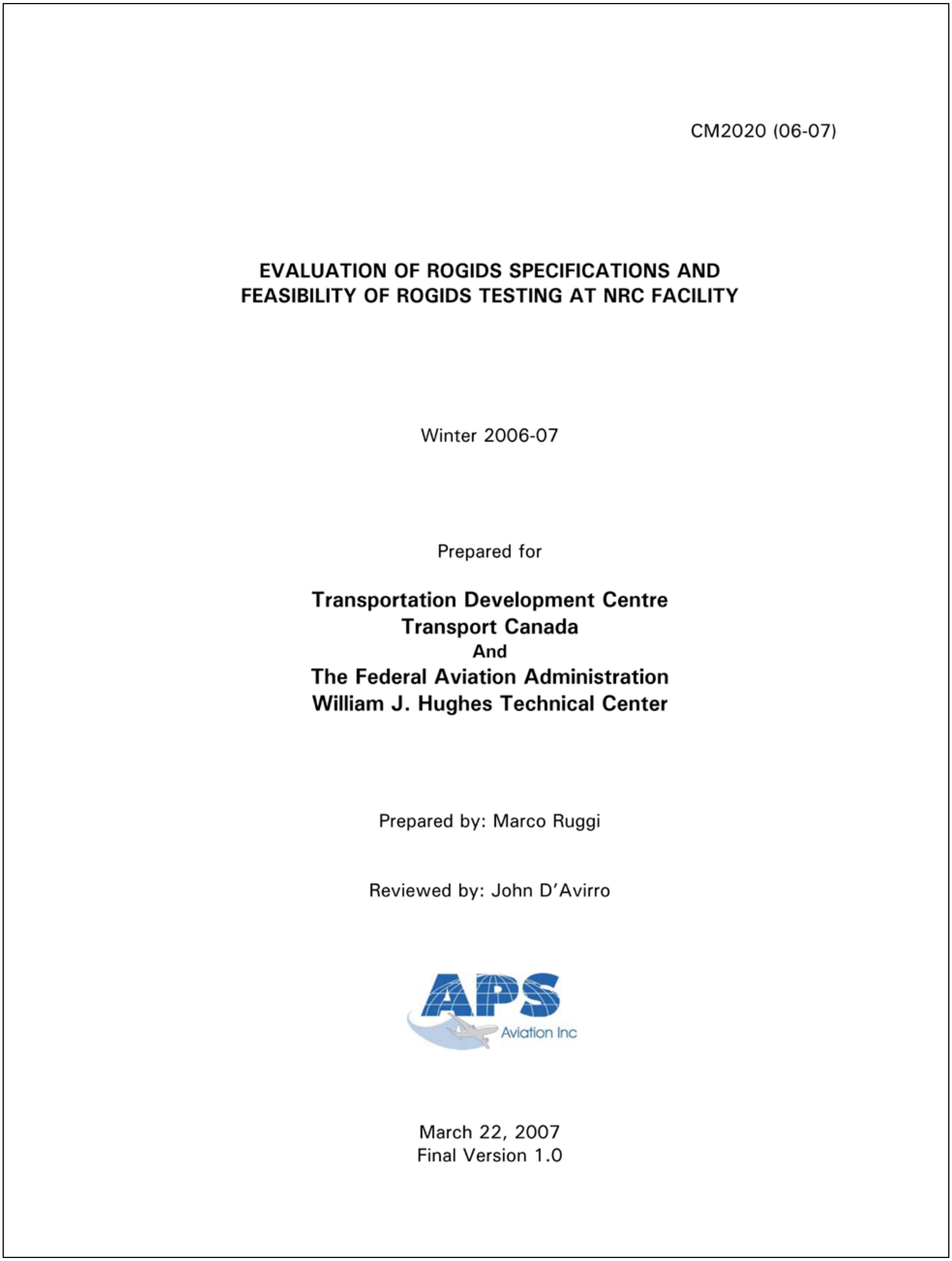
APPENDIX D

EXPERIMENTAL PROGRAM: EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY



CM2020 (06-07)

EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY

Winter 2006-07

Prepared for

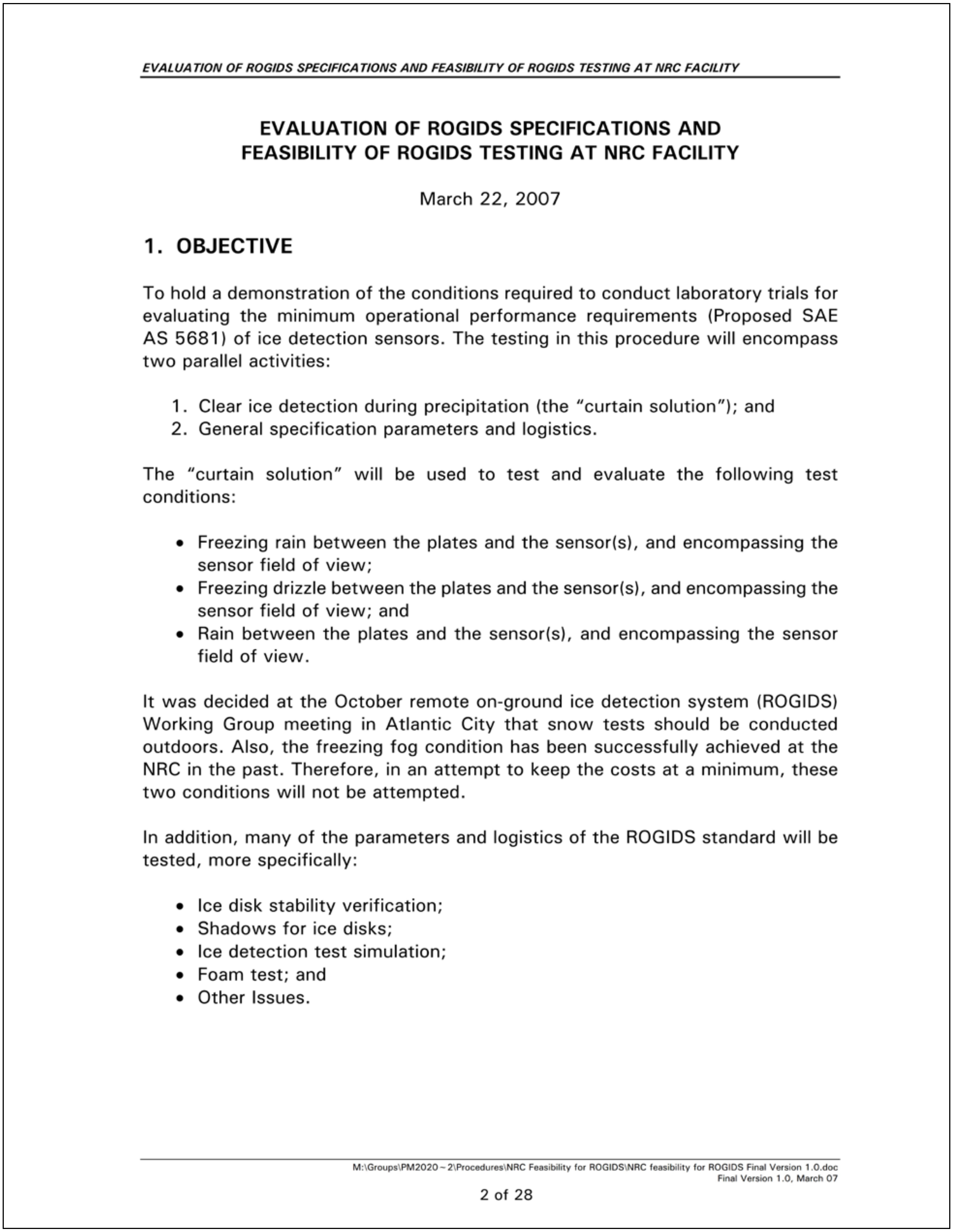
Transportation Development Centre
Transport Canada
And
The Federal Aviation Administration
William J. Hughes Technical Center

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

APS Aviation Inc

March 22, 2007
Final Version 1.0



EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY

March 22, 2007

1. OBJECTIVE

To hold a demonstration of the conditions required to conduct laboratory trials for evaluating the minimum operational performance requirements (Proposed SAE AS 5681) of ice detection sensors. The testing in this procedure will encompass two parallel activities:

1. Clear ice detection during precipitation (the "curtain solution"); and
2. General specification parameters and logistics.

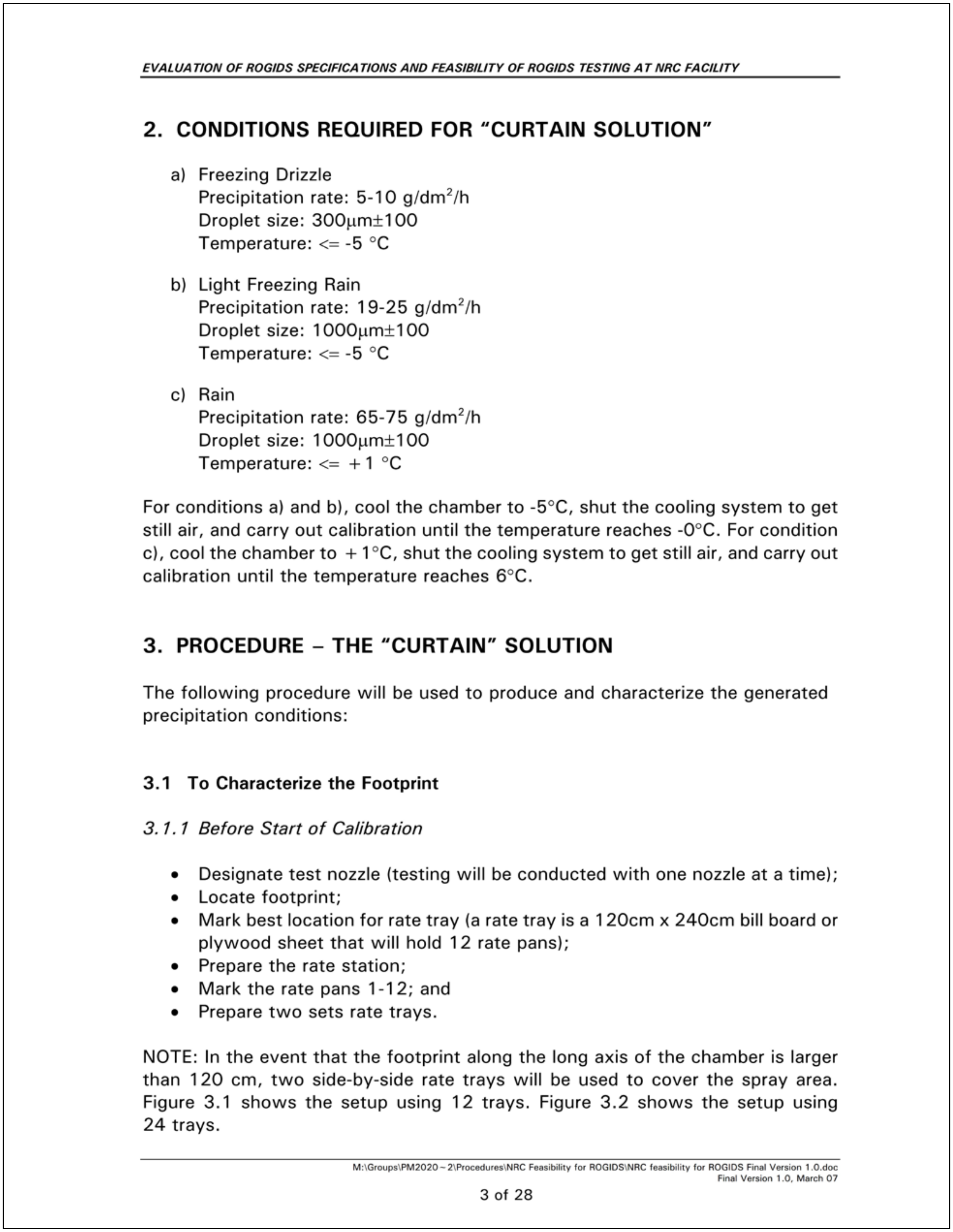
The "curtain solution" will be used to test and evaluate the following test conditions:

- Freezing rain between the plates and the sensor(s), and encompassing the sensor field of view;
- Freezing drizzle between the plates and the sensor(s), and encompassing the sensor field of view; and
- Rain between the plates and the sensor(s), and encompassing the sensor field of view.

It was decided at the October remote on-ground ice detection system (ROGIDS) Working Group meeting in Atlantic City that snow tests should be conducted outdoors. Also, the freezing fog condition has been successfully achieved at the NRC in the past. Therefore, in an attempt to keep the costs at a minimum, these two conditions will not be attempted.

In addition, many of the parameters and logistics of the ROGIDS standard will be tested, more specifically:

- Ice disk stability verification;
- Shadows for ice disks;
- Ice detection test simulation;
- Foam test; and
- Other Issues.



2. CONDITIONS REQUIRED FOR “CURTAIN SOLUTION”

a) Freezing Drizzle
Precipitation rate: 5-10 g/dm^2/h
Droplet size: 300µm±100
Temperature: <= -5 °C

b) Light Freezing Rain
Precipitation rate: 19-25 g/dm^2/h
Droplet size: 1000µm±100
Temperature: <= -5 °C

c) Rain
Precipitation rate: 65-75 g/dm^2/h
Droplet size: 1000µm±100
Temperature: <= +1 °C

For conditions a) and b), cool the chamber to -5°C, shut the cooling system to get still air, and carry out calibration until the temperature reaches -0°C. For condition c), cool the chamber to +1°C, shut the cooling system to get still air, and carry out calibration until the temperature reaches 6°C.

3. PROCEDURE – THE “CURTAIN” SOLUTION

The following procedure will be used to produce and characterize the generated precipitation conditions:

3.1 To Characterize the Footprint

3.1.1 Before Start of Calibration

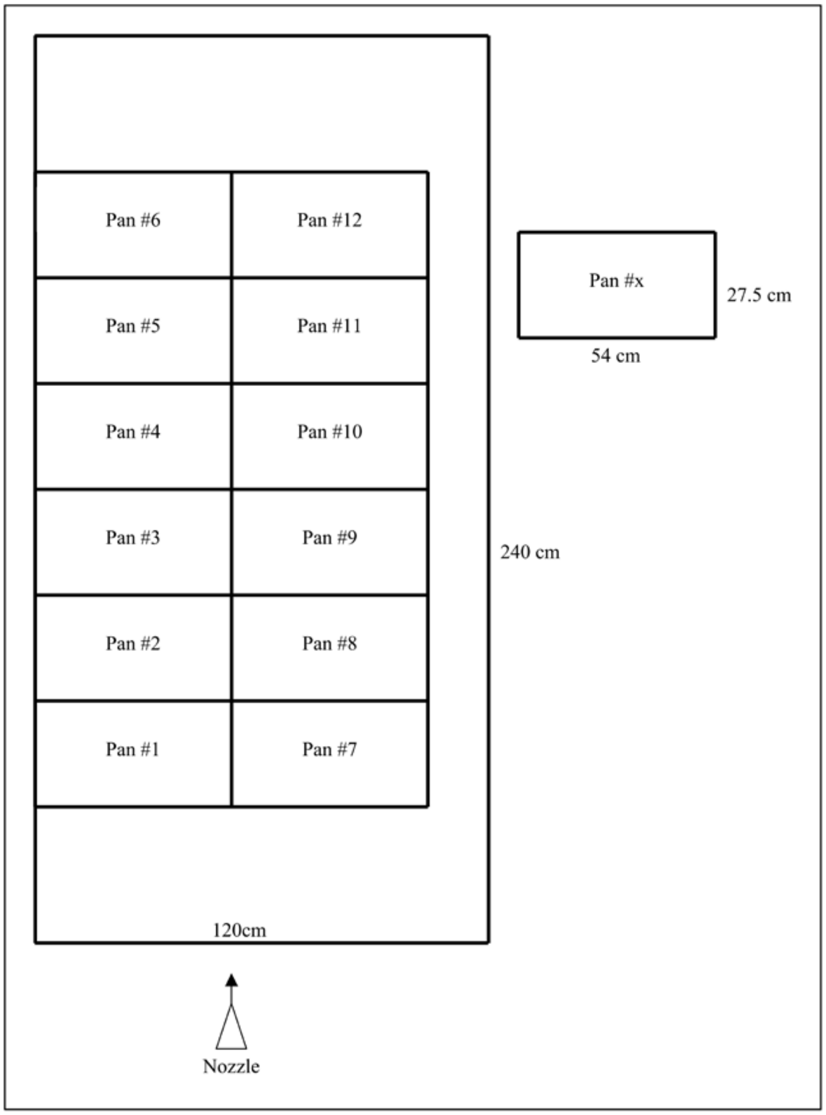
- Designate test nozzle (testing will be conducted with one nozzle at a time);
- Locate footprint;
- Mark best location for rate tray (a rate tray is a 120cm x 240cm bill board or plywood sheet that will hold 12 rate pans);
- Prepare the rate station;
- Mark the rate pans 1-12; and
- Prepare two sets rate trays.

NOTE: In the event that the footprint along the long axis of the chamber is larger than 120 cm, two side-by-side rate trays will be used to cover the spray area. Figure 3.1 shows the setup using 12 trays. Figure 3.2 shows the setup using 24 trays.

3.1.2 Start Calibration

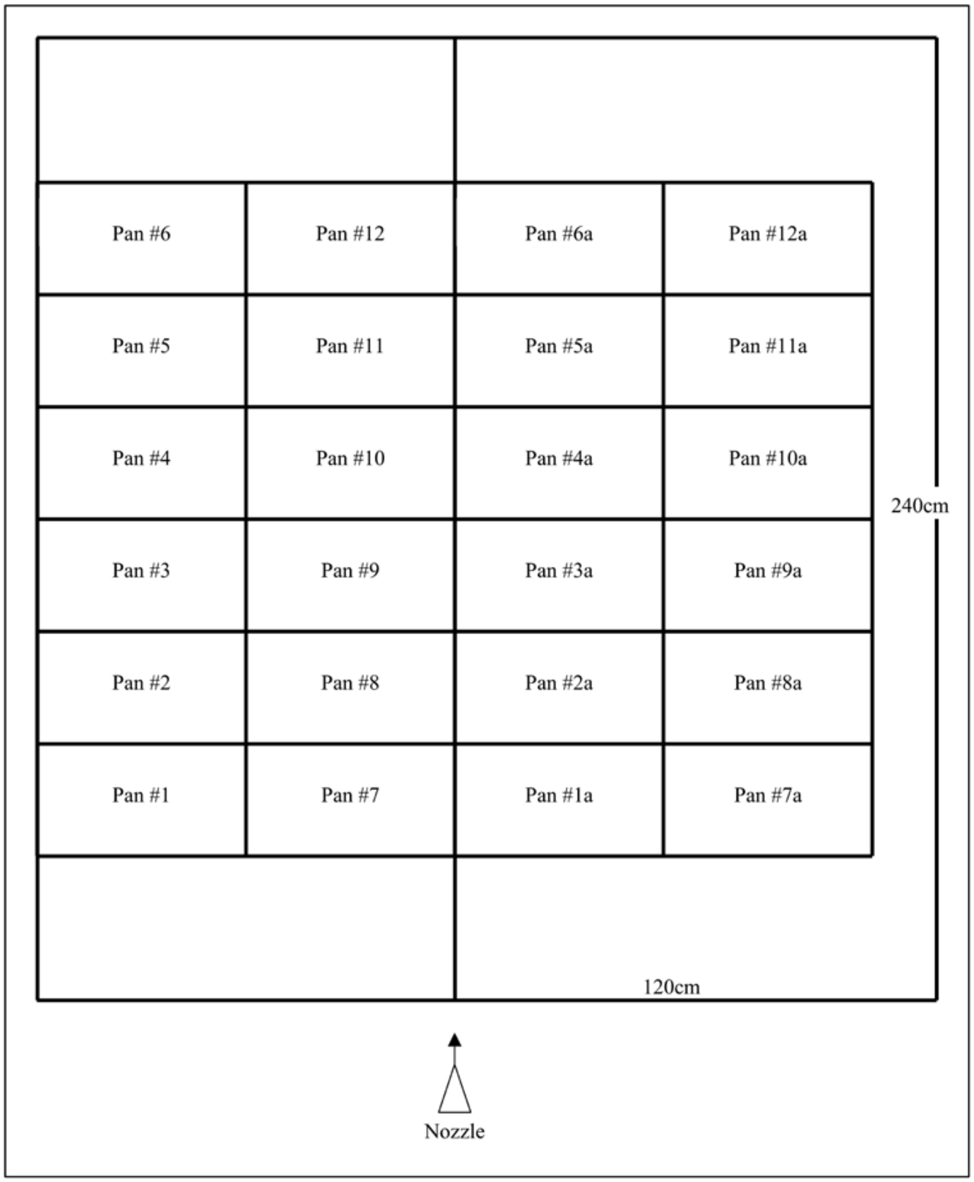
- Slide rate tray A to marked location on footprint (note start time);
- Ensure pans are placed beneath the entire footprint along the long axis of the chamber with minimal distances between the pans (pans can be spaced out along the short axis of the chamber)
- If 12 pans do not cover the entire footprint along the long axis of the chamber, use 24 or 36 pans.
- Leave rate pans for 10 minutes;
- Slide the rate tray A away from footprint (note end time);
- Weigh each of the 12 pans to calculate rate for rate tray A;
- Monitor and record water flow using a flow meter; and
- Adjust water flow according to rate of precipitation requirements.

Figure 3.1: Twelve Tray Setup



EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY

Figure 3.2: Twenty-Four Tray Setup



Pan #6	Pan #12	Pan #6a	Pan #12a
Pan #5	Pan #11	Pan #5a	Pan #11a
Pan #4	Pan #10	Pan #4a	Pan #10a
Pan #3	Pan #9	Pan #3a	Pan #9a
Pan #2	Pan #8	Pan #2a	Pan #8a
Pan #1	Pan #7	Pan #1a	Pan #7a

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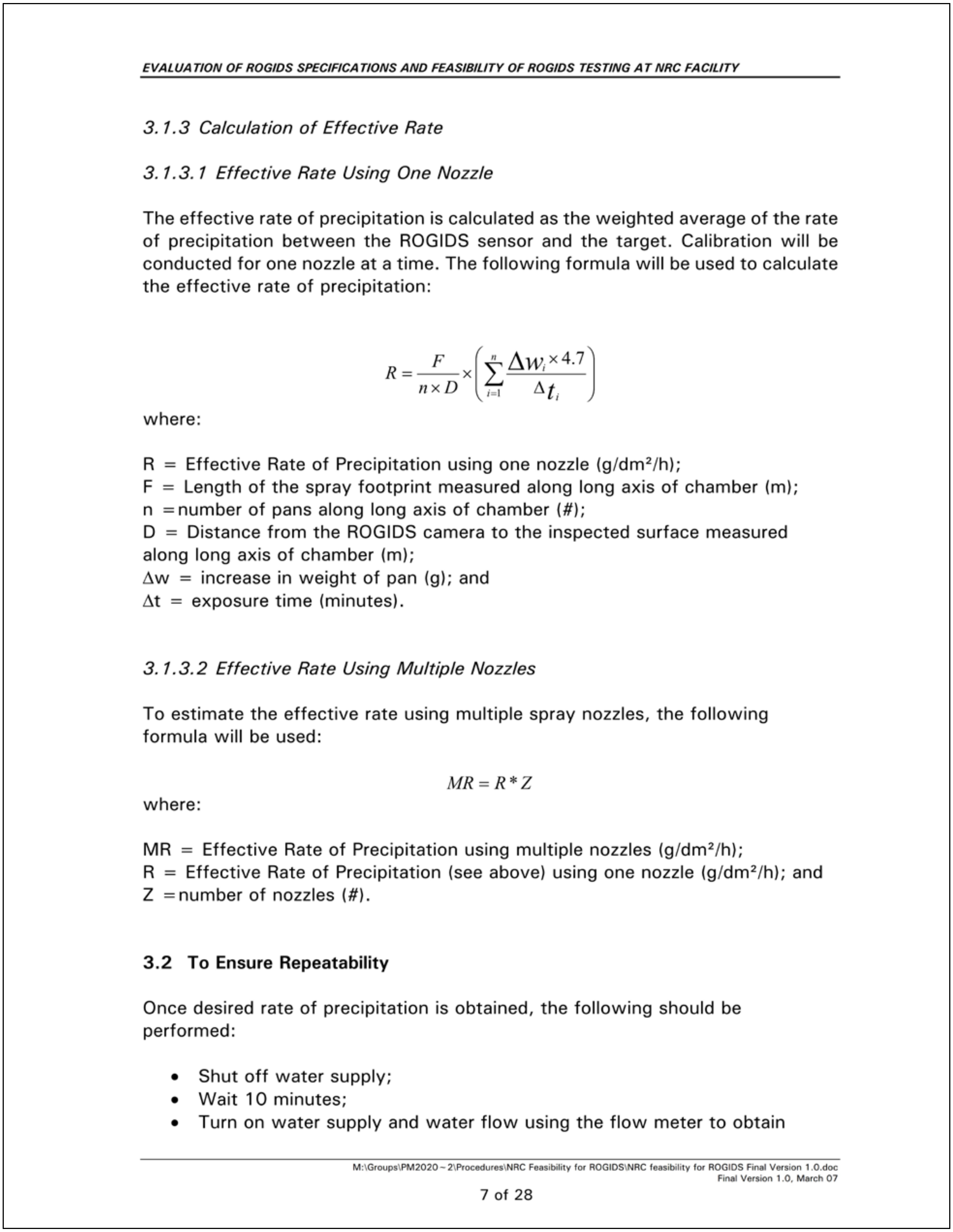


3.1.3 Calculation of Effective Rate

3.1.3.1 Effective Rate Using One Nozzle

The effective rate of precipitation is calculated as the weighted average of the rate of precipitation between the ROGIDS sensor and the target. Calibration will be conducted for one nozzle at a time. The following formula will be used to calculate the effective rate of precipitation:

$$R = \frac{F}{n \times D} \times \left(\sum_{i=1}^{n} \frac{\Delta w_i \times 4.7}{\Delta t_i} \right)$$

where:

R = Effective Rate of Precipitation using one nozzle (g/dm²/h);
F = Length of the spray footprint measured along long axis of chamber (m);
n = number of pans along long axis of chamber (#);
D = Distance from the ROGIDS camera to the inspected surface measured along long axis of chamber (m);
Δw = increase in weight of pan (g); and
Δt = exposure time (minutes).

3.1.3.2 Effective Rate Using Multiple Nozzles

To estimate the effective rate using multiple spray nozzles, the following formula will be used:

$$MR = R * Z$$

where:

MR = Effective Rate of Precipitation using multiple nozzles (g/dm²/h);
R = Effective Rate of Precipitation (see above) using one nozzle (g/dm²/h); and
Z = number of nozzles (#).

3.2 To Ensure Repeatability

Once desired rate of precipitation is obtained, the following should be performed:

- Shut off water supply;
- Wait 10 minutes;
- Turn on water supply and water flow using the flow meter to obtain

desired rate of precipitation; and
- Repeat calibration (Section 3.1.2 and 3.1.3).

3.3 To Verify that the Other Two Nozzles Behave in the Same Manner

Partially repeat 3.1.1 to 3.1.3 for the other two nozzles.

4. PROCEDURE – ICE DISK STABILITY VERIFICATION

APS will investigate the validity of the current procedure for verifying the stability of the ice disks with fluid.

4.1 Manufacturing Ice Disks

Ice disks will be made on standard aluminum test plates. The detailed steps for manufacturing ice disk samples are included in Attachment I; however note that for this demonstration over the next 3 days that the ice disks will be made using a spray bottle rather than the spray gun procedure described in Attachment I.

