WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A COMMON RESEARCH MODEL VERTICAL STABILIZER

APS Aviation Inc.

TP 15538E
Final Version 1.0
November 2022

Prepared for:

Transport Canada
Programs Group
Innovation Centre

In cooperation with:

Federal Aviation Administration
William J. Hughes Technical Center

Transport Canada
Civil Aviation

Federal Aviation Administration
Flight Standards – Air Carrier Operations

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Prepared by

Marco Ruggi

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PREFACE

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

- To develop holdover time data for all new de/anti-icing fluids;
- To conduct testing to determine holdover times for Type II, III, and IV fluids in snow at temperatures below -14°C;
- To conduct additional testing and analysis to evaluate and/or determine appropriate holdover times for Type I fluids in snow at temperatures below -14°C;
- To evaluate and develop the use of artificial snow machines for holdover time development;
- To conduct wind tunnel testing with a thin high performance wing model to support the development of guidance material for operating in ice pellet conditions;
- To conduct wind tunnel testing with a vertical stabilizer common research model to evaluate contaminated fluid flow-off before and after a simulated takeoff;
- To conduct comparative endurance time testing and evaluate endurance times in mixed snow and freezing fog conditions;
- To conduct general and exploratory de/anti-icing research;
- To conduct analysis to support harmonization of the Transport Canada and the Federal Aviation Administration visibility table guidance;
- To finalize the publication and delivery of current and historical reports;
- To update the regression information report to reflect changes made to the holdover time guidelines; and
- To update the holdover time guidance materials for annual publication by Transport Canada and the Federal Aviation Administration.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2021-22 are documented in seven reports. The titles of the reports are as follows:

- TP 15534E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2021-22 Winter;
- TP 15535E Regression Coefficients and Equations Used to Develop the Winter 2022-23 Aircraft Ground Deicing Holdover Time Tables;
- TP 15536E Aircraft Ground Icing General Research Activities During the 2021-22 Winter;
- TP 15537E Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2021-22;
- TP 15538E Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Common Research Model Vertical Stabilizer;

- TP 15539E Artificial Snow Research Activities for the 2020-21 and 2021-22 Winters; and
- TP 15540E Evaluation of Fluid Endurance Times in Mixed Snow and Freezing Fog Conditions.

This report, TP 15538E, has the following objective:

- To evaluate contaminated fluid flow-off from a vertical stabilizer.

This objective was met by conducting a series of full-scale wind tunnel tests at the National Research Council Canada Icing Wind Tunnel located in Ottawa, Canada.

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by the Transport Canada Programs Group Innovation Centre, with support from the Federal Aviation Administration William J. Hughes Technical Center, Transport Canada Civil Aviation, and Federal Aviation Administration Flight Standards – Air Carrier Operations. This program could not have been accomplished without the participation of many organizations. APS Aviation Inc. would therefore like to thank Transport Canada, the Federal Aviation Administration, National Research Council Canada, and supporting members of the SAE International G-12 Aircraft Ground Deicing Committees.

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data, completion of data analysis, and preparation of reports. This includes the following people: Brandon Auclair, Steve Baker, David Beals, Stephanie Bendickson, Benjamin Bernier, Chloë Bernier, Christopher D'Avirro, John D'Avirro, Peter Dawson, Francine De Ladurantaye, Sean Devine, Ali Etemad, Noemie Gokhool, Kyra Kinderman-McCormick, Peter Kitchener, Diana Lalla, Shahdad Movaffagh, Shamim Nakhaei, William Ethan Payne, Dany Posteraro, Alex K. Raymond, Annaelle Reuveni, Marco Ruggi, Javad Safari, Alexa-Kiran Sareen-Diacoumacos, Niroshaan Sivarajah, Saba Tariq, Nicole Thomson, and Ian Wittmeyer.

Special thanks are extended to Antoine Lacroix, Yvan Chabot, Warren Underwood, and Charles J. Enders, who on behalf of Transport Canada and the Federal Aviation Administration, have participated, contributed, and provided guidance in the preparation of these documents.

PROJECT ACKNOWLEDGEMENTS

APS Aviation Inc. would like to acknowledge the following:

- The team at the National Research Council Canada who operate the Icing Wind Tunnel, especially Catherine Clark, for their engineering support and aerodynamic expertise;

- Andy Broeren of National Aeronautics and Space Administration whose engineering support and aerodynamic expertise have been crucial to the development of wind tunnel testing protocols used today;
- John Macomber and Mark Weiland from Boeing whose participation and aerodynamic expertise provided valuable operational insight into the data collected; and
- The fluid manufacturers who have provided samples over the years in support of the wind tunnel testing.

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Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada (TC). These are available from the TC Programs Group Innovation Centre. 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

As part of a larger research program, APS Aviation Inc. (APS) conducted a series of full-scale tests in the National Research Council Canada (NRC) 3 m x 6 m Icing Wind Tunnel (IWT) evaluating contaminated fluid flow-off from a common research model (CRM) vertical stabilizer.

The calibration and validation of procedures ensured reliability and repeatability of the testing protocols. The fluid and precipitation application procedures were refined, and the videography and live streaming setup was updated and finalized. The safety checks and shakedown runs ensured a safe and successful test campaign. The IWT provided an effective means to carry out the anticipated research accommodating the installation of an appropriately sized model and allowing the application of de/anti-icing fluids.

The testing demonstrated that some amount of fluid and contamination was always present at the end of each test run. The amount of residual fluid increased or decreased based on the severity of the condition tested and was affected by the sideslip and rudder deflection, the level of contamination, the temperature at which the test was run, the type of fluid used, and other factors.

Testing conducted in snow conditions demonstrated that failed fluid, which had a slushy consistency, generally had poor flow-off. In contrast, fluid that was not failed, because it was either clean or when limited amounts of contamination was applied, flowed off better. Freezing rain tests demonstrated results similar to the snow tests but had the added complexity of adherence to the surface, making flow-off more difficult. The early fluid failure observed on the model was due to the near vertical orientation of the surface which allows gravity to pull the fluid down resulting in a thinner protection layer (this is well documented in previous vertical surfaces research as well).

The one engine inoperative and crosswind simulations generally demonstrated better flow-off as compared to the static configuration test. It is important to understand these conservative results to determine the potential impact on guidance development going forward. The effect of speed and takeoff time was negligible in the test conducted, however the effects on contamination have yet to be explored and may provide different results.

The load cells for the CRM should be acquired and installed for any future testing with the CRM to allow for collection of aerodynamic data. Some improvements to the facility, including better lighting and observation windows, are recommended for a better viewing of the tests in person and remotely. Future testing should build upon the testing matrix developed for this testing. Testing should also focus on areas not extensively explored during this preliminary phase of testing, including colder temperatures, different contamination types and levels, asymmetric contamination, and different fluids.

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

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

16. Résumé

Dans le cadre d'un plus vaste programme de recherche, APS Aviation Inc. (APS) a mené une série d'essais pleine grandeur dans la soufflerie de givrage de 3 m sur 6 m du Conseil national de recherches Canada (CNRC) afin d'évaluer les propriétés de ruissellement de liquides contaminés sur la surface d'un stabilisateur vertical d'un modèle consensuel de recherche (MCR).

L'étalonnage et la validation des procédures ont assuré la fiabilité et la répétabilité des protocoles d'essai. Les procédures d'application des liquides et des précipitations ont été perfectionnées, et la configuration de la vidéographie et de la diffusion en direct a été mise à jour et finalisée. Les contrôles de sécurité et les tests préliminaires ont assuré la sécurité et la réussite de la campagne d'essais. La soufflerie de givrage s'est avérée un excellent moyen de poursuivre les activités de recherche prévues puisqu'elle peut accueillir l'installation d'un modèle aux dimensions adéquates et permettre l'application de liquides de dégivrage/d'antigivrage.

Les essais ont démontré qu'il y avait toujours présence d'une certaine quantité de liquide et de contamination au terme de chaque séance de test. Les manœuvres de glissade et de débattement de la direction, le degré de contamination, la température au moment de l'essai, le type de liquide utilisé et d'autres facteurs se sont avérés avoir une incidence sur la quantité de liquide résiduel, qui augmentait ou diminuait selon la gravité des conditions d'essai.

Les essais menés dans des conditions de neige ont démontré que le ruissellement d'un liquide défaillant ayant la consistance de neige fondante était généralement mauvais. En revanche, un liquide non défaillant, c'est-à-dire intact ou auquel seule une quantité limitée de contaminants avait était appliquée, s'est avéré ruisseler plus facilement. Les essais se rapportant à la pluie verglaçante ont généré des résultats semblables à ceux pour la neige, mais la complexité accrue amenée par l'adhérence à la surface rendait le ruissellement plus difficile. La défaillance précoce d'un liquide qui a été observée sur le modèle découlait de l'orientation presque verticale de la surface, où la gravité attire le liquide vers le bas, entraînant ainsi un amincissement de la couche protectrice (ce phénomène est d'ailleurs bien documenté dans le cadre de travaux de recherche antérieurs).

Les simulations de vent de travers ou de défaillance d'un moteur ont généralement démontré un degré supérieur de ruissellement comparativement aux essais en configuration statique. Il est important de bien comprendre ces résultats limités pour en déterminer les répercussions potentielles sur la mise au point de lignes directrices dans le futur. La vitesse du décollage et le délai qui précède celui-ci n'ont eu qu'une influence négligeable dans les essais menés; cela dit, les effets de la contamination, que l'on n'a pas encore explorés, pourraient générer des résultats différents.

Des capteurs de pression adaptés au MCR doivent être achetés, puis installés sur l'appareil pour permettre la collecte de données relatives à l'aérodynamisme. On recommande de procéder à certaines améliorations à l'installation, notamment l'ajout de meilleurs dispositifs d'éclairage et de fenêtres d'observation, pour accroître la visibilité des tests en personne et à distance. Les futurs essais se baseraient sur la matrice élaborée à cet effet. Les essais doivent également être axés sur les aspects n'ayant pas été explorés de façon approfondie au cours de cette phase préliminaire, par exemple, les températures très froides, les divers types et degrés de contamination, la contamination asymétrique et les différents liquides.

17. Mots clés Stabilisateur vertical, modèle consensuel de recherche, rotation à vitesse élevée, rotation à faible vitesse, type II, type III, type IV, adhérence des liquides, ruissellement des liquides, soufflerie, soufflerie de givrage, comportement aérodynamique des ailes, défaillance d'un moteur, vent de travers	18. Diffusion Disponible auprès du Centre d'innovation du groupe de programmes de Transports Canada

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EXECUTIVE SUMMARY

Under contract to the Transport Canada (TC) Programs Group Innovation Centre, with support from the Federal Aviation Administration (FAA) William J. Hughes Technical Center, TC Civil Aviation, and FAA Flight Standards – Air Carrier Operations, APS Aviation Inc. (APS) carried out research in the winter of 2021-22 in support of the aircraft ground icing research program.

As part of a larger research program, APS conducted a series of full-scale tests in the National Research Council Canada (NRC) 3 m x 6 m Icing Wind Tunnel (IWT) evaluating contaminated fluid flow-off from a vertical stabilizer.

Background and Objective

There is a lack of standardization in the treatment of vertical surfaces during deicing operations. A wind tunnel testing program was developed for the winter of 2021-22 with the primary objectives of conducting aerodynamic testing to document contaminated fluid flow-off using a custom-built common research model (CRM) vertical stabilizer.

Conclusions

The calibration and validation of procedures ensured reliability and repeatability of the testing protocols. The fluid and precipitation application procedures were refined, and the videography and live streaming setup was updated and finalized. The safety checks and shakedown runs ensured a safe and successful test campaign. The IWT provided an effective means to carry out the anticipated research accommodating the installation of an appropriately sized model and allowing the application of de/anti-icing fluids.

The testing demonstrated that some amount of fluid and contamination was always present at the end of each test run. The amount of residual fluid increased or decreased based on the severity of the condition tested and was affected by the sideslip and rudder deflection, the level of contamination, the temperature at which the test was run, the type of fluid used, and other factors.

Testing conducted in snow conditions demonstrated that failed fluid, which had a slushy consistency, generally had poor flow-off. In contrast, fluid that was not failed, because it was either clean or when limited amounts of contamination were applied, flowed off better. Freezing rain tests demonstrated results similar to the snow tests but had the added complexity of adherence to the surface, making flow-off more difficult. The early fluid failure observed on the model was due to the near vertical orientation of the surface which allowed gravity to pull the fluid down resulting in a thinner protection layer (this is well documented in previous vertical surfaces research as well).

The one engine inoperative and crosswind simulations generally demonstrated better flow-off as compared to the static configuration test. It is important to understand these conservative results to determine the potential impact on guidance development going forward. The effect of speed and time to takeoff was negligible in the test conducted, however the effects on contamination have yet to be explored and may provide different results.

Recommendations

The load cells for the CRM should be acquired and installed for any future testing with the CRM to allow for collection of aerodynamic data. Some improvements to the facility, including better lighting and observation windows, are recommended for a better viewing of the tests in person and remotely. Future testing should build upon the testing matrix developed for this testing. Testing should also focus on areas not extensively explored during this preliminary phase of testing, including colder temperatures, different contamination types and levels, asymmetric contamination, and different fluids.

SOMMAIRE

En vertu d'un contrat avec le groupe des programmes du Centre d'innovation de Transports Canada (TC) et avec le soutien du William J. Hughes Technical Center de la Federal Aviation Administration (FAA), du département de l'aviation civile de TC, et de la FAA Flight Standards – Air Carrier Operations, APS Aviation inc. (APS) a mené des essais au cours de l'hiver 2021-2022 dans le cadre d'un programme de recherche sur le givrage d'aéronefs au sol.

Dans le cadre d'un plus vaste programme de recherche, APS a mené une série d'essais pleine grandeur dans la soufflerie de givrage de 3 m sur 6 m du Conseil national de recherches Canada (CNRC) afin d'évaluer les propriétés de ruissellement de liquides contaminés sur la surface d'un stabilisateur vertical.

Contexte et objectifs

On constate un manque de normalisation dans le traitement de surfaces verticales dans le cadre d'opérations de dégivrage. Un programme d'essais en soufflerie a été élaboré pour l'hiver 2021-2022 avec comme principaux objectifs de mener des tests d'aérodynamisme visant à documenter les propriétés de ruissellement de liquides contaminés sur la surface d'un stabilisateur vertical d'un modèle consensuel de recherche (MCR) construit sur mesure.

Conclusions

L'étalonnage et la validation des procédures ont assuré la fiabilité et la répétabilité des protocoles d'essai. Les procédures d'application des liquides et des précipitations ont été perfectionnées, et la configuration de la vidéographie et de la diffusion en direct a été mise à jour et finalisée. Les contrôles de sécurité et les tests préliminaires ont assuré la sécurité et la réussite de la campagne d'essais. La soufflerie de givrage s'est avérée un excellent moyen de poursuivre les activités de recherche prévues puisqu'elle peut accueillir l'installation d'un modèle aux dimensions adéquates et permettre l'application de liquides de dégivrage/d'antigivrage.

Les essais ont démontré qu'il y avait toujours présence d'une certaine quantité de liquide et de contamination au terme de chaque séance de test. Les manœuvres de glissade et de débattement de la direction, le degré de contamination, la température au moment de l'essai, le type de liquide utilisé et d'autres facteurs se sont avérés avoir une incidence sur la quantité de liquide résiduel, qui augmentait ou diminuait selon la gravité des conditions d'essai.

Les essais menés dans des conditions de neige ont démontré que le ruissellement d'un liquide défaillant ayant la consistance de neige fondante était généralement mauvais. En revanche, un liquide non défaillant, c'est-à-dire intact ou auquel seule une quantité limitée de contaminants avait était appliquée, s'est avéré ruisseler plus facilement. Les essais se rapportant à la pluie verglaçante ont généré des résultats semblables à ceux pour la neige, mais la complexité accrue amenée par l'adhérence à la surface rendait le ruissellement plus difficile. La défaillance précoce d'un liquide qui a été observée sur le modèle découlait de l'orientation presque verticale de la surface, où la gravité attire le liquide vers le bas, entraînant ainsi un amincissement de la couche protectrice (ce phénomène est d'ailleurs bien documenté dans le cadre de travaux de recherche antérieurs).

Les simulations de vent de travers ou de défaillance d'un moteur ont généralement démontré un degré supérieur de ruissellement comparativement aux essais en configuration statique. Il est important de bien comprendre ces résultats limités pour en déterminer les répercussions potentielles sur la mise au point de lignes directrices dans le futur. La vitesse du décollage et le délai qui précède celui-ci n'ont eu qu'une influence négligeable dans les essais menés; cela dit, les effets de la contamination, que l'on n'a pas encore explorés, pourraient générer des résultats différents.

Recommandations

Des capteurs de pression adaptés au MCR doivent être achetés, puis installés sur l'appareil pour permettre la collecte de données relatives à l'aérodynamisme. On recommande de procéder à certaines améliorations à l'installation, notamment l'ajout de meilleurs dispositifs d'éclairage et de fenêtres d'observation, pour accroître la visibilité des tests en personne et à distance. Les futurs essais se baseraient sur la matrice élaborée à cet effet. Les essais doivent également être axés sur les aspects n'ayant pas été explorés de façon approfondie au cours de cette phase préliminaire, par exemple, les températures très froides, les divers types et degrés de contamination, la contamination asymétrique et les différents liquides.

CONTENTS

Page

LIST OF APPENDICES

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LIST OF TABLES — Page

LIST OF FIGURES — Page

LIST OF PHOTOS — Page

GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
AWG	Aerodynamics Working Group
CCTV	Closed-Circuit Television System
CRM	Common Research Model
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
IWT	3 m x 6 m Icing Wind Tunnel
NASA	National Aeronautics and Space Administration
NRC	National Research Council Canada
OAT	Outside Air Temperature
OEI	One Engine Inoperative
PG	Propylene Glycol
RTD	Resistance Temperature Detector
SAE	SAE International
TC	Transport Canada
V1	The maximum speed at which a rejected takeoff can be initiated in the event of an emergency
β	Effective Sideslip
δ_r	Rudder Deflection

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1. INTRODUCTION

Under winter precipitation conditions, aircraft are cleaned prior to takeoff. This is typically done with aircraft ground deicing fluids, which are freezing point depressant fluids developed specifically for aircraft use. If required, aircraft are then protected against further accumulation of precipitation by the application of aircraft ground anti-icing fluids, which are also freezing point depressant fluids. Most anti-icing fluids contain thickeners to extend protection time.

Prior to the 1990s, aircraft ground de/anti-icing had not been extensively researched. However, following several ground icing related incidents in the late 1980s, an aircraft ground icing research program was initiated by Transport Canada (TC). The objective of the program is to improve knowledge, enhance safety, and advance operational capabilities of aircraft operating in winter precipitation conditions.

Since its inception in the early 1990s, the aircraft ground icing research program has been managed by TC, with the co-operation of the United States Federal Aviation Administration (FAA), the National Research Council Canada (NRC), several major airlines, and de/anti-icing fluid manufacturers.

There is still an incomplete understanding of some of the hazards related to aircraft ground icing. As a result, the aircraft ground icing research program continues, with the objective of further reducing the risks posed by the operation of aircraft in winter precipitation conditions.

Under contract to the TC Programs Group Innovation Centre, with support from the FAA William J. Hughes Technical Center, TC Civil Aviation, and FAA Flight Standards – Air Carrier Operations, APS Aviation Inc. (APS) carried out research in the winter of 2021-22 in support of the aircraft ground icing research program. Each major project completed as part of the 2021-22 research is documented in a separate individual report. This report documents the wind tunnel research performed to evaluate contaminated fluid flow-off from a common research model (CRM) vertical stabilizer.

1.1 Background

There is a lack of standardization in the treatment of vertical surfaces during deicing operations. Some operators in the United States and Canada exclude the treatment of vertical surfaces, including the tail, while others only consider treatment during ongoing freezing precipitation. In some cases, the tail may only be deiced while the wings are being deiced and anti-iced. Some reports have also indicated that treatment of the tail may worsen takeoff performance as the anti-icing fluid on the tail may lead to increased accumulation of contamination in active precipitation conditions.

Current TC and FAA rules and regulations require that critical surfaces be free of contamination prior to takeoff, and the vertical stabilizer is defined as a critical surface by both TC and the FAA. However, from a regulatory implementation and enforcement standpoint, there is currently no standardized guidance that offers inspectors a means to determine if an air operator is complying with operational rules. If current operational rules aim to achieve the clean aircraft concept – which requires the tail to have zero adhering frozen contamination – the question remains: How can this be adequately achieved, or appropriately mitigated by operators, to ensure a satisfactory level of safety?

TC and the FAA, with the support of APS, National Aeronautics and Space Administration (NASA), and the NRC, have been directing research to explore de/anti-icing of vertical surfaces. The discussion has also been brought to the SAE International (SAE) G-12 Aerodynamics Working Group (AWG) meetings to obtain additional expert feedback from the group's original equipment manufacturers and aerodynamicists.

1.2 Previous Related Research

Flat plate testing conducted in 2015-16 demonstrated the variability in both fluid protection times and characteristics of contamination on vertical surfaces (see the TC report, TP 15340E, *Aircraft Ground Icing General Research Activities During the 2015-16 Winter* [1]).

In 2019-20, aerodynamic testing to document contaminated fluid flow-off on a Piper PA-34-200T Seneca II vertical stabilizer demonstrated that fluid and contamination were always present at the end of each test run (see the TC report, TP 15454E, *Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Vertical Stabilizer* [2]). The amount of residual increased or decreased based on the severity of the condition tested and was affected by the sideslip and rudder deflection, the level of contamination, the temperature at which the test was run, the type of fluid used, and other factors. The applicability of these results to commercial airliners was reviewed by the SAE G-12 AWG, and it was recommended that a new generic model be designed to allow for better, more relevant data to be collected.

1.3 Working Group Discussion

Through discussions with the SAE G-12 AWG, a CRM was designed based on an analysis of existing aircraft geometries and was built by the NRC in preparation for testing for the winter of 2021-22. A preliminary plan was developed to use the TC-owned CRM to conduct testing at the NRC 3 m x 6 m Icing Wind Tunnel (IWT) in Ottawa to qualify the contaminated fluid flow-off characteristics. This data could then be used by aircraft manufacturers to better understand the expected impacts on their specific aircraft types.

1.4 Project Objectives

A wind tunnel testing program was developed for the winter of 2021-22 with the primary objectives of conducting aerodynamic testing to document contaminated fluid flow-off on a CRM vertical stabilizer.

Table 1.1 demonstrates the groupings for the global set of tests conducted at the wind tunnel during the winter of 2021-22 using the vertical stabilizer model. It should be noted that this research was coordinated in conjunction with the yearly TC/FAA wind tunnel ice pellet research campaign.

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

Table 1.1: Summary of 2021-22 Vertical Stabilizer Tests by Objective

Objective #	Objective	# of Runs
1	Calibration and Validation of Procedures	-
2	Dry Wing Airflow Characterization	44
3	Fluid Testing and Flow-Off Characterization	43
Total		**87**

1.5 Report Format

The following list provides short descriptions of subsequent sections of this report:

a) Section 2 describes the methodology used in testing, as well as equipment and personnel requirements necessary to carry out testing;

b) Section 3 describes data collected during the wind tunnel testing;

c) Section 4 describes the results from the calibration and validation of procedures;

d) Section 5 describes the results from the dry wing testing, tuft visualization, and boundary layer rake testing;

e) Section 6 describes the results from the fluid testing and flow-off characterization;

f) Section 7 describes the ongoing discussions about vertical stabilizer research with the SAE G-12 AWG;

g) Section 8 provides a summary of the conclusions; and

h) Section 9 provides a summary of the recommendations.

2. METHODOLOGY

This section provides a brief description of the test methodology and equipment specific to the full-scale aerodynamic tests conducted at the NRC IWT.

2.1 Test Schedule

Eight days of overnight and daytime testing were organized between February 4 and February 15, 2022. Setup and teardown times were kept to a minimum and done during the first two hours on the first day of testing and during the last two hours on the last day of testing, respectively. Table 2.1 presents a summary of the total wind tunnel tests performed with the CRM vertical stabilizer. At the beginning of each test day, a plan was developed that included the list of tests (taken from the global test plan) to be completed based on the weather conditions and testing priorities. This daily plan was discussed, approved, and modified (if necessary) by TC, the FAA, and APS.

Table 2.1: 2021-22 Summary of Total Tests

Date (Start date of testing)	**# of Tests Run**
February 4, 2022	7
February 6, 2022	11
February 7, 2022	9
February 8, 2022	5
February 9, 2022	13
February 10, 2022	10
February 14, 2022	16
February 15, 2022	16
Total	**87**

2.1.1 Wind Tunnel Procedure

To satisfy the fluid testing objective, simulated takeoff and climb-out tests were performed with the vertical stabilizer. Different parameters including fluid thickness, wing temperature, and fluid freezing point were recorded at designated times during the tests.

The typical procedure for each fluid test is described below.

- The vertical stabilizer was treated with deicing or anti-icing fluid, applied over a clean dry surface.
- When applicable, contamination, in the form of simulated ice pellets, freezing rain, and/or snow, was applied to the vertical stabilizer. Test parameters were measured at the beginning and end of the exposure to contamination.
- At the end of the contamination period, the tunnel was cleared of all equipment and scaffolding.
- The wind tunnel was subsequently operated through a simulated takeoff and climb-out test.
- The behaviour of the fluid during takeoff and climb-out was recorded with video cameras and digital high-speed still cameras. In addition, windows overlooking the wing section allowed observers to document the fluid elimination performance in real-time.

The procedures for the wind tunnel trials are included in Appendix B. The procedures include details regarding the test objectives, test plan, methodologies, and pertinent information and documentation.

In addition, dry wing characterization tests were conducted with boundary layer rakes and tufts. These were separate tests that did not require fluids and were conducted with a variety of different testing parameters specific to the individual objectives.

2.1.2 Test Sequence

The duration of each test (from start of setup to end of last measurement) varied largely due to the length of exposure to precipitation (if applicable). Time required for setup and teardown as well as preparing and configuring the vertical stabilizer was relatively consistent from test to test. Figure 2.1 demonstrates a sample timeline for a typical wind tunnel trial. It should be noted that a precipitation exposure time of 30 minutes was used for illustrative purposes; this time varied for each test depending on the objective. In addition, dry wing characterization tests were conducted with boundary layer rakes and tufts that did not require fluid application.

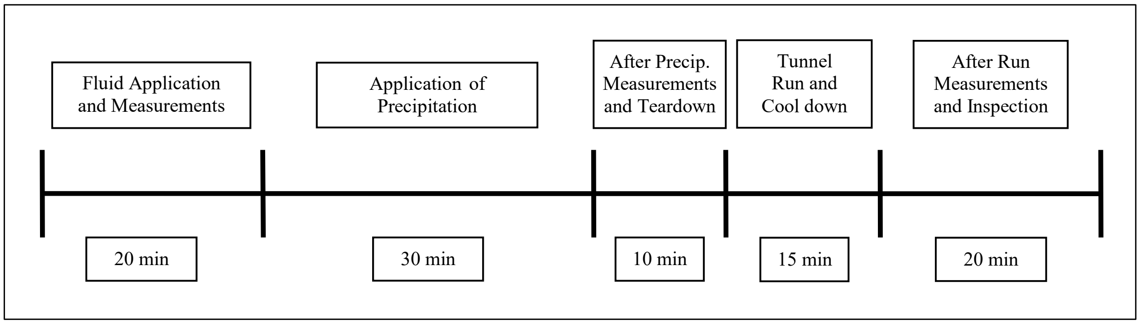

Figure 2.1: Typical Wind Tunnel Test Timeline

2.2 Wind Tunnel and Vertical Stabilizer Model Technical Overview

The following subsections describe the wind tunnel and major test components.

2.2.1 Wind Tunnel Test Site

IWT tests are performed at the NRC Aerospace Facilities, Building M-46, at the NRC Montreal Road campus, located in Ottawa, Canada. Figure 2.2 provides a schematic of the NRC Montreal Road campus showing the location of the NRC IWT. Photo 2.1 shows an outside view of the wind tunnel trial facility. Photo 2.2 shows an inside view of the wind tunnel test section with the CRM installed. The open-circuit layout, with a fan at entry, permits contaminants associated with the test articles (such as heat or de/anti-icing fluid) to discharge directly, without recirculating or contacting the fan. The test section is 3 m (10 ft.) wide by 6 m (20 ft.) high by 12 m (40 ft.) long, with a maximum wind speed of 78 knots when using the electrical turbine drive and with a maximum wind speed of just over 115 knots when using the gas turbine drive. The fan is normally driven electrically, but high-speed operation can be accommodated by a gas turbine drive system. Due to the requirements of both high-speed and low-speed operations during the testing, the gas turbine was selected to allow for greater flexibility; the gas turbine drive can perform both low- and high-speed operations, whereas the electric drive is limited to low-speed operations.

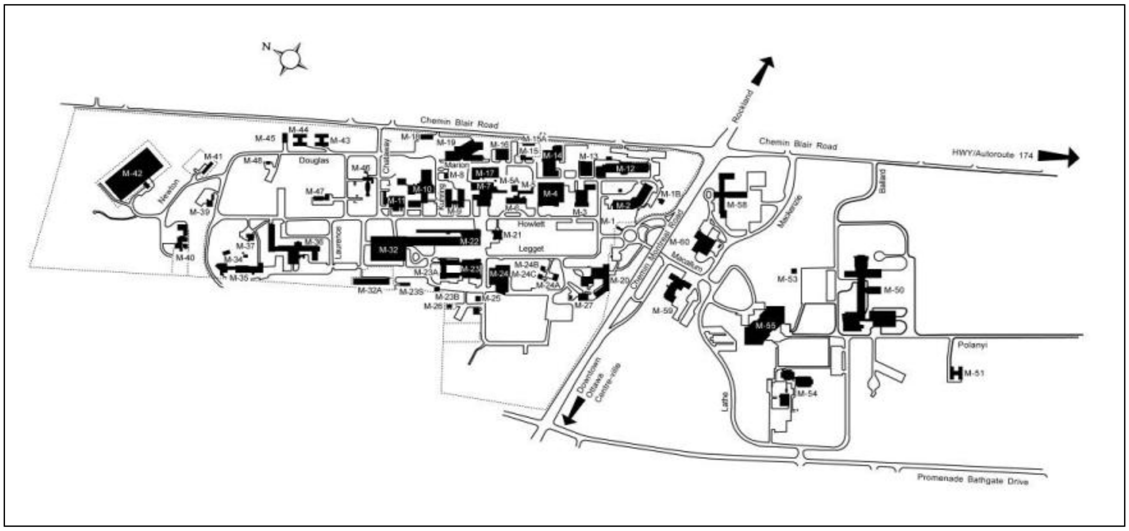

Figure 2.2: Schematic of the NRC Montreal Road Campus

2.2.2 Common Research Model Vertical Stabilizer

In consultation with the SAE G-12 AWG, a CRM was designed and built by the NRC (see Photo 2.3). The geometry (see summary in Table 2.2) was based on an analysis of existing aircraft geometries and designed to be a best representation of commercial aviation aircraft while maintaining a size and span of the section small enough to test in the IWT. The model (see Figure 2.3) was installed and characterized for testing in the winter of 2021-22 (see Photo 2.4).

Table 2.2: Summary of CRM Geometry Parameters

Parameter	Value
Aspect Ratio	1.07
Taper Ratio (C_{tip}/C_{base})	0.50
¼ Chord Sweep	40°
C_{Rudder}/C_{VS}	0.38*
Height	1.83 m / 6 ft.
Mean Chord	1.71 m / 5.6 ft.

*Design specification for rudder chord was 0.3, but the actual value was 0.38.

As shown in Photo 2.5, the vertical stabilizer was mounted on a splitter plate to minimize the aerodynamic effects from the tunnel floor. The splitter plate was attached to a turntable in the floor that allowed the effective sideslip angle of the model to be changed dynamically prior to and during a test. The effective sideslip (β) of the model ranged from -10 to +10 degrees. The rudder was servo-actuated and could also be changed dynamically prior to and during a test. The rudder deflection (δ_r) of the model ranged from -20 to +20 degrees. The sideslip and rudder limits were selected such that they provided adequate structural safety margins based on the load forces when in the tunnel. Crosswind effects were simulated by controlling the effective sideslip. Figure 2.4 demonstrates the effective sideslip and rudder deflection angles that would occur during a crosswind lift-off. Figure 2.5 demonstrates the simulated crosswind takeoff configuration used in the NRC IWT for the scenario shown in Figure 2.4. Figure 2.6 describes the sign conventions when referring to the CRM in the IWT.

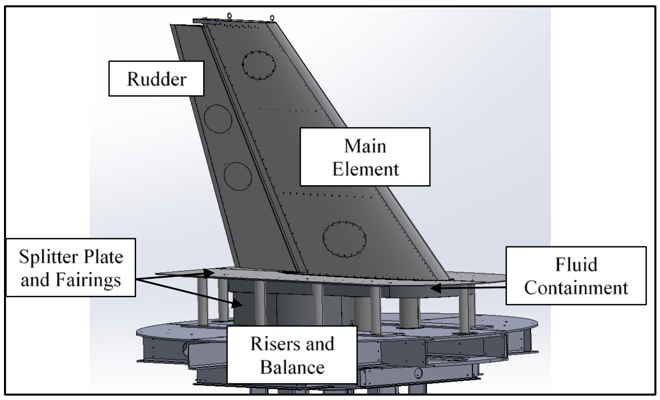

Figure 2.3: Common Research Model Vertical Stabilizer

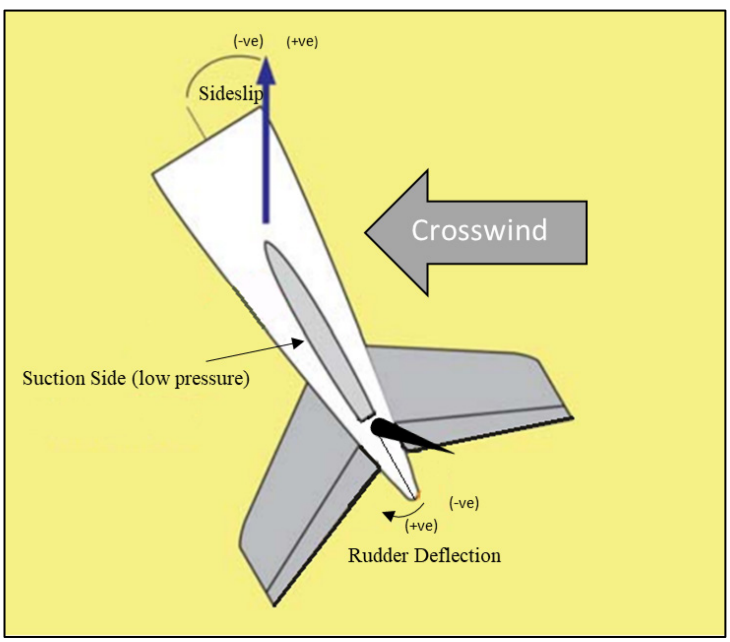

Figure 2.4: Effective Sideslip and Rudder Deflection Angles During a Crosswind Lift-off

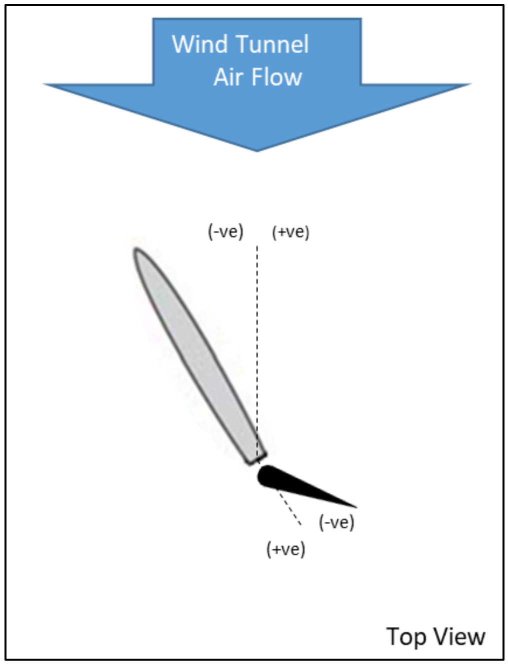

Figure 2.5: Simulated Crosswind Takeoff Configuration in the NRC IWT

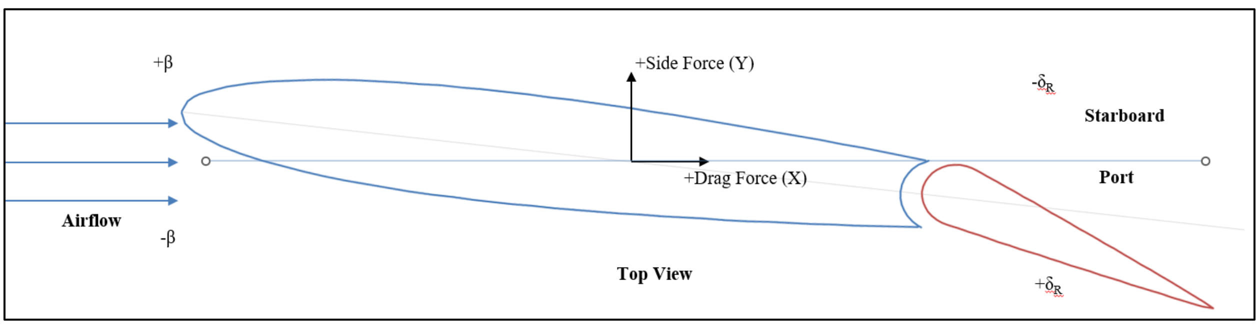

Figure 2.6: Sign Conventions for the CRM

2.2.3 Wind Tunnel Measurements

The vertical stabilizer was equipped with eight resistance temperature detectors (RTDs); these were installed by NRC personnel to record the skin temperature on both the port and starboard sides on the model. The eight RTDs were positioned at approximately one- and two-thirds the span of the port and starboard sides of the main element and rudder. The RTDs were labeled Main Port Lower, Main Port Upper, Main Starboard Lower, Main Starboard Upper, Rudder Port Lower, Rudder Port Upper, Rudder Starboard Lower, and Rudder Starboard Upper, accordingly. Figure 2.7 shows the approximate location of the RTDs on the port side; the starboard side would be symmetric, but it is not shown in the figure.

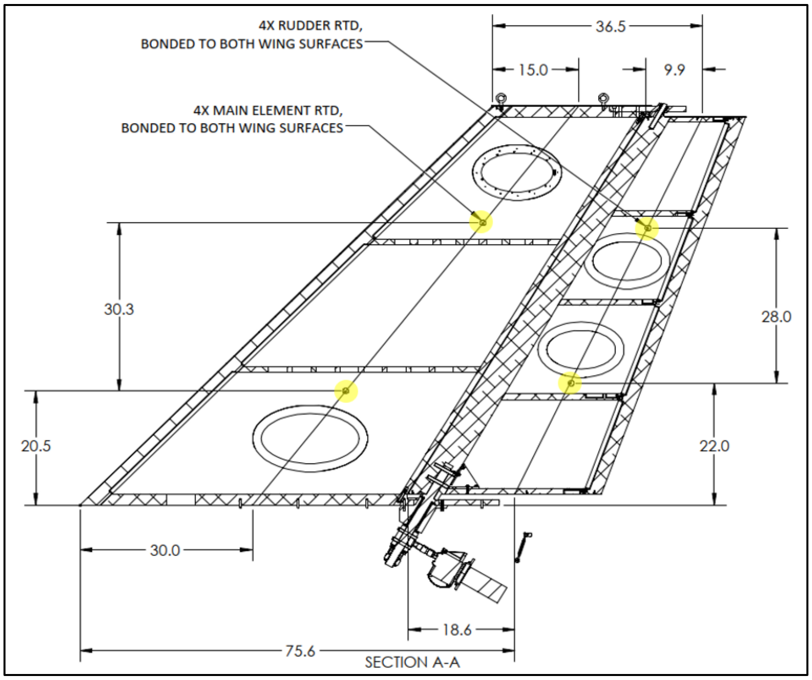

Figure 2.7: Location of RTDs on CRM

The wind tunnel was also equipped with sensors recording the following parameters:

1. Ambient temperature inside the tunnel;
2. Outside air temperature (OAT);
3. Air pressure;
4. Wind speed; and
5. Relative humidity.

It should be noted that aerodynamic forces on the model were not measured. The vertical stabilizer model was designed to include load cells for aerodynamic measurements; however, due to issues with procurement, dummy cells were used for Winter 2021-22. It is expected that these load cells will be acquired by the NRC during the summer of 2022 and will be available for future test campaigns with the CRM.

2.3 Simulated Precipitation

The following types of precipitation have been simulated for aerodynamic research in the IWT:

- Ice Pellets;
- Snow;
- Freezing Rain/Rain; and
- Other conditions related to holdover times (HOTs).

2.3.1 Ice Pellets

Simulated ice pellets were produced with diameters ranging from 1.4 mm to 4.0 mm to represent the most common ice pellet sizes observed during natural events. The ice pellets were manufactured on-site inside a refrigerated truck (see Photo 2.6). Cubes of ice were crushed and passed through calibrated sieves (see Photo 2.7) to obtain the required ice pellet size range. Hand-held motorized dispensers (see Photo 2.8) were used to dispense the ice pellets. The ice pellets were applied to the port and starboard sides of the vertical stabilizer at the same time.

2.3.2 Snow

Snow was produced using the same method for producing ice pellets. The snow used consisted of small ice crystals measuring less than 1.4 mm in diameter. Historical testing conducted by APS investigated the dissolving properties of the artificial snow versus natural snow. The artificial snow was selected as an appropriate substitute for natural snow.

The snow was manufactured on-site inside a refrigerated truck (see Photo 2.6). Cubes of ice were crushed and passed through calibrated sieves (see Photo 2.7) to obtain the required snow size range. Hand-held motorized dispensers were used to dispense the snow. The snow was applied to the port and starboard sides of the vertical stabilizer at the same time.

2.3.3 Freezing Rain/Rain

The NRC sprayer head and scanner that is typically used for HOT testing and has been retrofitted to work in the wind tunnel for the RJ wing model could not be used due to the location of the equipment versus the location of the vertical stabilizer.

Instead, a mix of water and ice in a garden sprayer was used to dispense simulated freezing rain (see Photo 2.9). A constant "S" shape spray pattern was produced manually, and the quantity of water being sprayed was measured before, after, and at several increments during the contamination period to ensure even distribution and a proper rate of precipitation.

2.3.4 Definition of Precipitation Rates

For the simulation of precipitation rates for full-scale and plate testing, the rate limits defined in SAE Aerospace Recommended Practice (ARP) 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type II, III, and IV* (3), and SAE ARP5945, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type I* (4), for standard HOT testing were referenced. Figure 2.8 demonstrates the HOT testing rate precipitation breakdown as follows:

- Light Ice Pellets: 13-25 g/dm²/h;
- Moderate Ice Pellets: 25-75 g/dm²/h;
- Light Freezing Rain: 13-25 g/dm²/h;
- Freezing Drizzle (Heavy): 5-13 g/dm²/h;
- Light Rain: 13-25 g/dm²/h;
- Moderate Rain: 25-75 g/dm²/h;
- Light Snow: 4-10 g/dm²/h; and
- Moderate Snow: 10-25 g/dm²/h.

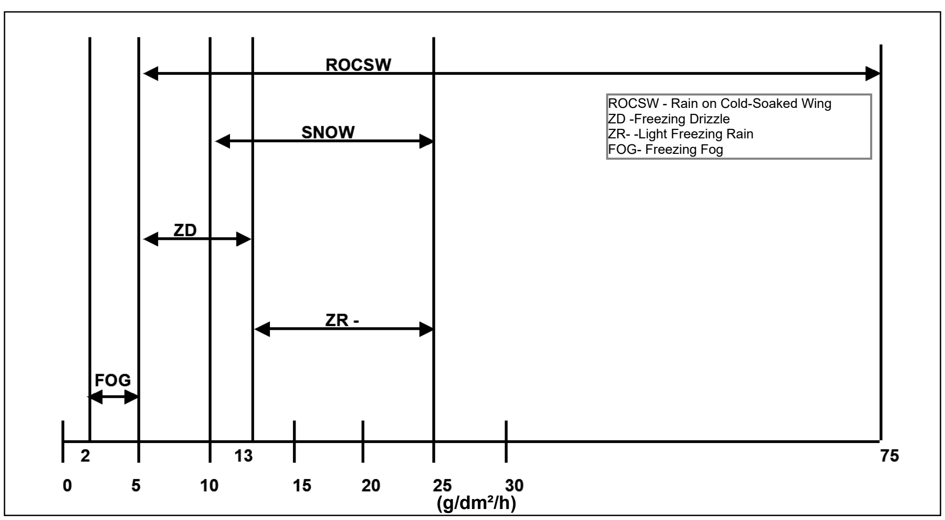

Figure 2.8: Precipitation Rate Breakdown

2.3.5 Simulated Crosswind Contamination

The test plan originally included a test parameter that was set to simulate the effect of high crosswinds. This high-crosswind scenario would result in an asymmetric contamination to one side of the vertical stabilizer versus the other. This would be simulated by applying contamination to only one side.

It should be noted that due to changing priorities during the test campaign, the simulated crosswind contamination tests (asymmetric contamination) were not performed. All contamination applied to the model was symmetric on both sides.

2.4 Fluid Failure on the Vertical Stabilizer Model

The time of visual failure was observed for each fluid test. The fluid was determined to have failed visually when the snow or precipitation was no longer absorbed by the fluid and began to accumulate on the fluid surface. A 10 percent failure coverage was historically used during TC/FAA full-scale aircraft fluid testing in the 1990s and was determined to correlate with the 33 percent failure coverage on the standard aluminum 10º angled test plates that have since been used to develop the HOTs. A fluid is expected to have visual failure at the end of the HOT.

2.5 Test Equipment

A considerable amount of test equipment was used. Key items are described in the following subsections. A full list of equipment is provided in the test procedure, which is included in Appendix B.

2.5.1 Video and Photo Equipment

Osmo® and GoPro® cameras were used for wide-angle filming of fluid flow-off during the test runs. Due to facility occupancy and travel restrictions, a closed-circuit television (CCTV) system was installed by APS and allowed remote viewing of the tests by participants using iPad®-based software. The CCTV cameras were positioned to provide different angle views of the vertical stabilizer model.

Photo 2.10 and Photo 2.11 demonstrate the camera setup used for the testing period.

2.5.2 Refractometer/Brixometer

Fluid freezing points were measured using a hand-held Misco 10431VP refractometer with a Brix scale (shown in Figure 2.9). The freezing points of the various fluid samples were determined using the conversion curve or table provided to APS by the fluid manufacturer.

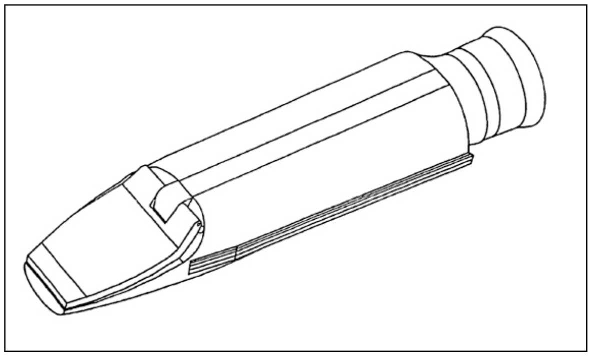

Figure 2.9: Hand-Held Refractometer/Brixometer

2.5.3 Wet Film Thickness Gauges

Wet film thickness gauges, shown in Figure 2.10, were used to measure fluid film thickness. These gauges were selected because they provide an adequate range of thicknesses (0.1 mm to 10.2 mm) for Type I/II/III/IV fluids. The rectangular gauge has a finer scale and was used in some cases when the fluid film was thinner (toward the end of a test). The observer recorded a thickness value (in mils), as read directly from the thickness gauge. The recorded value was the last wetted tooth of the thickness gauge; however, the true thickness lies between the last wetted tooth and the next un-wetted tooth; the measured thickness was corrected accordingly.

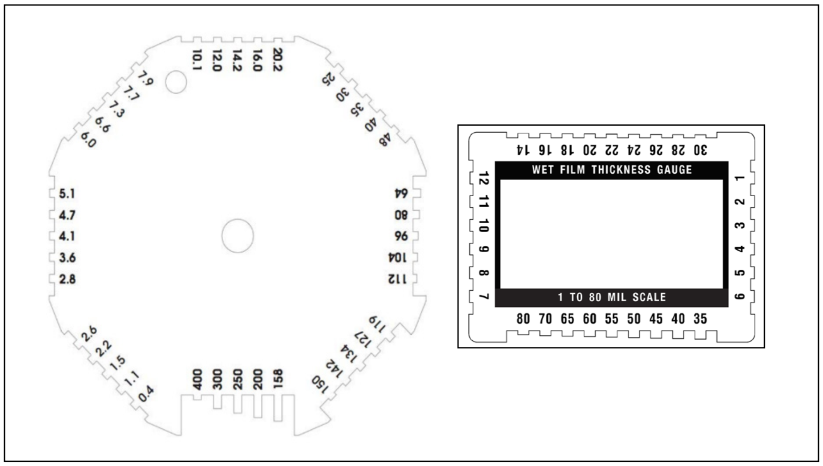

Figure 2.10: Wet Film Thickness Gauges

2.5.4 Hand-Held Immersion and Surface Temperature Probes

Hand-held immersion and surface temperature probes were used to provide instantaneous spot measurements during testing. These devices have an accuracy of ±0.4°C with 2-3 seconds read time. Figure 2.11 shows the schematic of the probes.

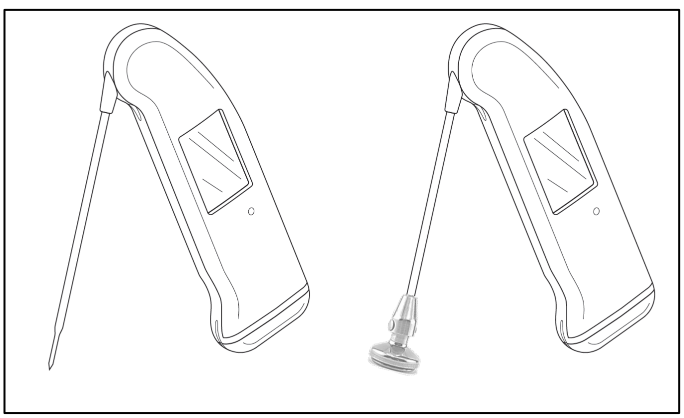

Figure 2.11: Hand-Held Immersion and Surface Temperature Probes

2.6 Personnel

During the fluid testing and exploratory research testing, three APS staff members were required to conduct the tests, and five additional personnel from Ottawa were tasked to manufacture and dispense ice pellets as well as to help with general setup tasks. A professional photographer was retained to record digital images of the test setup and test runs. Three persons from the NRC were required to operate the tunnel.

Representatives from TC and the FAA provided direction in testing and participated virtually as observers. Photo 2.12 shows a portion of the research team (due to scheduling, not all participants were available for the photo).

2.7 Data Forms

Several different forms were used to facilitate the documentation of the various data collected in the wind tunnel trials. Copies of these forms are provided in the test procedure, which is included in Appendix B. Completed vertical stabilizer temperature, fluid thickness, and fluid Brix data forms have been included in Appendix C.

2.8 Data Collection

Fluid thickness, fluid Brix, and skin temperature measurements were collected by APS personnel. The measurements, along with other pertinent data parameters, were collected before and after fluid application, after the application of contamination, and at the end of the test. Visual evaluations of the model were also documented before, during, and after the takeoff runs. The completed data forms have been scanned and included in Appendix C for referencing purposes.

Video and photography were also taken during the tests. Due to the large amount of data available, photos of the individual tests have not been included in this report, but the high-resolution photos and video have been provided to TC in electronic format and can be made available upon request.

2.9 De/Anti-Icing Fluids

Three fluids were used for testing:

- Dow Chemical Company UCAR™ propylene glycol (PG) aircraft deicing Concentrate Type I Fluid (measured viscosity n/a);
- Cryotech Deicing Technology Polar Guard® Advance Type IV Fluid (measured viscosity 13,860 cP); and
- Dow Chemical Company UCAR™ Endurance EG106 De/Anti-Icing Type IV Fluid (measured viscosity 43,000 cP).

2.9.1 Viscometer

Historically, viscosity measurements have been carried out using a Brookfield viscometer (shown in Photo 2.14) fitted with a recirculating fluid bath and small sample adapter. In recent years, on-site measurements are also done with the Stony Brook PDVdi-120 Falling Ball Viscometer whenever possible (Photo 2.15) to obtain a quick verification of the fluid integrity. The falling ball tests are much faster and more convenient to perform compared to tests with the Brookfield viscometer. The falling ball, however, does not provide the absolute value of viscosity, but rather a time interval that is compared to historical samples to identify changes in viscosity.

2.9.2 Fluid Application Equipment

The Type II/III/IV fluids were stored outside the wind tunnel and were kept at ambient temperature. Type II, III, and IV fluids are generally received in 20 L containers; however, some fluids are received in large 200 L barrels or larger 1000 L totes.

The fluid was applied to the model by using a garden sprayer with the atomizing nozzle removed to minimize fluid shearing (Photo 2.13). Type I fluid was diluted with hard water and heated in large pots using hot plates. The Type I fluid heated to 60°C was applied to the vertical stabilizer using a garden sprayer.