4.2 Fluid Application to Ice Disks

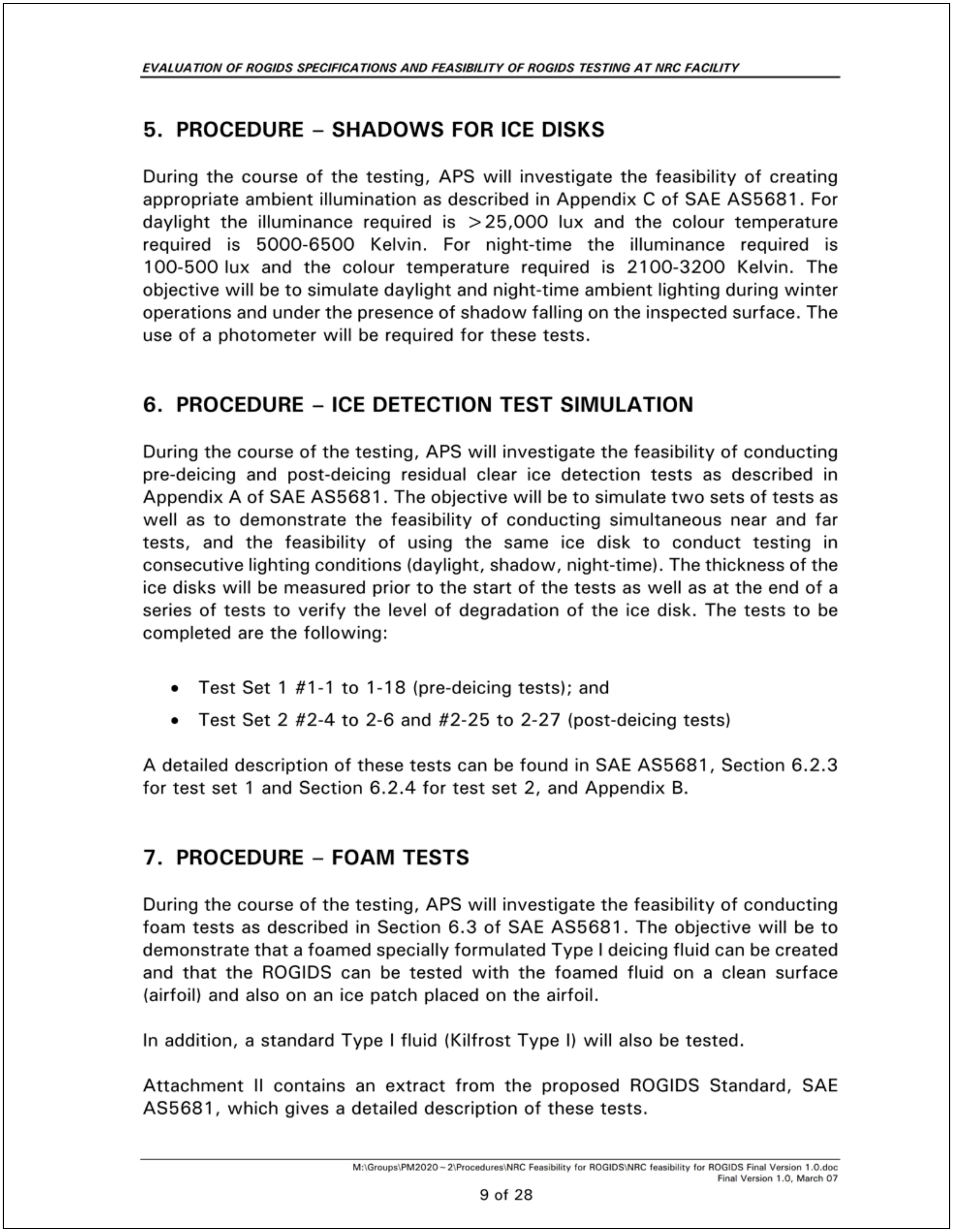
Prepare fluids for testing by monitoring temperatures and amount to be applied for each test. The fluid types, fluid amounts and application temperatures are specific for each test.

- Type I fluid needed for each test is 15 ml, to achieve 0.1 +/- 0.05 mm fluid thicknesses; and
- Type IV fluid needed for each test is 450 ml, to achieve 3 +/- 0.5 mm.

The followings steps will be performed for the fluid application and verification of decay of the ice disk samples:

1) Apply fluid on plate around the circumference of the ice disk.
2) Using a brush gently spread the fluid on the plate making sure that it is evenly distributed.

NOTE: Fluid applied should be maintained at the coldest temperature possible (-30 to -40°C). Ice disk samples will be valid for inspection tests for 2 minutes following a one step de/anti-icing fluid application, and for 1 minute following a two-step de/anti-icing application. Once the allotted time has expired, a new disk sample is required.



5. PROCEDURE – SHADOWS FOR ICE DISKS

During the course of the testing, APS will investigate the feasibility of creating appropriate ambient illumination as described in Appendix C of SAE AS5681. For daylight the illuminance required is >25,000 lux and the colour temperature required is 5000-6500 Kelvin. For night-time the illuminance required is 100-500 lux and the colour temperature required is 2100-3200 Kelvin. The objective will be to simulate daylight and night-time ambient lighting during winter operations and under the presence of shadow falling on the inspected surface. The use of a photometer will be required for these tests.

6. PROCEDURE – ICE DETECTION TEST SIMULATION

During the course of the testing, APS will investigate the feasibility of conducting pre-deicing and post-deicing residual clear ice detection tests as described in Appendix A of SAE AS5681. The objective will be to simulate two sets of tests as well as to demonstrate the feasibility of conducting simultaneous near and far tests, and the feasibility of using the same ice disk to conduct testing in consecutive lighting conditions (daylight, shadow, night-time). The thickness of the ice disks will be measured prior to the start of the tests as well as at the end of a series of tests to verify the level of degradation of the ice disk. The tests to be completed are the following:

- Test Set 1 #1-1 to 1-18 (pre-deicing tests); and
- Test Set 2 #2-4 to 2-6 and #2-25 to 2-27 (post-deicing tests)

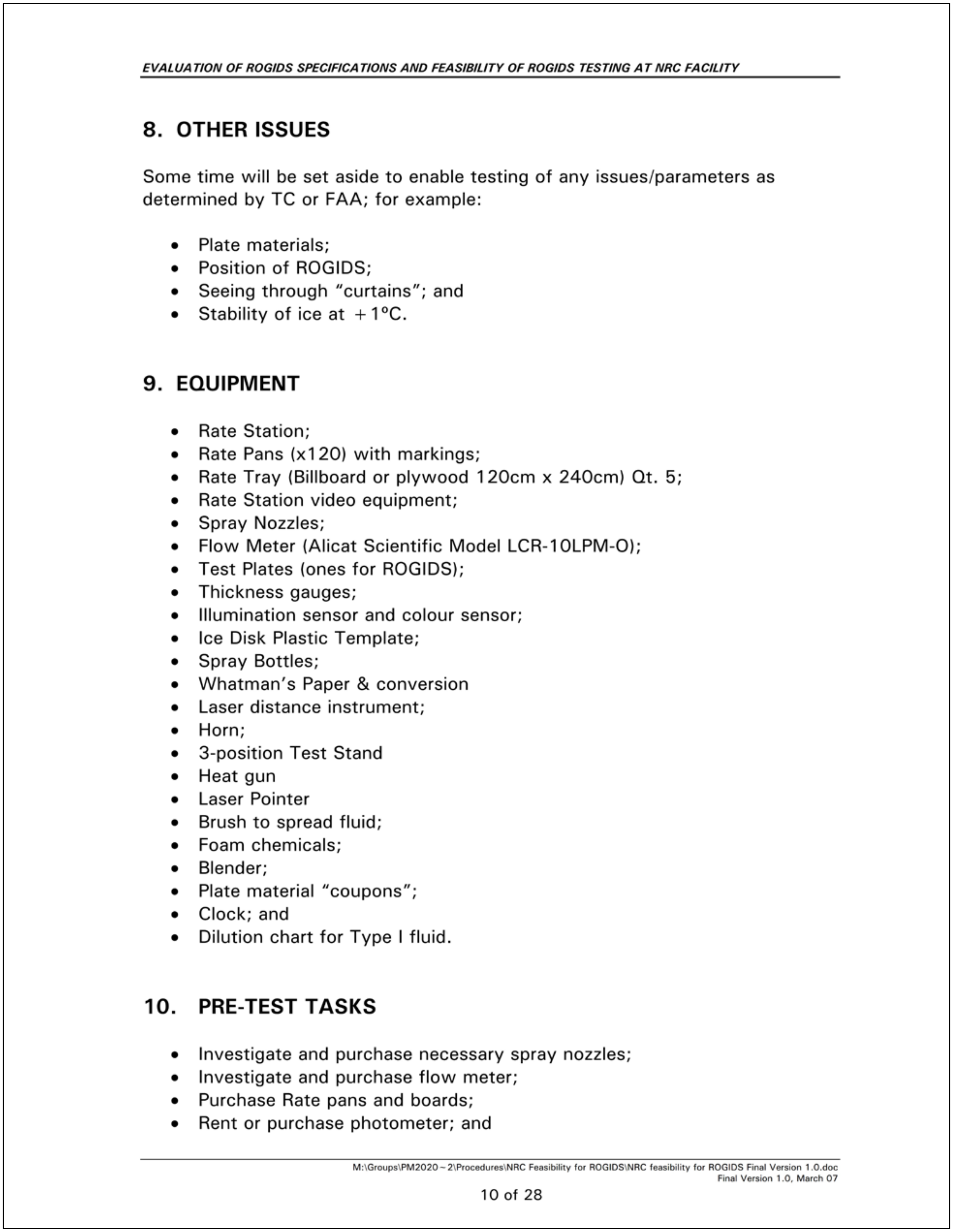
A detailed description of these tests can be found in SAE AS5681, Section 6.2.3 for test set 1 and Section 6.2.4 for test set 2, and Appendix B.

7. PROCEDURE – FOAM TESTS

During the course of the testing, APS will investigate the feasibility of conducting foam tests as described in Section 6.3 of SAE AS5681. The objective will be to demonstrate that a foamed specially formulated Type I deicing fluid can be created and that the ROGIDS can be tested with the foamed fluid on a clean surface (airfoil) and also on an ice patch placed on the airfoil.

In addition, a standard Type I fluid (Kilfrost Type I) will also be tested.

Attachment II contains an extract from the proposed ROGIDS Standard, SAE AS5681, which gives a detailed description of these tests.



8. OTHER ISSUES

Some time will be set aside to enable testing of any issues/parameters as determined by TC or FAA; for example:

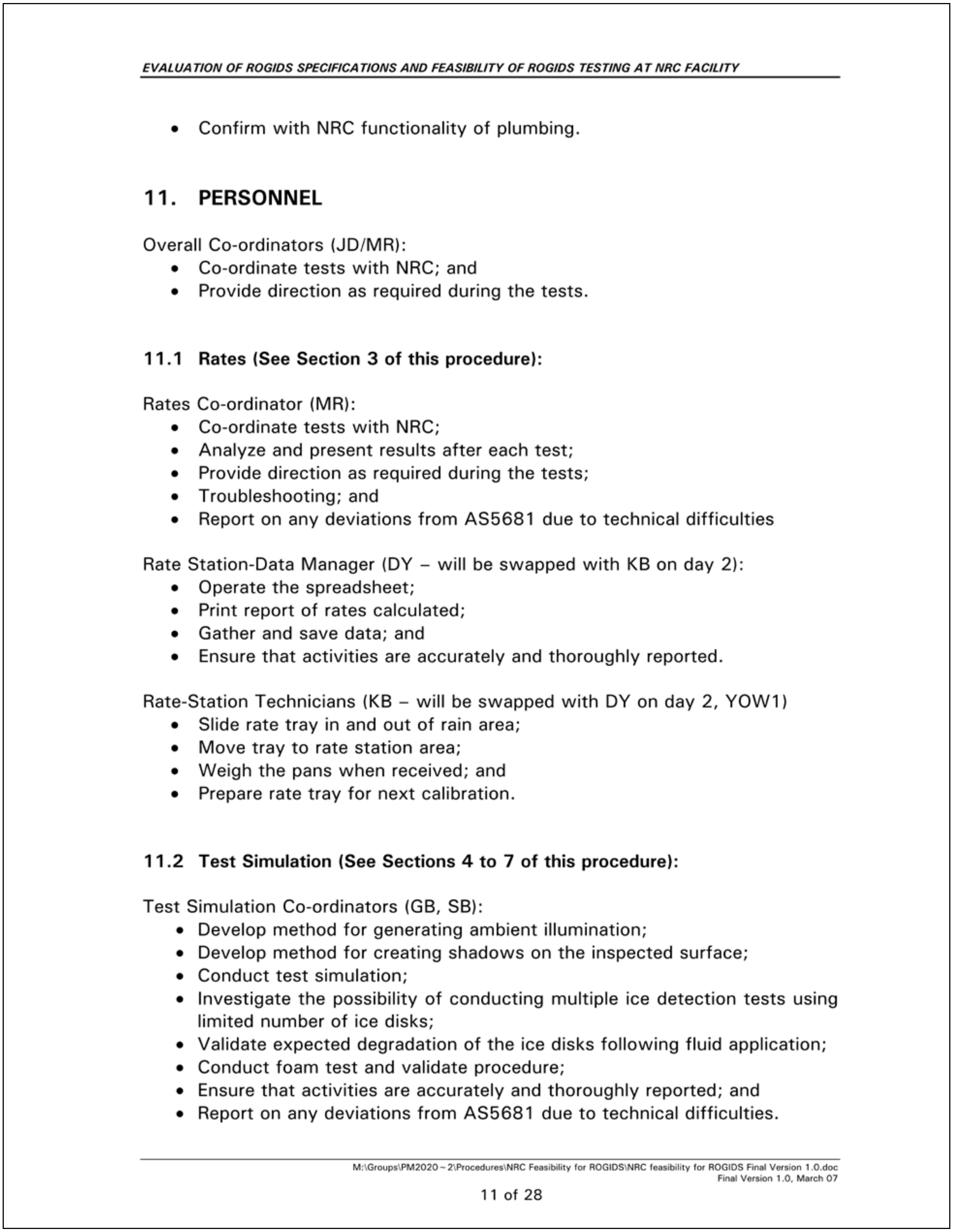
- Plate materials;
- Position of ROGIDS;
- Seeing through "curtains"; and
- Stability of ice at +1°C.

9. EQUIPMENT

- Rate Station;
- Rate Pans (x120) with markings;
- Rate Tray (Billboard or plywood 120cm x 240cm) Qt. 5;
- Rate Station video equipment;
- Spray Nozzles;
- Flow Meter (Alicat Scientific Model LCR-10LPM-O);
- Test Plates (ones for ROGIDS);
- Thickness gauges;
- Illumination sensor and colour sensor;
- Ice Disk Plastic Template;
- Spray Bottles;
- Whatman's Paper & conversion
- Laser distance instrument;
- Horn;
- 3-position Test Stand
- Heat gun
- Laser Pointer
- Brush to spread fluid;
- Foam chemicals;
- Blender;
- Plate material "coupons";
- Clock; and
- Dilution chart for Type I fluid.

10. PRE-TEST TASKS

- Investigate and purchase necessary spray nozzles;
- Investigate and purchase flow meter;
- Purchase Rate pans and boards;
- Rent or purchase photometer; and



- Confirm with NRC functionality of plumbing.

11. PERSONNEL

Overall Co-ordinators (JD/MR):
- Co-ordinate tests with NRC; and
- Provide direction as required during the tests.

11.1 Rates (See Section 3 of this procedure):

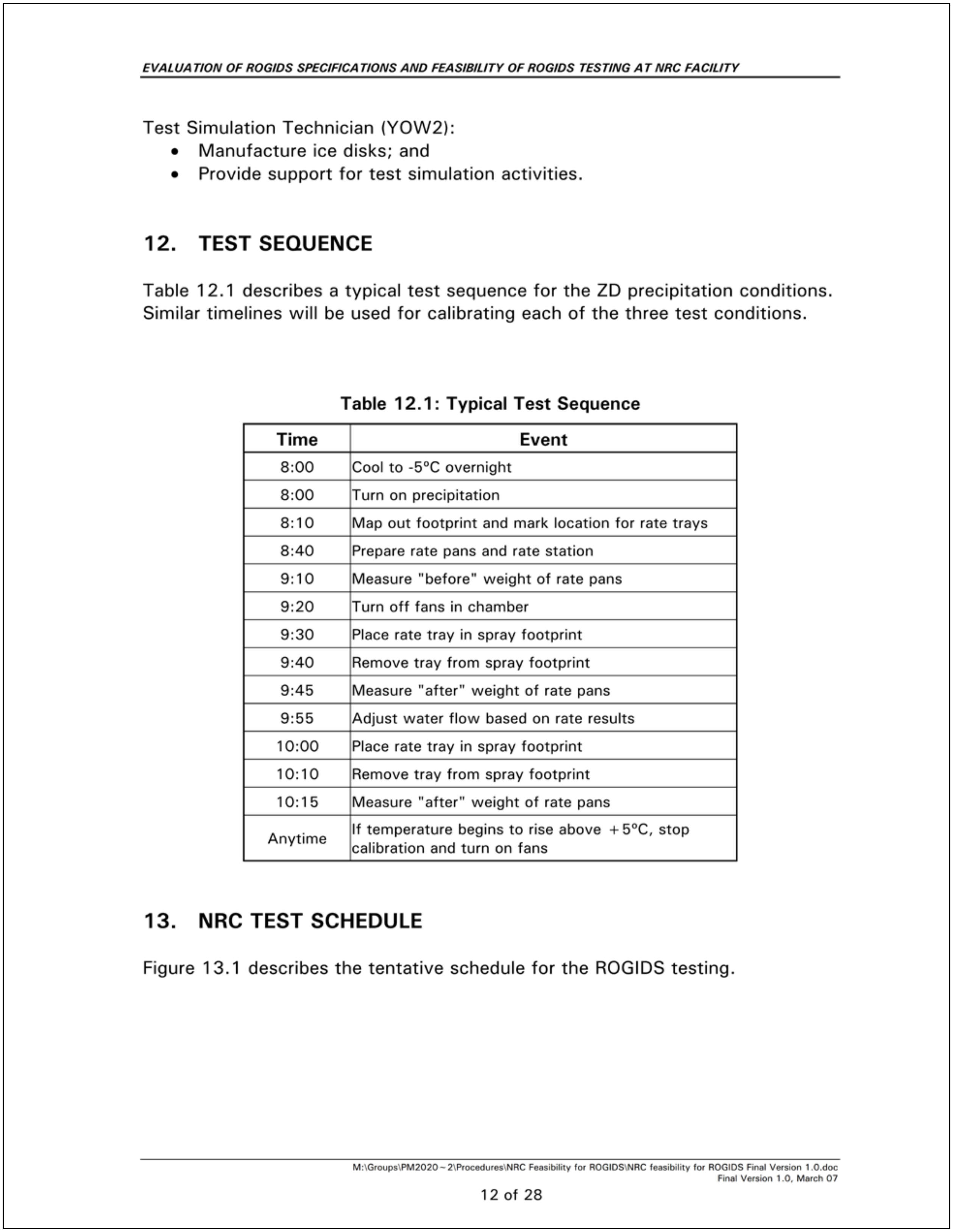
Rates Co-ordinator (MR):
- Co-ordinate tests with NRC;
- Analyze and present results after each test;
- Provide direction as required during the tests;
- Troubleshooting; and
- Report on any deviations from AS5681 due to technical difficulties

Rate Station-Data Manager (DY – will be swapped with KB on day 2):
- Operate the spreadsheet;
- Print report of rates calculated;
- Gather and save data; and
- Ensure that activities are accurately and thoroughly reported.

Rate-Station Technicians (KB – will be swapped with DY on day 2, YOW1)
- Slide rate tray in and out of rain area;
- Move tray to rate station area;
- Weigh the pans when received; and
- Prepare rate tray for next calibration.

11.2 Test Simulation (See Sections 4 to 7 of this procedure):

Test Simulation Co-ordinators (GB, SB):
- Develop method for generating ambient illumination;
- Develop method for creating shadows on the inspected surface;
- Conduct test simulation;
- Investigate the possibility of conducting multiple ice detection tests using limited number of ice disks;
- Validate expected degradation of the ice disks following fluid application;
- Conduct foam test and validate procedure;
- Ensure that activities are accurately and thoroughly reported; and
- Report on any deviations from AS5681 due to technical difficulties.



Test Simulation Technician (YOW2):

- Manufacture ice disks; and
- Provide support for test simulation activities.

12. TEST SEQUENCE

Table 12.1 describes a typical test sequence for the ZD precipitation conditions. Similar timelines will be used for calibrating each of the three test conditions.

Table 12.1: Typical Test Sequence

Time	Event
8:00	Cool to -5ºC overnight
8:00	Turn on precipitation
8:10	Map out footprint and mark location for rate trays
8:40	Prepare rate pans and rate station
9:10	Measure "before" weight of rate pans
9:20	Turn off fans in chamber
9:30	Place rate tray in spray footprint
9:40	Remove tray from spray footprint
9:45	Measure "after" weight of rate pans
9:55	Adjust water flow based on rate results
10:00	Place rate tray in spray footprint
10:10	Remove tray from spray footprint
10:15	Measure "after" weight of rate pans
Anytime	If temperature begins to rise above +5ºC, stop calibration and turn on fans

13. NRC TEST SCHEDULE

Figure 13.1 describes the tentative schedule for the ROGIDS testing.

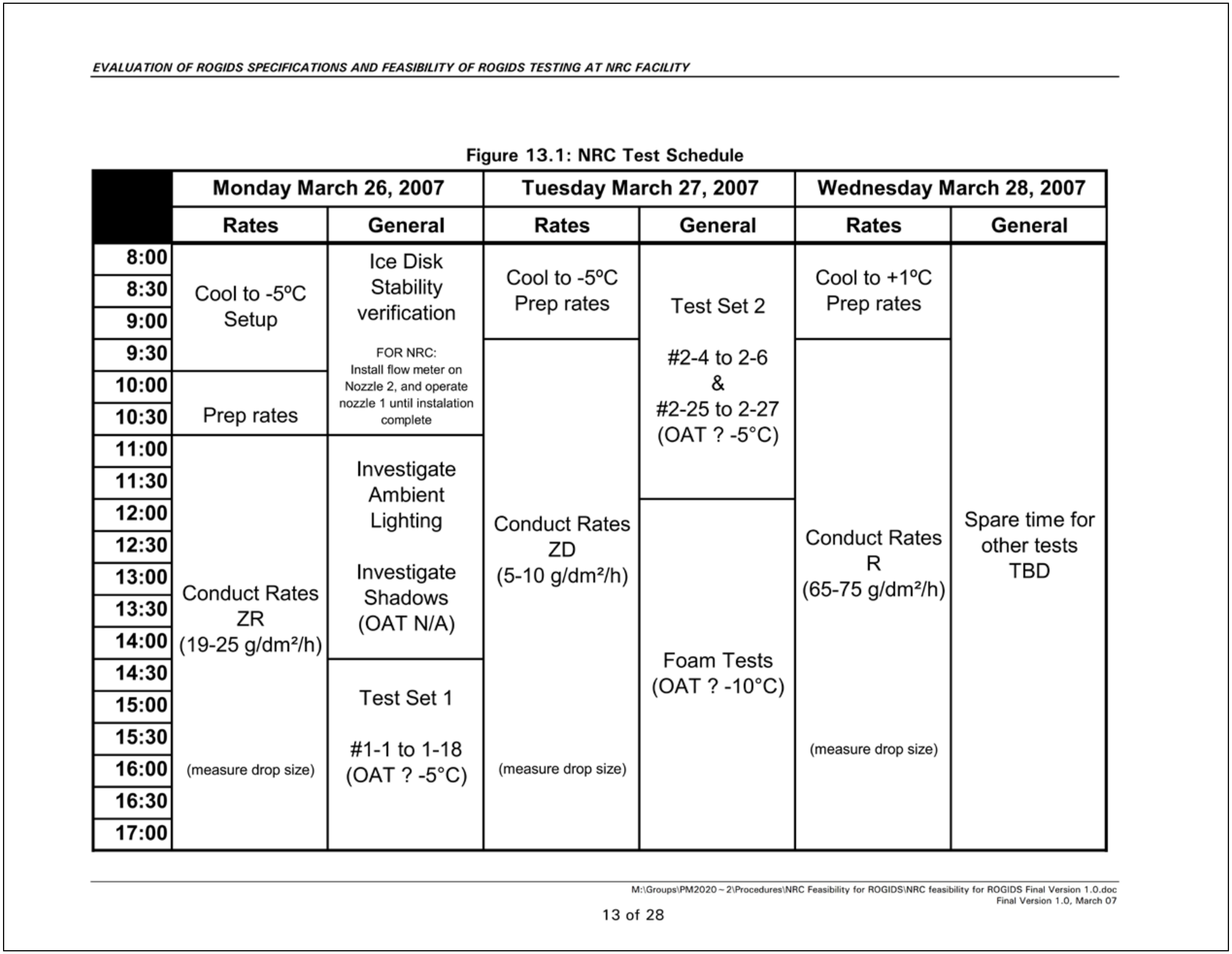


Figure 13.1: NRC Test Schedule

	Monday March 26, 2007		Tuesday March 27, 2007		Wednesday March 28, 2007	
	Rates	**General**	**Rates**	**General**	**Rates**	**General**
8:00	Cool to -5ºC Setup	Ice Disk Stability verification FOR NRC: Install flow meter on Nozzle 2, and operate nozzle 1 until instalation complete	Cool to -5ºC Prep rates	Test Set 2 #2-4 to 2-6 & #2-25 to 2-27 (OAT ? -5°C)	Cool to +1ºC Prep rates	Spare time for other tests TBD
8:30						
9:00						
9:30			Conduct Rates ZD (5-10 g/dm²/h) (measure drop size)		Conduct Rates R (65-75 g/dm²/h) (measure drop size)	
10:00	Prep rates					
10:30						
11:00	Conduct Rates ZR (19-25 g/dm²/h) (measure drop size)	Investigate Ambient Lighting Investigate Shadows (OAT N/A)				
11:30						
12:00				Foam Tests (OAT ? -10°C)		
12:30						
13:00						
13:30						
14:00						
14:30		Test Set 1 #1-1 to 1-18 (OAT ? -5°C)				
15:00						
15:30						
16:00						
16:30						
17:00						

14. DATA FORMS

The following data forms will be used for these tests. Note that many of the data forms were extracted from previous procedures and may not pertain exactly to the procedure used in these tests. The persons responsible to fill in the forms are designated below.

For the "curtain solution" the following data forms are required.

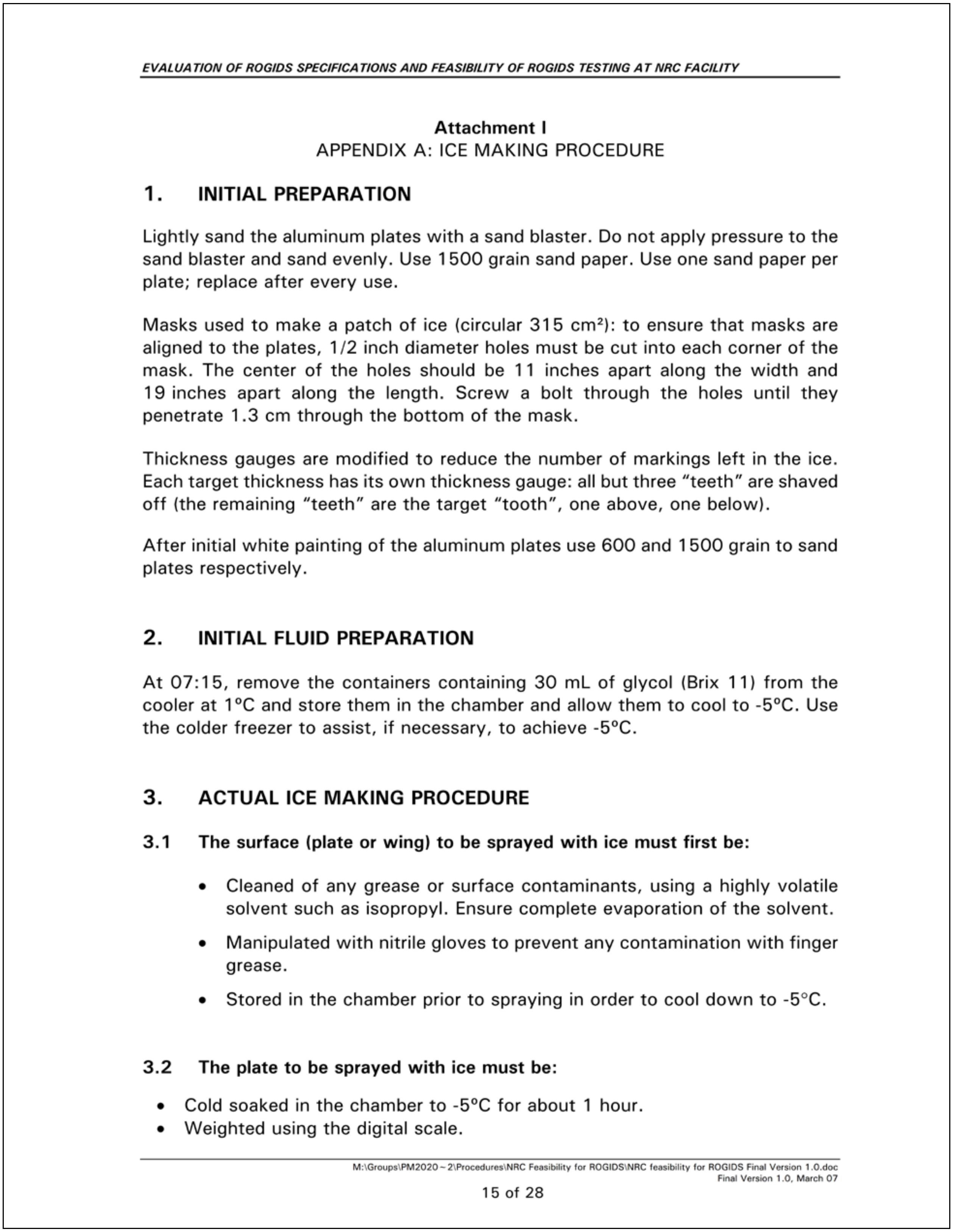
- Attachment III: Spray Calibration Form (KB);
- Attachment IV: General NRC Tests (KB);
- Attachment V: Plan View of NRC Chamber (KB);
- Attachment VI: Physical Location of Nozzles (KB); and
- Attachment VII: Physical Location of Test Equipment (KB).