2.9.3 Waste Fluid Collection

APS personnel used a vacuum to collect the fluid that would drip onto the tunnel floor prior to each test. The NRC also fitted the wind tunnel with appropriate drainage tubes to collect spent fluid during the takeoff test runs. At the end of the testing period, the services of a waste removal company were employed to safely dispose of the waste glycol fluid.

Photo 2.1: Outside View of the NRC Wind Tunnel Facility

Photo 2.2: Inside View of the NRC Icing Wind Tunnel Test Section with CRM

Photo 2.3: Collage of Images During Manufacturing of the CRM

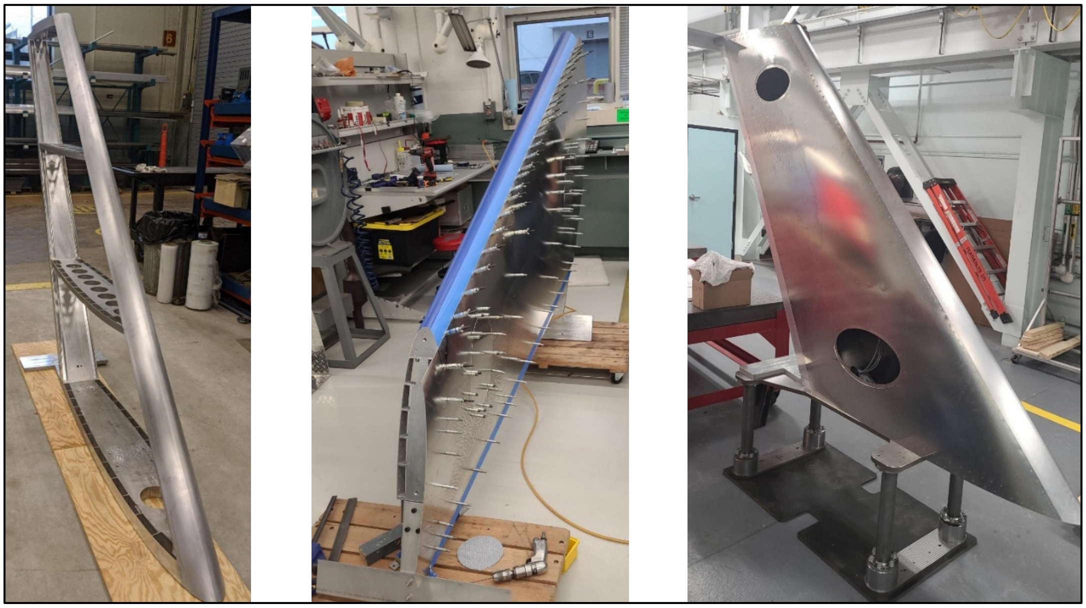

Photo 2.4: Vertical Stabilizer Mounted in the NRC IWT for Testing

Photo 2.5: View of Splitter Plate Used to Mount the CRM

Photo 2.6: Refrigerated Truck Used for Manufacturing Ice Pellets

Photo 2.7: Calibrated Sieves Used to Obtain Desired Size Distribution

Photo 2.8: Ice Pellet/Snow Dispenser Operated by APS Personnel

Photo 2.9: Simulating Freezing Rain with Garden Sprayer

Photo 2.10: Osmo® and CCTV Video Camera Installed on Wall of Wind Tunnel

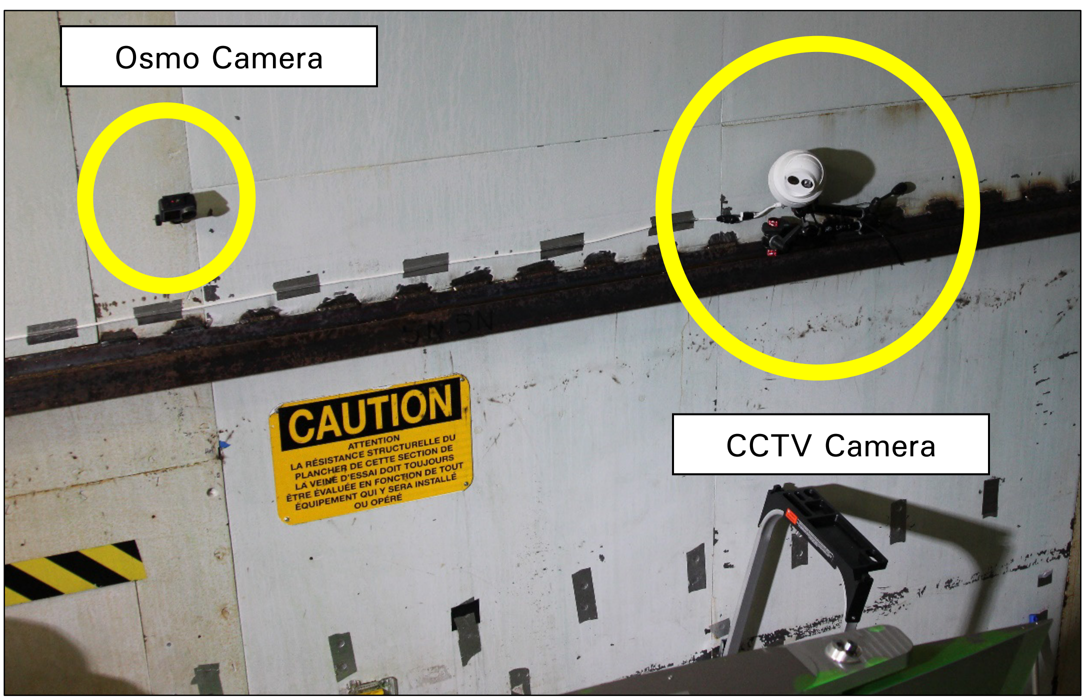

Photo 2.11: Location of Osmo® and CCTV Video Camera Mounts

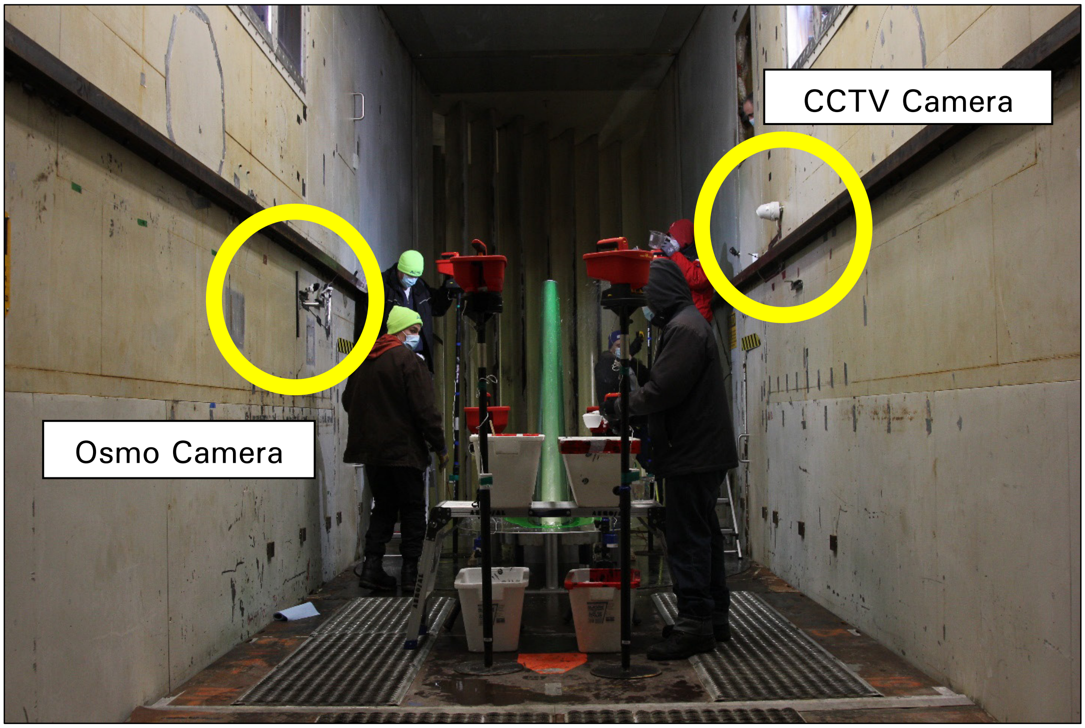

Photo 2.12: 2021-22 Research Team

Photo 2.13: Garden Sprayer Hand-Held Wand Applying Fluid

Photo 2.14: Brookfield Digital Viscometer

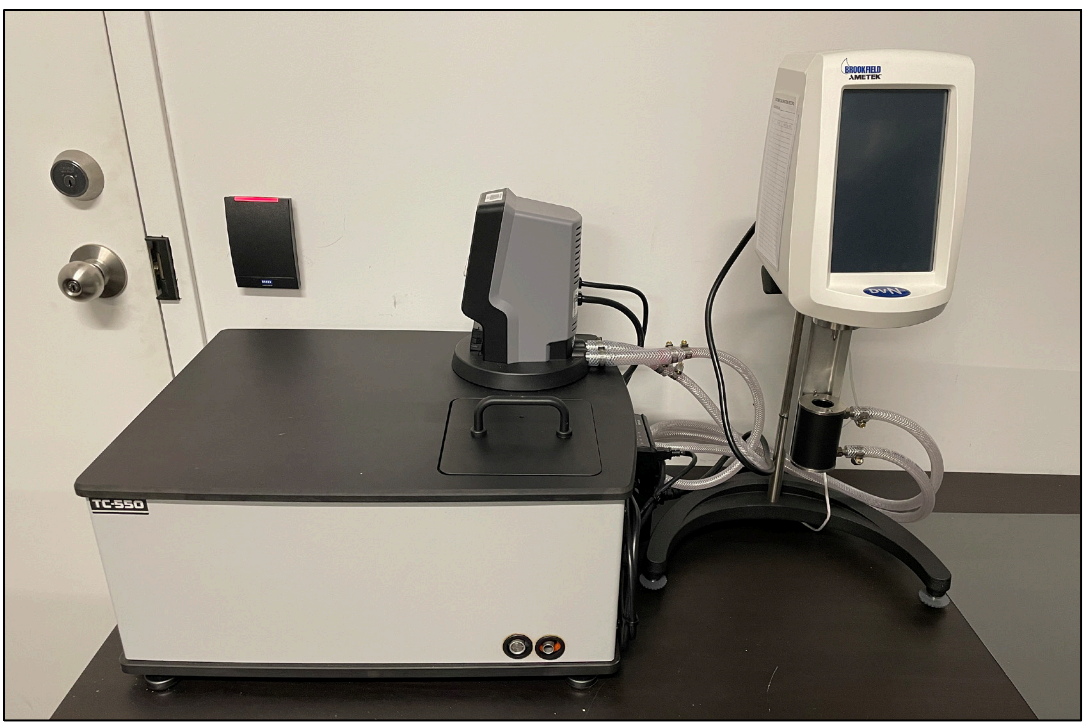

Photo 2.15: Stony Brook PDVdi-120 Falling Ball Viscometer

3. FULL-SCALE DATA COLLECTED

3.1 Test Log

A detailed log of the tests conducted in the NRC IWT during the winter of 2021-22 is included in Table 3.1. The log provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. The following is a brief description of the column headings for the logs included in Table 3.1.

Test #:	Exclusive number identifying each test run.
Date:	Date when the test was conducted.
Test Objective:	Description of the test objective.
Fluid Name:	Aircraft anti-icing fluid used during the test.
Sideslip β*:*	The effective sideslip angle of the model during the test, ranging from +10° to -10°.
Rudder Deflection δ_r*:*	The rudder deflection angle during the test, ranging from +20° to -20°.
Speed (kts):	Maximum speed obtained during simulated takeoff run, recorded in knots.
Tunnel Temp. Before Test (°C):	Static tunnel air temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius. *Note: This parameter was used as the actual test temperature for analysis.*
OAT Before Test (°C):	OAT recorded just before the start of the simulated takeoff test, measured in degrees Celsius. *Note: This is not an important parameter as "Tunnel Temp. Before Test" was used as the actual test temperature for analysis.*
Precipitation Rate (Type: [g/dm²/h]):	Simulated freezing precipitation rate (or combination of different precipitation rates); "-" indicates that no precipitation was applied.

Exposure Time:	Simulated precipitation period, recorded in minutes.
Extra Comments:	Extra comments describing methodology changes or observations related to the test.

Table 3.1: Test Log

Test #	Date	Test Objective	Fluid Name	Sideslip (β)	Rudder Deflection (δ_r)	Speed (kts)	Tunnel Temp. Before Test (°C)	OAT Before Test (°C)	Precip. Rate (g/dm²/h)	Exposure Time (min)	Extra Comments
1	4-Feb-22	Tufts	None	β = 0°	δ_r = 0 to -20 @2° incr.	100	n/a	n/a	-	-	Tufts on both sides
2	4-Feb-22	Tufts	None	β = 0°	δ_r = 0 to +20 @2° incr.	100	n/a	n/a	-	-	Tufts on both sides
3	4-Feb-22	Tufts	None	β = -5°	δ_r = 0 to -20 @2° incr.	100	n/a	n/a	-	-	Tufts on both sides
4	4-Feb-22	Tufts	None	β = -5	δ_r = 0 to +20 @2° incr.	100	n/a	n/a	-	-	Tufts on both sides
5	4-Feb-22	Tufts	None	β = -10	δ_r = 0 to -20 @2° incr.	100	n/a	n/a	-	-	Tufts on both sides
6	4-Feb-22	Tufts	None	β = -10	δ_r = 0 to +20 @2° incr.	100	n/a	n/a	-	-	Tufts on both sides
7	4-Feb-22	Tufts	None	β = 0	δ_r = 10 to 14 @2° incr.	100	-8.49	-10.2	-	-	Tufts on both sides
8	6-Feb-22	Dry Wing	None	β = 0 to -10 (dynamic)	δ_r = 0 to -20°	100	-8.57	-11.1	-	-	To be done at start of each day
9	6-Feb-22	Fluid Only	Polar Guard Advance	β = 0°	δ_r = 0°	100	-7.43	-10.7	-	-	Flooded the top flat surface of the main element and rudder during application
10	6-Feb-22	Fluid Only	Polar Guard Advance	β = 0°	δ_r = -10°	100	-7.79	-10.6	-	-	Flooded the top flat surface of the main element and rudder during application
11	7-Feb-22	Fluid Only	Polar Guard Advance	β = 0°	δ_r = -10°	100	-8	-10.4	-	-	-
12	7-Feb-22	Fluid Only	Polar Guard Advance	β = 0°	δ_r = 0°	100	-7.5	-10.2	-	-	-

Table 3.1: Test Log (cont'd)

Test #	Date	Test Objective	Fluid Name	Sideslip (β)	Rudder Deflection (δ_r)	Speed (kts)	Tunnel Temp. Before Test (°C)	OAT Before Test (°C)	Precip. Rate (g/dm²/h)	Exposure Time (min)	Extra Comments
13	7-Feb-22	Fluid Only	Polar Guard Advance	β = 0°	δ_r = -20°	100	-6.83	-9.8	-	-	-
14	7-Feb-22	Fluid Only	Polar Guard Advance	β = -10°	δ_r = -20°	100	-7.36	-9.7	-	-	-
15	7-Feb-22	Fluid Only	EG106	β = 0°	δ_r = 0°	100	-5.23	-9.3	-	-	-
16	7-Feb-22	Fluid Only	EG106	β = 0°	δ_r = -10°	100	-6.86	-9.5	-	-	-
17	7-Feb-22	Fluid Only	EG106	β = 0°	δ_r = -20°	100	-7.28	-9.9	-	-	-
18	7-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	-6.6	-10.1	-	-	-
19	7-Feb-22	Dry Wing	None	β = 0 to -10° (dynamic)	δ_r = 0 to -20°	100	-2.02	-5	-	-	To be done at start of each day
20	7-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	-3.05	-5	-	-	-
21	7-Feb-22	Fluid Only	TI	β = 0°	δ_r = 0°	100	-2.77	-5.1	-	-	-
22	7-Feb-22	Fluid Only	TI	β = 0°	δ_r = -10°	100	-0.96	-5.2	-	-	-
23	8-Feb-22	Fluid Only	TI	β = 0°	δ_r = -20°	100	-2.5	-5.4	-	-	-
24	8-Feb-22	Fluid Only	TI	β = -10°	δ_r = -20°	100	-2.75	-5.4	-	-	-
25	8-Feb-22	Fluid and Cont. (SN)	EG106	β = 0°	δ_r = -10°	100	-2.15	-5.5	SN: 25	40	Exposure to HOT

Table 3.1: Test Log (cont'd)

Test #	Date	Test Objective	Fluid Name	Sideslip (β)	Rudder Deflection (δ_r)	Speed (kts)	Tunnel Temp. Before Test (°C)	OAT Before Test (°C)	Precip. Rate (g/dm²/h)	Exposure Time (min)	Extra Comments
26	8-Feb-22	Fluid and Cont. (SN)	EG106	β = 0°	δ_r = -10°	100	-2.02	-5.4	SN: 25	15	Exposure to V-Stab 10% fail
27	8-Feb-22	Fluid and Cont. (SN)	EG106	β = -10°	δ_r = -20°	100	-1.29	-5.6	SN: 25	15	Exposure to V-Stab 10% fail
28	8-Feb-22	Dry Wing	None	β = 0 to -10° (dynamic)	δ_r = 0 to -20°	100	-1.49	-2.1	-	-	To be done at start of each day
29	9-Feb-22	Fluid and Cont. (SN)	Polar Guard Advance	β = 0°	δ_r = -10°	100	-3.46	-3.8	SN: 25	70	Exposure to HOT
30	9-Feb-22	Fluid and Cont. (SN)	Polar Guard Advance	β = 0°	δ_r = 0°	100	-3.27	-4	SN: 25	15	Exposure to V-Stab 10% fail
31	9-Feb-22	Fluid and Cont. (SN)	Polar Guard Advance	β = 0°	δ_r = -10°	100	-3.36	-4.8	SN: 25	15	Exposure to V-Stab 10% fail
32	9-Feb-22	Fluid and Cont. (FZR)	Polar Guard Advance	β = 0°	δ_r = -10°	100	-4	-6.1	ZR: 25	75	Exposure to HOT
33	9-Feb-22	Dry Wing	None	β = 0 to -10° (dynamic)	δ_r = 0 to -20°	100	-0.15	-2.3	-	-	To be done at start of each day
34	9-Feb-22	Fluid Only	Polar Guard Advance	β = -10°	δ_r = -20°	100	-0.41	-2.4	-	-	-
35	9-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	0.9	-2.2	-	-	Wing rotates back to home too early (skipped post measurements)
36	9-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	-0.69	-2.2	-	-	-
37	9-Feb-22	Fluid Only (1 engine out + crosswind)	EG106	β = +10° to 0° (dynamic)	δ_r = -20°	100	-0.66	-2.13	-	-	-
38	10-Feb-22	Fluid Only (1 engine out)	EG106	β = 0°	δ_r = 0 to -20° (dynamic)	100	0.04	-2.04	-	-	-

Table 3.1: Test Log (cont'd)

Test #	Date	Test Objective	Fluid Name	Sideslip (β)	Rudder Deflection (δ_r)	Speed (kts)	Tunnel Temp. Before Test (°C)	OAT Before Test (°C)	Precip. Rate (g/dm²/h)	Exposure Time (min)	Extra Comments
39	10-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	0.31	-1.9	-	-	Fluid only on pressure side
40	10-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	0.57	-1.9	-	-	Fluid only on suction side
41	10-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	115	1.31	-1.9	-	-	-
42	10-Feb-22	Fluid Only	EG106	β = 0°	δ_r = -20°	115	1.22	-1.7	-	-	-
43	10-Feb-22	Fluid Only	EG106	β = 0°	δ_r = -10°	100	1.81	-1.6	-	-	Fluid only on pressure side
44	10-Feb-22	Fluid Only	Polar Guard Advance	β = 0°	δ_r = -10°	100	1.05	-1.7	-	-	Fluid only on pressure side
45	10-Feb-22	Fluid Only	Polar Guard Advance	β = -10°	δ_r = -20°	100	1.05	-1.6	-	-	Fluid only on pressure side
46	10-Feb-22	Dry Wing	None	β = 0 to -10° (dynamic)	δ_r = 0 to -20°	100	2.18	1.5	-	-	To be done at start of each day
47	10-Feb-22	Fluid Only	EG106	β = 0°	δ_r = -20°	100	1.85	1.4	-	-	Fluid only on pressure side
48	10-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	1.61	1	-	-	Longer takeoff 60+ sec
49	11-Feb-22	Fluid Only (1 engine out + crosswind)	EG106	β = +10° to -10° (dynamic)	δ_r = -20°	100	1.64	0.9	-	-	-
50	11-Feb-22	Fluid Only (1 engine out + crosswind)	EG106	β = +10° to -10° (dynamic)	δ_r = -20°	115	1.23	0.8	-	-	Trigger rudder and sideslip deflection at 100 knots
51	11-Feb-22	Fluid Only (1 engine out + crosswind)	EG106	β = +10° to -10° (dynamic)	δ_r = -20°	115	1.23	0.5	-	-	-

Table 3.1: Test Log (cont'd)

Test #	Date	Test Objective	Fluid Name	Sideslip (β)	Rudder Deflection (δ_r)	Speed (kts)	Tunnel Temp. Before Test (°C)	OAT Before Test (°C)	Precip. Rate (g/dm²/h)	Exposure Time (min)	Extra Comments
52	11-Feb-22	Fluid Only	EG106	β = +10°	δ_r = -20°	100	1.3	0.5	-	-	-
53	11-Feb-22	Fluid Only	EG106	β = -10°	δ_r = -20°	100	2.22	0.54	-	-	Fluid only on bottom half
54	11-Feb-22	Fluid Only	EG106	β = 0°	δ_r = -10°	100	1.52	0.5	-	-	RE-RUN OF 54: Fluid only on bottom half
55	11-Feb-22	Fluid Only (1 engine out + crosswind)	Polar Guard Advance	β = +10° to 0° (dynamic)	δ_r = -20°	100	1.26	0.5	-	-	-
56	14-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to -20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
57	14-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to +20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
58	14-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to -20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
59	14-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to +20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
60	14-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to -20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
61	14-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to +20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
62	14-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to -20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
63	14-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to +20 @2° incr.	100	-10	-13.7	-	-	#1 BLR Location (main port)
64	14-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to -20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)

Table 3.1: Test Log (cont'd)

Test #	Date	Test Objective	Fluid Name	Sideslip (β)	Rudder Deflection (δ_r)	Speed (kts)	Tunnel Temp. Before Test (°C)	OAT Before Test (°C)	Precip. Rate (g/dm²/h)	Exposure Time (min)	Extra Comments
65	14-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to +20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)
66	14-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to -20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)
67	14-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to +20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)
68	14-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to -20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)
69	14-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to +20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)
70	14-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to -20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)
71	14-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to +20 @2° incr.	100	-11.3	-13.1	-	-	#3 BLR Location (main stbd)
72	15-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to -20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)
73	15-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to +20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)
74	15-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to -20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)
75	15-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to +20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)
76	15-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to -20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)
77	15-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to +20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)

Table 3.1: Test Log (cont'd)

Test #	Date	Test Objective	Fluid Name	Sideslip (β)	Rudder Deflection (δ_r)	Speed (kts)	Tunnel Temp. Before Test (°C)	OAT Before Test (°C)	Precip. Rate (g/dm²/h)	Exposure Time (min)	Extra Comments
78	15-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to -20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)
79	15-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to +20 @2° incr.	100	-10.4	-14.1	-	-	#4 BLR Location (rudder stbd)
80	15-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to -20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)
81	15-Feb-22	Boundary Layer Rake	None	β = 0°	δ_r = 0 to +20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)
82	15-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to -20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)
83	15-Feb-22	Boundary Layer Rake	None	β = -5°	δ_r = 0 to +20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)
84	15-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to -20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)
85	15-Feb-22	Boundary Layer Rake	None	β = -10°	δ_r = 0 to +20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)
86	15-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to -20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)
87	15-Feb-22	Boundary Layer Rake	None	β = +10°	δ_r = 0 to +20 @2° incr.	100	-10.4	-11.8	-	-	#2 BLR Location (rudder port)

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4. CALIBRATION AND VALIDATION OF PROCEDURES

This section describes the activities related to the calibration and validation of the testing procedures.

4.1 Safety Checks and Shakedown Runs

The CRM vertical stabilizer was built custom by the NRC for this research activity. The structural integrity and mounting needed to be verified to ensure that the model would safely withstand the air speeds in the wind tunnel. Several tests were done prior to the start of the testing program for this purpose, and additional tests were done on the first day of testing. Minor adjustments were made accordingly, and no major modifications were required.

4.2 Fluid Application Procedures

The CRM was approximately twice as large, chord wise, as compared to the Piper Seneca II model used in 2019-20. As such, the previously developed fluid application methods had to be reviewed and modified for the CRM.

Due to the height and vertical orientation of the model, fluid hand pouring was not possible; therefore, a manual garden sprayer was used. To accelerate the process, and due to the larger area to cover, battery-operated motorized garden spreaders were acquired to apply fluid to the CRM for 2021-22. The atomizing nozzle was removed from the sprayer to prevent shearing of the fluid. The sprayer's hand-held wand attachment allowed personnel to apply fluid directly to the model with minimal waste. Due to the cold weather effects on the battery, additional care was taken to ensure batteries were fully charged and ready on standby for testing. The fluid application procedures were refined on the first day of testing and typically took about 10 minutes to complete for each test.

4.3 Precipitation Application Procedures

The CRM was approximately twice as large, chord wise, compared to the Piper Seneca II model used in similar tests conducted in 2019-20. As such, the precipitation application methods employed previously had to be revisited and modified for the CRM.

The dispensers historically used for the ice pellet allowance time research were adapted for this vertical stabilizer research. A separate calibration procedure was performed with the dispensers to determine the vertical footprint of the dispenser output when dispersing snow, the details of which can be found in the procedure included in Appendix B.

The vertical stabilizer was mounted on a splitter plate that elevated the model off the ground. As such, the team needed to employ specialized ladders to safely and properly dispense snow at the heights necessary to properly contaminate the top of the model. Several different ladders and configurations were tested before proceeding to ensure a safe and efficient setup that could be easily mounted and torn down. The setup was finalized on the first day of testing.

4.4 Viewing Platforms and Live Video Feeds

Viewing windows are located on both sides of the wind tunnel. To obtain a view of both sides of the model, a CCTV system was installed by APS and allowed viewing of the tests by stakeholders on-site and remotely. The CCTV cameras were positioned to provide different angle views of the vertical stabilizer model. In addition, Osmo® and GoPro® cameras were used for wide-angle high-definition filming of fluid flow-off during the test runs.

4.5 General Observation

The IWT provided an effective setting to carry out the anticipated research, accommodating the installation of an appropriate-size model and allowing the application of de/anti-icing fluids.