For general testing the following data forms are required:

- Attachment VIII: Contaminated Surface Treated With Fluid (After Deicing) Form (SB) – *for test set 1, test set 2, and foam test*;
- Attachment IX: Shadows Form (SB); and
- Attachment X: Area Detection and Visibility Tests (Visibility) Form – for test set 3 (SB).

For the camera position tests Attachments IV to VII will be required (SB).

Attachment XI shows the conversion chart of spot diameter to drop diameter.



Attachment I
APPENDIX A: ICE MAKING PROCEDURE

1. INITIAL PREPARATION

Lightly sand the aluminum plates with a sand blaster. Do not apply pressure to the sand blaster and sand evenly. Use 1500 grain sand paper. Use one sand paper per plate; replace after every use.

Masks used to make a patch of ice (circular 315 cm²): to ensure that masks are aligned to the plates, 1/2 inch diameter holes must be cut into each corner of the mask. The center of the holes should be 11 inches apart along the width and 19 inches apart along the length. Screw a bolt through the holes until they penetrate 1.3 cm through the bottom of the mask.

Thickness gauges are modified to reduce the number of markings left in the ice. Each target thickness has its own thickness gauge: all but three “teeth” are shaved off (the remaining “teeth” are the target “tooth”, one above, one below).

After initial white painting of the aluminum plates use 600 and 1500 grain to sand plates respectively.

2. INITIAL FLUID PREPARATION

At 07:15, remove the containers containing 30 mL of glycol (Brix 11) from the cooler at 1ºC and store them in the chamber and allow them to cool to -5ºC. Use the colder freezer to assist, if necessary, to achieve -5ºC.

3. ACTUAL ICE MAKING PROCEDURE

3.1 The surface (plate or wing) to be sprayed with ice must first be:

- Cleaned of any grease or surface contaminants, using a highly volatile solvent such as isopropyl. Ensure complete evaporation of the solvent.
- Manipulated with nitrile gloves to prevent any contamination with finger grease.
- Stored in the chamber prior to spraying in order to cool down to -5°C.

3.2 The plate to be sprayed with ice must be:

- Cold soaked in the chamber to -5ºC for about 1 hour.
- Weighted using the digital scale.

Note 1: A 1/8 inch (3.175 mm) thick aluminum plate needs approximately 30 minutes of cold soaking at -12ºC for it to cool to a temperature of -5ºC.

Note 2: The ice mask must be cold soaked the same way to prevent icicles from forming.

3.3 Adjust the following:

- Spray gun air pressure at 40 psi;
- Open fluid knob 2 full turns;
- Open air knob 66% of its full range in order to have an adequate spray from 10 cm above the mask; and
- Use distilled water at a temperature of 35ºC ± 5ºC.

Note: The temperature of the water within the insulated spray gun container decreases about 7ºC in 40 minutes when in the chamber. Water at 17.5ºC will heat up to approximately 20ºC ± 1ºC in 30 minutes to 1 hour when placed in the heater. Water will continue to heat up 2ºC every 40 minutes.

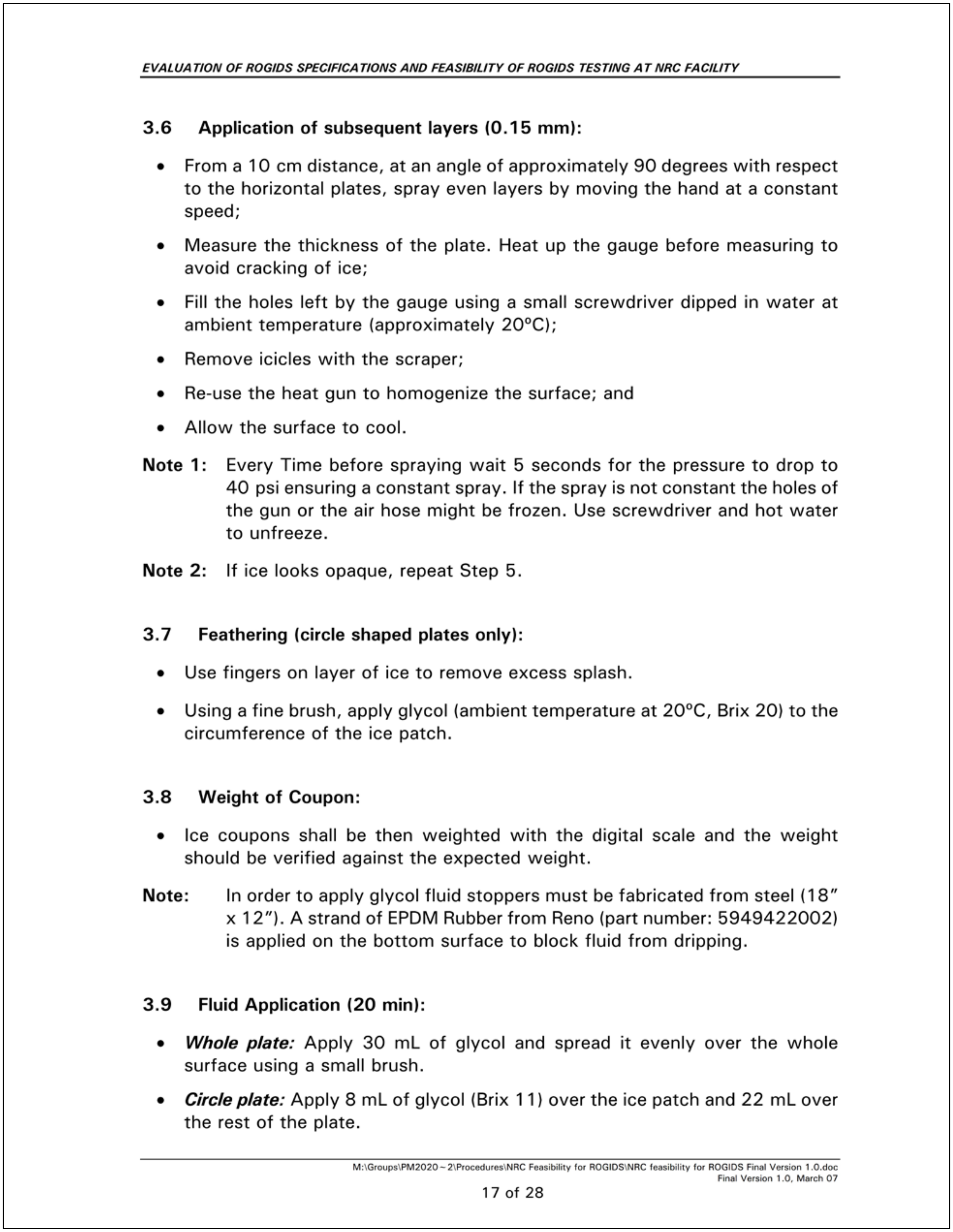
3.4 Spraying the first coats (primer):

- Place the ice mask over the plates that require a circular shape; and
- From a distance of 20 cm with rapid hand movement spray 6 fine coats (0.025 mm). The ice will appear opaque. Make sure the surface in question (circle or full plate) is evenly covered.

Note: Since the ice layers are so fine they will freeze on contact.

3.5 Making the ice clear:

- ***Plain aluminum:*** adjust the heat gun in the High Position (2) and slowly heat the ice until the crystals melt and the ice becomes clear. Allow 2 minutes for the ice to cool before applying other coats.
- ***White aluminum:*** heat the tip of the fingers with the heat gun and then slowly rub the ice until it becomes clear.



3.6 Application of subsequent layers (0.15 mm):

- From a 10 cm distance, at an angle of approximately 90 degrees with respect to the horizontal plates, spray even layers by moving the hand at a constant speed;
- Measure the thickness of the plate. Heat up the gauge before measuring to avoid cracking of ice;
- Fill the holes left by the gauge using a small screwdriver dipped in water at ambient temperature (approximately 20ºC);
- Remove icicles with the scraper;
- Re-use the heat gun to homogenize the surface; and
- Allow the surface to cool.

Note 1: Every Time before spraying wait 5 seconds for the pressure to drop to 40 psi ensuring a constant spray. If the spray is not constant the holes of the gun or the air hose might be frozen. Use screwdriver and hot water to unfreeze.

Note 2: If ice looks opaque, repeat Step 5.

3.7 Feathering (circle shaped plates only):

- Use fingers on layer of ice to remove excess splash.
- Using a fine brush, apply glycol (ambient temperature at 20ºC, Brix 20) to the circumference of the ice patch.

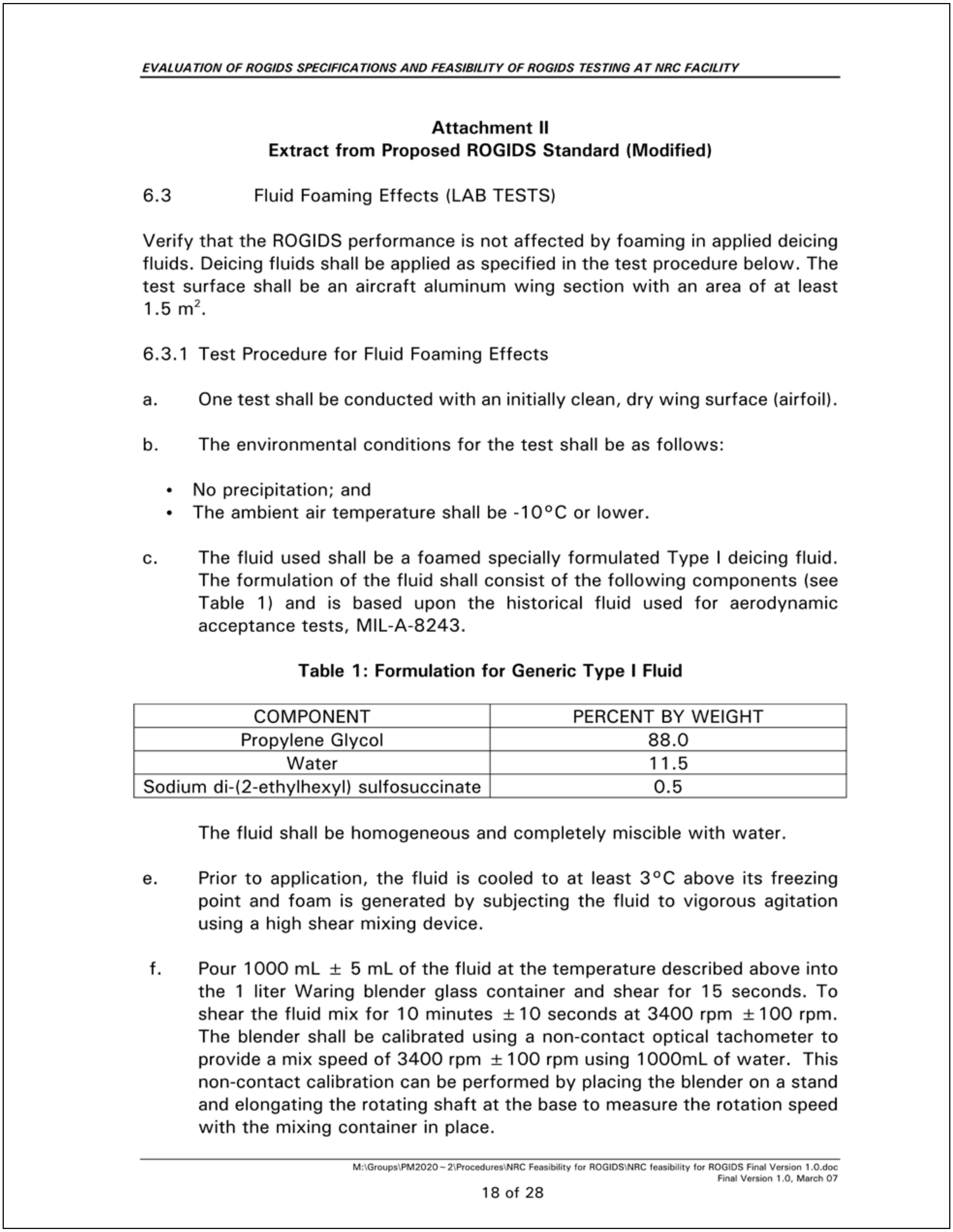
3.8 Weight of Coupon:

- Ice coupons shall be then weighted with the digital scale and the weight should be verified against the expected weight.

Note: In order to apply glycol fluid stoppers must be fabricated from steel (18″ x 12″). A strand of EPDM Rubber from Reno (part number: 5949422002) is applied on the bottom surface to block fluid from dripping.

3.9 Fluid Application (20 min):

- ***Whole plate:*** Apply 30 mL of glycol and spread it evenly over the whole surface using a small brush.
- ***Circle plate:*** Apply 8 mL of glycol (Brix 11) over the ice patch and 22 mL over the rest of the plate.



Attachment II
Extract from Proposed ROGIDS Standard (Modified)

6.3 Fluid Foaming Effects (LAB TESTS)

Verify that the ROGIDS performance is not affected by foaming in applied deicing fluids. Deicing fluids shall be applied as specified in the test procedure below. The test surface shall be an aircraft aluminum wing section with an area of at least 1.5 m^2.

6.3.1 Test Procedure for Fluid Foaming Effects

a. One test shall be conducted with an initially clean, dry wing surface (airfoil).

b. The environmental conditions for the test shall be as follows:

- No precipitation; and
- The ambient air temperature shall be -10°C or lower.

c. The fluid used shall be a foamed specially formulated Type I deicing fluid. The formulation of the fluid shall consist of the following components (see Table 1) and is based upon the historical fluid used for aerodynamic acceptance tests, MIL-A-8243.

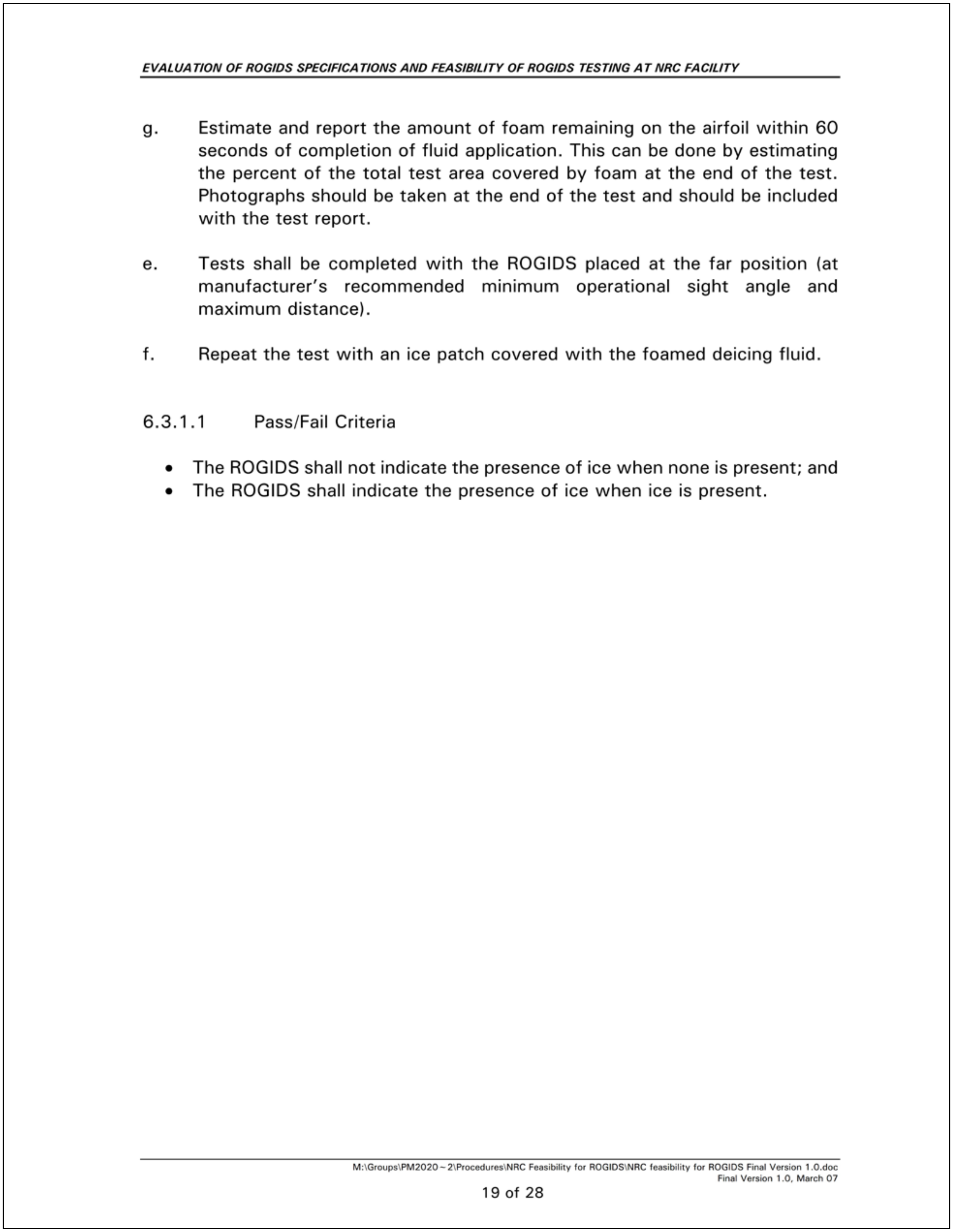
Table 1: Formulation for Generic Type I Fluid

COMPONENT	PERCENT BY WEIGHT
Propylene Glycol	88.0
Water	11.5
Sodium di-(2-ethylhexyl) sulfosuccinate	0.5

The fluid shall be homogeneous and completely miscible with water.

e. Prior to application, the fluid is cooled to at least 3°C above its freezing point and foam is generated by subjecting the fluid to vigorous agitation using a high shear mixing device.

f. Pour 1000 mL ± 5 mL of the fluid at the temperature described above into the 1 liter Waring blender glass container and shear for 15 seconds. To shear the fluid mix for 10 minutes ±10 seconds at 3400 rpm ±100 rpm. The blender shall be calibrated using a non-contact optical tachometer to provide a mix speed of 3400 rpm ±100 rpm using 1000mL of water. This non-contact calibration can be performed by placing the blender on a stand and elongating the rotating shaft at the base to measure the rotation speed with the mixing container in place.



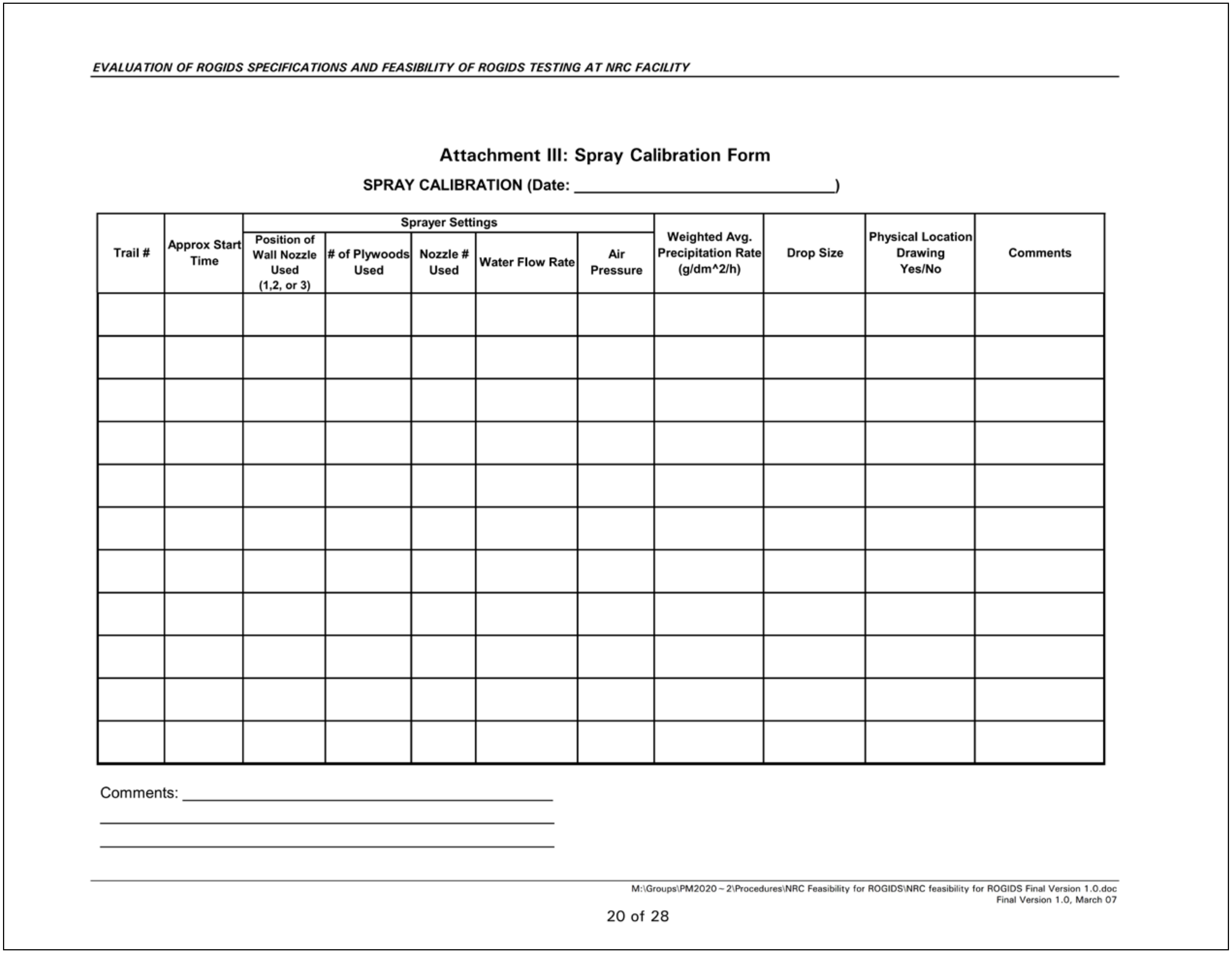
g. Estimate and report the amount of foam remaining on the airfoil within 60 seconds of completion of fluid application. This can be done by estimating the percent of the total test area covered by foam at the end of the test. Photographs should be taken at the end of the test and should be included with the test report.

e. Tests shall be completed with the ROGIDS placed at the far position (at manufacturer's recommended minimum operational sight angle and maximum distance).

f. Repeat the test with an ice patch covered with the foamed deicing fluid.

6.3.1.1 Pass/Fail Criteria

- The ROGIDS shall not indicate the presence of ice when none is present; and
- The ROGIDS shall indicate the presence of ice when ice is present.



Attachment III: Spray Calibration Form

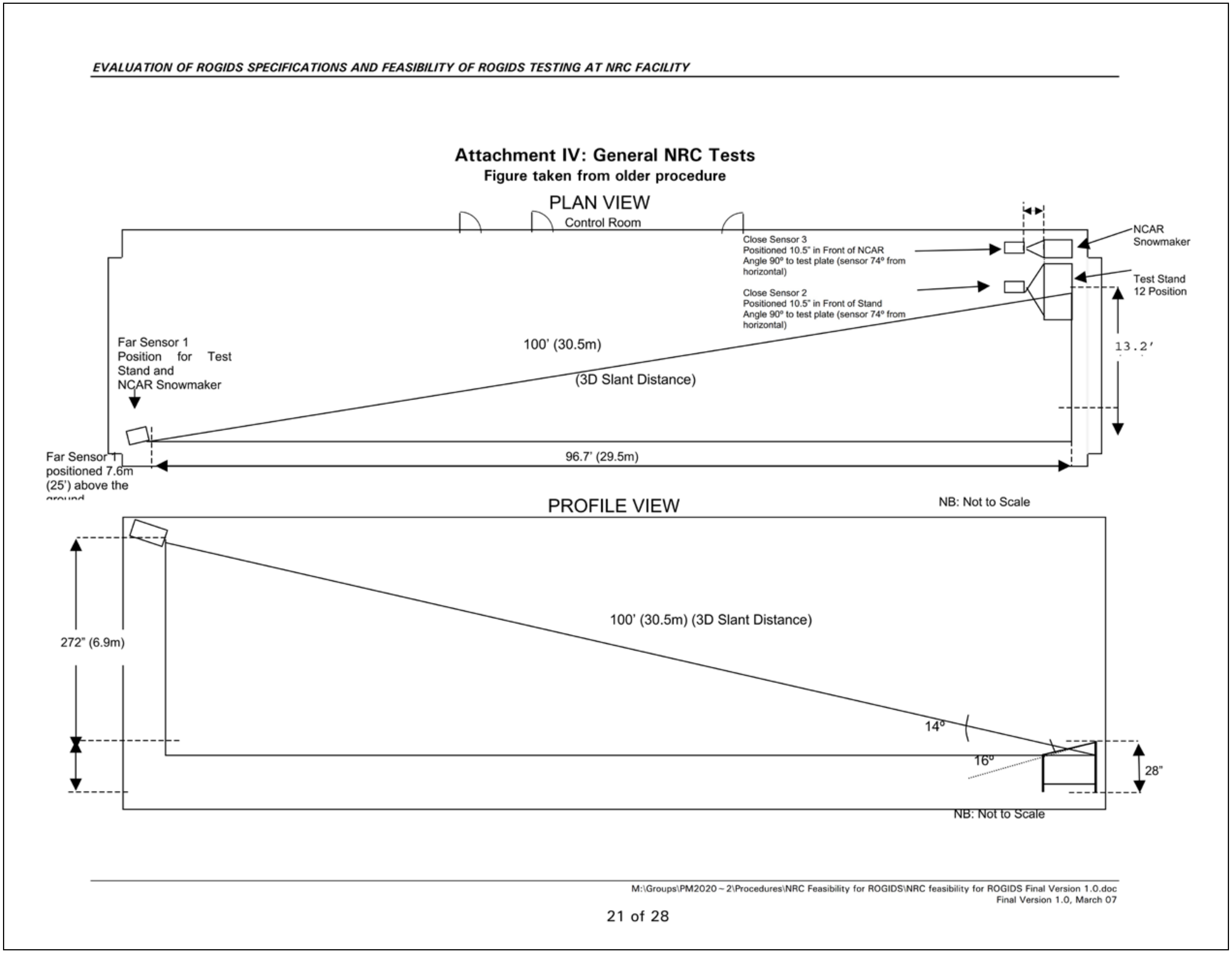
SPRAY CALIBRATION (Date: ______________________________)

Trail #	Approx Start Time	Sprayer Settings					Weighted Avg. Precipitation Rate (g/dm^2/h)	Drop Size	Physical Location Drawing Yes/No	Comments
		Position of Wall Nozzle Used (1,2, or 3)	# of Plywoods Used	Nozzle # Used	Water Flow Rate	Air Pressure				