5. DRY WING, TUFT VISUALIZATION, AND BOUNDARY LAYER RAKE TESTING

This section describes activities related to the dry surface testing, tuft visualization, and boundary layer rake testing.

5.1 Dry Surface Testing

The CRM vertical stabilizer was designed to have load cells to measure aerodynamic forces; however, they were not available at the time of testing, and dummy cells were installed instead for the 2021-22 testing. As such, the dry surface testing was limited to the shakedown runs done as part of the initial calibration and validation tests.

In the future, if a model equipped with load cells were to be used for testing, more extensive dry surface testing would be recommended to explore the effect of sideslip and rudder deflection angles on the aerodynamic forces recorded.

5.2 Tuft Visualization

The tuft testing aimed to evaluate the aerodynamic flow over the surface of the vertical stabilizer model. The objective was to identify the different patterns of airflow associated with different sideslip (β) and rudder deflection (δ_r) angle configurations. The tufts, which were pieces of white yarn attached to the model using speed tape, were used for flow visualization (see Photo 5.1). The motion of the tufts would help identify the flow patterns (boundary layer separation, reattachment, etc.) on areas of the model. For the purpose of this testing, the definitions below were used.

1. Attached: Most of the tufts are straight, but areas where some tufts will "shimmy" indicate flow disturbance.
2. Separated: The tufts move around erratically, indicating high turbulence, flow separation, and flow reversal.

During testing, the rudder deflection and the effective sideslip could be changed dynamically by activating the rudder servo motor or rotating the mechanical turntable that supported the model. The model's angle configurations were changed dynamically once the tunnel reached the 100-knot speed.

The tuft visualization testing included rudder deflection configurations in 2º increments from 0° to -20° and from 0° to +20°. These tests were run with 0°, -5°, and -10° effective sideslip angles. It should be noted that the aerodynamic effects were expected to be symmetric; consequently, the angle selection was biased towards the port side, which allowed the best visual observations from the viewing platform.

The limits of the model configuration were $\beta = 0°$, $\delta_r = 0°$ (the neutral configuration) and $\beta = \pm 10°$, $\delta_r = \pm 20°$ (full sideslip and full rudder deflection).

Photo 5.2 and Photo 5.3 represent both configurations during the test run. The photos demonstrate examples of attached airflow on the main element and the rudder and attached airflow on the main element and separated flow on the rudder, respectively. The objective of the tuft visualization test matrix was to determine at which point the flow began to separate. Through the testing, the $\beta = 0°$, $\delta_r = -12°$ configuration was found to be the point at which separation began on the rudder. Table 5.1 provides a summary of the results observed.

Through discussions with TC, the FAA, NASA, Boeing, and APS, it was decided that $\beta = 0°$, $\delta_r = -10°$ (see Photo 5.4) would be selected as the “baseline” or “standard” configuration for testing to “bound” the ideal flow conditions. Through this configuration, any separation or excessively turbulent airflow could be attributed to any external affects from test variables such as fluid and contamination. The effective sideslip remained 0º intentionally to avoid complicating the testing protocol unnecessarily, as it was determined that modifying this value would only amplify or reduce the effects of the chosen rudder deflection.

Table 5.1: Summary of Aerodynamic Effects Visualized with Varying Configurations

Effective Sideslip β	Rudder Deflection δ_r	Flow Characteristics
0˚	0˚	Flow was attached with little turbulence.
-10˚	-20˚	Flow separated on the rudder on the suction side.
0˚	-12˚	Flow separation began (tip of the rudder on the suction side).
0˚	**-10˚**	**Selected as the limit of where flow remained attached.**

Based on the configuration selected, the basic research protocol (which could be modified based on objective) was the following:

- Configure effective sideslip angle to 0º;
- Configure rudder deflection angle to -10º;
- Apply fluid and contamination;
- Accelerate to 100 knots; and
- Evaluate flow-off and compare to dry or baseline tests.

5.3 Boundary Layer Rake Testing

The boundary layer rake testing aimed to capture air pressure data in a series of different model configurations in order to quantify the flow characteristics over the surface of the model at select points. The boundary layer rake pressure ports were positioned at increasing heights in parallel to the airstream, and a reference static pressure port (with the wind) was also included. Three boundary layer rakes were available for simultaneous use, and were installed at approximately 30 percent, 50 percent, and 70 percent of model span. The boundary layer rakes were mounted near the trailing edges of main element and rudder (see Photo 5.5 and Photo 5.6). Measurements were taken with rudder deflection configurations in 2º increments from 0° to -20° and from 0° to +20° with effective sideslip angles of 0°, -5°, and -10°.The data collected was analysed by the NRC and a separate report will be prepared for TC and the FAA; however, the following provides a brief summary.

The test runs indicated uniform, attached flow and model symmetry with rudder deflection and sideslip. The results also indicated that the boundary layer was thicker at the bottom of the model and thinner at top, a function of the greater chord length at bottom. It was also observed that the boundary layer was thicker over the rudder compared to the main element. While the main element of the tail did not stall, the rudder stalled at 12° for the top boundary layer rake and at 16° for the middle and bottom boundary layer rakes. The boundary rake testing did not identify any anomalies in the flow characteristics.

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Photo 5.1: Tufts Attached to the Vertical Stabilizer Model Using Speed Tape

Photo 5.2: Attached/Turbulent Airflow

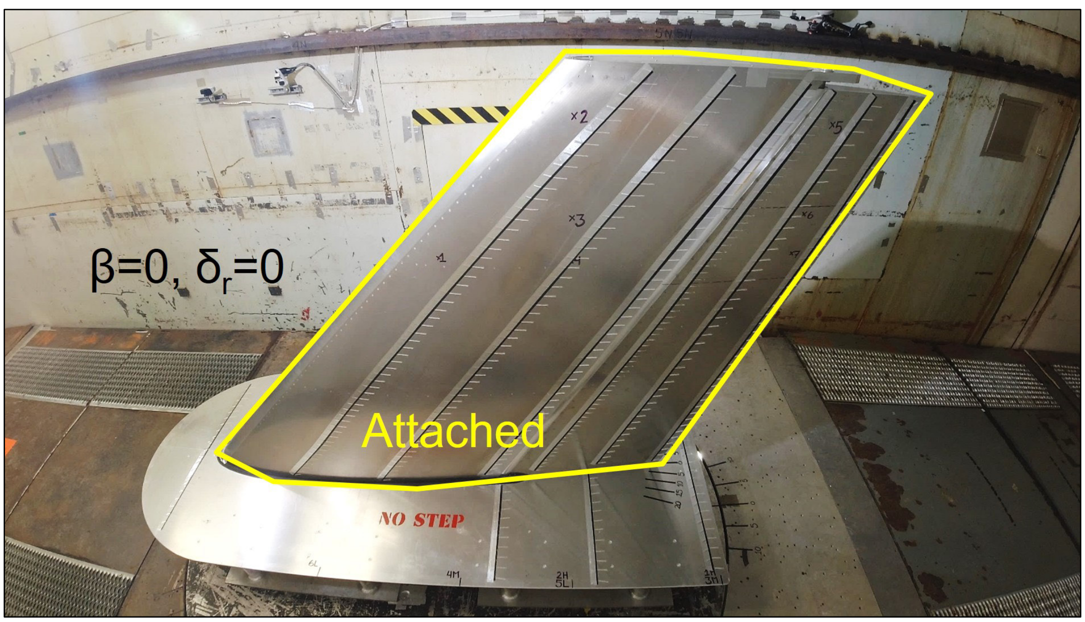

Photo 5.3: Attached/Turbulent Airflow on the Main Element and Separated Flow on the Rudder

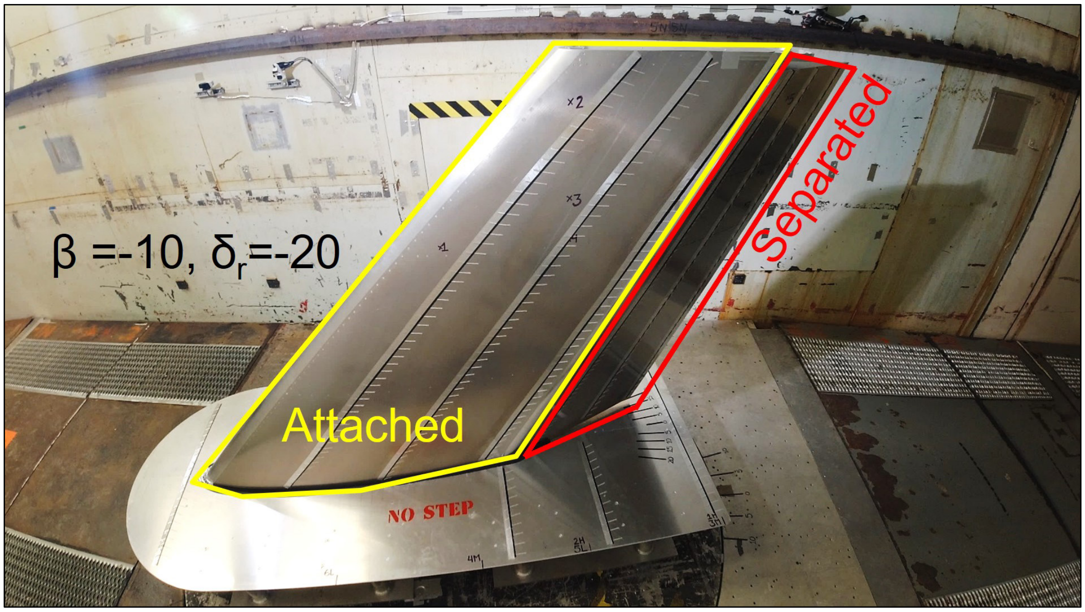

Photo 5.4: Limit of Attached/Turbulent Airflow

Photo 5.5: Schematic and Actual Photos of Boundary Layer Rake

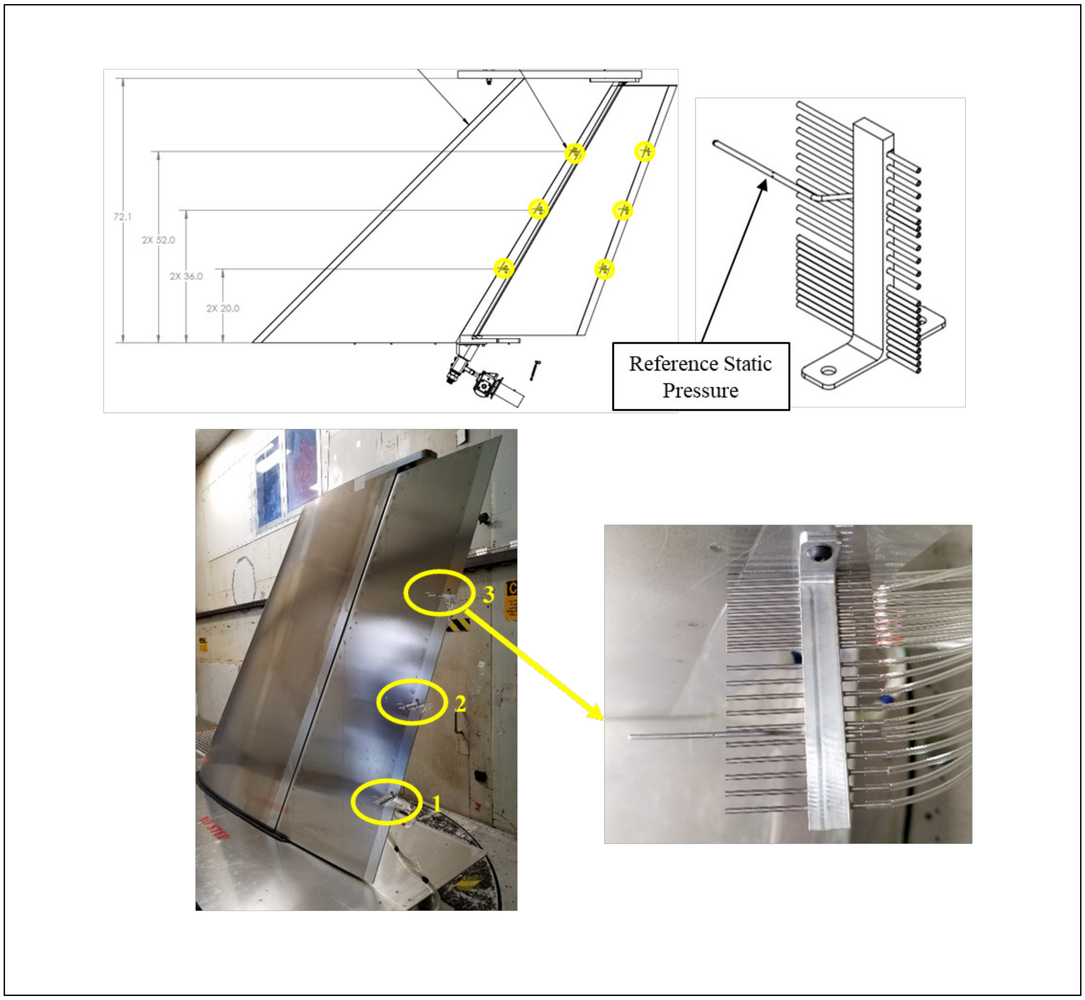

Photo 5.6: Additional Photos of Boundary Layer Rake Installation

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6. FLUID TESTING AND FLOW-OFF CHARACTERIZATION

This section describes the activities related to the fluid testing and flow-off characterization.

6.1 Overview of Testing Strategy

The CRM vertical stabilizer testing was preliminary and limited; therefore, tests to be performed were strategically chosen based on their likeliness to provide the most informative data. This testing was primarily conducted with Type IV ethylene glycol (EG) based fluid to get a more wholistic view of the expected performance in varying conditions. In addition, the dye in the EG fluid allowed for better visibility during the exploratory testing. Complementary testing was also conducted with Type I and Type IV PG fluids in specific conditions to evaluate the similarities or differences of the fluid types.

The plan for the fluid testing and flow-off characterization can be summarized by the following major headings.

1. Fluid-Only Testing
    a. Type IV EG Fluid Only
    b. Type IV PG Fluid Only
    c. Type I PG Fluid Only
2. Fluid and Contamination Testing
    a. Type IV EG Fluid – Simulated Moderate Snow
    b. Type IV PG Fluid – Simulated Moderate Snow
    c. Type IV PG Fluid – Simulated Freezing Rain
3. One Engine Inoperative (OEI) and Crosswind Simulations
    a. Type IV EG Fluid – OEI
    b. Type IV EG Fluid – OEI + Crosswind #1
    c. Type IV EG Fluid – OEI + Crosswind #2
    d. Type IV EG Fluid – OEI + Crosswind #2 @100-115 Kts
    e. Type IV EG Fluid – OEI + Crosswind #2 @115 Kts
    f. Type IV PG Fluid – OEI + Crosswind #1

4. Non-Standard Fluid Applications to Isolate Specific Aerodynamic Parameters
    a. Type IV EG Fluid – Fluid Only on Pressure Side
    b. Type IV PG Fluid – Fluid Only on Pressure Side
    c. Type IV EG Fluid – Fluid Only on Suction Side
    d. Type IV EG Fluid – Fluid Only on Bottom Half
5. Different Takeoff Profiles
    a. Type IV EG Fluid – 115 Kts vs. 100 Kts
    b. Type IV EG Fluid – Longer Takeoff
    c. Type IV EG Fluid – Yaw Effect

A photographic summary of each set of tests is included at the end of this section. In addition, a summary of the fluid thickness measurements for each set of tests is included in Appendix D. For ease of cross-referencing, the photo number in Section 6 refers to the corresponding figure number in Appendix D (e.g., Photo 6.3 refers to Figure 3).

6.2 Fluid-Only Testing

The following subsections provide a summary of the fluid-only testing.

6.2.1 Type IV EG Fluid Only

Four comparative Type IV EG fluid-only tests (#15, #16, #17, and #18/20) were conducted with an approximate tunnel temperature of -6˚C, where the only variables changed were the β and δ_r angles. Four different configurations of β and δ_r were explored:

- Test #15: β = 0°, δ_r = 0° (a zero-crosswind scenario);
- Test #16: β = 0°, δ_r = -10° (the “basic” configuration);
- Test #17: β = 0°, δ_r = -20° (a full rudder configuration); and
- Tests #18/20: β = -10°, δ_r = -20° (a max crosswind scenario).

The test results demonstrated that the fluid was generally well removed from the forward part (main element) of the vertical stabilizer; however, some pooled fluid remained on the rudder on the suction side. The observed residual fluid increased as the β and δ_r decreased. The locations of the residual fluid were consistent with the results observed during the tuft tests that demonstrated turbulent flow or flow separation in those same areas. The dye in the EG fluid made it very helpful to identify the fluid present during the test. Photo 6.1 provides a photographic summary of these tests.

6.2.2 Type IV PG Fluid Only

Four comparative Type IV PG fluid-only tests (#9/12, #10/11, #13, and #14) were conducted with an approximate tunnel temperature of -7˚C, where the only variables changed were the β and δ_r angles. The same four different configurations of β and δ_r were explored:

- Tests #9/12: β = 0°, δ_r = 0° (a zero-crosswind scenario);
- Tests #10/11: β = 0°, δ_r = -10° (the "basic" configuration);
- Test #13: β = 0°, δ_r = -20° (a full rudder configuration); and
- Test #14: β = -10°, δ_r = -20° (a max crosswind scenario).

The test results were similar to the EG fluid results in that they demonstrated that the fluid was generally well removed from the forward part (main element) of the vertical stabilizer; however, some pooled fluid remained on the rudder on the suction side. The residual fluid observed increased as the β and δ_r decreased. The locations of the residual fluid were consistent with the results observed during the tuft tests that demonstrated turbulent flow or flow separation in those same areas. However, the pale green dye in the PG fluid was not as visually prominent as with the EG fluid and therefore made it more difficult to visually observe the thin fluid layers during the takeoff simulation. Photo 6.2 provides a photographic summary of these tests.

6.2.3 Type I PG Fluid Only

Four comparative Type I PG fluid-only tests (#21, #22, #23, and #24) were conducted with an approximate tunnel temperature of -2˚C, where the only variables changed were the β and δ_r angles. Four different configurations of β and δ_r were explored:

- Test #21: β = 0°, δ_r = 0° (a zero-crosswind scenario);
- Test #22: β = 0°, δ_r = -10° (the "basic" configuration);
- Test #23: β = 0°, δ_r = -20° (a full rudder configuration); and
- Test #24: β = -10°, δ_r = -20° (a max crosswind scenario).

The test results were similar to the Type IV EG and PG fluid results in that they demonstrated that the fluid was generally well removed from the forward part (main element) of the vertical stabilizer; however, some fluid remained on the rudder on the suction side. The residual fluid observed increased as the β and δ_r decreased. The locations of the residual fluid were consistent with the results observed during the tuft tests that demonstrated turbulent flow or flow separation in those same areas. However, the thinner fluid layer coupled with the pale red dye was not as visually prominent as compared to the Type IV fluids, especially the Type IV EG fluid, and therefore made it more difficult to visually observe the thin fluid layers during the takeoff simulation. Photo 6.3 provides a photographic summary of these tests.

6.3 Fluid and Contamination Testing

The following subsections provide a summary of the fluid and contamination testing.

6.3.1 Type IV EG Fluid – Simulated Moderate Snow

Two comparative Type IV EG tests (#25 and #26) were conducted at an approximate tunnel temperature of -2°C with the model configured to the "basic" configuration $\beta = 0°$ and $\delta_r = -10°$. At -1°C, the HOT estimated from the Type IV HOT Guidelines was approximately 40 minutes.

In the first test (#25), the model was exposed to artificial snow precipitation for the full HOT of 40 minutes and resulted in a fluid that was 100 percent failed (entire surface covered in failed fluid) by the end of exposure. In the second test (#26), application of contamination was stopped after 15 minutes, at which point approximately 10 percent of the vertical stabilizer surface was failed.

The flow-off performance was much different in the two scenarios. In the first test, slushy contamination remained on various areas of the main element and rudder, especially in the areas where the fluid had thinned out or dried out during the contamination period. The contamination remaining after the test was not adhered (could be easily moved around with a finger), but neither was it removed by the shear forces during the test run. In the second test, the uncontaminated fluid was easily removed by the air stream, and the failed portions also sheared off.

A third comparative Type IV EG test (#27) was conducted with the model configured to max sideslip and rudder deflection angles of $\beta = -10°$ and $\delta_r = -20°$. Similar to Test #26, contamination was applied for 15 minutes and resulted in approximately 10 percent failure. The results were visually comparable; however, the fluid thickness indicates a slightly higher residual fluid thickness for Test #27. Photo 6.4 provides a photographic summary of these tests.

6.3.2 Type IV PG Fluid – Simulated Moderate Snow

Two comparative Type IV PG tests (#29 and #31) were conducted at an approximate tunnel temperature of -3°C with the model configured to $\beta = 0°$ and $\delta_r = -10°$. At -3°C, the HOT estimated from the Type IV HOT Guidelines was approximately 70 minutes.

In the first test (#29), the model was exposed to artificial snow precipitation for the full HOT of 70 minutes and resulted in a fluid that was 100 percent failed by the end of exposure. In the second test (#31), application of contamination was stopped after 15 minutes, at which point approximately 10 percent of the vertical stabilizer surface was failed.

Similar to the Type IV EG results, the flow-off performance was much different in the two scenarios. In the first test, slushy contamination remained on various areas of the main element and rudder, especially in the areas where the fluid had thinned out or dried out during the contamination period. The contamination remaining after the test was not adhered (could be easily moved around with a finger), but neither was it removed by the shear forces. In the second test, the fluid was easily removed by the air stream, and the failed portions also sheared off.

A third comparative Type IV PG test (#30) was conducted with the model configured to neutral sideslip and rudder deflection angles of $\beta = 0°$ and $\delta_r = 0°$. Similar to Test #26, contamination was applied for 15 minutes and resulted in approximately 10 percent failure. The results were visually comparable; however, the fluid thickness indicates a slightly lower residual fluid thickness as compared to Test #31. Photo 6.5 provides a photographic summary of these tests.

6.3.3 Type IV PG Fluid – Simulated Freezing Rain

One Type IV PG test (#32) was conducted at an approximate tunnel temperature of -4°C with the model configured to $\beta = 0°$ and $\delta_r = -10°$. At -4°C, the HOT estimated from the Type IV HOT Guidelines was approximately 75 minutes.

The model was exposed to simulated freezing rain precipitation for the full HOT of 75 minutes and resulted in a fluid that was 100 percent failed by the end of exposure. The contamination was mostly frozen and adhered to the surface of the model.

After the takeoff run, frozen and adhered contamination remained on the majority of the surface. Some frozen contamination was removed along the leading edge of the rudder on the suction side and a small section of the rudder on the pressure side. Photo 6.6 provides a photographic summary of these tests.

6.4 One Engine Inoperative and Crosswind Simulations

For the purposes of simulating OEI and crosswind scenarios in the wind tunnel, a NASA representative (with the support of the research team) developed simulation scenarios that could be run by modifying the parameters available.

The OEI scenario simulated an engine failure (assuming the port) with no crosswind occurring at V1 (the maximum speed at which a rejected takeoff can be initiated in the event of an emergency) during the takeoff. Failure of the port engine will cause counter clockwise yaw moment around the center of gravity. For any velocity greater than V1, rudder deflection would be needed to maintain the runway heading (see Figure 6.1). Therefore, with no crosswind, we would assume that the sideslip and rudder angles would be $\beta = 0^o$ and $\delta_r = 0^o$ up to engine failure at 100 knots (V1 in this simulation), and then the model would transition to $\beta = 0^o$ and $\delta_r = -20^o$ (at 4^o/sec), simulating the rudder deflection required to compensate for the counter clockwise yaw moment of the failed engine.

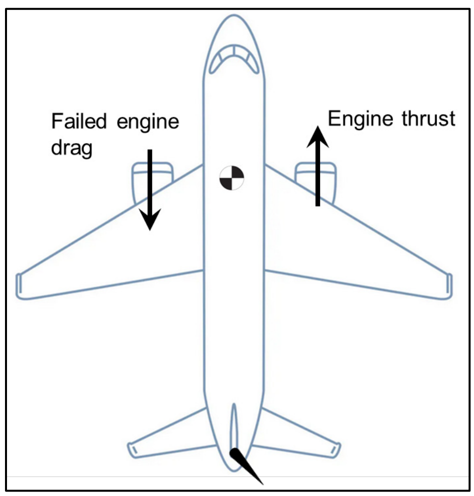


Figure 6.1: Schematic Representation of OEI Scenario

To simulate an OEI plus crosswind scenario, we would assume that in the initial takeoff roll prior to engine loss, nosewheel steering and rudder deflection is sufficient to maintain runway heading and prevent the aircraft from "weathervaning" into the wind. Rudder deflection is maintained as per the airplane flight manual for the OEI and crosswind condition. At the point of rotation, the nose wheel steering would no longer hold runway heading, allowing the aircraft to "weathervane" into the wind, and the resulting angle would be added at the point of rotation (see Figure 6.2). Assuming a crosswind condition from the port side, with port engine failure at V = 100 knots, this would be simulated with a starting configuration of $\beta = +10^o$ and $\delta_r = -20^o$ while accelerating to 100 knots and then transition to $\beta = -10^o$ (at 2.5^o/sec) and $\delta_r = -20^o$ (at 4^o/sec), or $\beta = 0^o$ and $\delta_r = -20^o$.

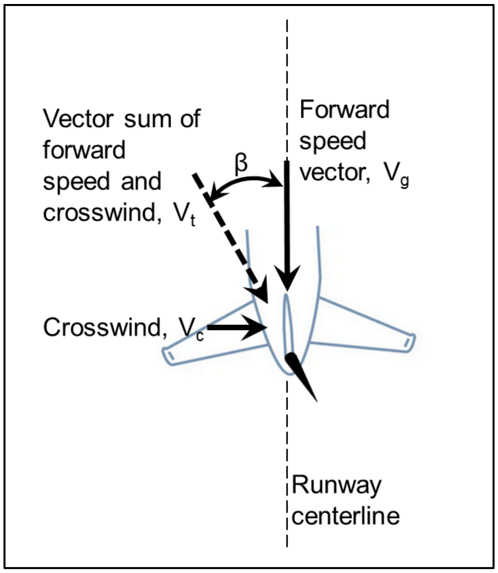


Figure 6.2: Schematic Representation of OEI + Crosswind Scenario

Based on these two scenarios, OEI and OEI plus crosswind, additional scenarios were run while further modifying specific parameters of the takeoff profile. The following subsections will provide a summary of the different scenarios explored.