Comments: ____

____

____



EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY

Attachment IV: General NRC Tests

Figure taken from older procedure

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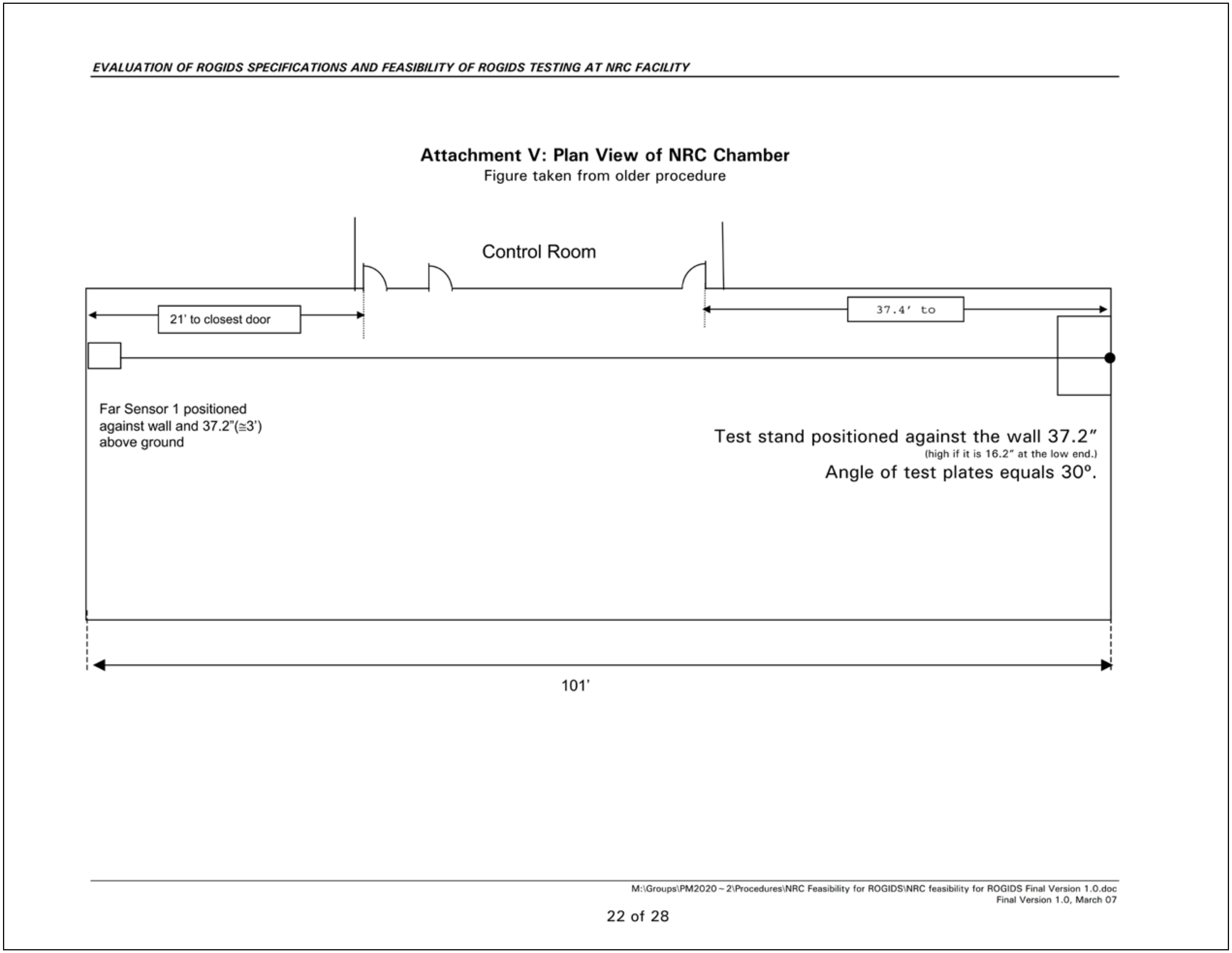

EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY

Attachment V: Plan View of NRC Chamber

Figure taken from older procedure

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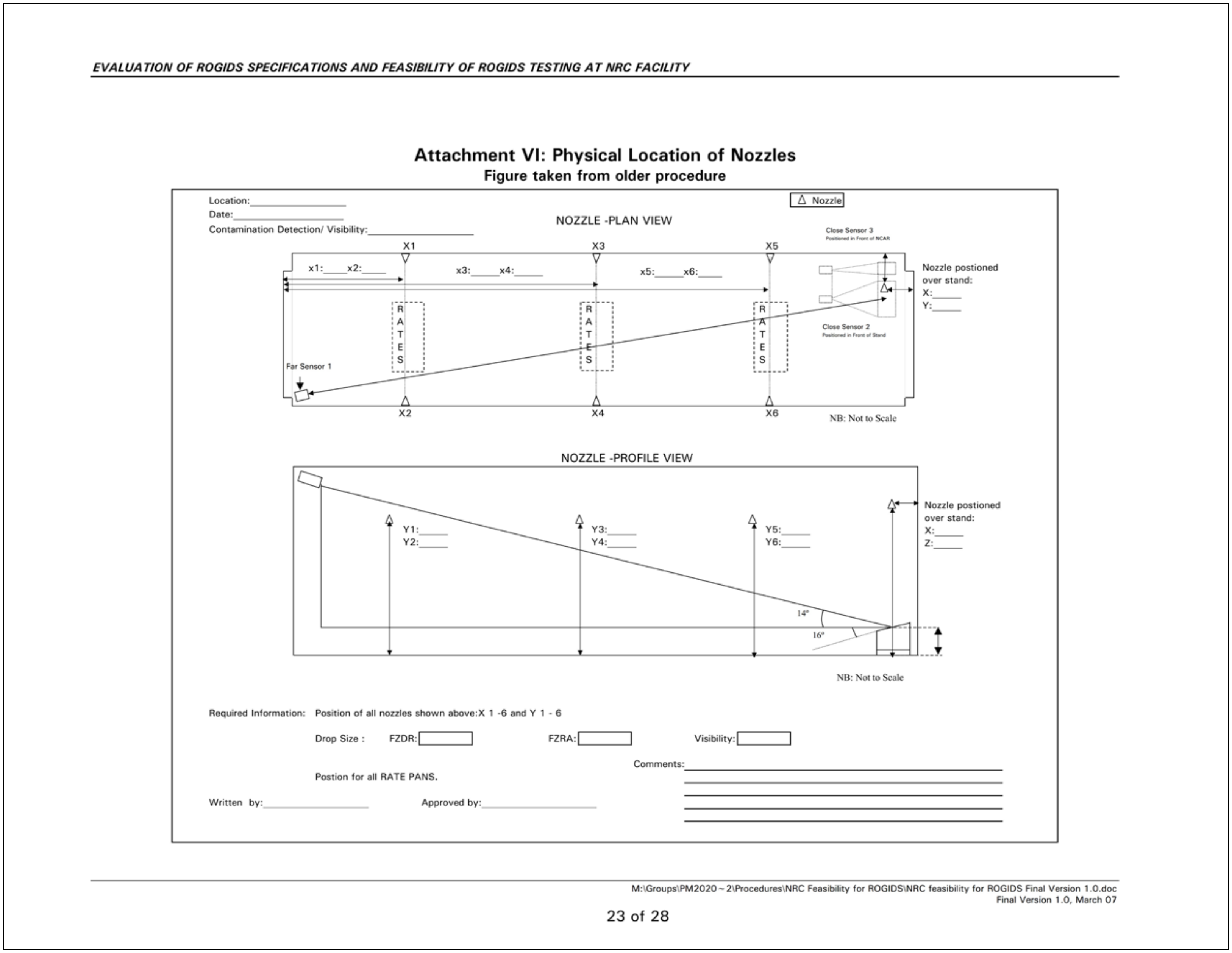


Attachment VI: Physical Location of Nozzles

Figure taken from older procedure

Location:__________________

Date:____________________

Contamination Detection/ Visibility:___________________

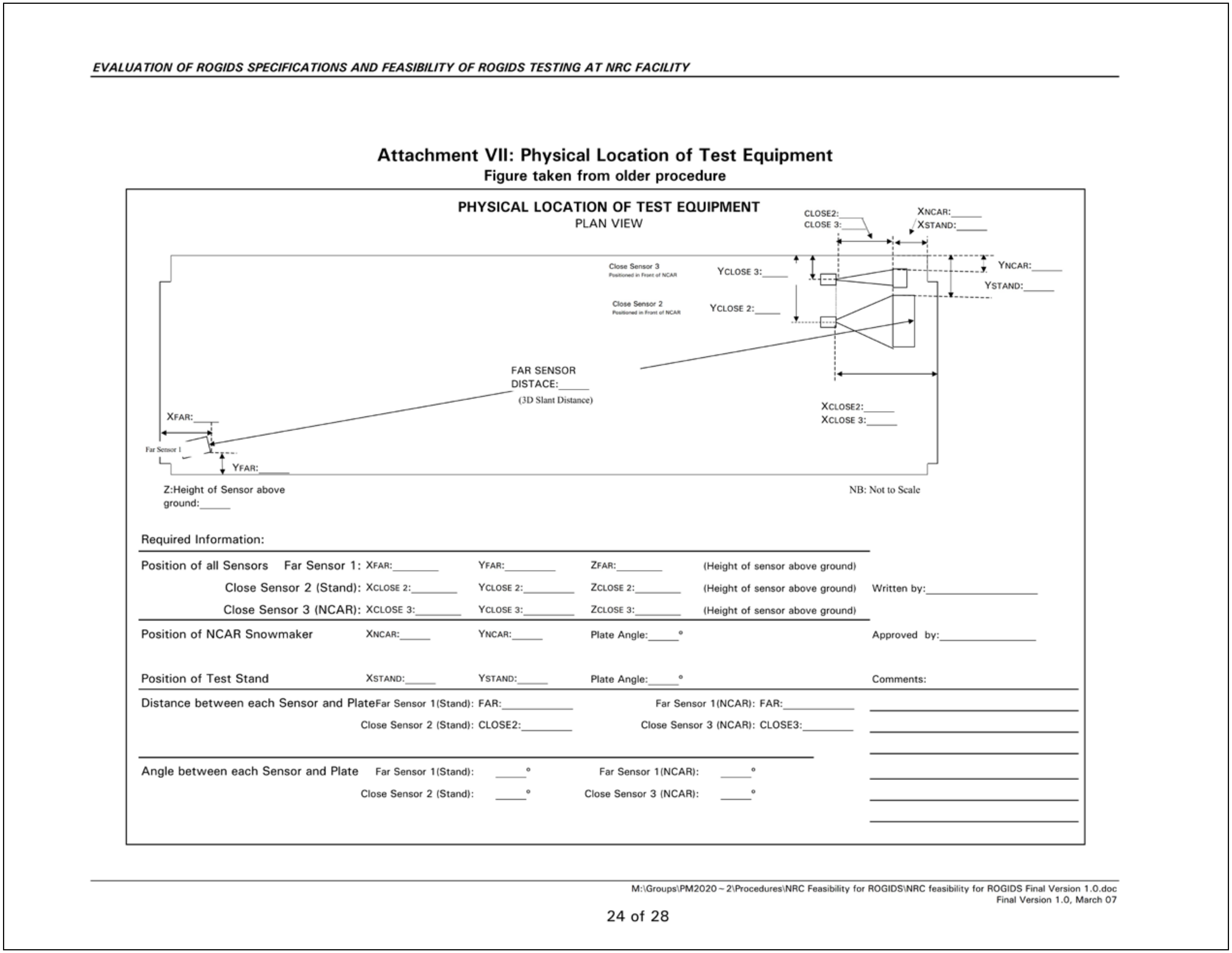
Required Information: Position of all nozzles shown above:X 1 -6 and Y 1 - 6

Drop Size : FZDR: ☐ FZRA: ☐ Visibility: ☐

Comments:______________________________

Postion for all RATE PANS.

Written by:__________________ Approved by:____________________



EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY

Attachment VII: Physical Location of Test Equipment

Figure taken from older procedure

Required Information:

Position of all Sensors Far Sensor 1: XFAR:________ YFAR:_________ ZFAR:________ (Height of sensor above ground)

Close Sensor 2 (Stand): XCLOSE 2:________ YCLOSE 2:_________ ZCLOSE 2:________ (Height of sensor above ground)

Close Sensor 3 (NCAR): XCLOSE 3:________ YCLOSE 3:_________ ZCLOSE 3:________ (Height of sensor above ground)

Written by:__________________

Position of NCAR Snowmaker XNCAR:_____ YNCAR:_____ Plate Angle:_____°

Approved by:________________

Position of Test Stand XSTAND:_____ YSTAND:_____ Plate Angle:_____°

Comments:

Distance between each Sensor and Plate Far Sensor 1(Stand): FAR:____________ Far Sensor 1(NCAR): FAR:____________

Close Sensor 2 (Stand): CLOSE2:_________ Close Sensor 3 (NCAR): CLOSE3:_________

Angle between each Sensor and Plate Far Sensor 1(Stand): _____° Far Sensor 1(NCAR): _____°

Close Sensor 2 (Stand): _____° Close Sensor 3 (NCAR): _____°

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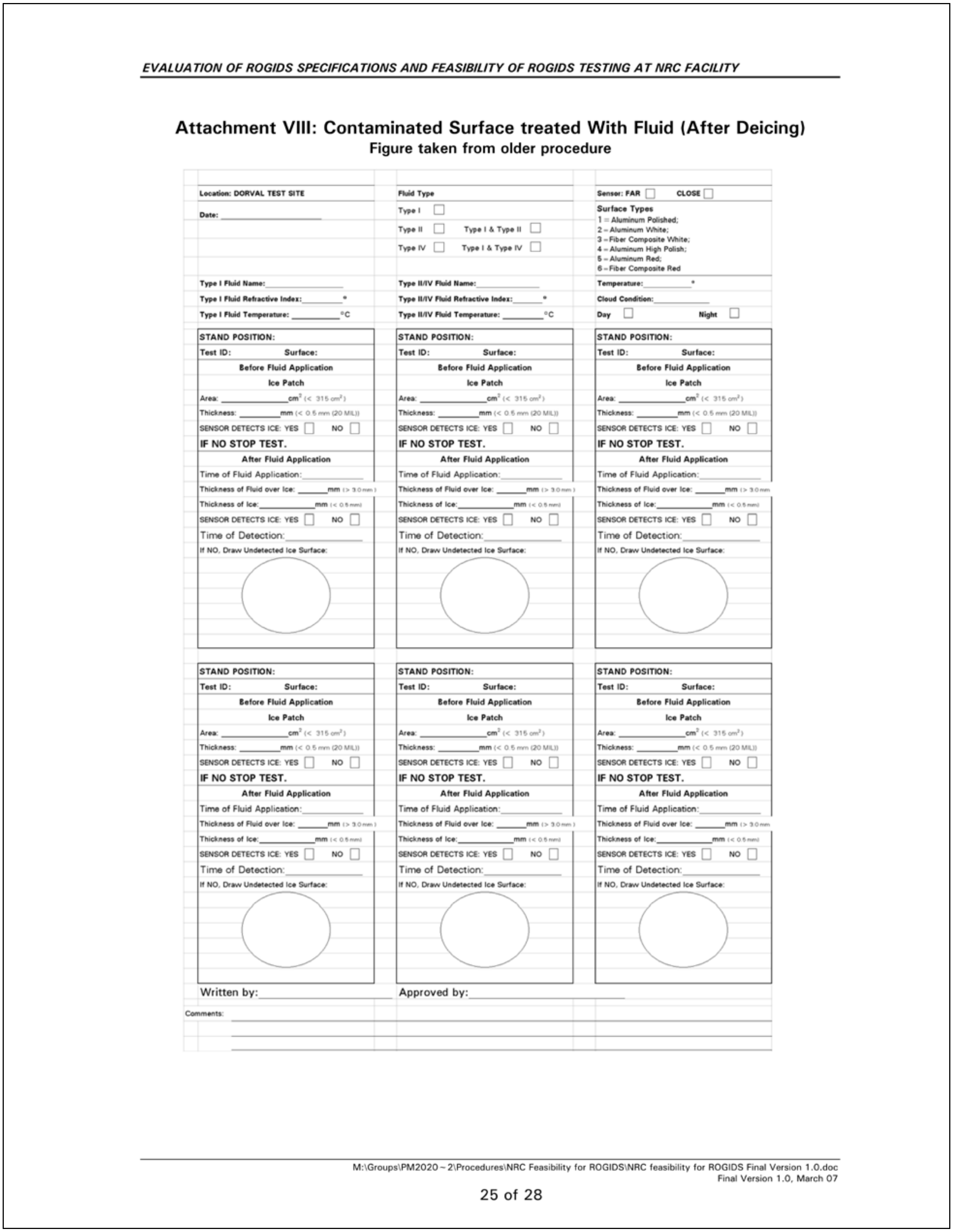

EVALUATION OF ROGIDS SPECIFICATIONS AND FEASIBILITY OF ROGIDS TESTING AT NRC FACILITY

Attachment VIII: Contaminated Surface treated With Fluid (After Deicing)

Figure taken from older procedure

Location: DORVAL TEST SITE	**Fluid Type**	**Sensor: FAR** ☐ **CLOSE** ☐
Date: ____________________	Type I ☐ Type II ☐ Type I & Type II ☐ Type IV ☐ Type I & Type IV ☐	**Surface Types** 1 = Aluminum Polished; 2 – Aluminum White; 3 – Fiber Composite White; 4 – Aluminum High Polish; 5 – Aluminum Red; 6 – Fiber Composite Red
Type I Fluid Name:________________	**Type II/IV Fluid Name:**______________	**Temperature:**__________°
Type I Fluid Refractive Index:________°	**Type II/IV Fluid Refractive Index:**_______°	**Cloud Condition:**____________
Type I Fluid Temperature: __________°C	**Type II/IV Fluid Temperature:** _________°C	**Day** ☐ **Night** ☐

STAND POSITION:	**STAND POSITION:**	**STAND POSITION:**
Test ID: Surface:	**Test ID: Surface:**	**Test ID: Surface:**
Before Fluid Application	**Before Fluid Application**	**Before Fluid Application**
Ice Patch	**Ice Patch**	**Ice Patch**
Area: ______________cm² (< 315 cm²)	Area: ______________cm² (< 315 cm²)	Area: ______________cm² (< 315 cm²)
Thickness: _________mm (< 0.5 mm (20 MIL))	Thickness: _________mm (< 0.5 mm (20 MIL))	Thickness: _________mm (< 0.5 mm (20 MIL))
SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐
IF NO STOP TEST.	**IF NO STOP TEST.**	**IF NO STOP TEST.**
After Fluid Application	**After Fluid Application**	**After Fluid Application**
Time of Fluid Application:____________	Time of Fluid Application:____________	Time of Fluid Application:____________
Thickness of Fluid over Ice: ______mm (> 3.0 mm)	Thickness of Fluid over Ice: ______mm (> 3.0 mm)	Thickness of Fluid over Ice: ______mm (> 3.0 mm
Thickness of Ice:____________mm (< 0.5 mm)	Thickness of Ice:____________mm (< 0.5 mm)	Thickness of Ice:____________mm (< 0.5 mm)
SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐
Time of Detection:______________	Time of Detection:______________	Time of Detection:______________
If NO, Draw Undetected Ice Surface:	If NO, Draw Undetected Ice Surface:	If NO, Draw Undetected Ice Surface:

STAND POSITION:	**STAND POSITION:**	**STAND POSITION:**
Test ID: Surface:	**Test ID: Surface:**	**Test ID: Surface:**
Before Fluid Application	**Before Fluid Application**	**Before Fluid Application**
Ice Patch	**Ice Patch**	**Ice Patch**
Area: ______________cm² (< 315 cm²)	Area: ______________cm² (< 315 cm²)	Area: ______________cm² (< 315 cm²)
Thickness: _________mm (< 0.5 mm (20 MIL))	Thickness: _________mm (< 0.5 mm (20 MIL))	Thickness: _________mm (< 0.5 mm (20 MIL))
SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐
IF NO STOP TEST.	**IF NO STOP TEST.**	**IF NO STOP TEST.**
After Fluid Application	**After Fluid Application**	**After Fluid Application**
Time of Fluid Application:____________	Time of Fluid Application:____________	Time of Fluid Application:____________
Thickness of Fluid over Ice: ______mm (> 3.0 mm)	Thickness of Fluid over Ice: ______mm (> 3.0 mm)	Thickness of Fluid over Ice: ______mm (> 3.0 mm
Thickness of Ice:____________mm (< 0.5 mm)	Thickness of Ice:____________mm (< 0.5 mm)	Thickness of Ice:____________mm (< 0.5 mm)
SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐	SENSOR DETECTS ICE: YES ☐ NO ☐
Time of Detection:______________	Time of Detection:______________	Time of Detection:______________
If NO, Draw Undetected Ice Surface:	If NO, Draw Undetected Ice Surface:	If NO, Draw Undetected Ice Surface:

Written by:______________________ Approved by:________________________

Comments:

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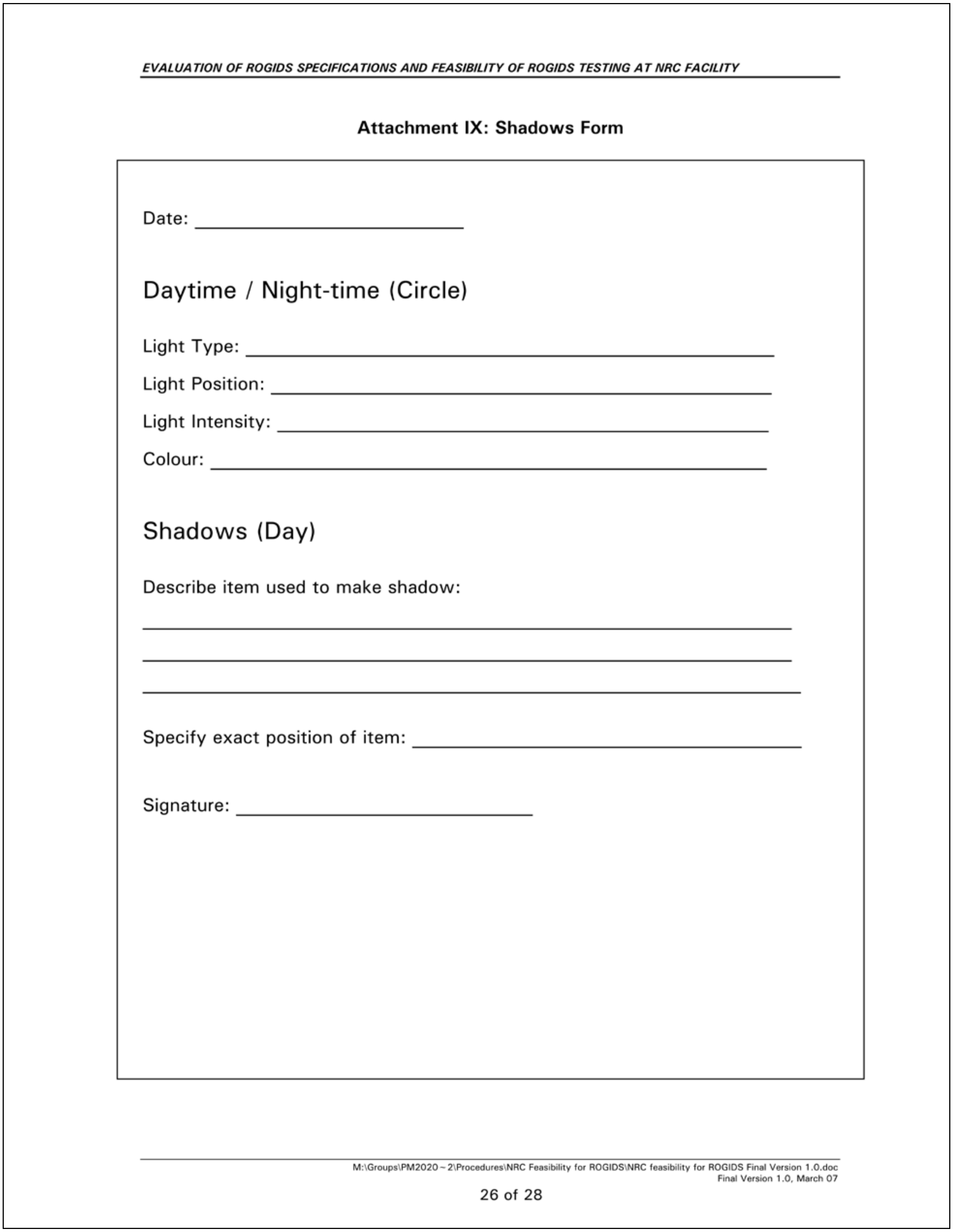


Attachment IX: Shadows Form

Date: ____________________

Daytime / Night-time (Circle)

Light Type: ____

Light Position: ______________________________________

Light Intensity: _____________________________________

Colour: ____

Shadows (Day)

Describe item used to make shadow:

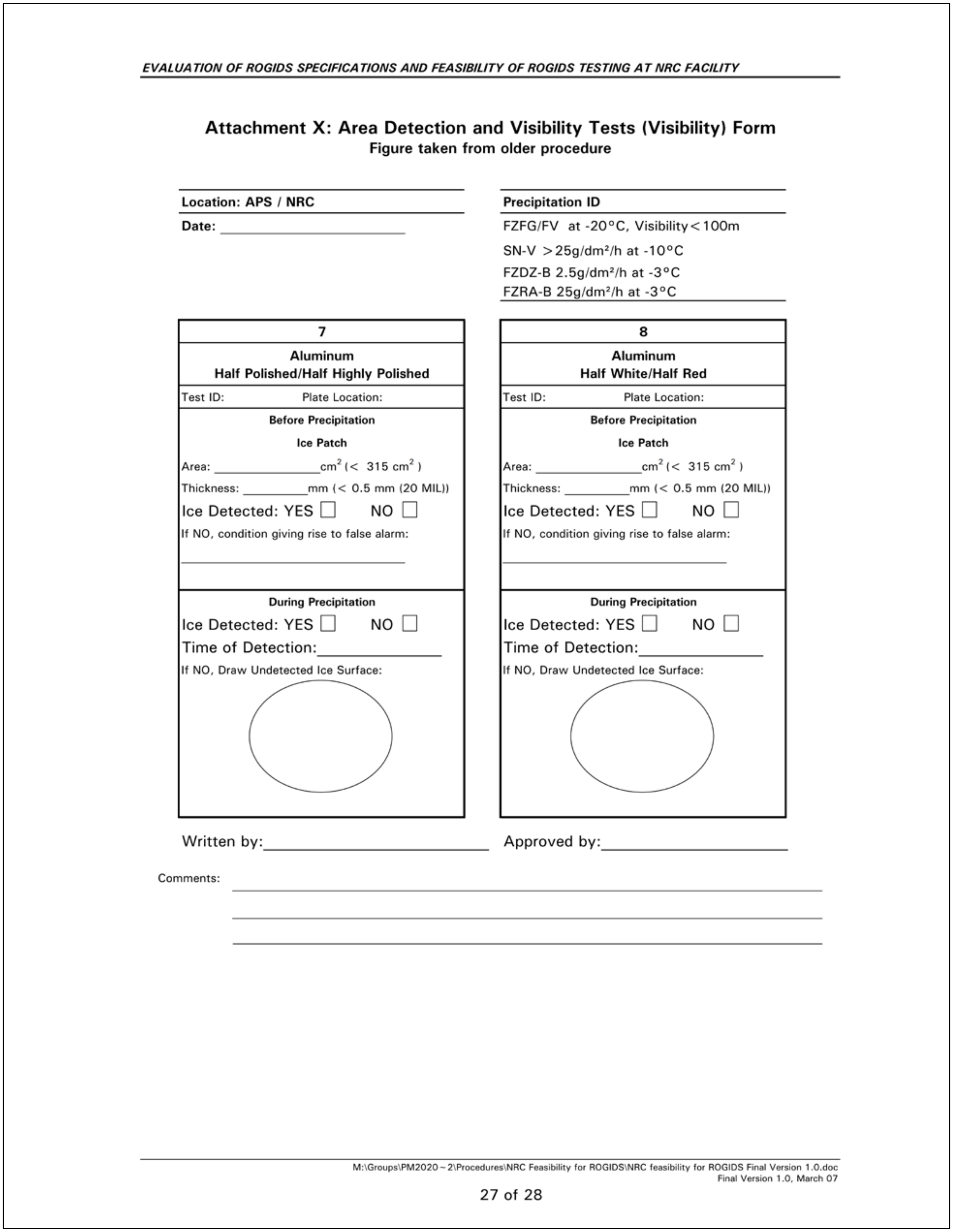
____

____

____

Specify exact position of item: ____________________________

Signature: _______________________



Attachment X: Area Detection and Visibility Tests (Visibility) Form

Figure taken from older procedure

Location: APS / NRC	**Precipitation ID**
Date: ______________________	FZFG/FV at -20°C, Visibility < 100m SN-V > $25g/dm^2/h$ at -10°C FZDZ-B $2.5g/dm^2/h$ at -3°C FZRA-B $25g/dm^2/h$ at -3°C

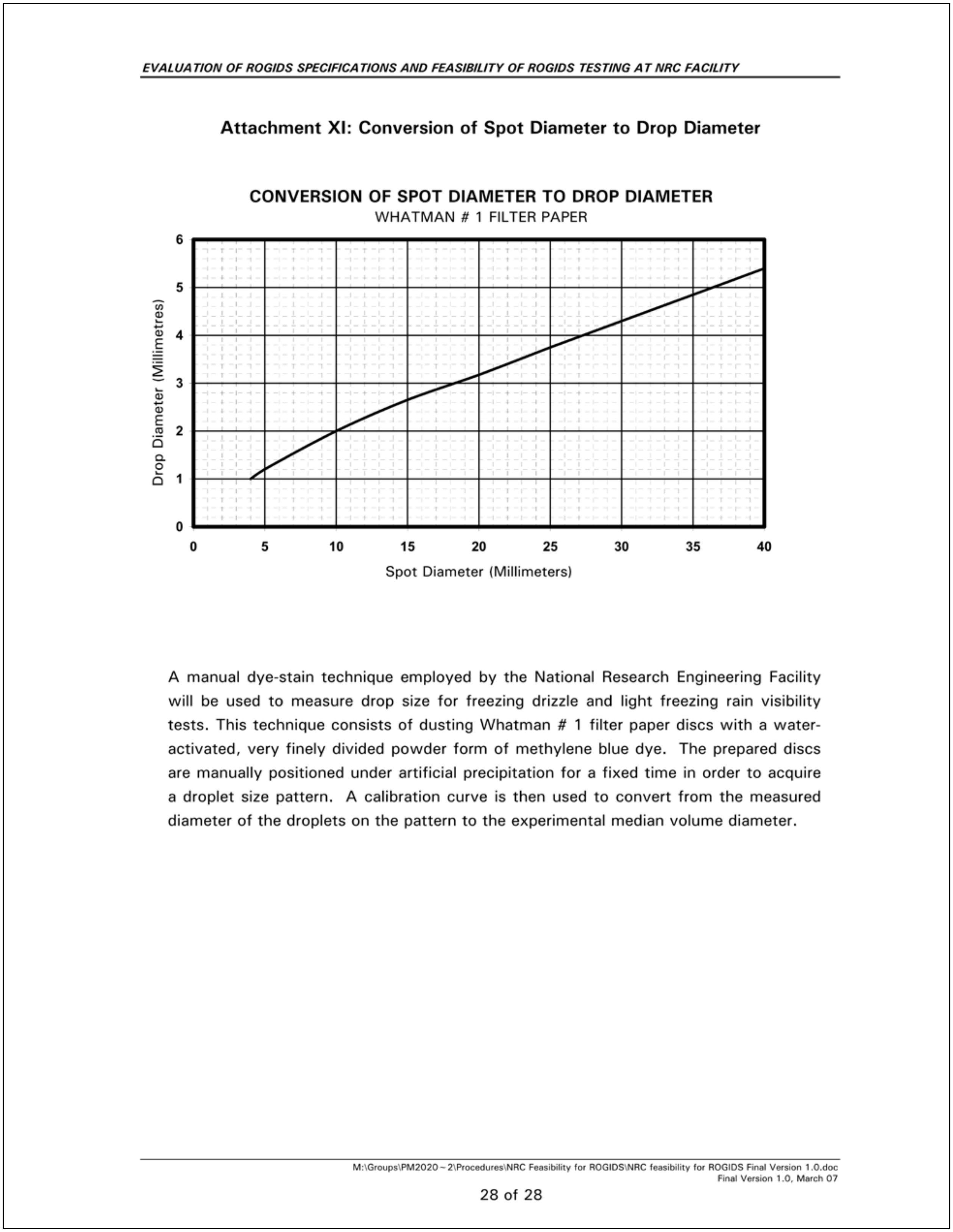
7	**8**
Aluminum **Half Polished/Half Highly Polished**	**Aluminum** **Half White/Half Red**
Test ID: Plate Location:	Test ID: Plate Location:
Before Precipitation **Ice Patch** Area: ______________ cm^2 (< 315 cm^2) Thickness: _________ mm (< 0.5 mm (20 MIL)) Ice Detected: YES ☐ NO ☐ If NO, condition giving rise to false alarm: ___________________________	**Before Precipitation** **Ice Patch** Area: ______________ cm^2 (< 315 cm^2) Thickness: _________ mm (< 0.5 mm (20 MIL)) Ice Detected: YES ☐ NO ☐ If NO, condition giving rise to false alarm: ___________________________
During Precipitation Ice Detected: YES ☐ NO ☐ Time of Detection: ______________ If NO, Draw Undetected Ice Surface:	**During Precipitation** Ice Detected: YES ☐ NO ☐ Time of Detection: ______________ If NO, Draw Undetected Ice Surface:

Written by: ________________________ Approved by: ____________________

Comments: ____

____

____



Attachment XI: Conversion of Spot Diameter to Drop Diameter

A manual dye-stain technique employed by the National Research Engineering Facility will be used to measure drop size for freezing drizzle and light freezing rain visibility tests. This technique consists of dusting Whatman # 1 filter paper discs with a water-activated, very finely divided powder form of methylene blue dye. The prepared discs are manually positioned under artificial precipitation for a fixed time in order to acquire a droplet size pattern. A calibration curve is then used to convert from the measured diameter of the droplets on the pattern to the experimental median volume diameter.

APPENDIX E

SUMMARY OF ROGIDS R&D TESTING

DAILY TEST REPORTS
MARCH 26-28, 2007

Memo

To: John D'Avirro

From: Stephanie Bendickson

Date: March 27, 2007

Re: **Summary of ROGIDS R&D Testing, Day 1**

Objective 1: Test Logistics

The first objective for the ROGIDS R&D testing was to confirm the validity of the procedure for creating ice disks. Specifically, to ensure that the thickness of the ice disks would not degrade within two minutes of application.

Ice disks were developed on standard aluminum test plates inside the cold chamber, which was cooled to approximately -5°C. Hand-held spray bottles were used in place of an air compressor spray gun required in the proposed aerospace standard. This was done to simplify the procedure, and was possible as the quality of the ice was not critical to the outcome of the tests. However, the thickness of the ice was important, and it was carefully measured. The ice disks were made to a thickness of 0.5 mm.

Once ice disks had been created on the test plates, the plates were placed on a test stand levelled to the horizontal. Type I fluid was diluted to a freezing point of -48°C (Brix = 38.5°, approximately 60% fluid/40% water) and supercooled to -40°C. 15 mL of the Type I fluid was measured and poured around the circumference of the ice disk. A paintbrush was used to evenly distribute the fluid over the ice disk and the test plate.

After two minutes, the fluid was removed from the test plate using a clean rag. The thickness of the ice was measured. The thickness was 0.5 mm, and therefore had not changed during the two minutes.

This test confirmed that the ice samples are valid for at least two minutes following application of Type I fluid.

Objective 2: Investigation of Ambient Lighting Conditions

The proposed aerospace standard gives three lighting conditions under which tests must be conducted: daylight, daylight with shadows, and night time. The second objective of the ROGIDS R&D testing was to investigate whether the ambient lighting conditions given in the proposed aerospace standard could be reproduced in the climate chamber. The proposed aerospace standard gives the following illumination and colour specifications:

	Illumination	**Colour**
Daylight	25,000 lux	5,000 to 6,500 K
Night time	100 to 500 lux	2,100 to 3,200 K

The daytime condition was replicated by using a setup of eight 500 watt halogen lights positioned approximately 1 metre above the test stand. This provided lighting on the test plates of 28,000 lux, which was relatively close to the specification value. However, the colour temperature provided by the setup was only 2,700 K, which fell significantly below the specification. Different types of lighting, notably xenon lighting, are believed to be able to provide the appropriate colour temperature. Over the remaining test days, an attempt will be made to obtain xenon lighting and produce the day time conditions using a combination of xenon and halogen lights.

To achieve the shadow condition, a wooden board was positioned above the plates to cast a shadow on one half of each of the plates. This proved that the shadow condition is easily achievable.

The night time condition was easily achieved. The standard lighting in the chamber provided illumination of 140 lux at a colour temperature of 3,500 K.

Memo

To: John D'Avirro

From: Stephanie Bendickson

Date: April 2, 2007

Re: **Summary of ROGIDS R&D Testing, Day 2**

Objective 1: Ice Detection Test Simulation

Tests were conducted on Day 2 to investigate the feasibility of conducting pre-deicing and post-deicing residual clear ice detection tests as described in Appendix A of AS5681.

The purpose of the pre-deicing tests was to illustrate that all 18 tests given in the pre-deicing test set (see AS5681, Table A1) could be conducted within a reasonable time frame. Tests were required to be conducted at both far and near camera distances, on all test surfaces and in each lighting condition (daylight, night-time and shadow). No fluid was required for these tests. It took less than 30 seconds to conduct all 18 tests. This was done by setting up the three test surfaces on one test stand, setting up two simulated cameras (far and near) and then turning the lights off for the night-time condition, on for the daylight condition, and inserting the shadow shield for the shadow condition.

The purpose of the post-deicing tests was to prove that 6 tests could be conducted within the two-minute window that exists for ice disk thickness stability. The tests were meant to simulate testing on all surfaces (painted aluminum plate, painted composite plate and a polished/unpolished aluminum plate), in the night time lighting condition from both near and far camera distances. It took approximately 30 seconds to conduct all 6 tests. For each test, the thickness of the ice patch on each test was measured, fluid was applied to the test plate and a simulated ROGIDS photo was taken. At the end of the test set the thickness of the ice on each test plate was measured. This was all done within 30 seconds, proving that it is feasible to conduct the 6 tests within the two-minute window that was previously established as the time that the ice disk thickness will not degrade following application of Type I fluid.

Objective 2: Investigation of Ambient Lighting Conditions

The investigation into ambient lighting conditions continued on Day 2. Two xenon lighting options were investigated. The first was a kitchen light, which did not produce appropriate light. The second was a xenon car headlight. It produced light at 4000 K, which again, did not meet the specifications.

Finally, a suitable solution for daylight lighting conditions was found. Purchased from a hydroponics store, the metal halide bulb produced the following lighting conditions:

- Light intensity: 28,000 lux (2 feet below bulb);
- Light intensity (with shadow): 1,000 – 2,000 lux; and
- Light colour: 5,870 K.

The specifications of the light are as follows:

- Sylvania Metalarc BT56;
- Metal Halide; and
- ANSI luminance code "S."

Objective 3: Foam Tests

Investigation was made into the suitability of the fluid foaming test included in the proposed ROGIDS standard. The purpose of this test in the standard is to verify that ROGIDS performance is not affected by foaming in applied deicing fluids.

The standard provides the following formulation for the fluid to be used for the foaming test (proportion by percent weight):

- sodium di (2-ethylhexyl) sulfosuccinate (0.5%);
- water (11.5%); and
- propylene glycol (88%).

The formulation is based upon the historical fluid used for aerodynamic acceptance tests, MIL-A-8243.

Two formulations of the surfactant (sodium di-sulfosuccinate) were obtained:

1. Dioctyle Sulfosuccinate Sodium: wax-like consistency; and
2. Diotyl Sulfosuccinate Docusate Sodium: powder consistency.

It was possible to dissolve the first surfactant formulation in water only after being microwaved for three minutes. The second formulation was substantially easier to dissolve; however, significant mixing was required and it was only possible at room temperature (not cooler).

On Day 2 the components were mixed as per the ratio given above and the resulting mixture was placed overnight in a freezer to cool.

Memo

To: John D'Avirro

From: Stephanie Bendickson

Date: April 2, 2007

Re: **Summary of ROGIDS R&D Testing, Day 3**

Objective 1: Foam Test

The objective of Day 3 was to finalize the procedure for conducting the AS5681 foam test.

The initial foam fluid formulation, which was mixed the previous day and cooled to approximately -35°C, was mixed in a blender using the procedure given in the proposed ROGIDS standard (1 L fluid, mixed for 15 seconds in a Waring blender at a speed of 3400 rpm). No foam or bubbles were produced using this formulation at this temperature.

500 mL of F1 was then mixed with 500 mL of water to produce a second formulation, F2. When F2 was mixed in the blender it became foamy. As per the ROGIDS procedure, F2 was applied to a clean, dry wing surface (in this case an airfoil). Some bubbles and foam were visible in the fluid following application.

Following further discussion, it was decided that a reasonable glycol dilution would be one mixed to a fluid freezing point of approximately -40°C. Different formulations were made, including one with 0.5% surfactant, one with 0.25% surfactant, heated applications and cold applications. In the end, it was concluded by the test observers that the fluid formulation and application method that was most suitable for inclusion in AS 5681 was as follows:

- Fluid formulation;
    - sodium di-sulfosuccinate (0.5%); and
    - propylene glycol/distilled water (95%, mixed to a Brix of 36°).
- Fluid heated to 60°C; and
- 2 Litres applied by pouring to a wing surface with an ice patch of approximately 1 mm thickness.

This application was compared with a Type I fluid application and was found to have more foam and bubbles present. The test observers felt this formulation and application method produced a worst-case scenario for a foamy Type I fluid application. These conclusions will be incorporated into AS5681.

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APPENDIX F

EVALUATION OF ICE DISK SAMPLE DECAY FOLLOWING APPLICATION OF DE/ANTI-ICING FLUID
TEST RESULTS

CM2020.002 (05-06)

EVALUATION OF ICE DISK SAMPLE DECAY FOLLWING APPLICATION OF DE/ANTI-ICING FLUID
TEST RESULTS

Fall 2006

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

September 2006
Draft Version 1.0

EVALUATION OF ICE DISK SAMPLE DECAY FOLLOWING APPLICATION OF DE/ANTI-ICING FLUID

TEST RESULTS

September 8, 2006

Table 1: Procedural Time Requirements

Average Time to Create Ice Disk (w/ spray bottle)	7 min.
Average Time To Apply Type I Fluid	17 sec.
Average Time To Apply Type IV Fluid	17 sec.
Average Time To Apply Two Step - Type I and Type IV	36 sec.

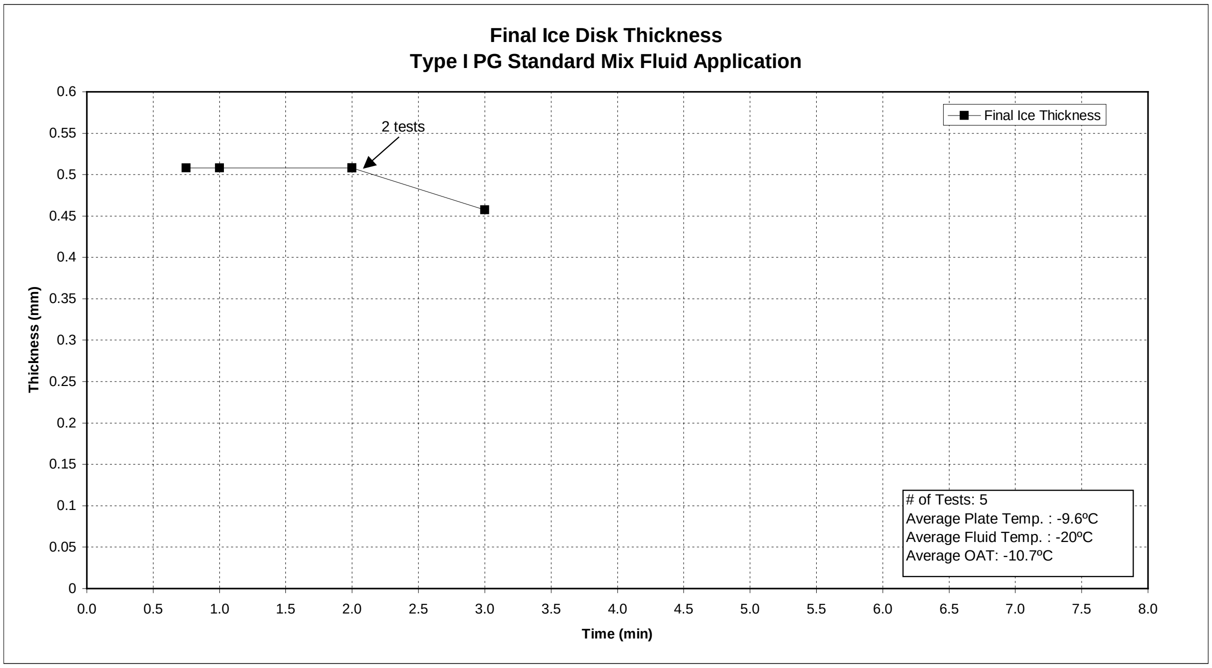


Figure 1: Ice Disk Decay Results Following Type I PG Standard Mix Application

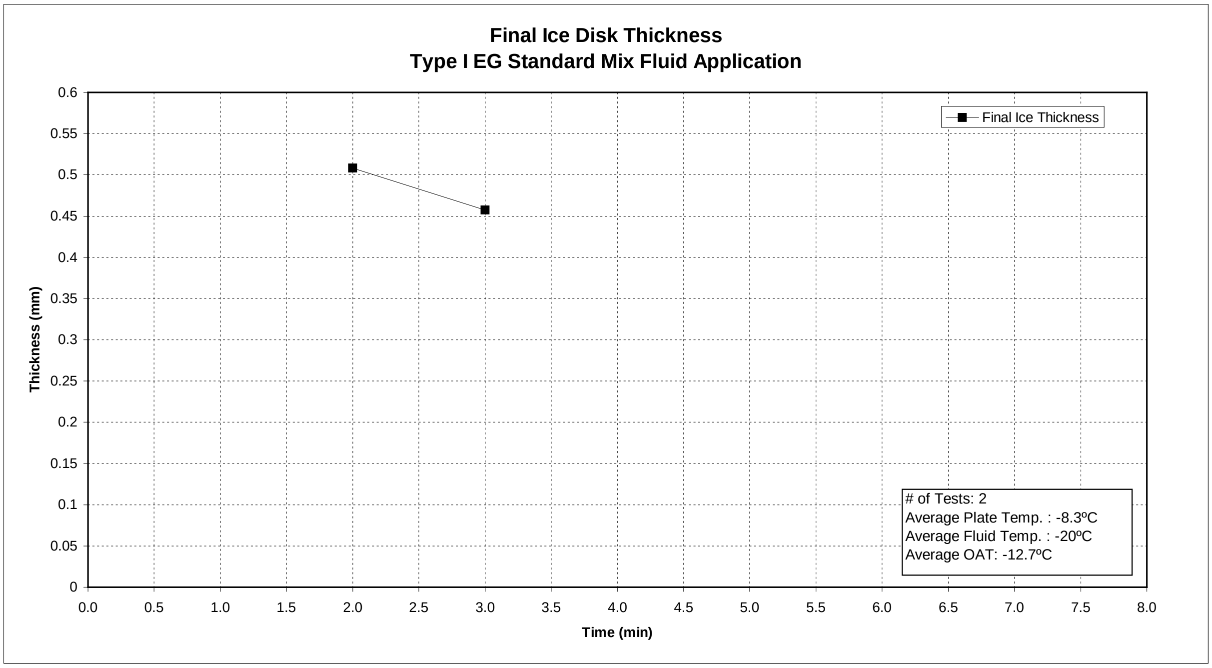


Figure 2: Ice Disk Decay Results Following Type I EG Standard Mix Application

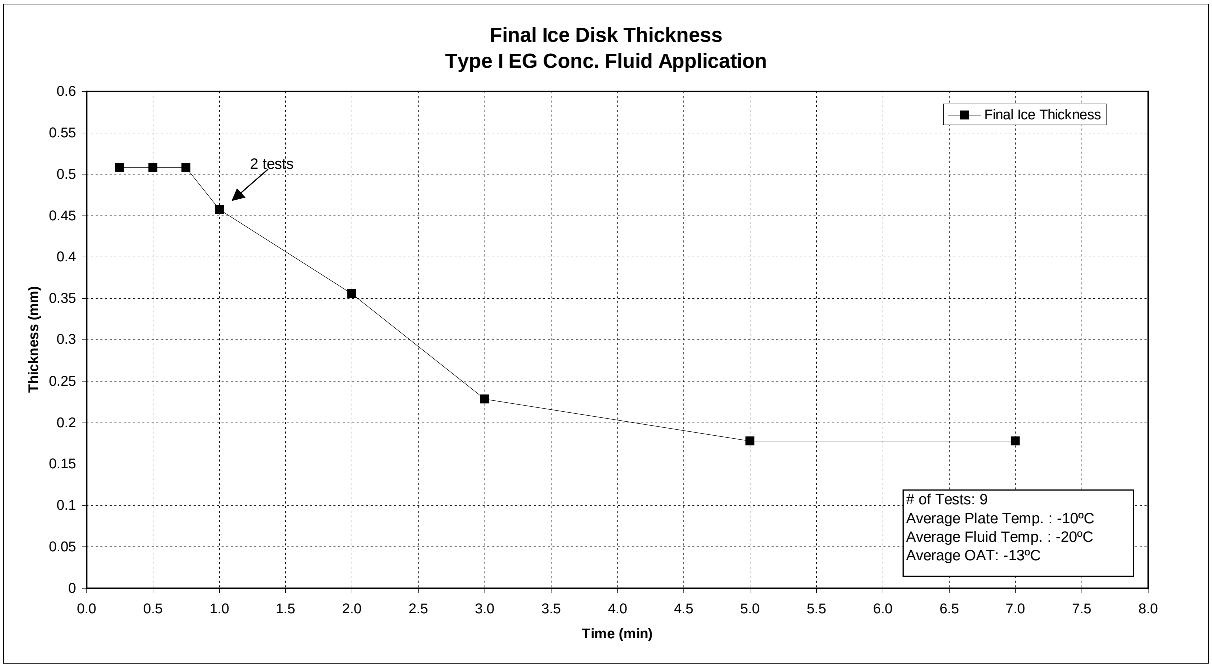


Figure 3: Ice Disk Decay Results Following Type I EG Concentrate Application

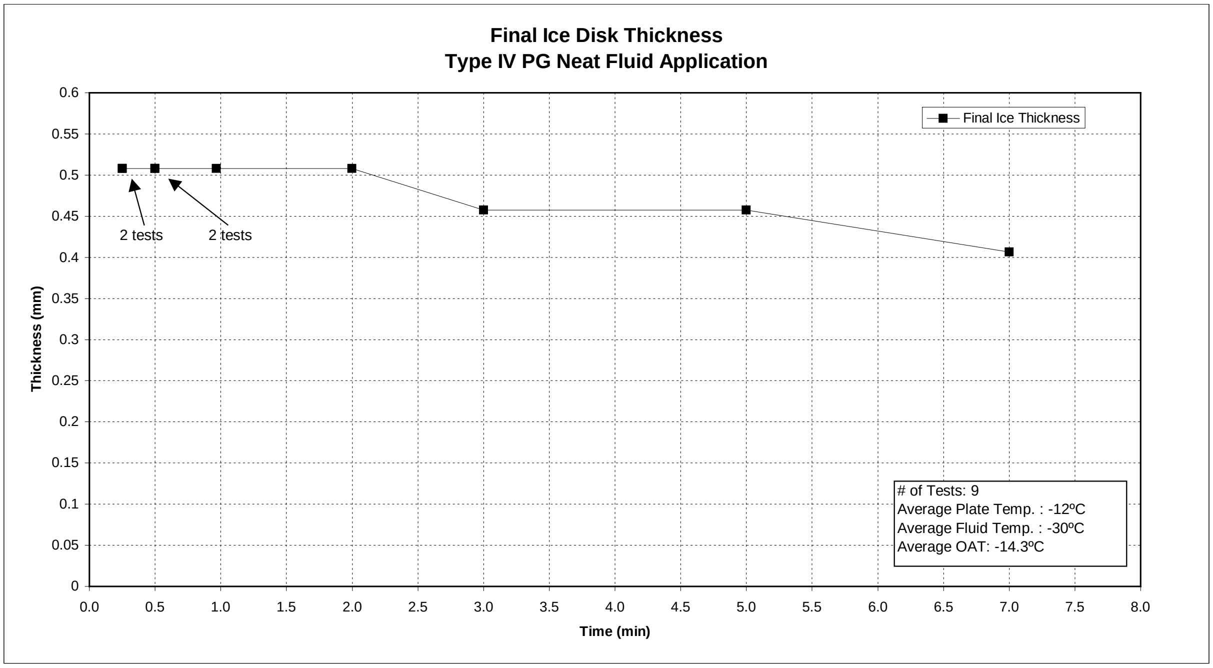


Figure 4: Ice Disk Decay Results Following Type IV PG Neat Application

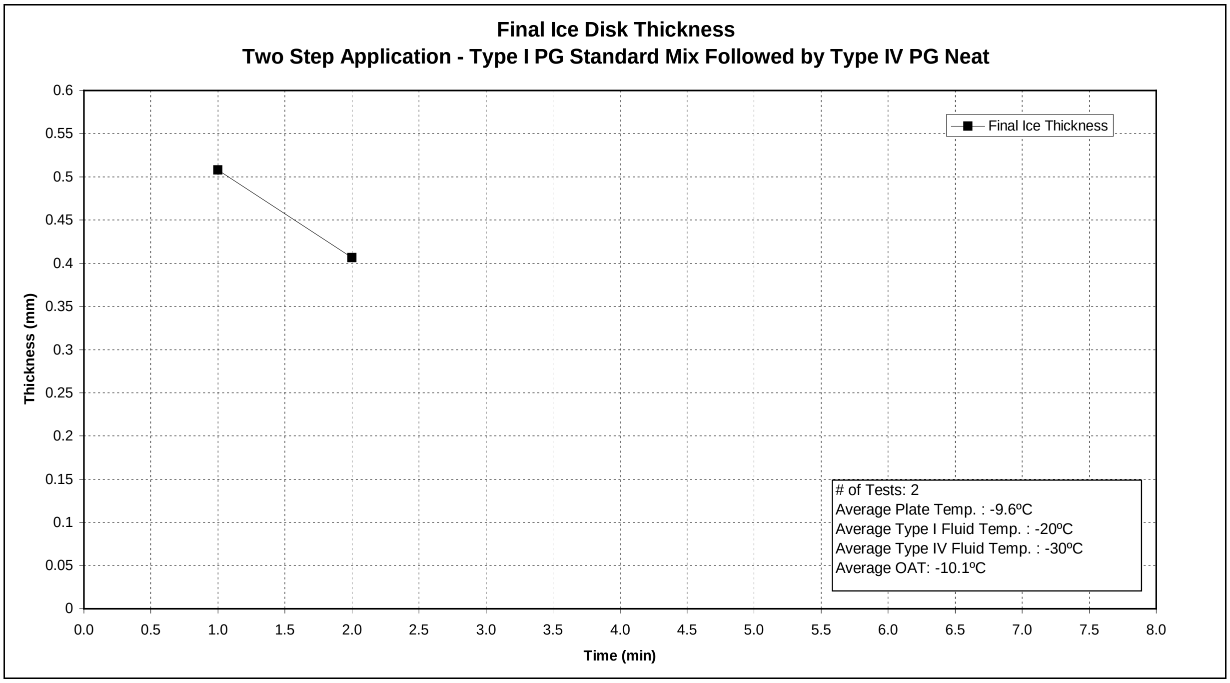


Figure 5: Ice Disk Decay Results Following Two Step Application – Type I PG Std. Mix and Type IV PG Neat Application

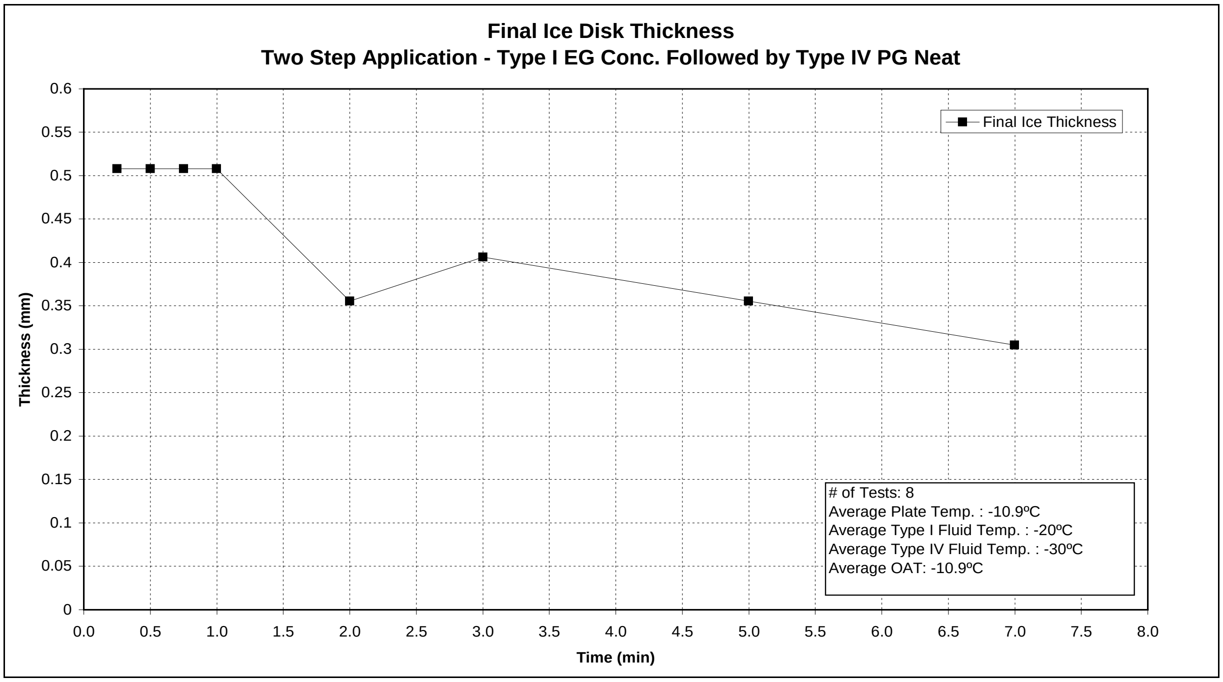


Figure 6: Ice Disk Decay Results Following Two Step Application – Type I EG Con. and Type IV PG Neat Application