6.4.1 Type IV EG Fluid – OEI

Two comparative Type IV EG fluid-only tests (#38 and #17) were conducted with an approximate tunnel temperature of 0˚C and -7ºC, respectively. Test #38 simulated the OEI by dynamically transitioning from $\beta = 0°/\delta_r = 0°$ to $\beta = 0°/\delta_r = -20°$ once a speed of 100 knots was achieved. The results were compared to Test #17, run with a static configuration of $\beta = 0°/\delta_r = -20°$. The results in the Test #38 OEI scenario demonstrated a generally improved flow-off as compared to the static scenario, as the ramp-up time spent at the $\beta = 0°/\delta_r = 0°$ configuration would have helped the fluid shear off prior to the transition. Photo 6.7 provides a photographic summary of these tests.

6.4.2 Type IV EG Fluid – OEI + Crosswind #1

Two comparative Type IV EG fluid-only tests (#37 and #17) were conducted with an approximate tunnel temperature of -1ºC and -7ºC. Test #37 simulated the OEI plus crosswind scenario by dynamically transitioning from $\beta = +10°/\delta_r = -20°$ to $\beta = 0°/\delta_r = -20°$ once a speed of 100 knots was achieved. The results were compared to Test #17, run with a static configuration of $\beta = 0°/\delta_r = -20°$. The results demonstrated a generally improved flow-off from the OEI scenario as compared to the static scenario. Photo 6.8 provides a photographic summary of these tests.

6.4.3 Type IV EG Fluid – OEI + Crosswind #2

Two comparative Type IV EG fluid-only tests (#49 and #36) were conducted with an approximate tunnel temperature of -1ºC and +2ºC, respectively. Test #49 simulated a variation of the OEI plus crosswind scenario by dynamically transitioning from $\beta = +10^\circ/\delta_r = -20^\circ$ to $\beta = -10^\circ/\delta_r = -20^\circ$ (instead of $\beta = 0^\circ/\delta_r = -20^\circ$) once a speed of 100 knots was achieved. The results were compared to Test #36, run with a static configuration of $\beta = -10^\circ/\delta_r = -20^\circ$. The results demonstrated a generally improved flow-off from the OEI and crosswind scenario as compared to the static scenario. Photo 6.9 provides a photographic summary of these tests.

6.4.4 Type IV EG Fluid – OEI + Crosswind #2 @100-115 Kts

Two comparative Type IV EG fluid-only tests (#50 and #36) were conducted with an approximate tunnel temperature of -1ºC and +1ºC, respectively. Test #50 simulated a variation of the OEI plus crosswind scenario by dynamically transitioning from $\beta = +10^\circ/\delta_r = -20^\circ$ to $\beta = -10^\circ/\delta_r = -20^\circ$ (instead of $\beta = 0^\circ/\delta_r = -20^\circ$) once a speed of 100 knots was achieved and by continuing to accelerate to a final speed 115 knots. The results were compared to Test #36, run with a static configuration of $\beta = -10^\circ/\delta_r = -20^\circ$. The results demonstrated a generally improved flow-off from the OEI and crosswind scenario as compared to the static scenario. Photo 6.10 provides a photographic summary of these tests.

6.4.5 Type IV EG Fluid – OEI + Crosswind #2 @115 Kts

Two comparative Type IV EG fluid-only tests (#51 and #36) were conducted with an approximate tunnel temperature of -1ºC and +1ºC, respectively. Test #51 simulated a variation of the OEI plus crosswind scenario by dynamically transitioning from $\beta = +10^\circ/\delta_r = -20^\circ$ to $\beta = -10^\circ/\delta_r = -20^\circ$ (instead of $\beta = 0^\circ/\delta_r = -20^\circ$) once a speed of 115 knots was achieved (not 100 knots). The results were compared to Test #36, run with a static configuration of $\beta = -10^\circ/\delta_r = -20^\circ$. The results demonstrated a generally improved flow-off from the OEI and crosswind scenario as compared to the static scenario. Photo 6.11 provides a photographic summary of these tests.

6.4.6 Type IV PG Fluid – OEI + Crosswind #1

Two comparative Type IV PG fluid-only tests (#55 and #14) were conducted with an approximate tunnel temperature of -7ºC and +1ºC, respectively. Test #55 simulated the OEI plus crosswind scenario by dynamically transitioning from $\beta = +10^\circ/\delta_r = -20^\circ$ to $\beta = 0^\circ/\delta_r = -20^\circ$ once a speed of 100 knots was achieved. The results were compared to Test #14, run with a static configuration of $\beta = 0^\circ/\delta_r = -20^\circ$. The results demonstrated a generally improved flow-off from the OEI scenario as compared to the static scenario, as well as similar results to the EG fluid run (see subsection 6.4.2). Photo 6.12 provides a photographic summary of these tests.

6.5 Non-Standard Fluid Applications to Isolate Specific Aerodynamic Parameters

To understand if fluid was migrating through the gap between the main element and the rudder, testing was done by applying fluid to only one side of the tail at a time. Sideslip and rudder configurations were also altered to understand the effects on the fluid migration. The following subsections provide a summary of the results.

6.5.1 Type IV EG Fluid – Fluid Only on Pressure Side

Three comparative Type IV EG fluid-only tests (#43, #47, and #39) were conducted with an approximate tunnel temperature of +1ºC with fluid applied only to the pressure side. The three tests were run with decreasing sideslip and rudder deflection angles: $\beta = 0^\circ/\delta_r = -10^\circ$, $\beta = 0^\circ/\delta_r = -20^\circ$, and finally $\beta = -10^\circ/\delta_r = -20^\circ$.

The test results showed that fluid applied to the pressure side flowed through the 3 mm gap between the main element and rudder. The fluid flowing through the gap was most prominent at $\beta = 0^\circ/\delta_r = -10^\circ$, likely because the airflow was still attached on the rudder and therefore the fluid migrating through the gap stayed attached and coated the rudder rather than going into the free stream. It was also observed that fluid flowed around the trailing edge of the rudder from the pressure side to the suction side due to the trailing edge separation. This was most prominent at the $\beta = -10^\circ/\delta_r = -20^\circ$ configuration when separation was greatest. In general, the amount of fluid observed on the suction side of the rudder at the end of the run was dependent upon the β and δ_r configuration. Photo 6.13 provides a photographic summary of these tests.

6.5.2 Type IV PG Fluid – Fluid Only on Pressure Side

Two comparative Type IV PG fluid-only tests (#45 and #44) were conducted with an approximate tunnel temperature of +1ºC with fluid applied only to the pressure side. The two tests were run with sideslip and rudder deflection angles of β = -10º/δ_r = -20ºand β = 0º/δ_r = -10º, respectively.

Similar to the EG fluid results, the test results showed that fluid applied to the pressure side flowed through the 3 mm gap between the main element and rudder. The fluid flowing through the gap was most prominent at β = 0º/δ_r = -10º, likely because the airflow was still attached on the rudder and therefore the fluid migrating through the gap stayed attached and coated the rudder rather than going into the free stream. It was also observed that fluid flowed around the trailing of the rudder from the pressure side to the suction side due to the trailing edge separation. This was most prominent at the β = -10º/δ_r = -20º configuration when separation was greatest. In general, the amount of fluid observed on the suction side of the rudder at the end of the run was dependent upon the β and δ_r configuration. Photo 6.14 provides a photographic summary of these tests.

6.5.3 Type IV EG Fluid – Fluid Only on Suction Side

One Type IV EG fluid-only test (#40) was conducted with an approximate tunnel temperature of +1ºC with fluid applied only to the suction side. The test was run with sideslip and rudder deflection angles of β = -10º/δ_r = -20º. As expected, no fluid migrated to the pressure side through the gap. Photo 6.15 provides a photographic summary of this test.

6.5.4 Type IV EG Fluid – Fluid Only on Bottom Half

Two comparative Type IV EG fluid-only tests (#36 and #53) were conducted with an approximate tunnel temperature of -1ºC and +2ºC, respectively. Test #36 was a standard fluid-only test with β = -10º/δ_r = -20º. Test #53 was run with the same β = -10º/δ_r = -20º configuration; however, fluid was only applied to the bottom half of the model to identify any spanwise effects. The results showed that the flow was along the chord with no noticeable spanwise effect. However, it was observed that fluid flowed around the trailing of the rudder from the pressure side to the suction side due to the trailing edge separation, and the fluid wrapping around crept upwards toward the tip of the model. Photo 6.16 provides a photographic summary of these tests.

6.5.5 Different Takeoff Profiles

To understand the effects of speed, time of rotation, and yaw, a series of test runs were conducted. The following subsections provide a summary of the results.

6.5.6 Type IV EG Fluid – 115 Kts vs. 100 Kts

Four comparative Type IV EG fluid-only tests (#41, #36, #42, and #17) were conducted with an approximate tunnel temperature of +1ºC, +1ºC, -1ºC, and -7ºC, respectively. Tests #41 and #36 were comparative tests configured to β = -10º/δ_r = -20º and run at 115 knots and 100 knots, respectively. Tests #42 and #17 were comparative tests configured to β = 0º/δ_r = -20º and run at 115 knots and 100 knots, respectively. In both cases, the results indicated that the higher shear forces did not result in a noticeable improvement in fluid removal, as much of the fluid shears off at the lower speeds while ramping up. Photo 6.17 provides a photographic summary of these tests.

6.5.7 Type IV EG Fluid – Longer Takeoff

Two comparative Type IV EG fluid-only tests (#36 and #48) were conducted with an approximate tunnel temperature of -1ºC and +2ºC, respectively. Tests #36 and #48 were comparative test runs at β= -10º/δ_r= -20º at 100 knots, however Test #48 was held at 100 knots for 60 seconds (instead of the usual 10 seconds) to simulate a climb-out. The results indicated that the residual fluid on the rudder during #48 was comparable to the baseline test, #36, with no noticeable improvement in fluid removal. It appeared that once fluid moved into the areas of the model where the flow was separated, the fluid collecting in those areas would not be subjected to great enough shear forces to continue to flow and would remain stagnant. Photo 6.18 provides a photographic summary of these tests.

6.5.8 Type IV EG Fluid – Yaw Effect

Two comparative Type IV EG fluid-only tests (#36 and #52) were conducted with an approximate tunnel temperature of -1ºC and +1ºC, respectively. Tests #36 and #52 were comparative test runs at β = -10º/δ_r = -20º and β =+10º/δ_r = -20º, respectively. The results indicated that the yaw had an effect on the residual fluid present on the rudder, and more fluid was present after the run with β= +10º/δ_r = -20º. The location of the stagnation point in the β =+10º/δ= -20º configuration test likely caused some fluid to collect on the main element leading edge. In addition, the attached flow on the rudder allowed the shearing fluid to flow onto the rudder rather than into the free stream, creating a greater fluid layer. Photo 6.19 provides a photographic summary of these tests.

6.6 Summary of Fluid Thickness Measurements

For all tests conducted with fluid, thickness measurements were taken at seven locations on the port side of the model and at seven locations on the starboard side of the model (see the procedure in Appendix B for more details). The data collected was summarized graphically per test set in Appendix D.

The fluid thickness data collected is summarized in Table 6.1 to provide minimum and maximum fluid thickness records for the port and starboard sides of the tail at the three different stages of the test: after fluid application, after precipitation application, and after takeoff. The summary includes only Type IV data and does not include the limited data with Type I fluid.

As expected, the “after fluid application” measurements were similar for all four test objectives. The snow tests were the only ones that had measurements taken after precipitation application, and the results indicated that the thickness could increase by more than three times to 2.5 mm. After the takeoff run, the fluid-only and the OEI and crosswind tests had similar residual fluid thicknesses. However, the snow contamination tests yielded the lowest thicknesses; this may be due to the snow diluting the fluid and causing it to thin out considerably, although slush was likely present.

Table 6.1: Summary of Fluid Thicknesses for Type IV Tests

Test Objective	Fluid Thickness (mm)											
	After Fluid Application				After Precip. Application				After Takeoff Run			
	Port		STBD		Port		STBD		Port		STBD	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Snow Contamination	0.3	0.7	0.2	0.6	0.1	2.5	0.1	2.2	0.0	0.1	0.0	0.3
Freezing Rain Contamination	0.3	0.6	0.3	0.5	-	-	-	-	0.0	0.0	0.0	0.0
Fluid Only	0.3	0.7	0.3	0.7	-	-	-	-	0.1	0.7	0.1	0.5
OEI + Crosswind	0.3	0.7	0.3	0.7	-	-	-	-	0.1	0.8	0.1	0.3