APPENDIX G

PRESENTATION
ICE DISK DEGRADATION FOLLOWING DE/ANTI-ICING APPLICATION

ICE DISK DEGREDATION FOLLOWING DE/ANTI-ICING APPLICATION

By

Marco Ruggi

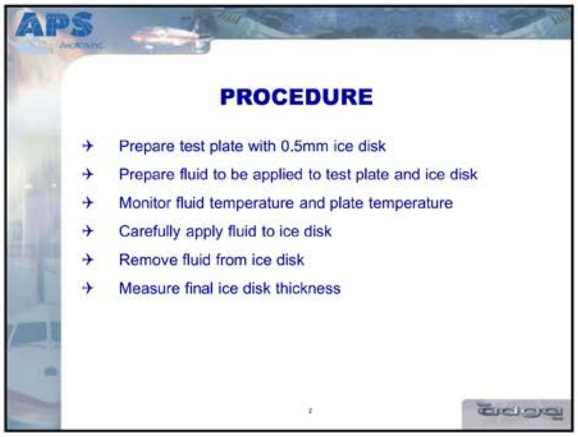
For

Transportation Development Centre
Transport Canada

and the

Federal Aviation Administration

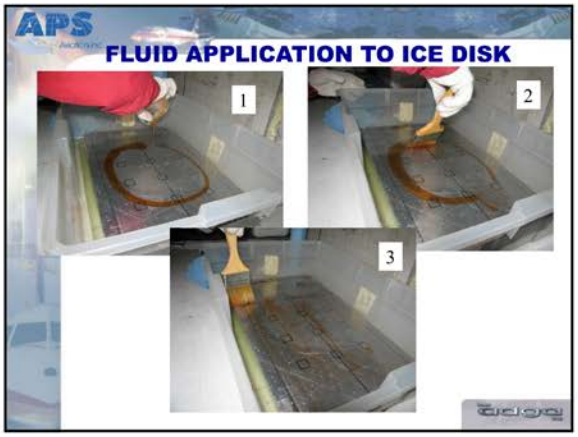
ISO 9001:2000



PROCEDURE

- Prepare test plate with 0.5mm ice disk
- Prepare fluid to be applied to test plate and ice disk
- Monitor fluid temperature and plate temperature
- Carefully apply fluid to ice disk
- Remove fluid from ice disk
- Measure final ice disk thickness

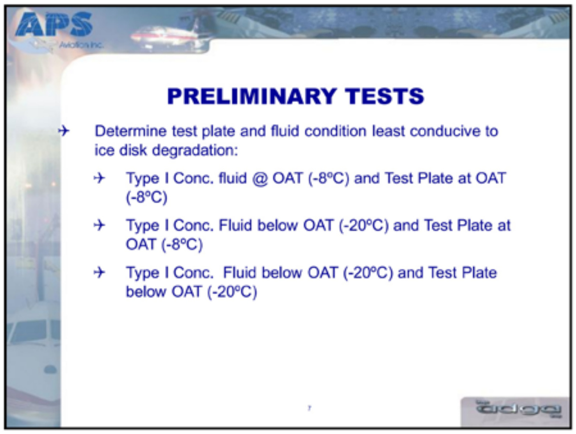
TEST PLATE PREPARED WITH ICE DISK



FLUID APPLICATION TO ICE DISK

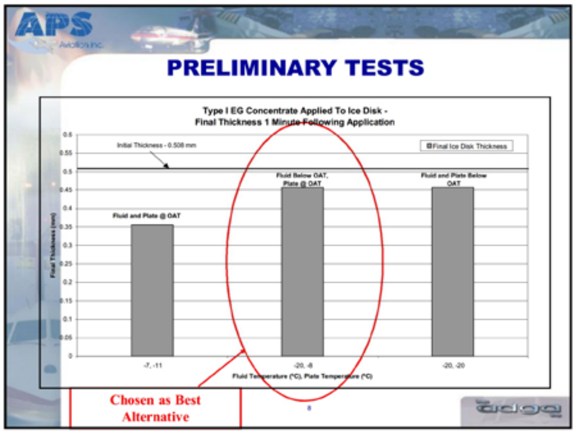
REMOVING FLUID FROM ICE DISK

ICE DISK FINAL THICKNESS MEASURMENT



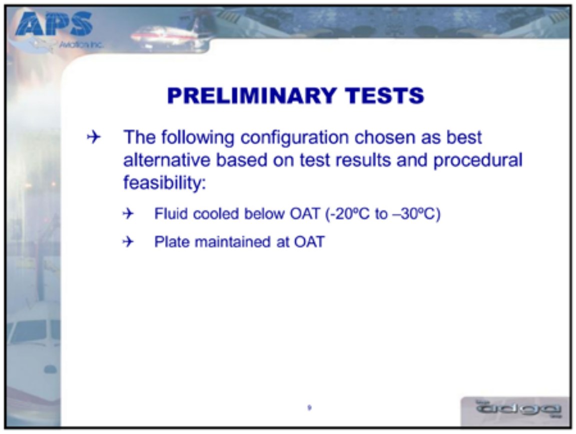
PRELIMINARY TESTS

- Determine test plate and fluid condition least conducive to ice disk degradation:
  - Type I Conc. fluid @ OAT (-8°C) and Test Plate at OAT (-8°C)
  - Type I Conc. Fluid below OAT (-20°C) and Test Plate at OAT (-8°C)
  - Type I Conc. Fluid below OAT (-20°C) and Test Plate below OAT (-20°C)



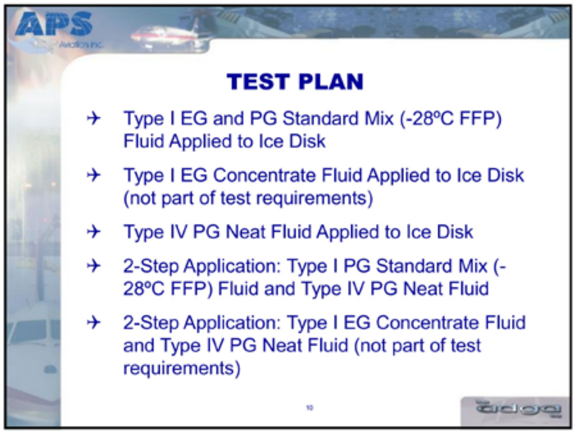
PRELIMINARY TESTS

Chosen as Best Alternative



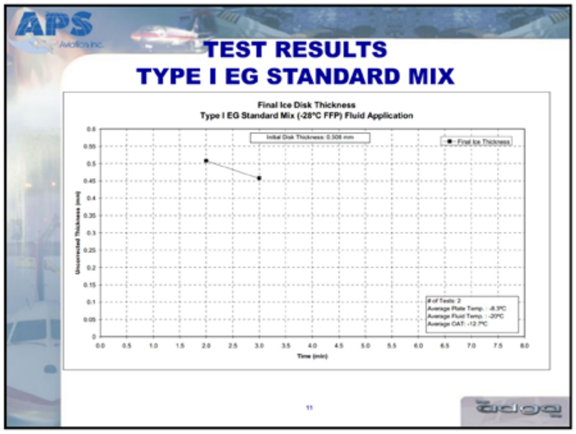
PRELIMINARY TESTS

- The following configuration chosen as best alternative based on test results and procedural feasibility:
  - Fluid cooled below OAT (-20°C to –30°C)
  - Plate maintained at OAT



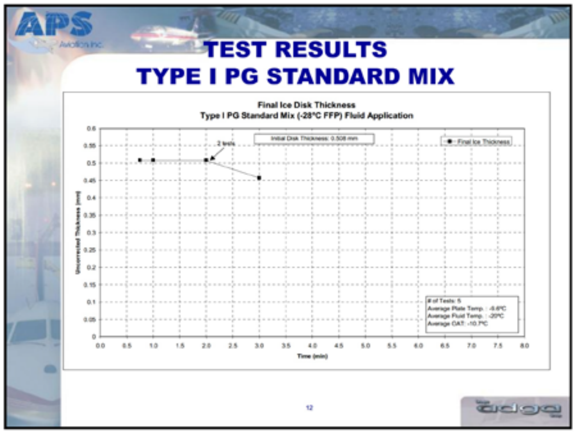
TEST PLAN

- Type I EG and PG Standard Mix (-28°C FFP) Fluid Applied to Ice Disk
- Type I EG Concentrate Fluid Applied to Ice Disk (not part of test requirements)
- Type IV PG Neat Fluid Applied to Ice Disk
- 2-Step Application: Type I PG Standard Mix (-28°C FFP) Fluid and Type IV PG Neat Fluid
- 2-Step Application: Type I EG Concentrate Fluid and Type IV PG Neat Fluid (not part of test requirements)



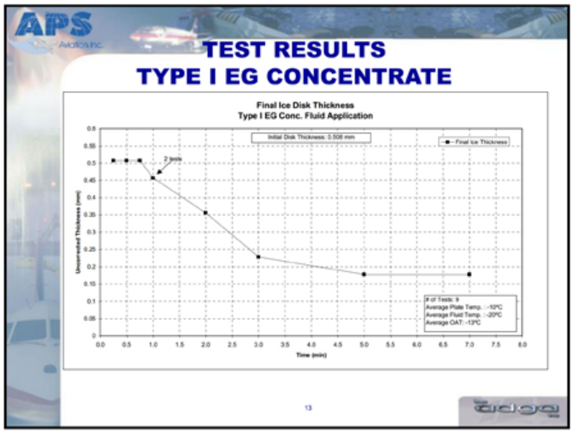
TEST RESULTS
TYPE I EG STANDARD MIX

of Tests: 2
Average Plate Temp.: -8.3°C
Average Fluid Temp.: -20°C
Average OAT: -12.7°C



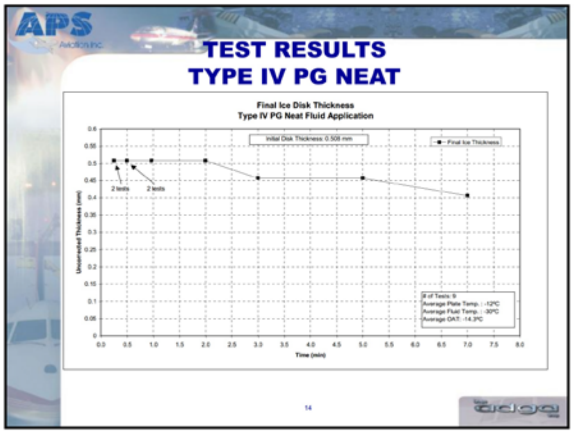
TEST RESULTS
TYPE I PG STANDARD MIX

of Tests: 5
Average Plate Temp.: -8.6°C
Average Fluid Temp.: -20°C
Average OAT: -10.7°C



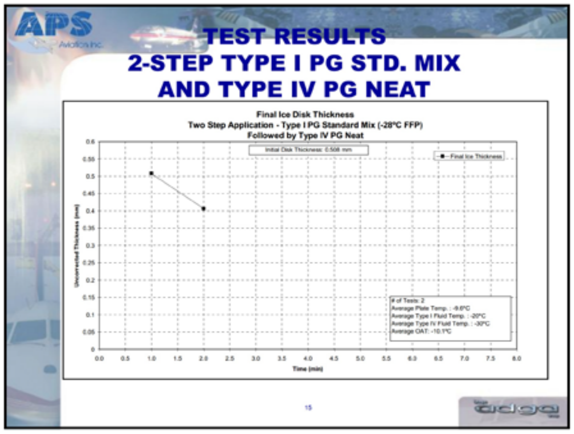
TEST RESULTS
TYPE I EG CONCENTRATE

Final Ice Disk Thickness
Type I EG Conc. Fluid Application



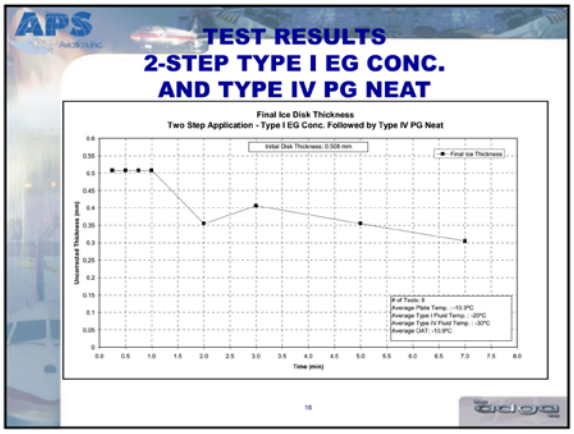
TEST RESULTS
TYPE IV PG NEAT

Final Ice Disk Thickness
Type IV PG Neat Fluid Application



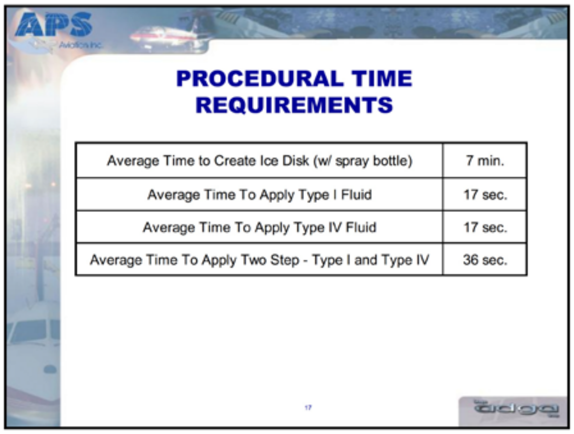
TEST RESULTS
2-STEP TYPE I PG STD. MIX AND TYPE IV PG NEAT

Final Ice Disk Thickness
Two Step Application - Type I PG Standard Mix (-28°C FFP)
Followed by Type IV PG Neat



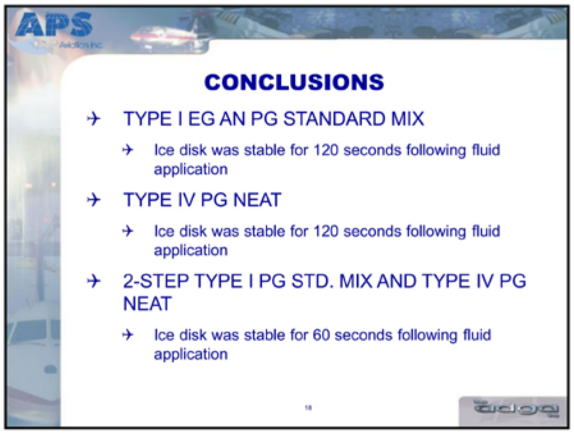
TEST RESULTS
2-STEP TYPE I EG CONC. AND TYPE IV PG NEAT

Final Ice Disk Thickness
Two Step Application - Type I EG Conc. Followed by Type IV PG Neat



PROCEDURAL TIME REQUIREMENTS

Average Time to Create Ice Disk (w/ spray bottle)	7 min.
Average Time To Apply Type I Fluid	17 sec.
Average Time To Apply Type IV Fluid	17 sec.
Average Time To Apply Two Step - Type I and Type IV	36 sec.



CONCLUSIONS

- TYPE I EG AN PG STANDARD MIX
  - Ice disk was stable for 120 seconds following fluid application
- TYPE IV PG NEAT
  - Ice disk was stable for 120 seconds following fluid application
- 2-STEP TYPE I PG STD. MIX AND TYPE IV PG NEAT
  - Ice disk was stable for 60 seconds following fluid application

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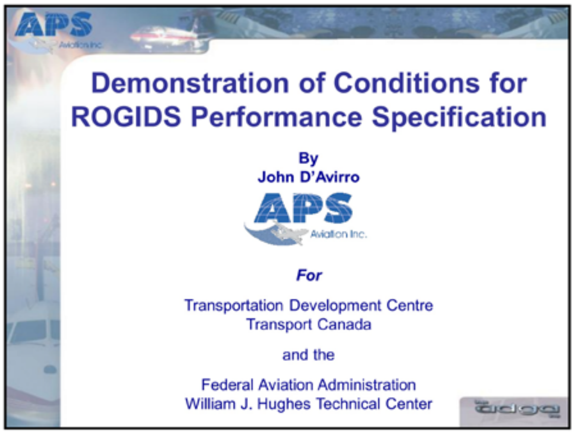
APPENDIX H

PRESENTATION
DEMONSTRATION OF CONDITIONS FOR ROGIDS PERFORMANCE SPECIFICATION



Demonstration of Conditions for ROGIDS Performance Specification

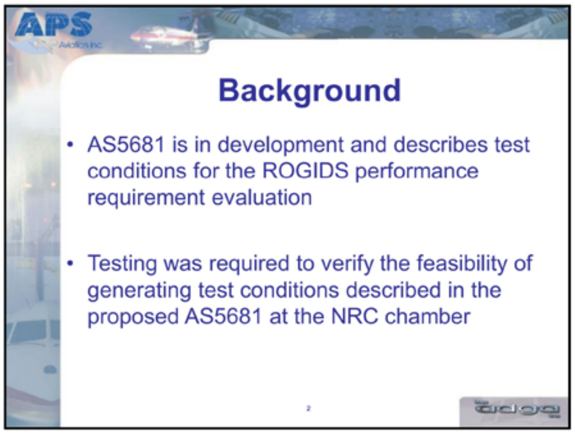
By
John D'Avirro
APS
Aviation Inc.

For

Transportation Development Centre
Transport Canada

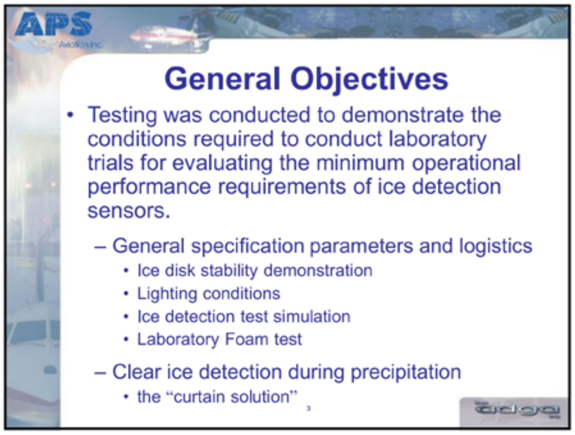
and the

Federal Aviation Administration
William J. Hughes Technical Center



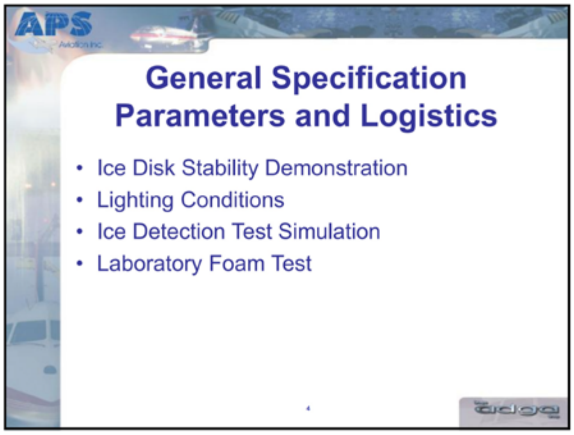
Background

- AS5681 is in development and describes test conditions for the ROGIDS performance requirement evaluation
- Testing was required to verify the feasibility of generating test conditions described in the proposed AS5681 at the NRC chamber



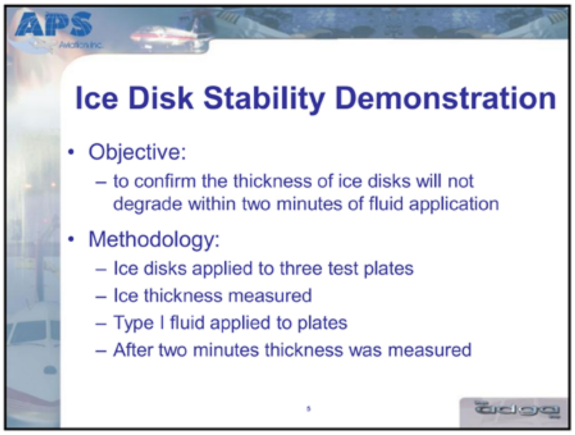
General Objectives

- Testing was conducted to demonstrate the conditions required to conduct laboratory trials for evaluating the minimum operational performance requirements of ice detection sensors.
  - General specification parameters and logistics
    - Ice disk stability demonstration
    - Lighting conditions
    - Ice detection test simulation
    - Laboratory Foam test
  - Clear ice detection during precipitation
    - the "curtain solution"



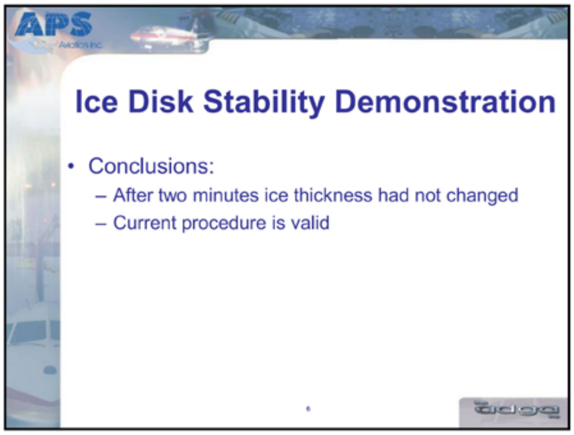
General Specification Parameters and Logistics

- Ice Disk Stability Demonstration
- Lighting Conditions
- Ice Detection Test Simulation
- Laboratory Foam Test



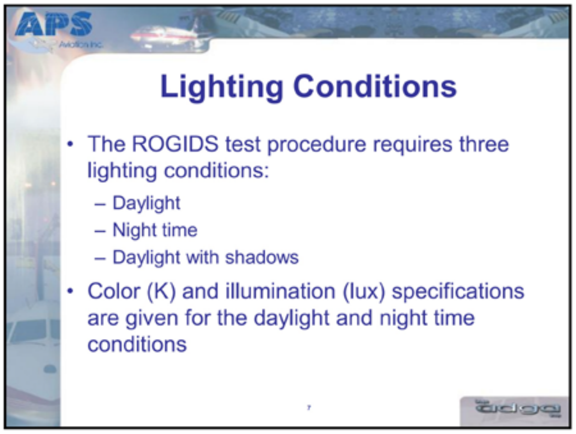
Ice Disk Stability Demonstration

- Objective:
  - to confirm the thickness of ice disks will not degrade within two minutes of fluid application
- Methodology:
  - Ice disks applied to three test plates
  - Ice thickness measured
  - Type I fluid applied to plates
  - After two minutes thickness was measured



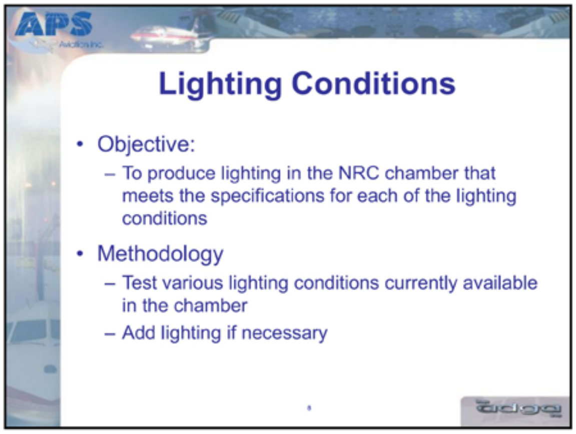
Ice Disk Stability Demonstration

- Conclusions:
  - After two minutes ice thickness had not changed
  - Current procedure is valid



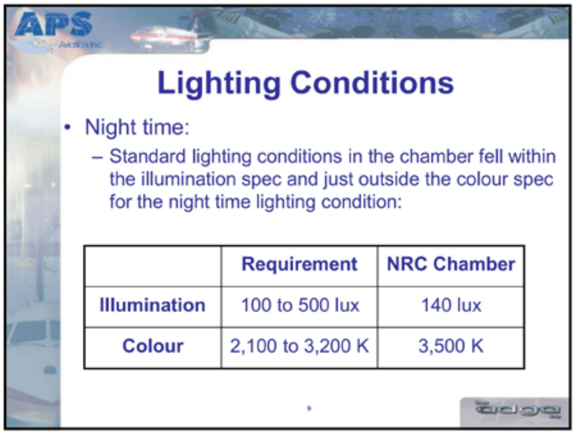
Lighting Conditions

- The ROGIDS test procedure requires three lighting conditions:
  - Daylight
  - Night time
  - Daylight with shadows
- Color (K) and illumination (lux) specifications are given for the daylight and night time conditions



Lighting Conditions

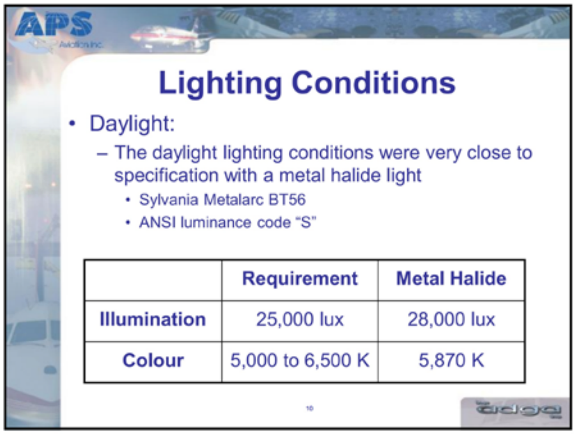
- Objective:
  - To produce lighting in the NRC chamber that meets the specifications for each of the lighting conditions
- Methodology
  - Test various lighting conditions currently available in the chamber
  - Add lighting if necessary



Lighting Conditions

- Night time:
  - Standard lighting conditions in the chamber fell within the illumination spec and just outside the colour spec for the night time lighting condition:

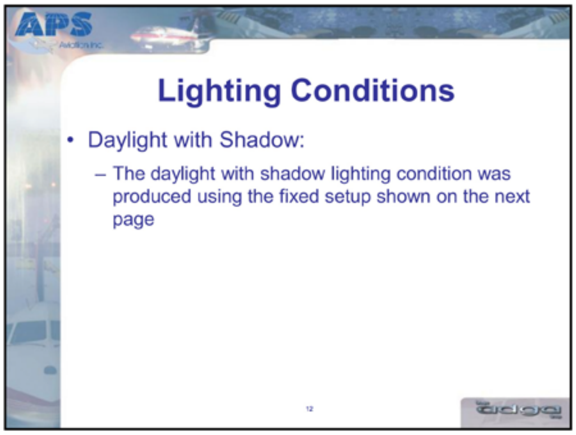
	Requirement	NRC Chamber
Illumination	100 to 500 lux	140 lux
Colour	2,100 to 3,200 K	3,500 K



Lighting Conditions

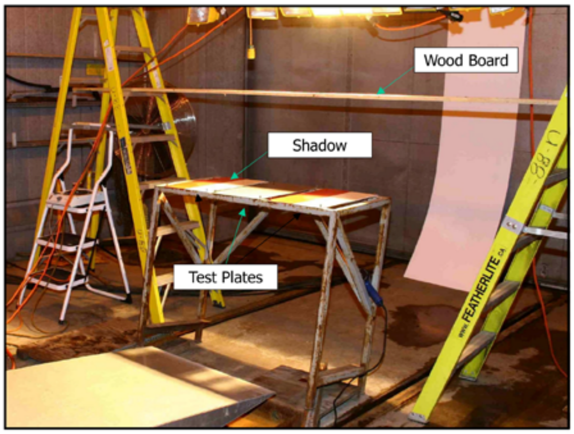
- Daylight:
  - The daylight lighting conditions were very close to specification with a metal halide light
    - Sylvania Metalarc BT56
    - ANSI luminance code "S"

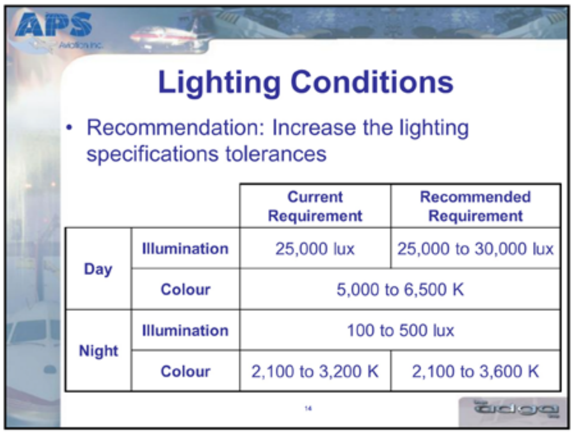
	Requirement	Metal Halide
Illumination	25,000 lux	28,000 lux
Colour	5,000 to 6,500 K	5,870 K



Lighting Conditions

- Daylight with Shadow:
  - The daylight with shadow lighting condition was produced using the fixed setup shown on the next page

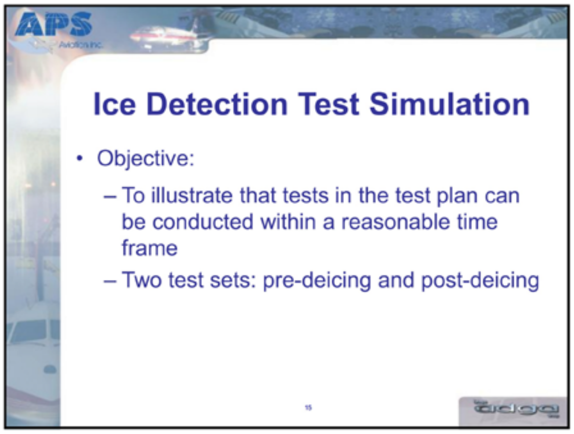




Lighting Conditions

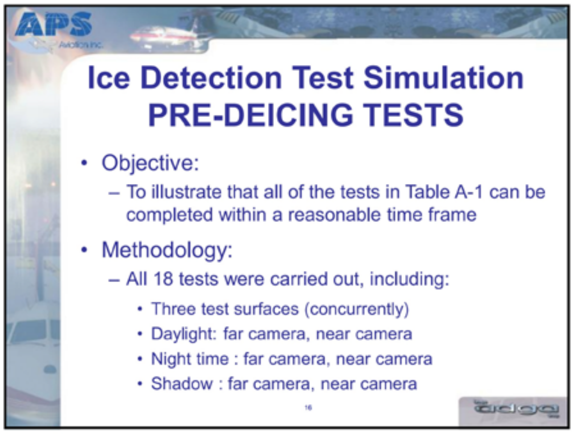
- Recommendation: Increase the lighting specifications tolerances

		Current Requirement	Recommended Requirement
Day	**Illumination**	25,000 lux	25,000 to 30,000 lux
	Colour	5,000 to 6,500 K	
Night	**Illumination**	100 to 500 lux	
	Colour	2,100 to 3,200 K	2,100 to 3,600 K



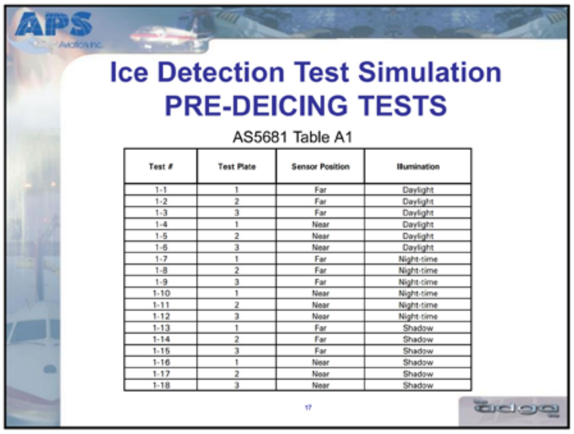
Ice Detection Test Simulation

- Objective:
  - To illustrate that tests in the test plan can be conducted within a reasonable time frame
  - Two test sets: pre-deicing and post-deicing



Ice Detection Test Simulation
PRE-DEICING TESTS

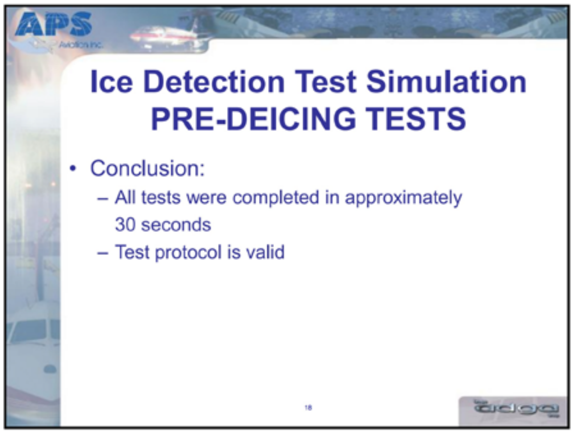
- Objective:
  - To illustrate that all of the tests in Table A-1 can be completed within a reasonable time frame
- Methodology:
  - All 18 tests were carried out, including:
    - Three test surfaces (concurrently)
    - Daylight: far camera, near camera
    - Night time : far camera, near camera
    - Shadow : far camera, near camera



Ice Detection Test Simulation
PRE-DEICING TESTS

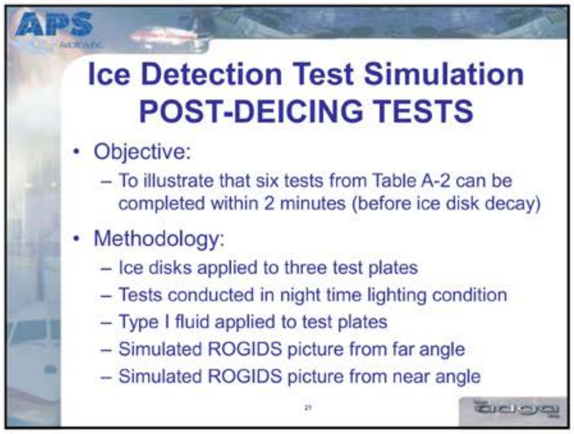
AS5681 Table A1

Test #	Test Plate	Sensor Position	Illumination
1-1	1	Far	Daylight
1-2	2	Far	Daylight
1-3	3	Far	Daylight
1-4	1	Near	Daylight
1-5	2	Near	Daylight
1-6	3	Near	Daylight
1-7	1	Far	Night-time
1-8	2	Far	Night-time
1-9	3	Far	Night-time
1-10	1	Near	Night-time
1-11	2	Near	Night-time
1-12	3	Near	Night-time
1-13	1	Far	Shadow
1-14	2	Far	Shadow
1-15	3	Far	Shadow
1-16	1	Near	Shadow
1-17	2	Near	Shadow
1-18	3	Near	Shadow



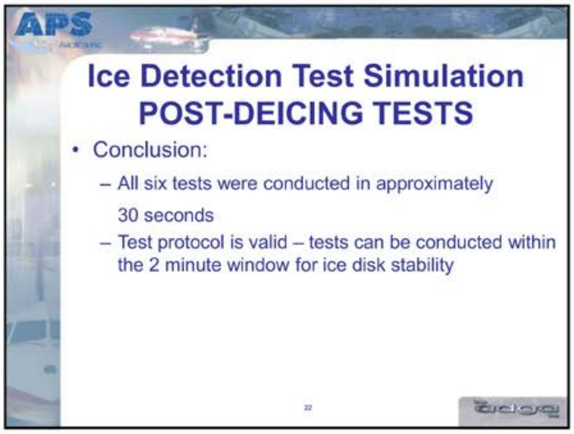
Ice Detection Test Simulation
PRE-DEICING TESTS

- Conclusion:
  - All tests were completed in approximately 30 seconds
  - Test protocol is valid



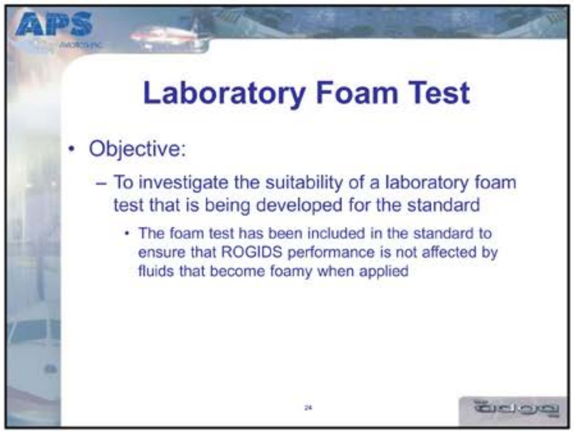
Ice Detection Test Simulation POST-DEICING TESTS

- Objective:
  - To illustrate that six tests from Table A-2 can be completed within 2 minutes (before ice disk decay)
- Methodology:
  - Ice disks applied to three test plates
  - Tests conducted in night time lighting condition
  - Type I fluid applied to test plates
  - Simulated ROGIDS picture from far angle
  - Simulated ROGIDS picture from near angle



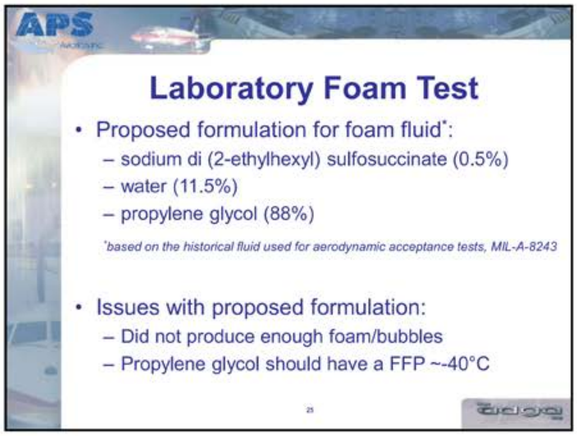
Ice Detection Test Simulation POST-DEICING TESTS

- Conclusion:
  - All six tests were conducted in approximately 30 seconds
  - Test protocol is valid – tests can be conducted within the 2 minute window for ice disk stability



Laboratory Foam Test

- Objective:
  - To investigate the suitability of a laboratory foam test that is being developed for the standard
    - The foam test has been included in the standard to ensure that ROGIDS performance is not affected by fluids that become foamy when applied

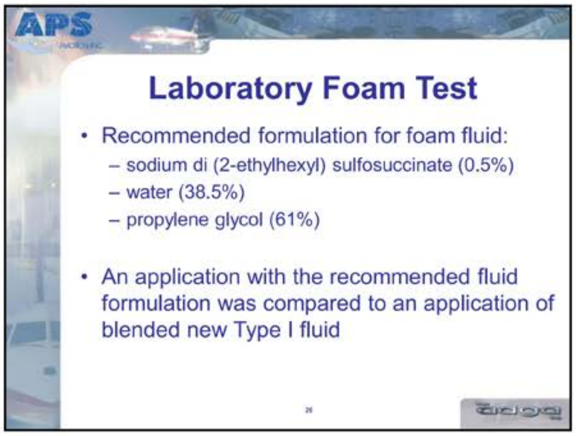


Laboratory Foam Test

- Proposed formulation for foam fluid*:
  - sodium di (2-ethylhexyl) sulfosuccinate (0.5%)
  - water (11.5%)
  - propylene glycol (88%)

based on the historical fluid used for aerodynamic acceptance tests, MIL-A-8243

- Issues with proposed formulation:
  - Did not produce enough foam/bubbles
  - Propylene glycol should have a FFP ~-40°C

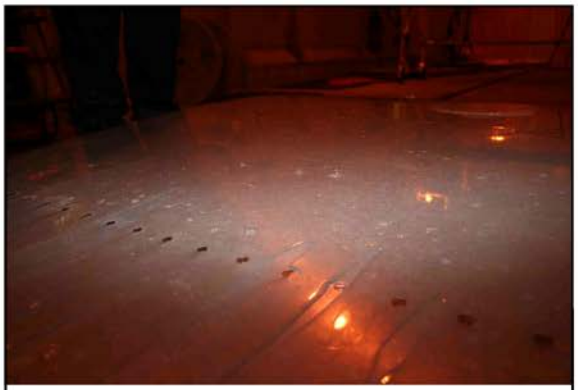


Laboratory Foam Test

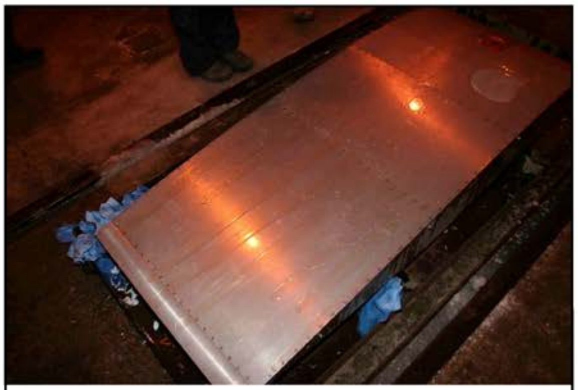
- Recommended formulation for foam fluid:
  - sodium di (2-ethylhexyl) sulfosuccinate (0.5%)
  - water (38.5%)
  - propylene glycol (61%)
- An application with the recommended fluid formulation was compared to an application of blended new Type I fluid

TYPE I APPLICATION

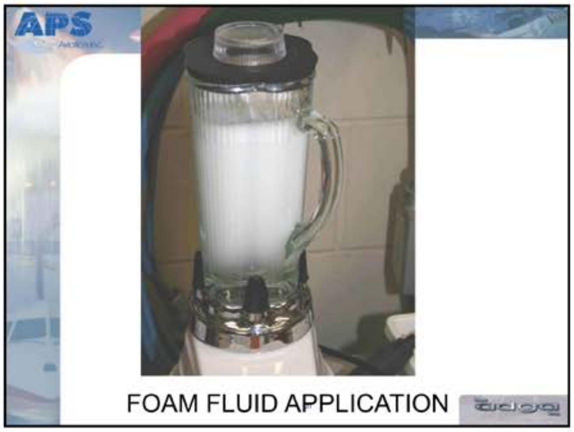
TYPE I APPLICATION



TYPE I APPLICATION

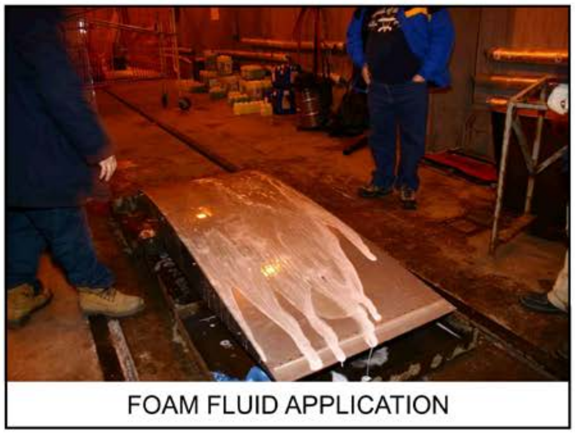


TYPE I APPLICATION



FOAM FLUID APPLICATION

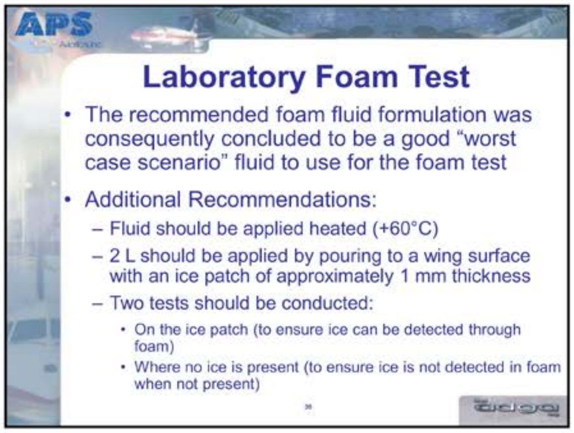
FOAM FLUID APPLICATION



FOAM FLUID APPLICATION

FOAM FLUID APPLICATION

FOAM FLUID APPLICATION



Laboratory Foam Test

- The recommended foam fluid formulation was consequently concluded to be a good "worst case scenario" fluid to use for the foam test
- Additional Recommendations:
  - Fluid should be applied heated (+60°C)
  - 2 L should be applied by pouring to a wing surface with an ice patch of approximately 1 mm thickness
  - Two tests should be conducted:
    - On the ice patch (to ensure ice can be detected through foam)
    - Where no ice is present (to ensure ice is not detected in foam when not present)

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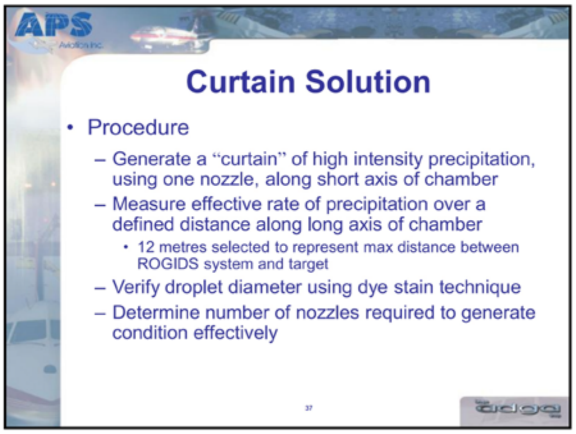
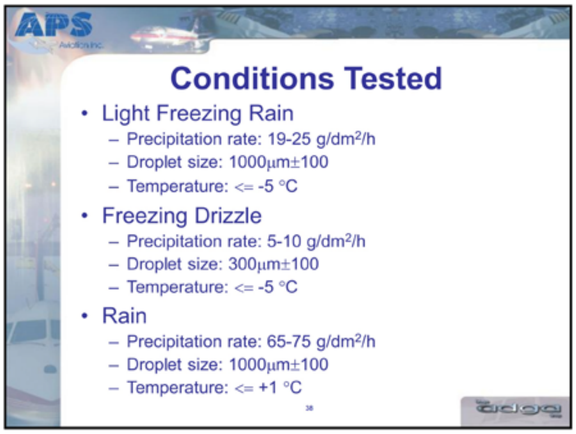


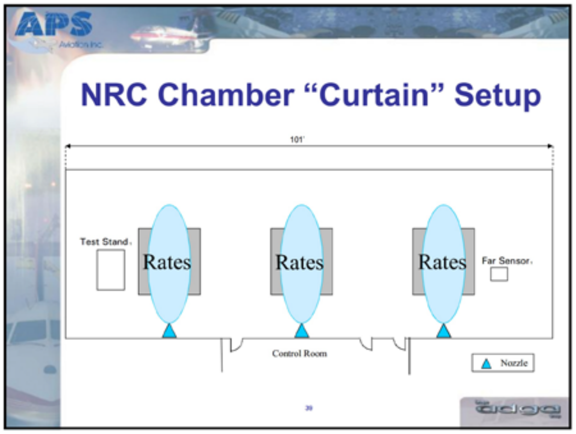
Curtain Solution

- Procedure
  - Generate a "curtain" of high intensity precipitation, using one nozzle, along short axis of chamber
  - Measure effective rate of precipitation over a defined distance along long axis of chamber
    - 12 metres selected to represent max distance between ROGIDS system and target
  - Verify droplet diameter using dye stain technique
  - Determine number of nozzles required to generate condition effectively

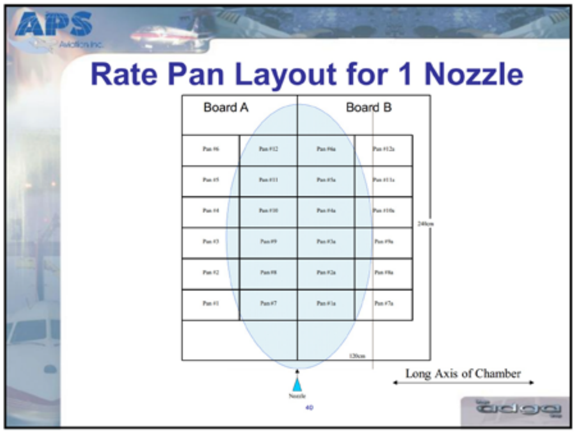


Conditions Tested

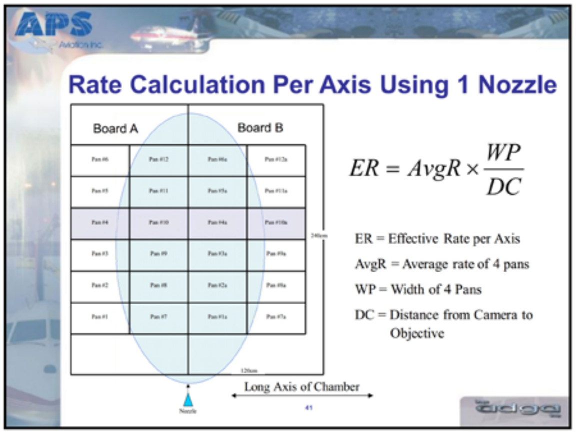
- Light Freezing Rain
  - Precipitation rate: 19-25 g/dm²/h
  - Droplet size: 1000µm±100
  - Temperature: <= -5 °C
- Freezing Drizzle
  - Precipitation rate: 5-10 g/dm²/h
  - Droplet size: 300µm±100
  - Temperature: <= -5 °C
- Rain
  - Precipitation rate: 65-75 g/dm²/h
  - Droplet size: 1000µm±100
  - Temperature: <= +1 °C



NRC Chamber "Curtain" Setup



Rate Pan Layout for 1 Nozzle



Rate Calculation Per Axis Using 1 Nozzle

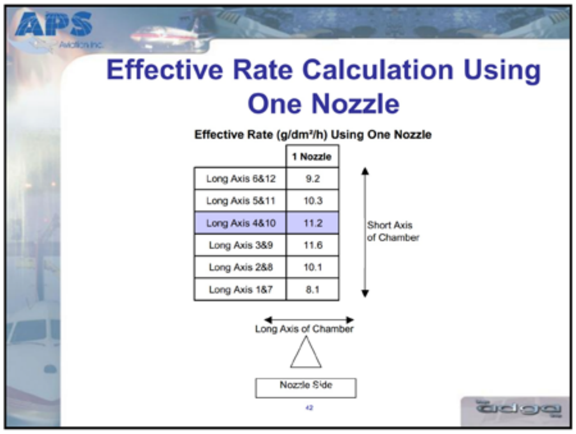
$$ER = AvgR \times \frac{WP}{DC}$$

ER = Effective Rate per Axis

AvgR = Average rate of 4 pans

WP = Width of 4 Pans

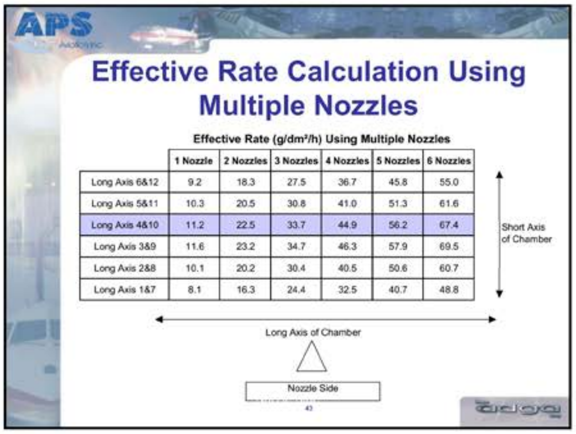
DC = Distance from Camera to Objective



Effective Rate Calculation Using One Nozzle

Effective Rate (g/dm²/h) Using One Nozzle

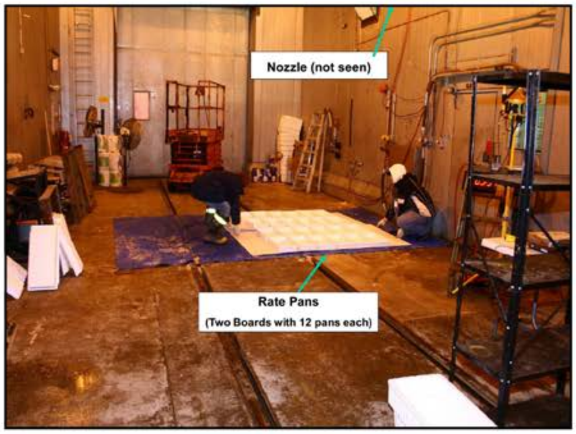
	1 Nozzle
Long Axis 6&12	9.2
Long Axis 5&11	10.3
Long Axis 4&10	11.2
Long Axis 3&9	11.6
Long Axis 2&8	10.1
Long Axis 1&7	8.1

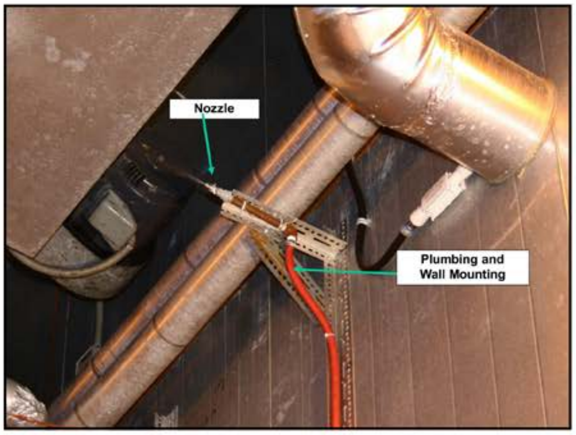


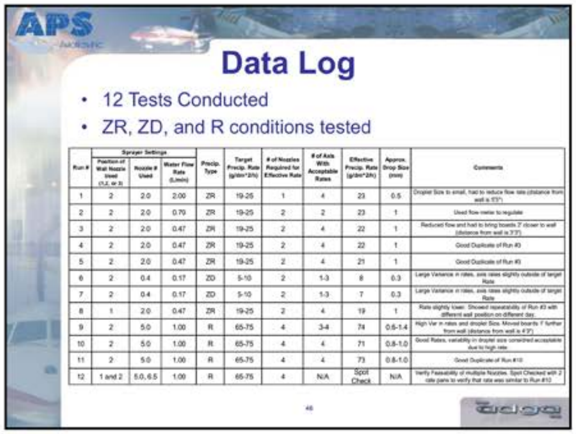
Effective Rate Calculation Using Multiple Nozzles

Effective Rate (g/dm²/h) Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.2	18.3	27.5	36.7	45.8	55.0
Long Axis 5&11	10.3	20.5	30.8	41.0	51.3	61.6
Long Axis 4&10	11.2	22.5	33.7	44.9	56.2	67.4
Long Axis 3&9	11.6	23.2	34.7	46.3	57.9	69.5
Long Axis 2&8	10.1	20.2	30.4	40.5	50.6	60.7
Long Axis 1&7	8.1	16.3	24.4	32.5	40.7	48.8



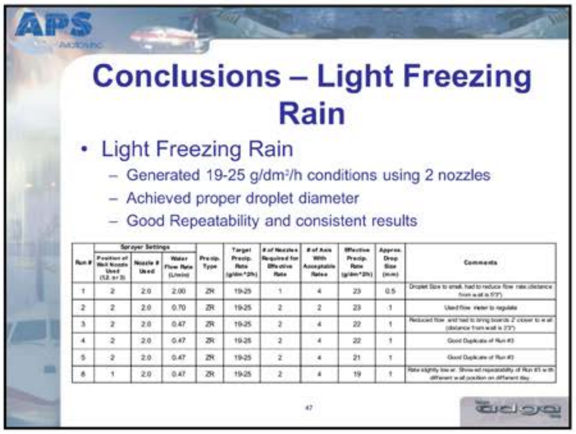




Data Log

- 12 Tests Conducted
- ZR, ZD, and R conditions tested

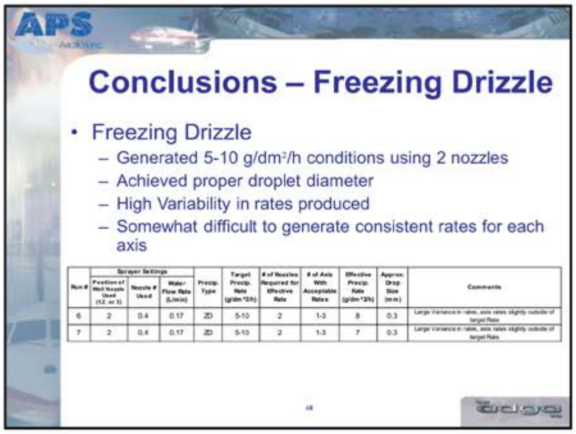
Run #	Sprayer Settings			Precip. Type	Target Precip. Rate (g/dm^2/h)	# of Nozzles Required for Effective Rate	# of Axis With Acceptable Rates	Effective Precip. Rate (g/dm^2/h)	Approx. Drop Size (mm)	Comments
	Position of Wall Nozzle Used (1,2, or 3)	Nozzle # Used	Water Flow Rate (L/min)							
1	2	2.0	2.00	ZR	19-25	1	4	23	0.5	Droplet Size to small, had to reduce flow rate (distance from wall is 5'3")
2	2	2.0	0.70	ZR	19-25	2	2	23	1	Used flow meter to regulate
3	2	2.0	0.47	ZR	19-25	2	4	22	1	Reduced flow and had to bring boards 2' closer to wall (distance from wall is 3'3")
4	2	2.0	0.47	ZR	19-25	2	4	22	1	Good Duplicate of Run #3
5	2	2.0	0.47	ZR	19-25	2	4	21	1	Good Duplicate of Run #3
6	2	0.4	0.17	ZD	5-10	2	1-3	8	0.3	Large Variance in rates, axis rates slightly outside of target Rate
7	2	0.4	0.17	ZD	5-10	2	1-3	7	0.3	Large Variance in rates, axis rates slightly outside of target Rate
8	1	2.0	0.47	ZR	19-25	2	4	19	1	Rate slightly lower. Showed repeatability of Run #3 with different wall position on different day.
9	2	5.0	1.00	R	65-75	4	3-4	74	0.6-1.4	High Var in rates and droplet Size. Moved boards 1' further from wall (distance from wall is 4'3")
10	2	5.0	1.00	R	65-75	4	4	71	0.8-1.0	Good Rates, variability in droplet size considered acceptable due to high rate
11	2	5.0	1.00	R	65-75	4	4	73	0.8-1.0	Good Duplicate of Run #10
12	1 and 2	5.0, 6.5	1.00	R	65-75	4	N/A	Spot Check	N/A	Verify Feasability of multiple Nozzles. Spot Checked with 2 rate pans to verify that rate was similar to Run #10



Conclusions – Light Freezing Rain

- Light Freezing Rain
  - Generated 19-25 g/dm²/h conditions using 2 nozzles
  - Achieved proper droplet diameter
  - Good Repeatability and consistent results