Photo 6.1: Type IV EG Fluid Only

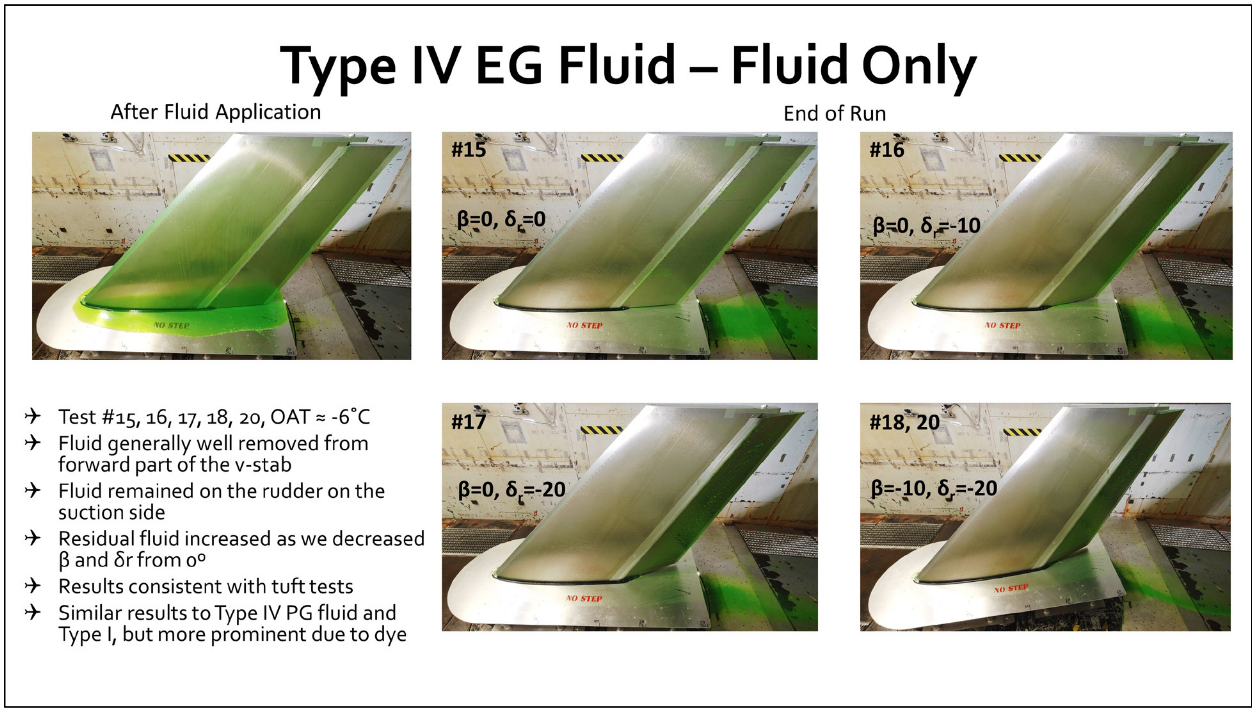


Photo 6.2: Type IV PG Fluid Only

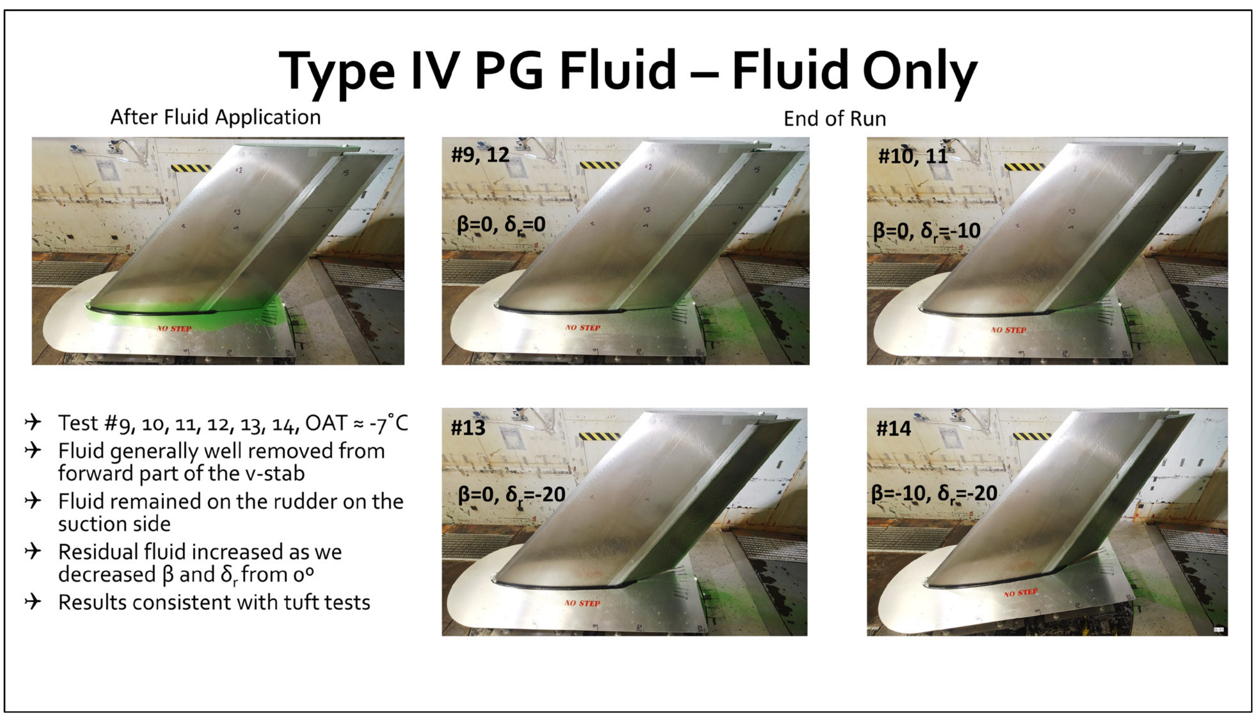


Photo 6.3: Type I PG Fluid Only

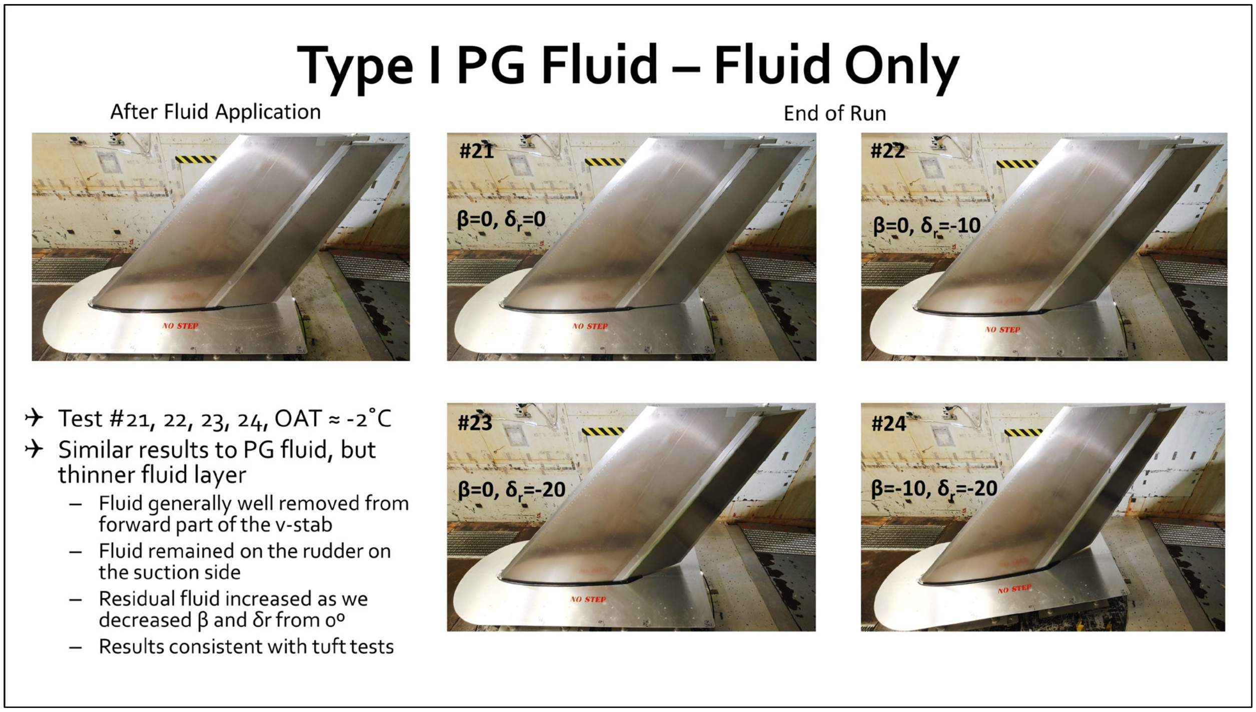


Photo 6.4: Type IV EG Fluid – Simulated Moderate Snow

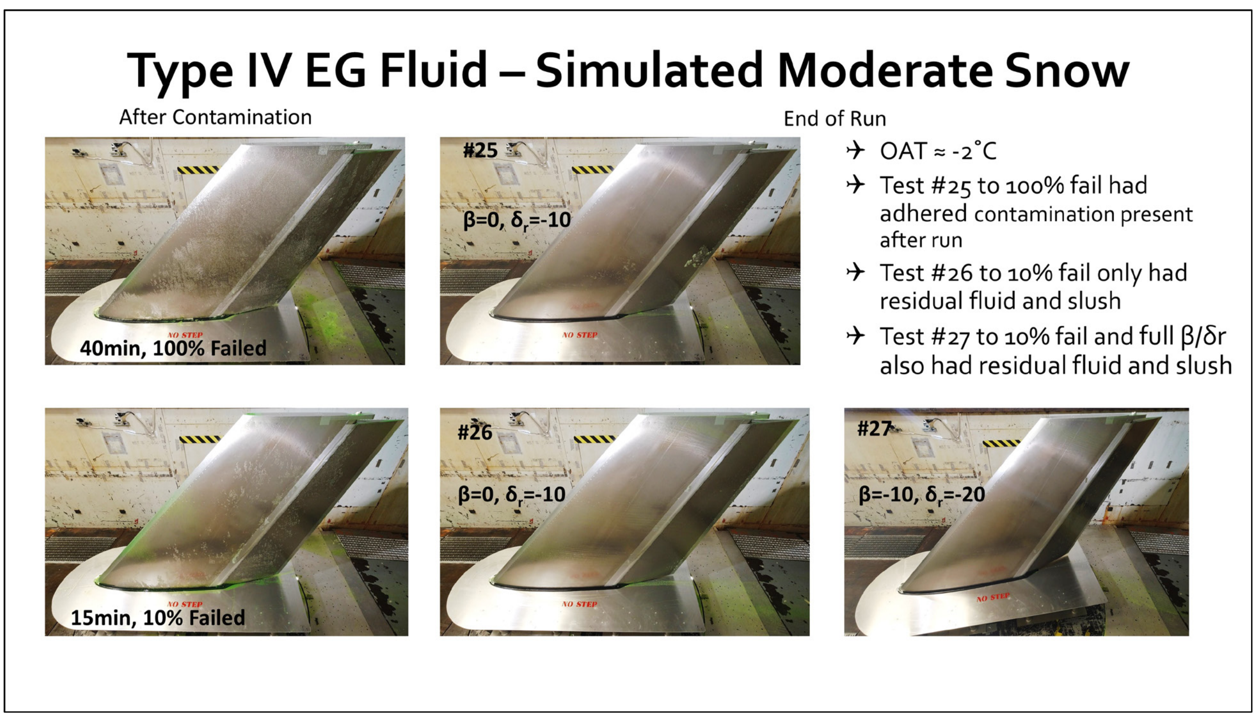


Photo 6.5: Type IV PG Fluid – Simulated Moderate Snow

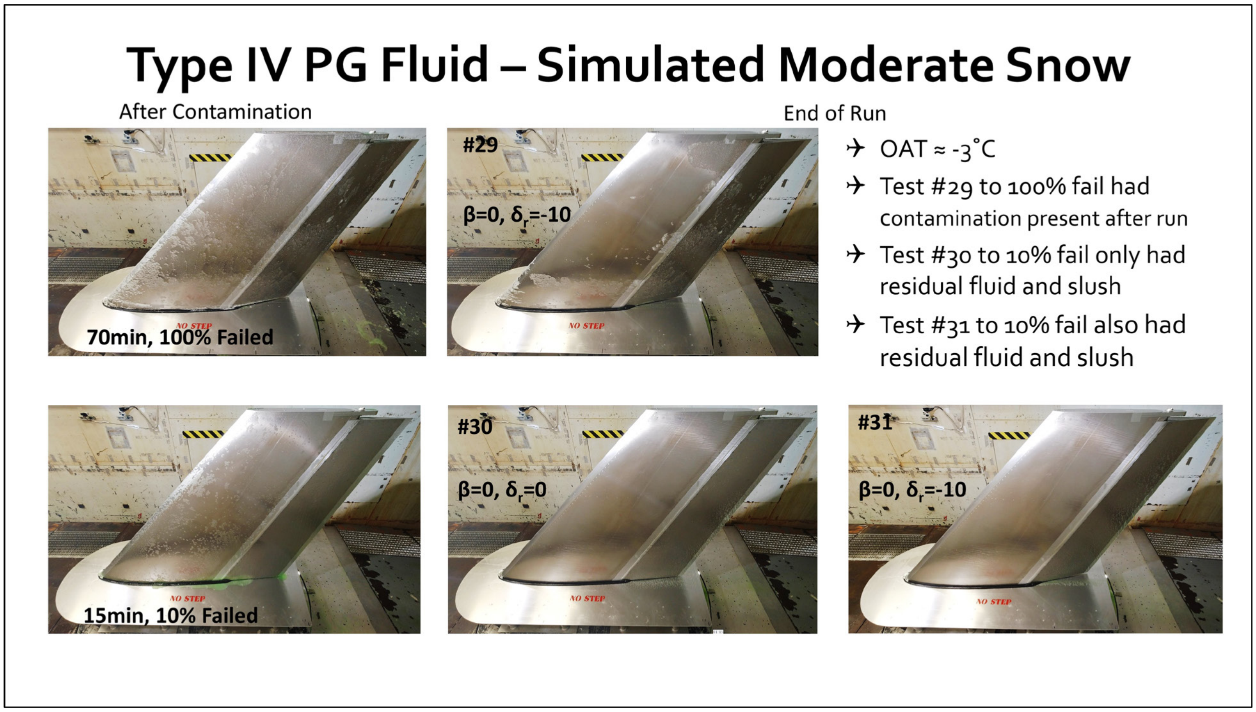


Photo 6.6: Type IV PG Fluid – Simulated Freezing Rain

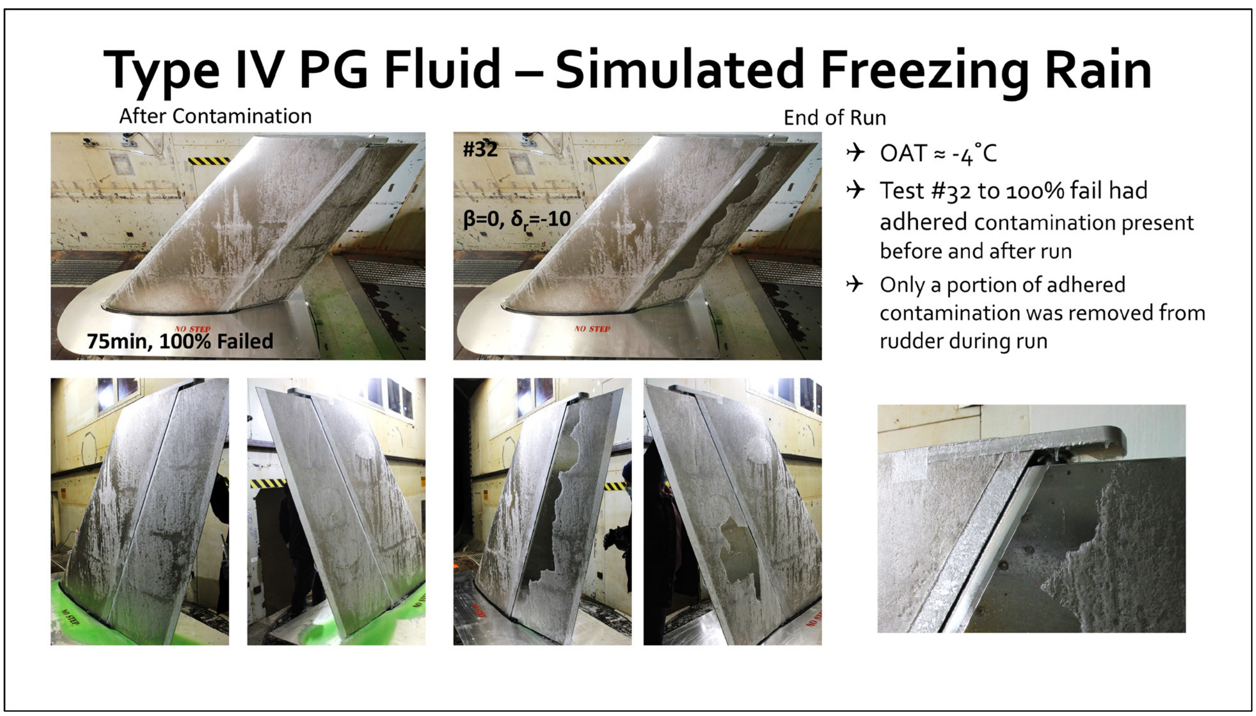


Photo 6.7: Type IV EG Fluid – OEI

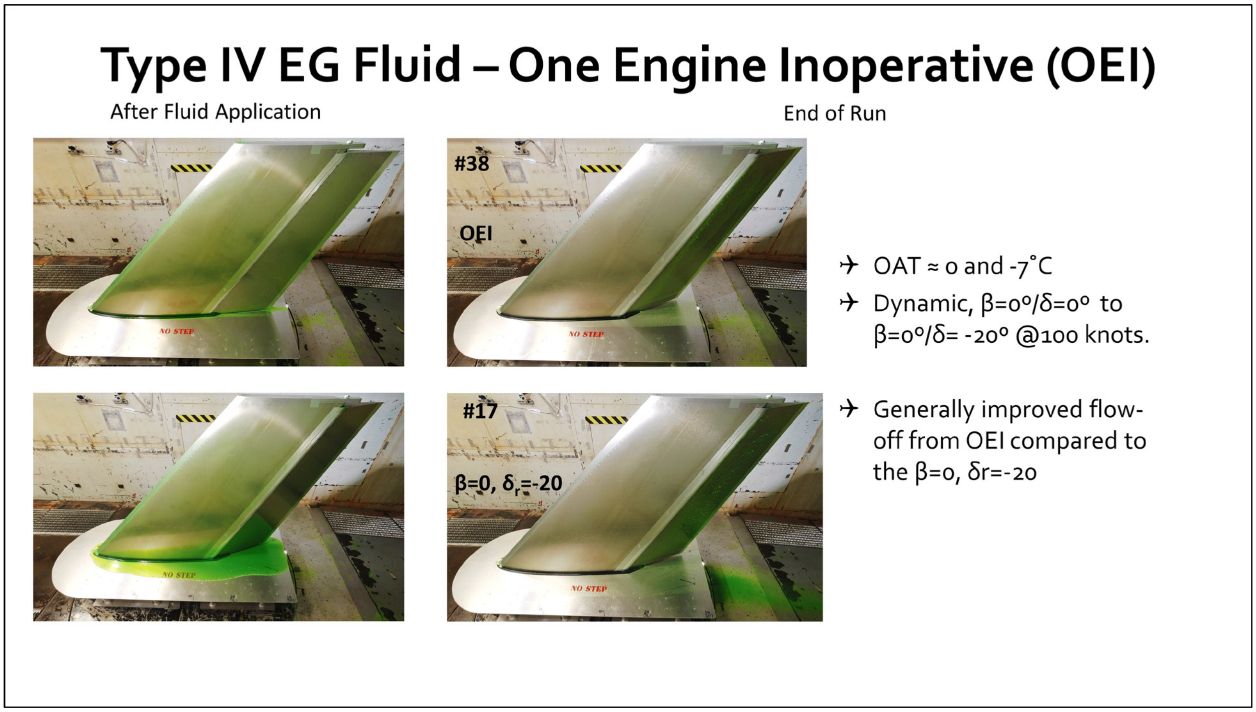


Photo 6.8: Type IV EG Fluid – OEI + Crosswind #1

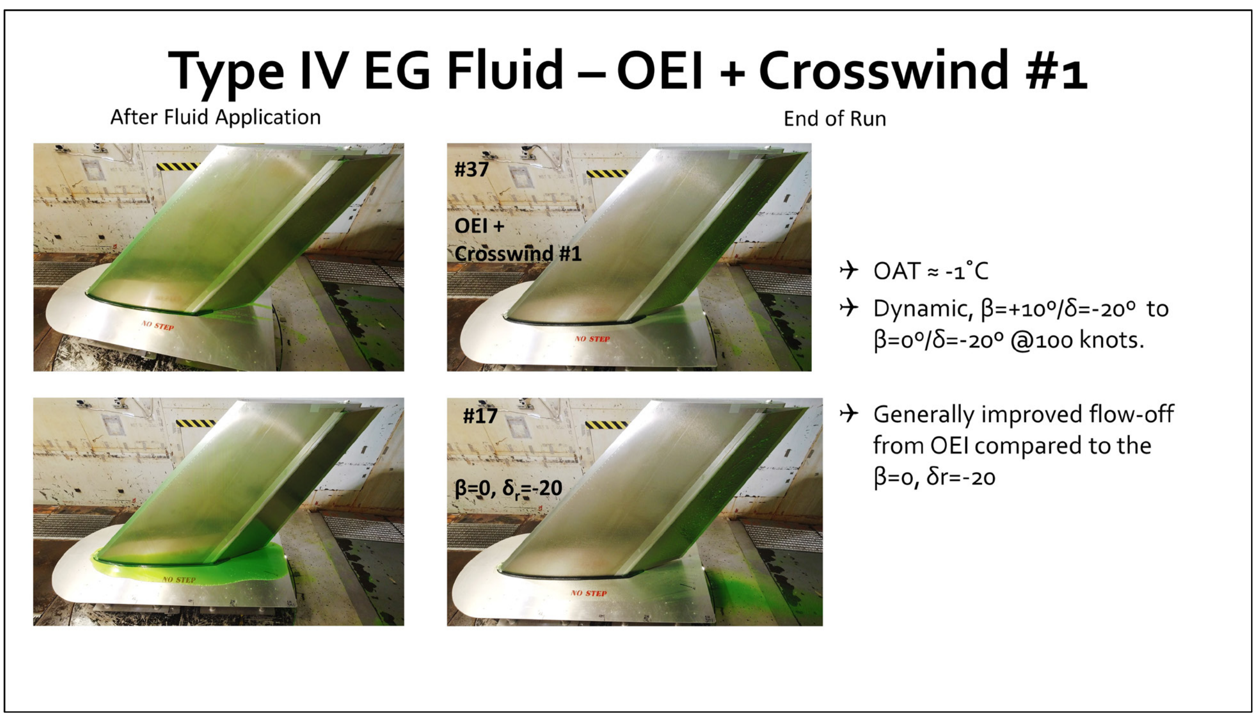


Photo 6.9: Type IV EG Fluid – OEI + Crosswind #2

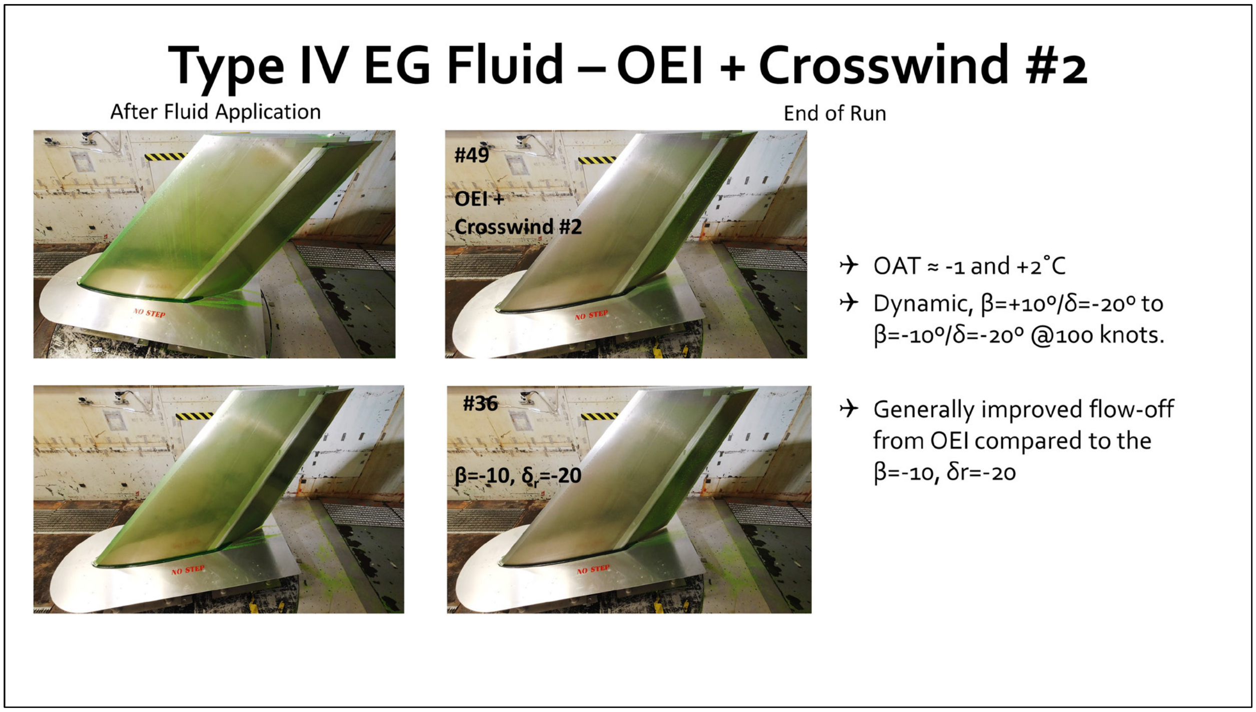


Photo 6.10: Type IV EG Fluid – OEI + Crosswind #2 @100-115 Kts

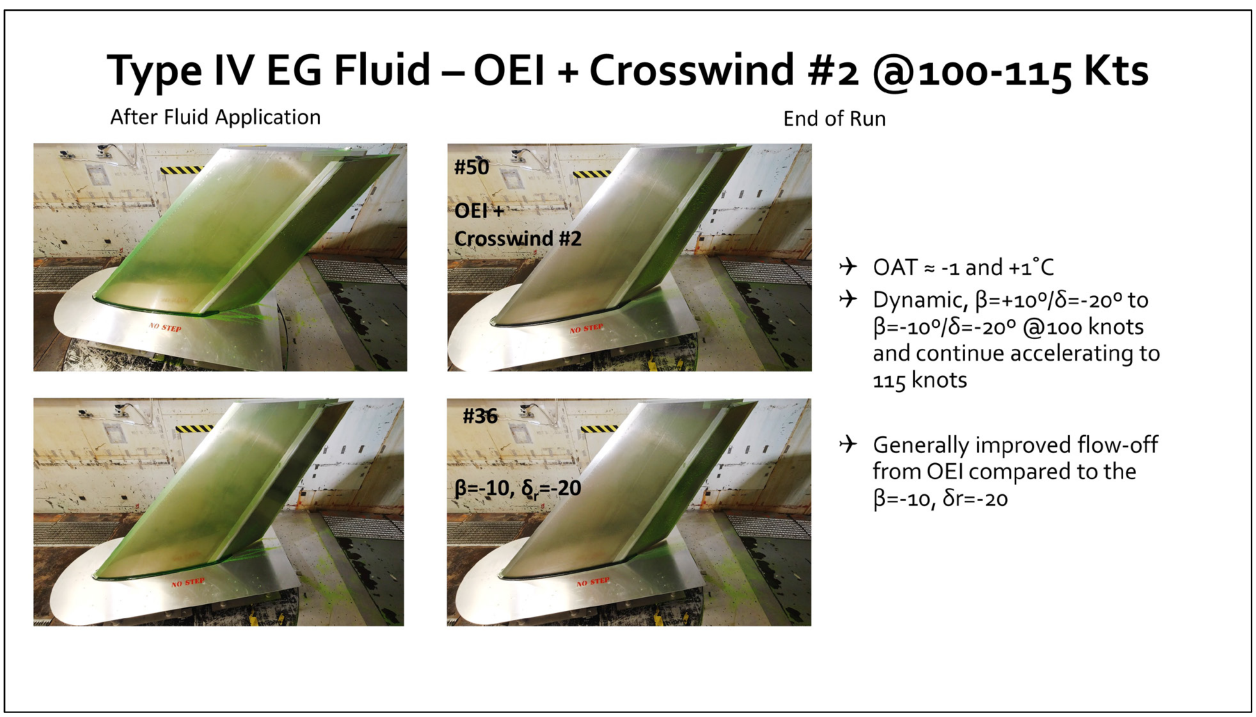


Photo 6.11: Type IV EG Fluid – OEI + Crosswind #2 @115 Kts

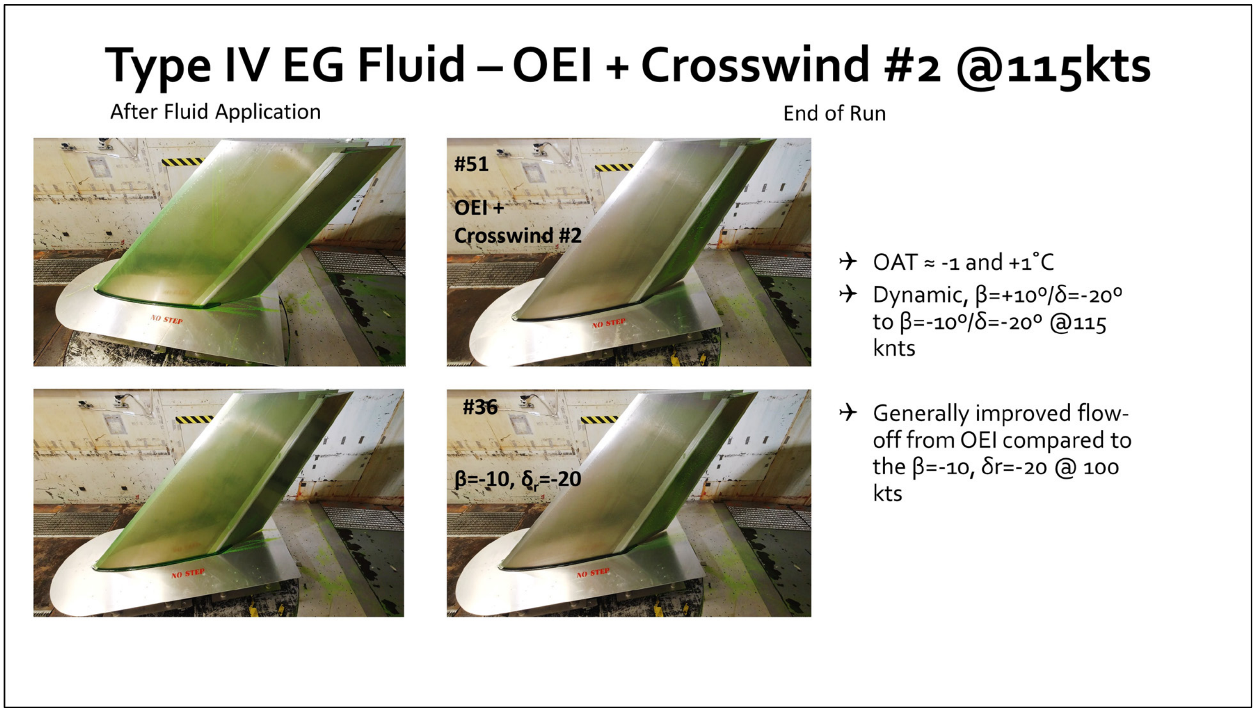


Photo 6.12: Type IV PG Fluid – OEI + Crosswind #1

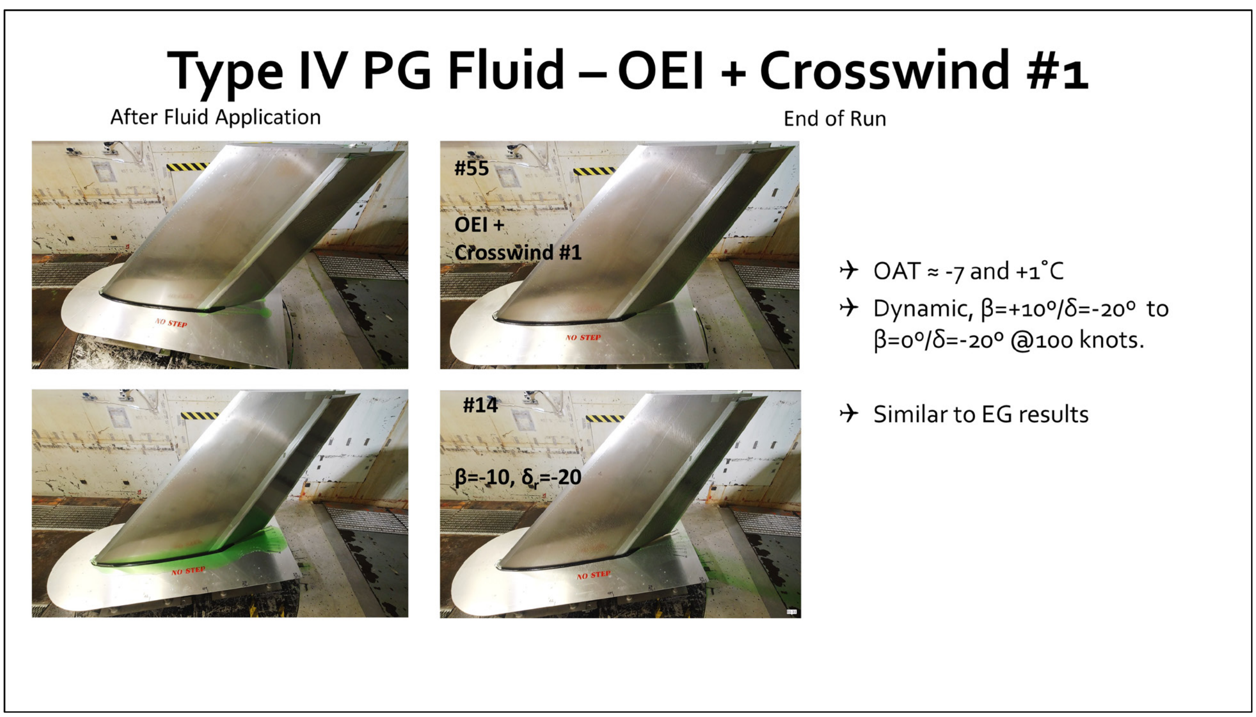


Photo 6.13: Type IV EG Fluid – Fluid Only on Pressure Side

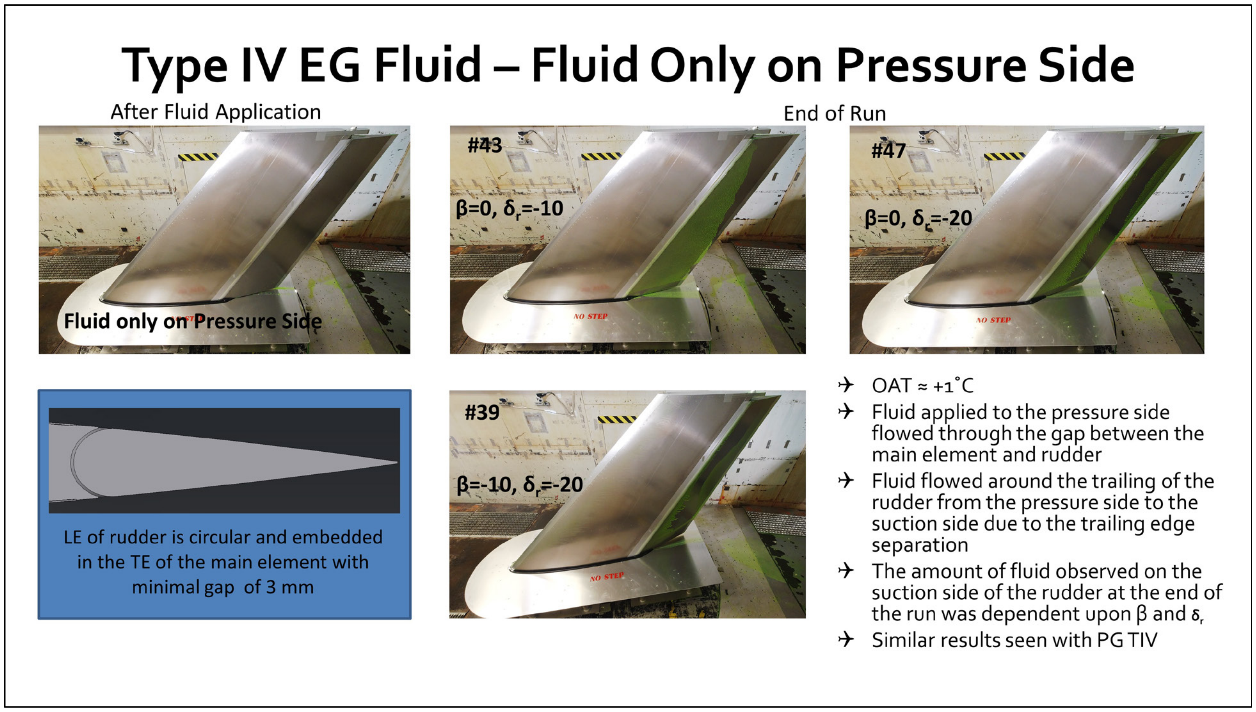


Photo 6.14: Type IV PG Fluid – Fluid Only on Pressure Side

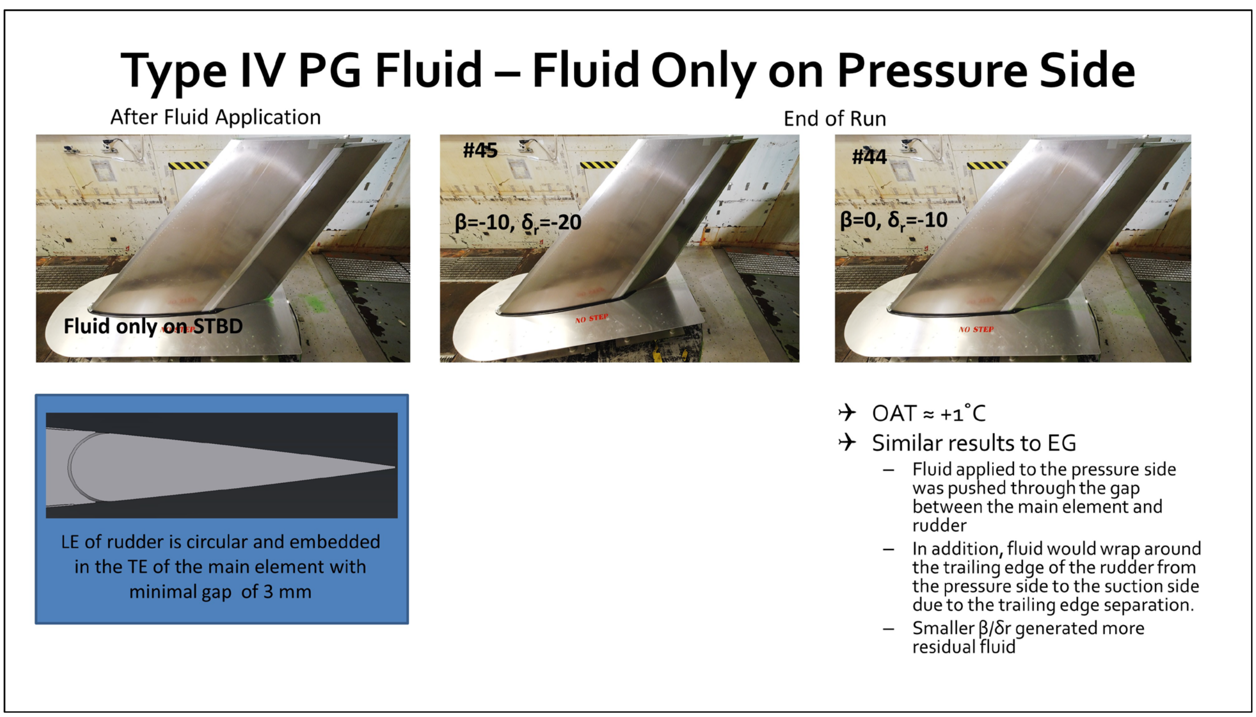
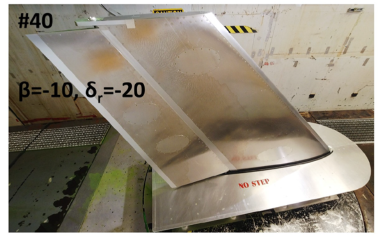