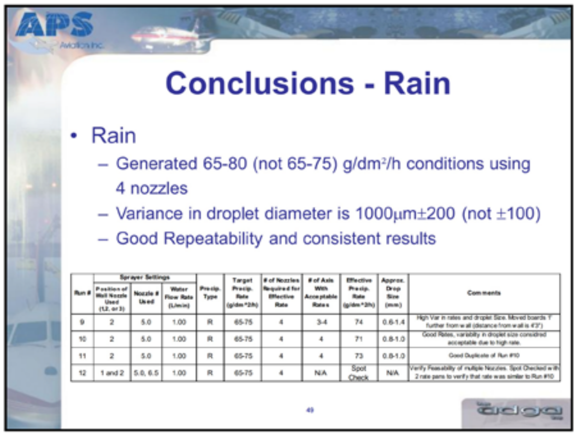
Run #	Sprayer Settings			Precip. Type	Target Precip. Rate (g/dm^2/h)	# of Nozzles Required for Effective Rate	# of Axis With Acceptable Rates	Effective Precip. Rate (g/dm^2/h)	Approx. Drop Size (mm)	Comments
	Position of Wall Nozzle Used (1,2, or 3)	Nozzle # Used	Water Flow Rate (L/min)							
1	2	2.0	2.00	ZR	19-25	1	4	23	0.5	Droplet Size to small, had to reduce flow rate (distance from wall is 5'3")
2	2	2.0	0.70	ZR	19-25	2	2	23	1	Used flow meter to regulate
3	2	2.0	0.47	ZR	19-25	2	4	22	1	Reduced flow and had to bring boards 2' closer to wall (distance from wall is 3'3")
4	2	2.0	0.47	ZR	19-25	2	4	22	1	Good Duplicate of Run #3
5	2	2.0	0.47	ZR	19-25	2	4	21	1	Good Duplicate of Run #3
8	1	2.0	0.47	ZR	19-25	2	4	19	1	Rate slightly lower. Showed repeatability of Run #3 with different wall position on different day



Conclusions – Freezing Drizzle

- Freezing Drizzle
  - Generated 5-10 g/dm²/h conditions using 2 nozzles
  - Achieved proper droplet diameter
  - High Variability in rates produced
  - Somewhat difficult to generate consistent rates for each axis

Run #	Sprayer Settings			Precip. Type	Target Precip. Rate (g/dm^2/h)	# of Nozzles Required for Effective Rate	# of Axis With Acceptable Rates	Effective Precip. Rate (g/dm^2/h)	Approx. Drop Size (mm)	Comments
	Position of Wall Nozzle Used (1,2, or 3)	Nozzle # Used	Water Flow Rate (L/min)							
6	2	0.4	0.17	ZD	5-10	2	1-3	8	0.3	Large Variance in rates, axis rates slightly outside of target Rate
7	2	0.4	0.17	ZD	5-10	2	1-3	7	0.3	Large Variance in rates, axis rates slightly outside of target Rate

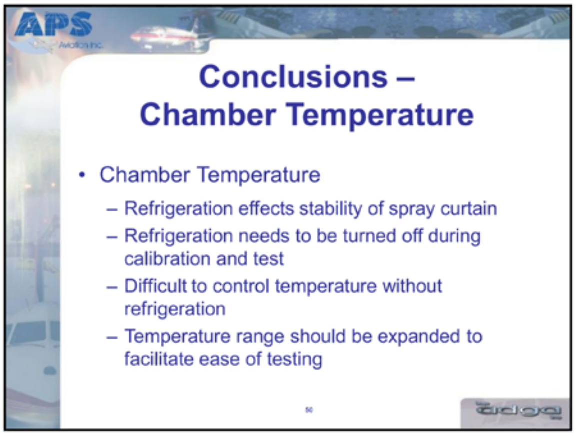


Conclusions - Rain

- Rain
  - Generated 65-80 (not 65-75) g/dm²/h conditions using 4 nozzles
  - Variance in droplet diameter is 1000µm±200 (not ±100)
  - Good Repeatability and consistent results

Run #	Sprayer Settings			Precip. Type	Target Precip. Rate (g/dm^2/h)	# of Nozzles Required for Effective Rate	# of Axis With Acceptable Rates	Effective Precip. Rate (g/dm^2/h)	Approx. Drop Size (mm)	Comments
	Position of Wall Nozzle Used (1,2, or 3)	Nozzle # Used	Water Flow Rate (L/min)							
9	2	5.0	1.00	R	65-75	4	3-4	74	0.6-1.4	High Var in rates and droplet Size. Moved boards 1' further from wall (distance from wall is 4'3")
10	2	5.0	1.00	R	65-75	4	4	71	0.8-1.0	Good Rates, variability in droplet size considred acceptable due to high rate.
11	2	5.0	1.00	R	65-75	4	4	73	0.8-1.0	Good Duplicate of Run #10
12	1 and 2	5.0, 6.5	1.00	R	65-75	4	N/A	Spot Check	N/A	Verify Feasability of multiple Nozzles. Spot Checked with 2 rate pans to verify that rate was similar to Run #10

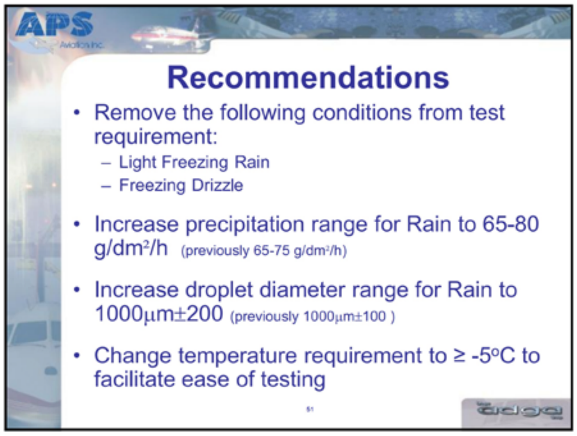
49



Conclusions – Chamber Temperature

- Chamber Temperature
  - Refrigeration effects stability of spray curtain
  - Refrigeration needs to be turned off during calibration and test
  - Difficult to control temperature without refrigeration
  - Temperature range should be expanded to facilitate ease of testing

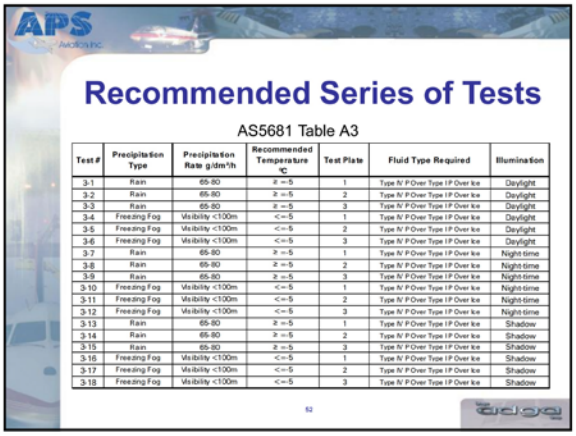
50



Recommendations

- Remove the following conditions from test requirement:
  - Light Freezing Rain
  - Freezing Drizzle
- Increase precipitation range for Rain to 65-80 g/dm²/h (previously 65-75 g/dm²/h)
- Increase droplet diameter range for Rain to 1000µm±200 (previously 1000µm±100)
- Change temperature requirement to ≥ -5°C to facilitate ease of testing

51

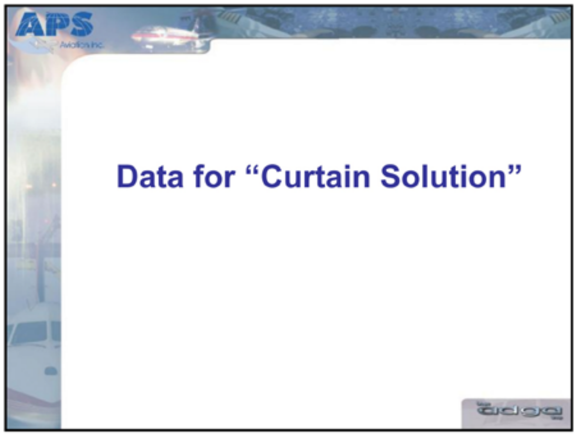


Recommended Series of Tests

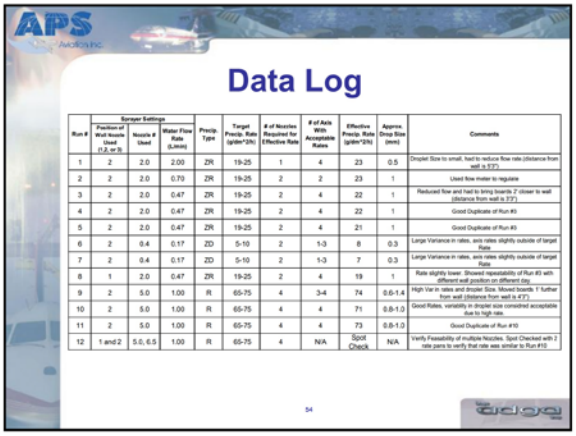
AS5681 Table A3

Test #	Precipitation Type	Precipitation Rate g/dm²/h	Recommended Temperature °C	Test Plate	Fluid Type Required	Illumination
3-1	Rain	65-80	≥ =-5	1	Type IV P Over Type I P Over Ice	Daylight
3-2	Rain	65-80	≥ =-5	2	Type IV P Over Type I P Over Ice	Daylight
3-3	Rain	65-80	≥ =-5	3	Type IV P Over Type I P Over Ice	Daylight
3-4	Freezing Fog	Visibility <100m	<=-5	1	Type IV P Over Type I P Over Ice	Daylight
3-5	Freezing Fog	Visibility <100m	<=-5	2	Type IV P Over Type I P Over Ice	Daylight
3-6	Freezing Fog	Visibility <100m	<=-5	3	Type IV P Over Type I P Over Ice	Daylight
3-7	Rain	65-80	≥ =-5	1	Type IV P Over Type I P Over Ice	Night-time
3-8	Rain	65-80	≥ =-5	2	Type IV P Over Type I P Over Ice	Night-time
3-9	Rain	65-80	≥ =-5	3	Type IV P Over Type I P Over Ice	Night-time
3-10	Freezing Fog	Visibility <100m	<=-5	1	Type IV P Over Type I P Over Ice	Night-time
3-11	Freezing Fog	Visibility <100m	<=-5	2	Type IV P Over Type I P Over Ice	Night-time
3-12	Freezing Fog	Visibility <100m	<=-5	3	Type IV P Over Type I P Over Ice	Night-time
3-13	Rain	65-80	≥ =-5	1	Type IV P Over Type I P Over Ice	Shadow
3-14	Rain	65-80	≥ =-5	2	Type IV P Over Type I P Over Ice	Shadow
3-15	Rain	65-80	≥ =-5	3	Type IV P Over Type I P Over Ice	Shadow
3-16	Freezing Fog	Visibility <100m	<=-5	1	Type IV P Over Type I P Over Ice	Shadow
3-17	Freezing Fog	Visibility <100m	<=-5	2	Type IV P Over Type I P Over Ice	Shadow
3-18	Freezing Fog	Visibility <100m	<=-5	3	Type IV P Over Type I P Over Ice	Shadow

52



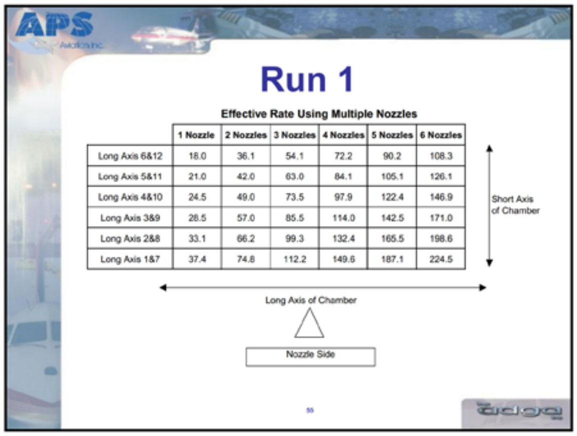
Data for "Curtain Solution"



Data Log

Run #	Sprayer Settings			Precip. Type	Target Precip. Rate (g/dm^2/h)	# of Nozzles Required for Effective Rate	# of Axis With Acceptable Rates	Effective Precip. Rate (g/dm^2/h)	Approx. Drop Size (mm)	Comments
	Position of Wall Nozzle Used (1,2, or 3)	Nozzle # Used	Water Flow Rate (L/min)							
1	2	2.0	2.00	ZR	19-25	1	4	23	0.5	Droplet Size to small, had to reduce flow rate.(distance from wall is 5'3")
2	2	2.0	0.70	ZR	19-25	2	2	23	1	Used flow meter to regulate
3	2	2.0	0.47	ZR	19-25	2	4	22	1	Reduced flow and had to bring boards 2' closer to wall (distance from wall is 3'3")
4	2	2.0	0.47	ZR	19-25	2	4	22	1	Good Duplicate of Run #3
5	2	2.0	0.47	ZR	19-25	2	4	21	1	Good Duplicate of Run #3
6	2	0.4	0.17	ZD	5-10	2	1-3	8	0.3	Large Variance in rates, axis rates slightly outside of target Rate
7	2	0.4	0.17	ZD	5-10	2	1-3	7	0.3	Large Variance in rates, axis rates slightly outside of target Rate
8	1	2.0	0.47	ZR	19-25	2	4	19	1	Rate slightly lower. Showed repeatability of Run #3 with different wall position on different day.
9	2	5.0	1.00	R	65-75	4	3-4	74	0.6-1.4	High Var in rates and droplet Size. Moved boards 1' further from wall (distance from wall is 4'3")
10	2	5.0	1.00	R	65-75	4	4	71	0.8-1.0	Good Rates, variability in droplet size considred acceptable due to high rate.
11	2	5.0	1.00	R	65-75	4	4	73	0.8-1.0	Good Duplicate of Run #10
12	1 and 2	5.0, 6.5	1.00	R	65-75	4	N/A	Spot Check	N/A	Verify Feasability of multiple Nozzles. Spot Checked with 2 rate pans to verify that rate was similar to Run #10

54



Run 1

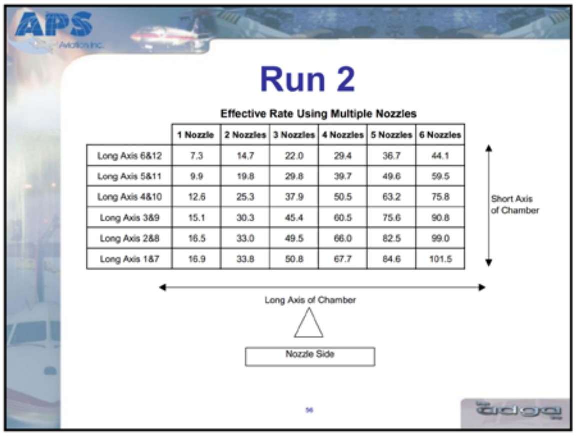
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	18.0	36.1	54.1	72.2	90.2	108.3
Long Axis 5&11	21.0	42.0	63.0	84.1	105.1	126.1
Long Axis 4&10	24.5	49.0	73.5	97.9	122.4	146.9
Long Axis 3&9	28.5	57.0	85.5	114.0	142.5	171.0
Long Axis 2&8	33.1	66.2	99.3	132.4	165.5	198.6
Long Axis 1&7	37.4	74.8	112.2	149.6	187.1	224.5

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 2

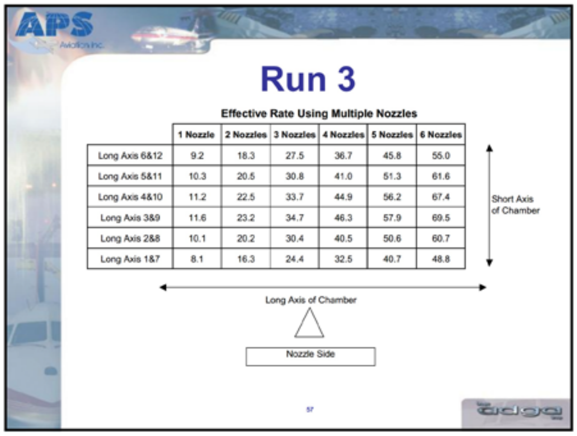
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	7.3	14.7	22.0	29.4	36.7	44.1
Long Axis 5&11	9.9	19.8	29.8	39.7	49.6	59.5
Long Axis 4&10	12.6	25.3	37.9	50.5	63.2	75.8
Long Axis 3&9	15.1	30.3	45.4	60.5	75.6	90.8
Long Axis 2&8	16.5	33.0	49.5	66.0	82.5	99.0
Long Axis 1&7	16.9	33.8	50.8	67.7	84.6	101.5

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 3

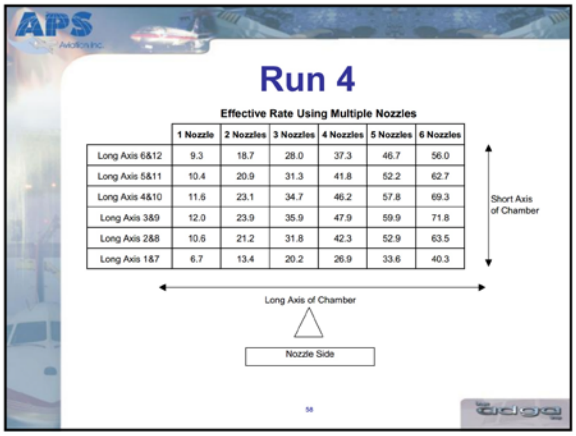
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.2	18.3	27.5	36.7	45.8	55.0
Long Axis 5&11	10.3	20.5	30.8	41.0	51.3	61.6
Long Axis 4&10	11.2	22.5	33.7	44.9	56.2	67.4
Long Axis 3&9	11.6	23.2	34.7	46.3	57.9	69.5
Long Axis 2&8	10.1	20.2	30.4	40.5	50.6	60.7
Long Axis 1&7	8.1	16.3	24.4	32.5	40.7	48.8

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 4

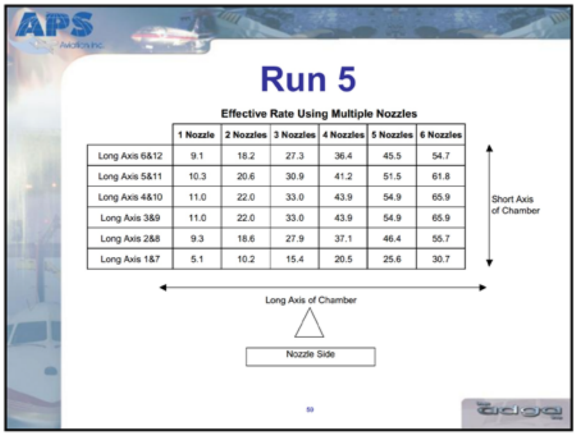
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.3	18.7	28.0	37.3	46.7	56.0
Long Axis 5&11	10.4	20.9	31.3	41.8	52.2	62.7
Long Axis 4&10	11.6	23.1	34.7	46.2	57.8	69.3
Long Axis 3&9	12.0	23.9	35.9	47.9	59.9	71.8
Long Axis 2&8	10.6	21.2	31.8	42.3	52.9	63.5
Long Axis 1&7	6.7	13.4	20.2	26.9	33.6	40.3

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 5

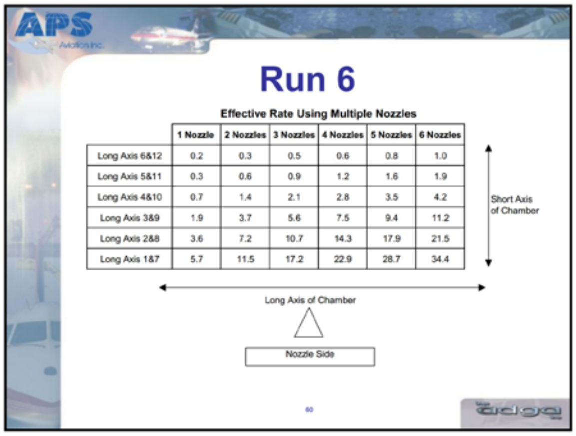
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	9.1	18.2	27.3	36.4	45.5	54.7
Long Axis 5&11	10.3	20.6	30.9	41.2	51.5	61.8
Long Axis 4&10	11.0	22.0	33.0	43.9	54.9	65.9
Long Axis 3&9	11.0	22.0	33.0	43.9	54.9	65.9
Long Axis 2&8	9.3	18.6	27.9	37.1	46.4	55.7
Long Axis 1&7	5.1	10.2	15.4	20.5	25.6	30.7

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 6

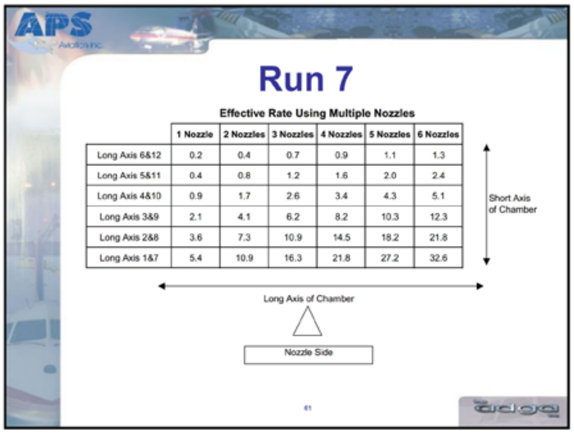
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	0.2	0.3	0.5	0.6	0.8	1.0
Long Axis 5&11	0.3	0.6	0.9	1.2	1.6	1.9
Long Axis 4&10	0.7	1.4	2.1	2.8	3.5	4.2
Long Axis 3&9	1.9	3.7	5.6	7.5	9.4	11.2
Long Axis 2&8	3.6	7.2	10.7	14.3	17.9	21.5
Long Axis 1&7	5.7	11.5	17.2	22.9	28.7	34.4

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 7

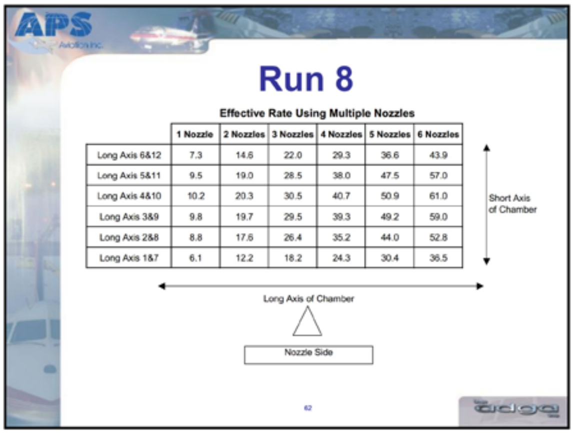
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	0.2	0.4	0.7	0.9	1.1	1.3
Long Axis 5&11	0.4	0.8	1.2	1.6	2.0	2.4
Long Axis 4&10	0.9	1.7	2.6	3.4	4.3	5.1
Long Axis 3&9	2.1	4.1	6.2	8.2	10.3	12.3
Long Axis 2&8	3.6	7.3	10.9	14.5	18.2	21.8
Long Axis 1&7	5.4	10.9	16.3	21.8	27.2	32.6

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 8

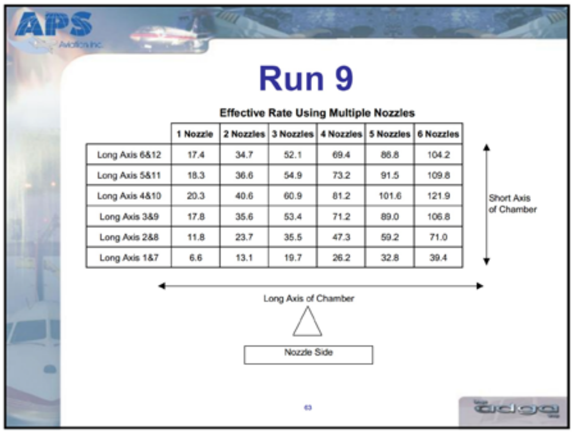
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	7.3	14.6	22.0	29.3	36.6	43.9
Long Axis 5&11	9.5	19.0	28.5	38.0	47.5	57.0
Long Axis 4&10	10.2	20.3	30.5	40.7	50.9	61.0
Long Axis 3&9	9.8	19.7	29.5	39.3	49.2	59.0
Long Axis 2&8	8.8	17.6	26.4	35.2	44.0	52.8
Long Axis 1&7	6.1	12.2	18.2	24.3	30.4	36.5

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 9

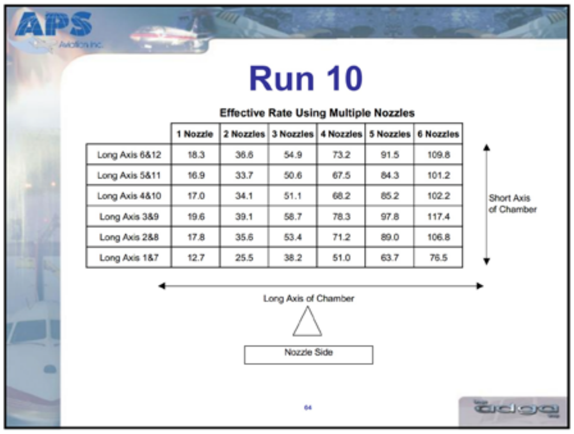
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	17.4	34.7	52.1	69.4	86.8	104.2
Long Axis 5&11	18.3	36.6	54.9	73.2	91.5	109.8
Long Axis 4&10	20.3	40.6	60.9	81.2	101.6	121.9
Long Axis 3&9	17.8	35.6	53.4	71.2	89.0	106.8
Long Axis 2&8	11.8	23.7	35.5	47.3	59.2	71.0
Long Axis 1&7	6.6	13.1	19.7	26.2	32.8	39.4

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 10

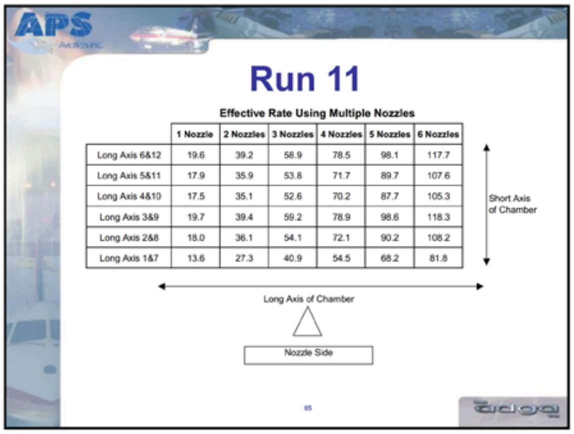
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	18.3	36.6	54.9	73.2	91.5	109.8
Long Axis 5&11	16.9	33.7	50.6	67.5	84.3	101.2
Long Axis 4&10	17.0	34.1	51.1	68.2	85.2	102.2
Long Axis 3&9	19.6	39.1	58.7	78.3	97.8	117.4
Long Axis 2&8	17.8	35.6	53.4	71.2	89.0	106.8
Long Axis 1&7	12.7	25.5	38.2	51.0	63.7	76.5

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Run 11

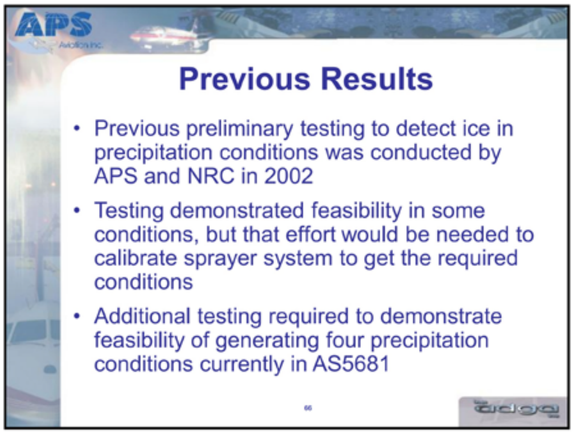
Effective Rate Using Multiple Nozzles

	1 Nozzle	2 Nozzles	3 Nozzles	4 Nozzles	5 Nozzles	6 Nozzles
Long Axis 6&12	19.6	39.2	58.9	78.5	98.1	117.7
Long Axis 5&11	17.9	35.9	53.8	71.7	89.7	107.6
Long Axis 4&10	17.5	35.1	52.6	70.2	87.7	105.3
Long Axis 3&9	19.7	39.4	59.2	78.9	98.6	118.3
Long Axis 2&8	18.0	36.1	54.1	72.1	90.2	108.2
Long Axis 1&7	13.6	27.3	40.9	54.5	68.2	81.8

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side



Previous Results

- Previous preliminary testing to detect ice in precipitation conditions was conducted by APS and NRC in 2002
- Testing demonstrated feasibility in some conditions, but that effort would be needed to calibrate sprayer system to get the required conditions
- Additional testing required to demonstrate feasibility of generating four precipitation conditions currently in AS5681

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