Photo 6.15: Type IV EG Fluid – Fluid Only on Suction Side

Type IV EG Fluid – Fluid Only on Suction Side

After Fluid Application

End of Run



- OAT ≈ +1˚C
- When applied only to suction side, no fluid migrated over

Photo 6.16: Type IV EG Fluid – Fluid Only on Bottom Half

Type IV EG Fluid – Fluid only on Bottom Half

After Fluid Application

End of Run

- OAT ≈ -1 and +2˚C
- Test conducted with fluid only on the bottom half of the v-stab to see if there was any spanwise effects on the wing.
- The flow was very much along chord and little spanwise effect was observed.
  - Some reversal of flow effect on rudder

Photo 6.17: Type IV EG Fluid – 115 Kts vs. 100 Kts

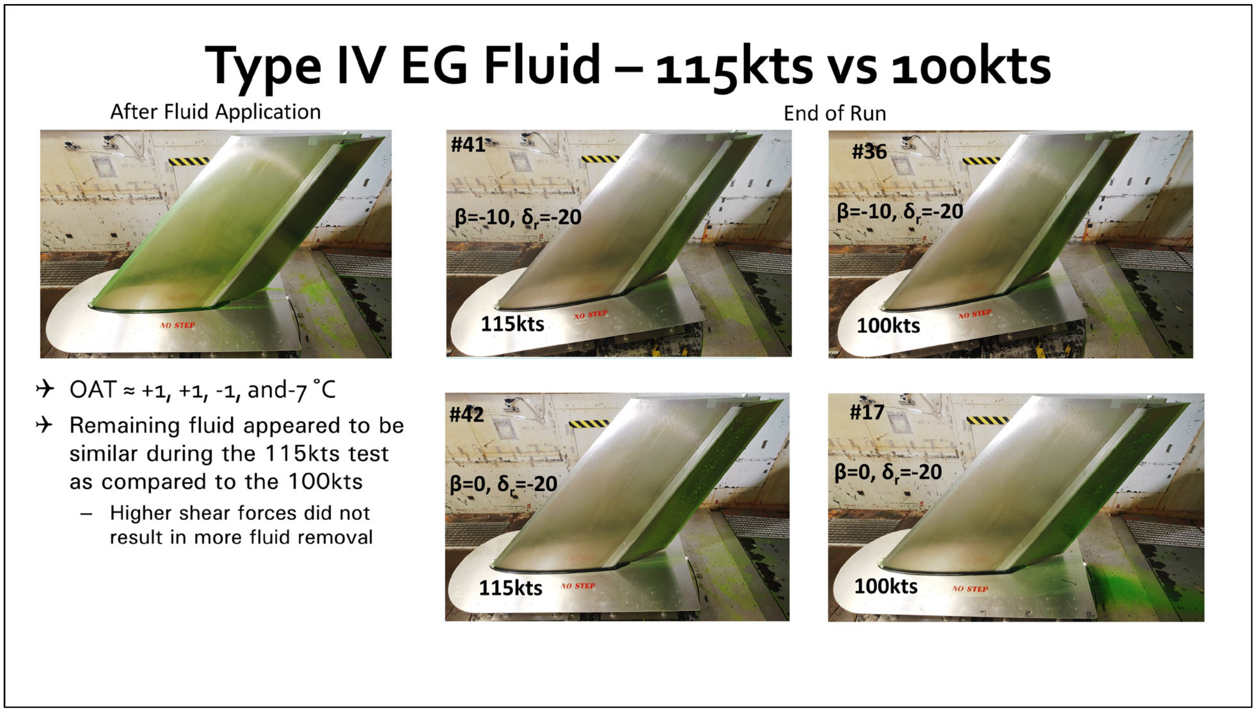


Photo 6.18: Type IV EG Fluid – Longer Takeoff

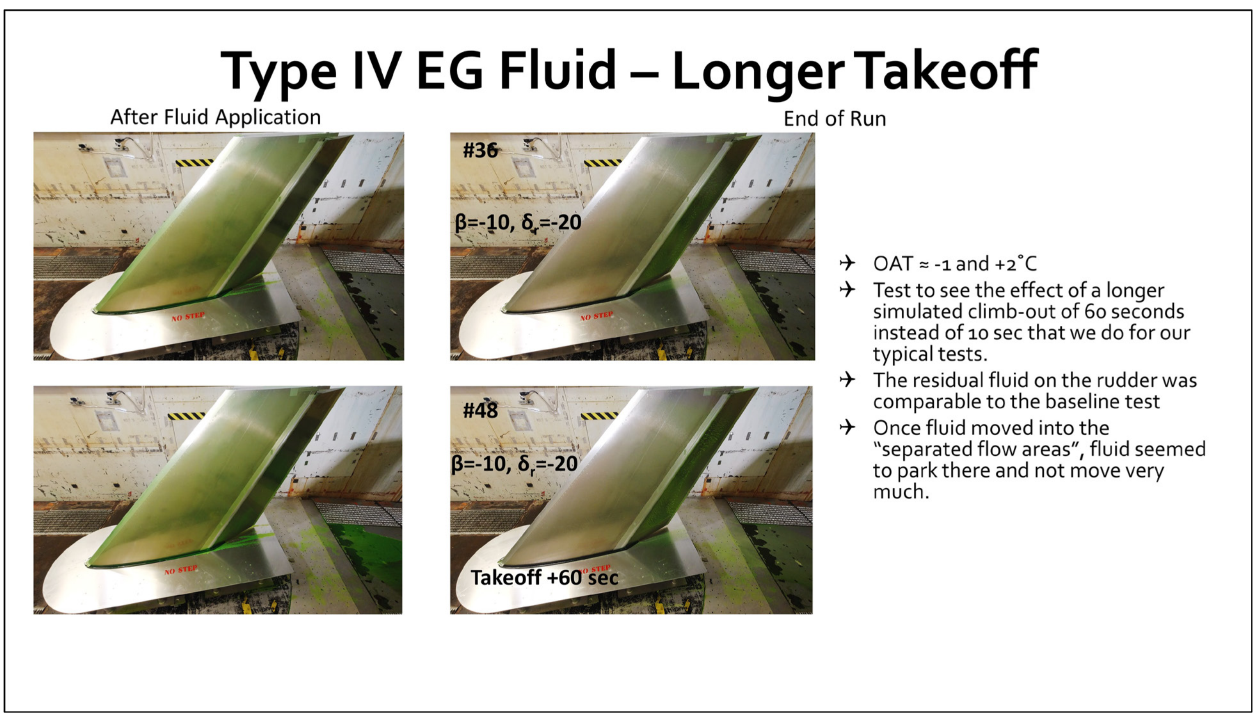
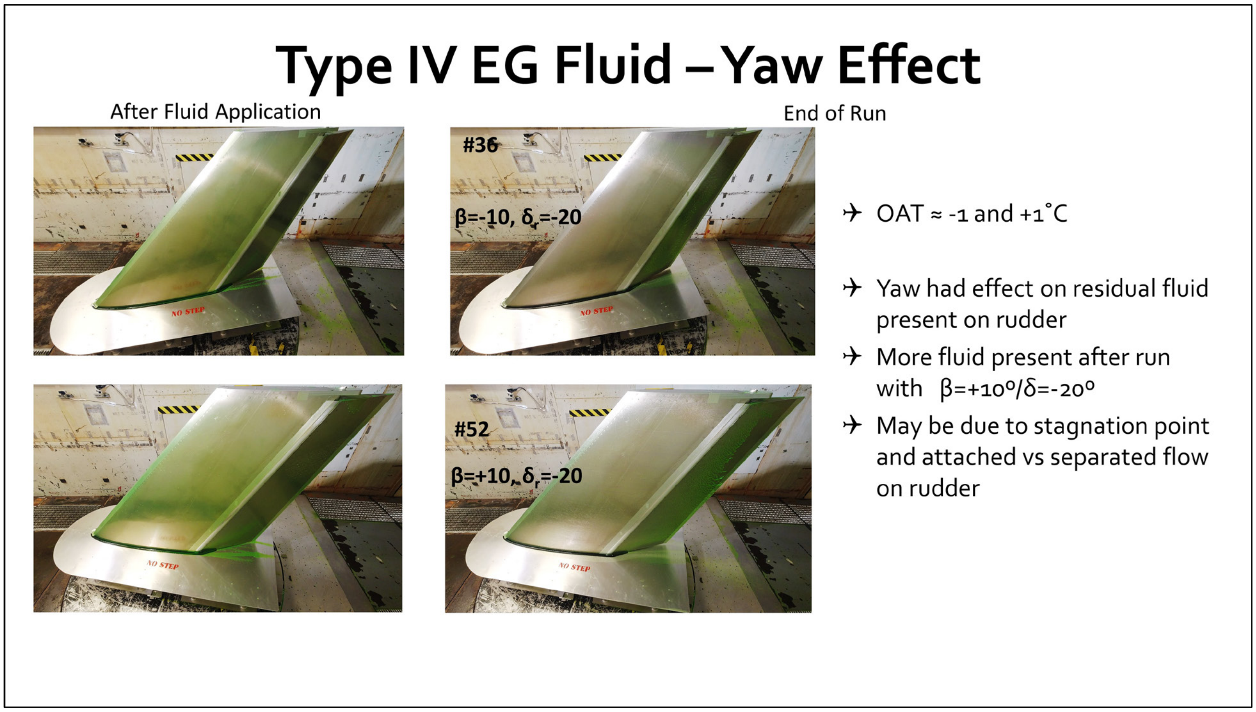


Photo 6.19: Type IV EG Fluid – Yaw Effect



7. DISCUSSIONS ABOUT VERTICAL STABILIZER RESEARCH WITH THE G-12 AWG

This section describes the ongoing discussions with the SAE G-12 AWG in relation to the development of a CRM vertical stabilizer.

7.1 Industry Participation in Testing

TC and the FAA have encouraged industry participation in the planning and execution of the vertical stabilizer research. The goal has been to ensure the relevance and applicability of the testing results obtained. The participation of Boeing in the 2019-20 (Piper Seneca Model) and 2021-22 (CRM) planning and testing is an example of this, which in turn provided useful industry feedback for the testing program from an airframe manufacturer.

7.2 Ongoing Discussion

These testing results were presented at the SAE G-12 AWG and HOT meetings in May 2022, which was planned for Portland, Oregon, but was held on Webex due to the COVID-19 pandemic. The feedback received from the group was that the testing provided valuable insight into fluid and contamination flow-off from a vertical stabilizer and that the size and shape of this model was better suited as compared to the previous Piper Seneca II model. The installation of load cells in future testing will also provide more data for the AWG to review and discuss. It is expected that the AWG will continue to provide feedback for the vertical stabilizer research going forward.

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8. CONCLUSIONS

These conclusions were derived from the testing conducted during the winter of 2021-22.

8.1 Calibration and Validation of Procedures

The calibration and validation of procedures ensured the reliability and repeatability of the testing protocols. The fluid and precipitation application procedures were refined, and the videography and live streaming setup was updated and finalized. The safety checks and shakedown runs ensured a safe and successful test campaign. The IWT provided an effective means to carry out the anticipated research, accommodating the installation of an appropriately sized model and allowing the application of de/anti-icing fluids.

8.2 Dry Surface Testing and Tuft Visualization

The dry surface testing and tuft visualization testing allowed the researchers to gain insight into the aerodynamic behaviour of the vertical stabilizer model in advance of testing with fluids and contamination.

Through the testing performed, the $\beta = 0°$, $\delta_r = -12°$ configuration was found to be the point at which separation began on the rudder. Through discussions with TC, the FAA, NASA, Boeing, and APS, $\beta = 0°$, $\delta_r = -10°$ was selected as the basic configuration for testing to "bound" the ideal flow conditions. Through this configuration, any separation or excessively turbulent airflow could be attributed to any externalities from test variables such as fluid and contamination.

8.3 Fluid Testing and Flow-Off Characterization

The CRM vertical stabilizer testing was preliminary and limited; therefore, tests to be performed were strategically chosen based on their likeliness to provide the most informative data. This testing was primarily conducted with Type IV EG-based fluid to get a more holistic view of the expected performance in varying conditions. In addition, the dye in the EG fluid allowed for a better visibility during the exploratory testing. Complementary testing was also conducted with Type IV PG fluid and Type I PG fluid in specific conditions to evaluate the similarities or differences of the fluid types. The aerodynamic effects on the fluids were similar and relative to the fluid thickness.

The testing demonstrated that some amount of fluid and contamination was always present at the end of each test run. The amount of residual increased or decreased based on the severity of the condition tested and was affected by the sideslip and rudder deflection, the level of contamination, the temperature at which the test was run, the type of fluid used, and other factors.

Testing conducted in snow conditions demonstrated that failed fluid, which had a slushy consistency, generally had poor flow-off. In contrast, fluid that was not failed, either because it was clean or because limited amounts of contamination were applied, had improved flow-off. Freezing rain tests demonstrated results similar to the snow tests but had the added complexity of adherence to the surface, impeding flow-off. The early fluid failure observed on the model was due to the near-vertical orientation of the surface, which allows gravity to pull the fluid down and results in a thinner protection layer (a phenomenon well documented in previous vertical surface research conducted by APS).

The OEI and crosswind simulations generally had better fluid flow-off as compared to the static configuration test. It is important to understand these conservative results to determine the potential impact on guidance development going forward. The effect of speed and takeoff time was negligible in the testing conducted; however, the effects on contaminated fluid flow-off have yet to be explored and may provide different results.

8.4 General Observations

In general, the test campaign confirmed the desired performance of the new model and helped in understanding the effects of sideslip and rudder deflection on pristine and contaminated fluid flow-off.

Feedback from the research team and the SAE G-12 AWG related to the tests conducted indicated that the V-Stab CRM is a good representative model for continued evaluation of ground icing situations, and is suitable for future testing.

9. RECOMMENDATIONS

These recommendations were derived from the testing conducted during the winter of 2021-22.

9.1 Acquisition and Installation of Load Cells for the CRM

The vertical stabilizer model was designed to include load cells for aerodynamic measurements; however, due to issues with procurement, dummy cells were used for Winter 2021-22; aerodynamic forces on the model were not measured. It is expected that these load cells will be acquired by the NRC during the summer of 2022 and will be available for future test campaigns with the CRM. The load cells should be installed for any future testing with the CRM.

9.2 Better Lighting and Viewing Windows

The location of the CRM when installed in the M-46 wind tunnel makes viewing the model during testing a challenge. The model sits on the floor of the tunnel, downwind of the observation windows with no overhead lighting. Additional, appropriately placed windows and lighting would greatly improve the viewing experience both in-person and remotely through the CCTV system.

9.3 Photogrammetry

Testing has demonstrated that the condition of the contaminated fluid can vary depending on the temperature, precipitation type, speed, etc. Although the current video and photography equipment provide excellent documentation of the condition of the vertical stabilizer, the two-dimensional views do not provide information related to the peaks and valleys of the fluid and contamination, either in static configurations or while shearing off. Photogrammetry technology providing three-dimensional documentation should be investigated and potentially included in future vertical surface testing campaigns.

9.4 Future Testing with the CRM Vertical Stabilizer

It is recommended that testing in 2022-23 be conducted with the CRM with the load cells installed in order to get real-time aerodynamic data. The testing plan should build upon the testing matrix described in this report, including calibration and validation of procedures, dry surface testing and tuft visualization, and fluid testing and flow-off characterization. Testing should also focus on areas not extensively explored during this preliminary phase, including colder temperatures, different contamination types and levels, asymmetric contamination, and different fluids.

9.5 Development of Recommended Operational Practices

Research conducted to date is still exploratory and has indicated benefits associated with specific fluid type applications (thickened or not) depending on the types of contamination and temperatures tested. Future research should focus on refining these observations through testing and industry discussion, with the aim of developing a recommended operational practice or practices.

REFERENCES

1. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2015-16 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, January 2017, TP 15340E, XX (to be published).

2. Ruggi, M., *Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Vertical Stabilizer*, APS Aviation Inc., Transport Canada, Montreal, December 2020, TP 15454E, 64.

3. Society of Automotive Engineers Aerospace Recommended Practice 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type II, III, and IV*, July 2004.

4. SAE International Aerospace Recommended Practice 5945, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type I*, July 2007.

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APPENDIX A

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2021-22

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2020-21

10. Wind Tunnel Testing – Planning and Setup Activities Only

Note: The NRC facility costs associated with manufacturing the test model and testing at M-46 are not included in this task and are dealt directly with TC through a M.O.U. agreement with NRC.

This budget associated with this project is only associated to tasks a) and b). Tasks c), d), e), and f) are budgeted as part of a separate project.

a) Coordinate with staff of NRC M-46 for scheduling and to organize any modifications to the wind tunnel, model, or related equipment. Review fluid requirements and request fluid samples from fluid manufacturers.

b) Develop a procedure and test plan and coordinate with the NRC staff that operates the PIWT.

11. Wind Tunnel Testing – Week 1 Activities (5 Days)

Note: The NRC facility costs associated with manufacturing the test model and testing at M-46 are not included in this task and are dealt directly with TC through a M.O.U. agreement with NRC.

This budget associated with this program element includes pre-testing activities and post-testing activities (including reporting and analysis) related to all wind tunnel testing activities. It also includes 5 days of testing.

a) Perform pre-testing activities including the preparation of equipment, purchasing of equipment, training of personnel, and transportation and setup of equipment.

b) Perform wind tunnel tests with the RJ, LS-0417, or the vertical stabilizer common research model. Testing objectives can include:

   i. Validation of the existing Type IV fluid allowance times for use with the newly certified anti-icing fluids, or with fluids for which data is lacking;

   ii. Further development of the EG-specific allowance time table to be able to benefit from potentially longer times;

   iii. Expansion of the allowance for Type III fluids at lower speeds to get longer times and guidance in more conditions; and

   iv. Evaluation of contaminated fluid flow-off from a vertical stabilizer.

The typical procedure is described as follows, but may be modified to address specific testing objectives. Prior to starting each test event, correlation testing is required to calibrate the TC model and to demonstrate repeatability. Wind tunnel tests will be performed with ethylene glycol and propylene glycol anti-icing fluids at below freezing temperatures; Type I deicing fluids may also be considered. Tests will simulate low speed or high speed takeoff runs. During contaminated test runs, a baseline fluid only case may be run immediately before, or after the contaminated test run to provide a direct correlation of the results. High resolution photos will be taken of the fluid motion. Observers will document the appearance of fluid on the vertical stabilizer during the simulated takeoff run and climb of the aircraft by analyzing the photographic records. The testing team will collect, among other things, the following data during the tests: type and amount of fluid applied, type and rate of contamination applied, and extent of fluid contamination prior to the test run.

c) Analyse data.

d) Report the findings and prepare presentation material for the SAE G-12 meeting.

12. Wind Tunnel Testing – Week 2 Activities (Additional 5 Days)

Note: The NRC facility costs associated with manufacturing the test model and testing at M-46 are not included in this task and are dealt directly with TC through a M.O.U. agreement with NRC.

This budget associated with this program element includes 5 days of testing. The related pre-testing and post-testing activities (including reporting and analysis) are associated with program element #11.

a) Perform wind tunnel tests with the RJ, LS-0417, or the vertical stabilizer common research model. Testing objectives can include:

   i. Validation of the existing Type IV fluid allowance times for use with the newly certified anti-icing fluids, or with fluids for which data is lacking;

   ii. Further development of the EG-specific allowance time table to be able to benefit from potentially longer times;

   iii. Expansion of the allowance for Type III fluids at lower speeds to get longer times and guidance in more conditions; and

   iv. Evaluation of contaminated fluid flow-off from a vertical stabilizer.

The typical procedure is described as follows, but may be modified to address specific testing objectives. Prior to starting each test event, correlation testing is required to calibrate the TC model and to demonstrate repeatability. Wind tunnel tests will be performed with ethylene glycol and propylene glycol anti-icing fluids at below freezing temperatures; Type I deicing fluids may also be considered. Tests will simulate low speed or high speed takeoff runs. During contaminated test runs, a baseline fluid only case may be run immediately before, or after the contaminated test run to provide a direct correlation of the results. High resolution photos will be taken of the fluid motion. Observers will document the appearance of fluid on the vertical stabilizer during the simulated takeoff run and climb of the aircraft by analyzing the photographic records. The testing team will collect, among other things, the following data during the tests: type and amount of fluid applied, type and rate of contamination applied, and extent of fluid contamination prior to the test run.

13. Wind Tunnel Testing – Week 3 Activities (Additional 5 Days)

Note: The NRC facility costs associated with manufacturing the test model and testing at M-46 are not included in this task and are dealt directly with TC through a M.O.U. agreement with NRC.

This budget associated with this program element includes 5 days of testing. The related pre-testing and post-testing activities (including reporting and analysis) are associated with program element #11.

a) Perform wind tunnel tests with the RJ, LS-0417, or the vertical stabilizer common research model. Testing objectives can include:

   i. Validation of the existing Type IV fluid allowance times for use with the newly certified anti-icing fluids, or with fluids for which data is lacking;

   ii. Further development of the EG-specific allowance time table to be able to benefit from potentially longer times;

   iii. Expansion of the allowance for Type III fluids at lower speeds to get longer times and guidance in more conditions; and

   iv. Evaluation of contaminated fluid flow-off from a vertical stabilizer.

   The typical procedure is described as follows, but may be modified to address specific testing objectives. Prior to starting each test event, correlation testing is required to calibrate the TC model and to demonstrate repeatability. Wind tunnel tests will be performed with ethylene glycol and propylene glycol anti-icing fluids at below freezing temperatures; Type I deicing fluids may also be considered. Tests will simulate low speed or high speed takeoff runs. During contaminated test runs, a baseline fluid only case may be run immediately before, or after the contaminated test run to provide a direct correlation of the results. High resolution photos will be taken of the fluid motion. Observers will document the appearance of fluid on the vertical stabilizer during the simulated takeoff run and climb of the aircraft by analyzing the photographic records. The testing team will collect, among other things, the following data during the tests: type and amount of fluid applied, type and rate of contamination applied, and extent of fluid contamination prior to the test run.

14. Wind Tunnel Testing – Week 4 Activities (Additional 5 Days)

Note: The NRC facility costs associated with manufacturing the test model and testing at M-46 are not included in this task and are dealt directly with TC through a M.O.U. agreement with NRC.

This budget associated with this program element includes 5 days of testing. The related pre-testing and post-testing activities (including reporting and analysis) are associated with program element #11.

a) Perform wind tunnel tests with the RJ, LS-0417, or the vertical stabilizer common research model. Testing objectives can include:

   i. Validation of the existing Type IV fluid allowance times for use with the newly certified anti-icing fluids, or with fluids for which data is lacking;

   ii. Further development of the EG-specific allowance time table to be able to benefit from potentially longer times;

   iii. Expansion of the allowance for Type III fluids at lower speeds to get longer times and guidance in more conditions; and

   iv. Evaluation of contaminated fluid flow-off from a vertical stabilizer.

   The typical procedure is described as follows, but may be modified to address specific testing objectives. Prior to starting each test event, correlation testing is required to calibrate the TC model and to demonstrate repeatability. Wind tunnel tests will be performed with ethylene glycol and propylene glycol anti-icing fluids at below freezing temperatures; Type I deicing fluids may also be considered. Tests will simulate low speed or high speed takeoff runs. During contaminated test runs, a baseline fluid only case may be run immediately before, or after the contaminated test run to provide a direct correlation of the results. High resolution photos will be taken of the fluid motion. Observers will document the appearance of fluid on the vertical stabilizer during the simulated takeoff run and climb of the aircraft by analyzing the photographic records. The testing team will collect, among other things, the following data during the tests: type and amount of fluid applied, type and rate of contamination applied, and extent of fluid contamination prior to the test run.

15. Wind Tunnel Testing – Week 5 Activities (Additional 5 Days)

Note: The NRC facility costs associated with manufacturing the test model and testing at M-46 are not included in this task and are dealt directly with TC through a M.O.U. agreement with NRC.

This budget associated with this program element includes 5 days of testing. The related pre-testing and post-testing activities (including reporting and analysis) are associated with program element #11.

a) Perform wind tunnel tests with the RJ, LS-0417, or the vertical stabilizer common research model. Testing objectives can include:

   i. Validation of the existing Type IV fluid allowance times for use with the newly certified anti-icing fluids, or with fluids for which data is lacking;

   ii. Further development of the EG-specific allowance time table to be able to benefit from potentially longer times;

   iii. Expansion of the allowance for Type III fluids at lower speeds to get longer times and guidance in more conditions; and

   iv. Evaluation of contaminated fluid flow-off from a vertical stabilizer.

   The typical procedure is described as follows, but may be modified to address specific testing objectives. Prior to starting each test event, correlation testing is required to calibrate the TC model and to demonstrate repeatability. Wind tunnel tests will be performed with ethylene glycol and propylene glycol anti-icing fluids at below freezing temperatures; Type I deicing fluids may also be considered. Tests will simulate low speed or high speed takeoff runs. During contaminated test runs, a baseline fluid only case may be run immediately before, or after the contaminated test run to provide a direct correlation of the results. High resolution photos will be taken of the fluid motion. Observers will document the appearance of fluid on the vertical stabilizer during the simulated takeoff run and climb of the aircraft by analyzing the photographic records. The testing team will collect, among other things, the following data during the tests: type and amount of fluid applied, type and rate of contamination applied, and extent of fluid contamination prior to the test run.

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APPENDIX B

PROCEDURE: WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A VERTICAL STABILIZER WINTER 2021-22

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PROCEDURE:

WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A VERTICAL STABILIZER

Winter 2021-22

Prepared for:

Transport Canada
Innovation Centre

In cooperation with:

Federal Aviation Administration
William J. Hughes Technical Center

Transport Canada
Civil Aviation

Federal Aviation Administration
Flight Standards – Air Carrier Operations

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

APS Aviation Inc.

August 1, 2022
Final Version 1.1

WIND TUNNEL TESTING TO EVALUATE CONTAMINATIED FLUID FLOW-OFF FROM A VERTICAL STABILIZER

Winter 2021-22

1. BACKGROUND

There is a lack of standardization in the treatment of vertical surfaces. Some operators in the United States and Canada exclude the treatment of vertical surfaces, including the tail, while others only consider treatment in ongoing freezing precipitation. Some reports have also indicated that treatment of the tail may worsen takeoff performance as the anti-icing fluid on the tail may lead to increased accumulation of contamination in active precipitation conditions.

Current Transport Canada (TC) and Federal Aviation Administration (FAA) rules and regulations require that critical surfaces be free of contamination prior to takeoff. The vertical stabilizer is defined as a critical surface by both TC and the FAA. However, from a regulatory implementation and enforcement standpoint, there is currently no standardized guidance that offers inspectors a means to determine if an air operator is complying with operational rules. If current operational rules aim to achieve the clean aircraft concept – which requires the tail to have zero adhering frozen contamination – the question remains: How can this be adequately achieved, or appropriately mitigated by operators, to ensure a satisfactory level of safety?

Flat plate testing conducted in 2015-16 demonstrated the variability in both fluid protection times and characteristics of contamination on vertical surfaces. In 2019-20, aerodynamic testing to document contaminated fluid flow-off on a Piper PA-34-200T Seneca II vertical stabilizer demonstrated that fluid and contamination was always present at the end of each test run. The amount of residual increased or decreased based on the severity of the condition tested and was affected by the sideslip and rudder deflection, the level of contamination, the temperature at which the test was run, the type of fluid used, and other factors. The applicability of these results to commercial airliners was reviewed by the G-12 Aerodynamics Working Group (AWG), and it was recommended that a new generic model be designed to allow for better, more relevant data to be collected.

Through discussions with the SAE International G-12 AWG, a "Common Research Model" (CRM) was designed based on an analysis of existing aircraft geometries and built by the National Research Council Canada (NRC) in preparation for testing for the winter of 2021-22. A preliminary plan has been developed to use the TC owned CRM model to conduct testing at the NRC Icing Wind Tunnel (IWT) in Ottawa to qualify the contaminated fluid flow-off characteristics. This data can then be used by aircraft manufacturers to better understand the expected impacts on their specific aircraft types.

2. OBJECTIVES AND TIMING

Twenty-four days of general wind tunnel testing are being planned based on TC/FAA funding resources, nine days of which are reserved for testing with the CRM. The sequence of testing is fixed due to availability of the wind tunnel and NRC personnel required to swap out the aerodynamic models (vertical stabilizer vs. wing).

2.1 Documentation of Contaminated Fluid Flow-Off on a Vertical Stabilizer

The objective of this testing is to conduct aerodynamic testing to document contaminated fluid flow-off on a vertical stabilizer.

To satisfy this objective, a CRM vertical stabilizer (see Figure 2.1) will be subjected to a series of tests in the NRC IWT.

Nine days of testing are required for the conduct of these tests.

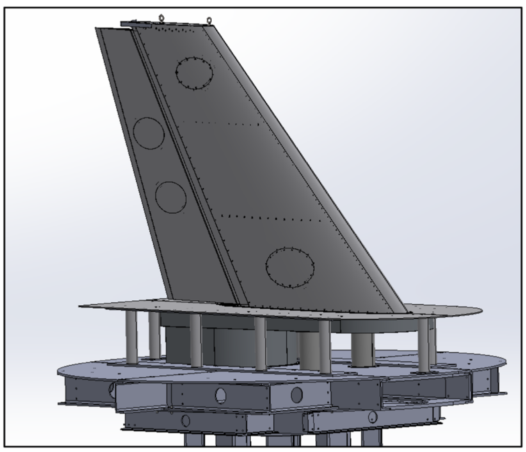


Figure 2.1: Vertical Stabilizer Mounted on Turntable

2.2 Ice Pellet Allowance Time Testing

As part of a separate project, aerodynamic testing with a thin high performance airfoil will be conducted to support the further development of the ice pellet allowance time guidelines. Fifteen days of testing are required for the conduct of these tests, the details of which are provided in a separate procedure.

2.3 Timing

Fifteen days are required for the "Ice Pellet Allowance Time Testing" (Subsection 2.2), and nine days are required for the "Documentation of Contaminated Fluid Flow-Off on a Vertical Stabilizer" (Subsection 2.1). This totals to 24 days of testing, based on the available TC/FAA funding resources.

At the time of writing this procedure, it is expected that testing with the RJ model (details described in a separate procedure) will start on January 9, 2022. Changing over of the aerodynamic models will require some down-time, which will occur during the week of January 30th. Testing will resume with the CRM model for an additional nine days of testing starting February 3rd. See Table 2.1 for details.

Testing will be conducted during overnight periods (9:30 pm to 5:30 am), with the exception of the weeks of December 19th, January 30th, and February 13th, which will be from 8:00 am to 4:00 pm. The weekends will be considered only if deemed necessary. The first two hours or more of the first day will be dedicated to setup and calibration of the rain sprayer and ice pellet and snow dispensers; time permitting testing will begin as per the test plan.

Table 2.1: Test Calendar

Week of	Sun	Mon	Tue	Wed	Thurs	Fri	Sat
19-Dec-21		APS Setup, Training, and Precip. Calibration	APS Setup, Training, and Precip. Calibration	Backup-day			
26-Dec-21							
02-Jan-22							
09-Jan-22	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests		
16-Jan-22	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests		
23-Jan-22	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests	APS RJ Fluid Tests		
30-Jan-22		Wing Changeover (no testing)	Wing Changeover (no testing)	Wing Changeover (no testing)	NRC CRM Shakedown and Calibration - Dry Runs	NRC CRM Shakedown and Calibration - Tufts	
06-Feb-22	APS CRM Fluid Tests	APS CRM Fluid Tests	APS CRM Fluid Tests	APS CRM Fluid Tests	APS CRM Fluid Tests		
13-Feb-22		NRC CRM Shakedown and Calibration -BL Tests	NRC CRM Shakedown and Calibration -BL Tests				

Note: Planned for 25 days. Revised to 24 based on scheduling availibilty.

Legend

APS Setup, Training, and Precip. Calibration	APS to setup equipment, setup remote vieweing cameras, conduct training for new staff, and (if possible) conduct calibration of precipitation dispensing.
NRC CRM Shakedown and Calibration	NRC lead activity to deliver a working and repeatable CRM model. APS to support. 1 day Shakedown and Dry Run Repeatability. 2 days Boundary Layer Rake Tests. 1 day Tuft tests.
Backup NRC week	Optional days for NRC Shakedown and Calibration in case of delays
APS CRM Fluid Tests	Fluid only, and fluid with contamination tests (SN, FZRA, PL). Up to 5 days
Wing Changeover (no testing)	NRC needs time to changover the CRM to the RJ wing.
APS RJ Fluid Tests	Ice pellet allowance time and related testing. 15 days.

3. TEST PLAN

The NRC IWT is an open circuit tunnel. The temperature inside the wind tunnel is dependent on the outside ambient temperature. Prior to testing, the weather should be monitored to ensure proper temperatures for testing.

Representative Type I/II/III/IV propylene glycol and ethylene glycol-based fluids in the 100/0 dilution (standard mix or 10-degree buffer for Type I) shall be evaluated against their uncontaminated performance.

A preliminary list of test objectives is shown in Table 3.1 (only Priority 1 objectives will be attempted unless indicated otherwise by TC/FAA directive). It should be noted that the order in which the tests will be carried out will depend on weather conditions and TC/FAA directive. A detailed test matrix (subject to change) related to items #1, #2, and #3 (CRM Testing) is shown in Table 3.2. It is expected that the shakedown runs, dry wing tests, tuft tests, and boundary layer rake tests will be conducted during the first week of testing, and the fluid testing will begin the week of January 9th, 2021. As this testing is exploratory, changes to the test plan may be made at the time of testing and will be confirmed by TC/FAA.

NOTE: The numbering of the test runs will be done in a sequential order starting with number 1.

Table 3.1: Preliminary List of Testing Objectives for Winter 2021-22 Wind Tunnel Testing

Item #	Objective	Priority	Description	# of Days
0	Setup and Precipitation Calibration	1	Setup of equipment and calibration of the rain sprayer and the ice pellet and snow dispensers (to be done on the first day of testing)	1
1	Dry Wing Baseline Repeatability	1	Baseline test at beginning of each day to ensure repeatability (part of NRC shakedown tests so no days allotted)	N/A
2	CRM V-Stab - Calibration and Characterization Testing	1	Shakedown and dry run repeatability, boundary layer rake tests, and tuft tests.	4
3	CRM V-Stab - Fluid Testing	1	Fluid only, and fluid with contamination tests (SN, FZRA, PL).	5
4	Type IV IP AT Validation (New Fluids)	1	Substantiate current times with new fluids	8
5	Development of EG Specific IP Allowance Times	1	Support the development of an EG fluid specific ice pellet allowance time table to benefit of potential longer times	4
6	General Allowance Time Expansion		New temperatures, conditions, etc. for allowance times i.e. Moderate snow mixed with ice pellets	3
7	Other R&D Activities	2	Could be selected from item # 7.1 to 7.7	0
7.1	METAR		Triplicate conditions and testing to support MWG activities	-
7.2	Type III Allowance Time Expansion	-	Expand the current Type III allowance times to have increased times, or more cells	-
7.3	Type III Low Speed Allowance Times	-	Validate the current Type III allowance times for use with low speed aircraft	-
7.4	Heavy Snow	-	Continue Heavy Snow Research comparing lift losses with Light/Moderate Snow vs. Heavy Snow	-
7.5	Heavy Contamination (Aero vs. Visual Failure)	-	Continue work looking at aerodynamic failure vs. HOT defined failure, and effect of surface roughness on lift degradation	-
7.6	Fluid + Contamination @ LOUT	-	Effect of contamination on fluid performance at LOUT with IP, SN, ZF, Frost etc.	-
7.7	Other	-	Any potential suggestions from industry	-

Total # of Days for Priority 1 Tests	24

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
1	1	Shakedown Runs	None	δ = TBDº, β = TBDº	Any	None	N/A	Parameters TBD as required
2	1	Dry Wing	None	δ = TBDº, β = TBDº (dynamic)	Any	None	N/A	To be done at start of each day
3	1	Dry Wing	None	δ = TBDº, β = TBDº (static)	Any	None	N/A	To be done at start of each day
4	1	Tufts	None	δ = 0 β = -10 to +10 @2º incr.	Any	None	N/A	Tufts on both sides
5	1	Tufts	None	δ = -5 β = -10 to +10 @2º incr.	Any	None	N/A	Tufts on both sides
6	1	Tufts	None	δ = -10 β = -10 to +10 @2º incr.	Any	None	N/A	Tufts on both sides
7	1	Tufts	None	δ = -15 β = -10 to +10 @2º incr.	Any	None	N/A	Tufts on both sides
8	1	Tufts	None	δ = -20 β = -10 to +10 @2º incr.	Any	None	N/A	Tufts on both sides
9	1	Tufts	None	δ = +10 β = -10 to +10 @2º incr.	Any	None	N/A	Tufts on both sides
10	1	Tufts	None	δ = TBDº, β = TBDº	Any	None	N/A	Tufts on both sides
11	1	Boundary Layer Rake	None	δ = 0 β = -10 to +10 @2º incr.	Any	None	N/A	#1 BLR Location
12	1	Boundary Layer Rake	None	δ = -5 β = -10 to +10 @2º incr.	Any	None	N/A	#1 BLR Location
13	1	Boundary Layer Rake	None	δ = -10 β = -10 to +10 @2º incr.	Any	None	N/A	#1 BLR Location
14	1	Boundary Layer Rake	None	δ = -15 β = -10 to +10 @2º incr.	Any	None	N/A	#1 BLR Location
15	1	Boundary Layer Rake	None	δ = -20 β = -10 to +10 @2º incr.	Any	None	N/A	#1 BLR Location
16	1	Boundary Layer Rake	None	δ = +10 β = -10 to +10 @2º incr.	Any	None	N/A	#1 BLR Location
17	1	Boundary Layer Rake	None	δ = TBDº, β = TBDº	Any	None	N/A	#1 BLR Location
18	1	Boundary Layer Rake	None	δ = 0 β = -10 to +10 @2º incr.	Any	None	N/A	#2 BLR Location
19	1	Boundary Layer Rake	None	δ = -5 β = -10 to +10 @2º incr.	Any	None	N/A	#2 BLR Location
20	1	Boundary Layer Rake	None	δ = -10 β = -10 to +10 @2º incr.	Any	None	N/A	#2 BLR Location
21	1	Boundary Layer Rake	None	δ = -15 β = -10 to +10 @2º incr.	Any	None	N/A	#2 BLR Location
22	1	Boundary Layer Rake	None	δ = -20 β = -10 to +10 @2º incr.	Any	None	N/A	#2 BLR Location
23	1	Boundary Layer Rake	None	δ = +10 β = -10 to +10 @2º incr.	Any	None	N/A	#2 BLR Location

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	Precipitation* *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	Sideslip (β) and Rudder Deflection (δ) ** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	Temperature *Cold, Warm, Any*	Fluid *In order of Priority: PG, TI, EG, None*	Contamination Application *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
24	1	Boundary Layer Rake	None	δ = TBD°, β = TBD°	Any	None	N/A	#2 BLR Location
25	1	Boundary Layer Rake	None	δ = 0 β = -10 to +10 @2° incr.	Any	None	N/A	#3 BLR Location
26	1	Boundary Layer Rake	None	δ = -5 β = -10 to +10 @2° incr.	Any	None	N/A	#3 BLR Location
27	1	Boundary Layer Rake	None	δ = -10 β = -10 to +10 @2° incr.	Any	None	N/A	#3 BLR Location
28	1	Boundary Layer Rake	None	δ = -15 β = -10 to +10 @2° incr.	Any	None	N/A	#3 BLR Location
29	1	Boundary Layer Rake	None	δ = -20 β = -10 to +10 @2° incr.	Any	None	N/A	#3 BLR Location
30	1	Boundary Layer Rake	None	δ = +10 β = -10 to +10 @2° incr.	Any	None	N/A	#3 BLR Location
31	1	Boundary Layer Rake	None	δ = TBD°, β = TBD°	Any	None	N/A	#3 BLR Location
32	1	Boundary Layer Rake	None	δ = 0 β = -10 to +10 @2° incr.	Any	None	N/A	#4 BLR Location
33	1	Boundary Layer Rake	None	δ = -5 β = -10 to +10 @2° incr.	Any	None	N/A	#4 BLR Location
34	1	Boundary Layer Rake	None	δ = -10 β = -10 to +10 @2° incr.	Any	None	N/A	#4 BLR Location
35	1	Boundary Layer Rake	None	δ = -15 β = -10 to +10 @2° incr.	Any	None	N/A	#4 BLR Location
36	1	Boundary Layer Rake	None	δ = -20 β = -10 to +10 @2° incr.	Any	None	N/A	#4 BLR Location
37	1	Boundary Layer Rake	None	δ = +10 β = -10 to +10 @2° incr.	Any	None	N/A	#4 BLR Location
38	1	Boundary Layer Rake	None	δ = TBD°, β = TBD°	Any	None	N/A	#4 BLR Location
39	1	Boundary Layer Rake	None	δ = 0 β = -10 to +10 @2° incr.	Any	None	N/A	#5 BLR Location
40	1	Boundary Layer Rake	None	δ = -5 β = -10 to +10 @2° incr.	Any	None	N/A	#5 BLR Location
41	1	Boundary Layer Rake	None	δ = -10 β = -10 to +10 @2° incr.	Any	None	N/A	#5 BLR Location
42	1	Boundary Layer Rake	None	δ = -15 β = -10 to +10 @2° incr.	Any	None	N/A	#5 BLR Location
43	1	Boundary Layer Rake	None	δ = -20 β = -10 to +10 @2° incr.	Any	None	N/A	#5 BLR Location
44	1	Boundary Layer Rake	None	δ = +10 β = -10 to +10 @2° incr.	Any	None	N/A	#5 BLR Location
45	1	Boundary Layer Rake	None	δ = TBD°, β = TBD°	Any	None	N/A	#5 BLR Location
46	1	Boundary Layer Rake	None	δ = 0 β = -10 to +10 @2° incr.	Any	None	N/A	#6 BLR Location

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
47	1	Boundary Layer Rake	None	δ= -5 β= -10 to +10 @2° incr.	Any	None	N/A	#6 BLR Location
48	1	Boundary Layer Rake	None	δ= -10 β= -10 to +10 @2° incr.	Any	None	N/A	#6 BLR Location
49	1	Boundary Layer Rake	None	δ= -15 β= -10 to +10 @2° incr.	Any	None	N/A	#6 BLR Location
50	1	Boundary Layer Rake	None	δ= -20 β= -10 to +10 @2° incr.	Any	None	N/A	#6 BLR Location
51	1	Boundary Layer Rake	None	δ= +10 β= -10 to +10 @2° incr.	Any	None	N/A	#6 BLR Location
52	1	Boundary Layer Rake	None	δ=TBD°, β=TBD°	Any	None	N/A	#6 BLR Location
53	2	Fluid Only	None	δ=0°, β=0°	Cold	PG	N/A	-
54	2	Fluid Only	None	δ=0°, β=0°	Warm	PG	N/A	-
55	2	Fluid Only	None	δ=TBD°, β=TBD°	Cold	PG	N/A	-
56	2	Fluid Only	None	δ=TBD°, β=TBD°	Warm	PG	N/A	-
57	2	Fluid Only	None	δ= -20°, β= -10°	Cold	PG	N/A	-
58	2	Fluid Only	None	δ= -20°, β= -10°	Warm	PG	N/A	-
59	3	Fluid Only	None	δ=0°, β=0°	Cold	TI	N/A	-
60	3	Fluid Only	None	δ=0°, β=0°	Warm	TI	N/A	-
61	3	Fluid Only	None	δ=TBD°, β=TBD°	Cold	TI	N/A	-
62	3	Fluid Only	None	δ=TBD°, β=TBD°	Warm	TI	N/A	-
63	3	Fluid Only	None	δ= -20°, β= -10°	Cold	TI	N/A	-
64	3	Fluid Only	None	δ= -20°, β= -10°	Warm	TI	N/A	-
65	4	Fluid Only	None	δ=0°, β=0°	Cold	EG	N/A	-
66	4	Fluid Only	None	δ=0°, β=0°	Warm	EG	N/A	-
67	4	Fluid Only	None	δ=TBD°, β=TBD°	Cold	EG	N/A	-
68	4	Fluid Only	None	δ=TBD°, β=TBD°	Warm	EG	N/A	-
69	4	Fluid Only	None	δ= -20°, β= -10°	Cold	EG	N/A	-

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
70	4	Fluid Only	None	δ = -20°, β = -10°	Warm	EG	N/A	-
71	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
72	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	PG	Asymmetric (either side)	Exposure to V-Stab 10% fail
73	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
74	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	PG	Asymmetric (either side)	Exposure to V-Stab 10% fail
75	2	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
76	2	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
77	2	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
78	2	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
79	2	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
80	2	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
81	2	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
82	2	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
83	2	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
84	2	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
85	2	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
86	2	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
87	3	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
88	3	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	TI	Asymmetric (either side)	Exposure to V-Stab 10% fail
89	3	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
90	3	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	TI	Asymmetric (either side)	Exposure to V-Stab 10% fail
91	3	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
92	3	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
93	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
94	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
95	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
96	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
97	3	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
98	3	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
99	3	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
100	3	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
101	3	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
102	3	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
103	4	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
104	4	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Cold	EG	Asymmetric (either side)	Exposure to V-Stab 10% fail
105	4	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
106	4	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Warm	EG	Asymmetric (either side)	Exposure to V-Stab 10% fail
107	4	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
108	4	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
109	4	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
110	4	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
111	4	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
112	4	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
113	4	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
114	4	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
115	4	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
116	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
117	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
118	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
119	5	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
120	5	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	None	Asymmetric (either side)	Exposure to V-Stab 10% fail
121	5	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
122	5	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	None	Asymmetric (either side)	Exposure to V-Stab 10% fail
123	5	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
124	5	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
125	5	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
126	5	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
127	5	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
128	5	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
129	5	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
130	5	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
131	5	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
132	5	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
133	5	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
134	5	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
135	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	PG	Symmetric (both sides)	Exposure to HOT
136	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	PG	Asymmetric (either side)	Exposure to HOT
137	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	PG	Symmetric (both sides)	Exposure to HOT
138	2	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	PG	Asymmetric (either side)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	Precipitation* *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	Sideslip (β) and Rudder Deflection (δ) ** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	Temperature *Cold, Warm, Any*	Fluid *In order of Priority: PG, TI, EG, None*	Contamination Application *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
139	2	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	PG	Symmetric (both sides)	Exposure to HOT
140	2	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
141	2	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
142	2	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	PG	Symmetric (both sides)	Exposure to HOT
143	2	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
144	2	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
145	2	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	PG	Symmetric (both sides)	Exposure to HOT
146	2	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
147	2	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
148	2	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	PG	Symmetric (both sides)	Exposure to HOT
149	2	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
150	2	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
151	3	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Cold	TI	Symmetric (both sides)	Exposure to HOT
152	3	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Cold	TI	Asymmetric (either side)	Exposure to HOT
153	3	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Warm	TI	Symmetric (both sides)	Exposure to HOT
154	3	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Warm	TI	Asymmetric (either side)	Exposure to HOT
155	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	TI	Symmetric (both sides)	Exposure to HOT
156	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
157	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
158	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	TI	Symmetric (both sides)	Exposure to HOT
159	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
160	3	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
161	3	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	TI	Symmetric (both sides)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
162	3	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
163	3	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
164	3	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	TI	Symmetric (both sides)	Exposure to HOT
165	3	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
166	3	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
167	4	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	EG	Symmetric (both sides)	Exposure to HOT
168	4	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	EG	Asymmetric (either side)	Exposure to HOT
169	4	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	EG	Symmetric (both sides)	Exposure to HOT
170	4	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Warm	EG	Asymmetric (either side)	Exposure to HOT
171	4	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	EG	Symmetric (both sides)	Exposure to HOT
172	4	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
173	4	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
174	4	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	EG	Symmetric (both sides)	Exposure to HOT
175	4	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
176	4	Fluid and Cont. (SN)	Snow	δ = TBD°, β = TBD°	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
177	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	EG	Symmetric (both sides)	Exposure to HOT
178	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
179	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
180	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	EG	Symmetric (both sides)	Exposure to HOT
181	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
182	4	Fluid and Cont. (SN)	Snow	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
183	5	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	None	Symmetric (both sides)	Exposure to HOT
184	5	Fluid and Cont. (SN)	Snow	δ = 0°, β = 0°	Cold	None	Asymmetric (either side)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
185	5	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Warm	None	Symmetric (both sides)	Exposure to HOT
186	5	Fluid and Cont. (SN)	Snow	δ = 0º, β = 0º	Warm	None	Asymmetric (either side)	Exposure to HOT
187	5	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	None	Symmetric (both sides)	Exposure to HOT
188	5	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
189	5	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
190	5	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	None	Symmetric (both sides)	Exposure to HOT
191	5	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
192	5	Fluid and Cont. (SN)	Snow	δ = TBDº, β = TBDº	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
193	5	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	None	Symmetric (both sides)	Exposure to HOT
194	5	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
195	5	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
196	5	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	None	Symmetric (both sides)	Exposure to HOT
197	5	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
198	5	Fluid and Cont. (SN)	Snow	δ = -20º, β = -10º	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
199	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
200	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	EG	Asymmetric (either side)	Exposure to V-Stab 10% fail
201	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
202	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	PG	Asymmetric (either side)	Exposure to V-Stab 10% fail
203	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
204	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	EG	Asymmetric (either side)	Exposure to V-Stab 10% fail
205	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
206	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	PG	Asymmetric (either side)	Exposure to V-Stab 10% fail
207	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
208	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
209	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
210	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
211	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
212	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
213	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
214	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
215	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
216	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
217	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
218	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
219	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
220	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
221	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
222	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
223	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
224	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
225	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
226	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
227	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
228	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
229	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
230	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	**Comments**
231	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
232	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Cold	TI	Asymmetric (either side)	Exposure to V-Stab 10% fail
233	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
234	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Warm	TI	Asymmetric (either side)	Exposure to V-Stab 10% fail
235	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
236	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
237	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
238	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
239	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
240	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
241	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
242	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
243	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
244	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
245	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
246	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
247	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
248	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Cold	None	Asymmetric (either side)	Exposure to V-Stab 10% fail
249	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
250	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Warm	None	Asymmetric (either side)	Exposure to V-Stab 10% fail
251	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
252	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
253	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
254	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
255	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
256	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
257	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
258	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
259	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
260	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
261	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
262	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
263	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	EG	Symmetric (both sides)	Exposure to HOT
264	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	EG	Asymmetric (either side)	Exposure to HOT
265	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	PG	Symmetric (both sides)	Exposure to HOT
266	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	PG	Asymmetric (either side)	Exposure to HOT
267	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	EG	Symmetric (both sides)	Exposure to HOT
268	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	EG	Asymmetric (either side)	Exposure to HOT
269	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	PG	Symmetric (both sides)	Exposure to HOT
270	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	PG	Asymmetric (either side)	Exposure to HOT
271	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	EG	Symmetric (both sides)	Exposure to HOT
272	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
273	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
274	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	PG	Symmetric (both sides)	Exposure to HOT
275	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
276	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
277	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	EG	Symmetric (both sides)	Exposure to HOT
278	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
279	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
280	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	PG	Symmetric (both sides)	Exposure to HOT
281	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
282	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
283	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	EG	Symmetric (both sides)	Exposure to HOT
284	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
285	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
286	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	PG	Symmetric (both sides)	Exposure to HOT
287	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
288	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
289	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	EG	Symmetric (both sides)	Exposure to HOT
290	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
291	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
292	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	PG	Symmetric (both sides)	Exposure to HOT
293	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
294	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20º, β = -10º	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
295	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	TI	Symmetric (both sides)	Exposure to HOT
296	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Cold	TI	Asymmetric (either side)	Exposure to HOT
297	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	TI	Symmetric (both sides)	Exposure to HOT
298	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0º, β = 0º	Warm	TI	Asymmetric (either side)	Exposure to HOT
299	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBDº, β = TBDº	Cold	TI	Symmetric (both sides)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
300	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
301	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
302	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	TI	Symmetric (both sides)	Exposure to HOT
303	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
304	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
305	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	TI	Symmetric (both sides)	Exposure to HOT
306	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
307	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
308	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	TI	Symmetric (both sides)	Exposure to HOT
309	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
310	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
311	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Cold	None	Symmetric (both sides)	Exposure to HOT
312	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Cold	None	Asymmetric (either side)	Exposure to HOT
313	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Warm	None	Symmetric (both sides)	Exposure to HOT
314	6	Fluid and Cont. (FZR)	Freezing Rain	δ = 0°, β = 0°	Warm	None	Asymmetric (either side)	Exposure to HOT
315	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	None	Symmetric (both sides)	Exposure to HOT
316	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
317	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
318	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	None	Symmetric (both sides)	Exposure to HOT
319	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
320	6	Fluid and Cont. (FZR)	Freezing Rain	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
321	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	None	Symmetric (both sides)	Exposure to HOT
322	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
323	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
324	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	None	Symmetric (both sides)	Exposure to HOT
325	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
326	6	Fluid and Cont. (FZR)	Freezing Rain	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
327	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
328	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	EG	Asymmetric (either side)	Exposure to V-Stab 10% fail
329	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
330	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	PG	Asymmetric (either side)	Exposure to V-Stab 10% fail
331	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
332	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	EG	Asymmetric (either side)	Exposure to V-Stab 10% fail
333	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
334	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	PG	Asymmetric (either side)	Exposure to V-Stab 10% fail
335	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
336	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
337	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
338	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
339	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
340	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
341	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
342	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
343	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
344	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
345	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
346	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
347	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
348	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
349	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
350	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
351	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
352	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
353	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	EG	Symmetric (both sides)	Exposure to V-Stab 10% fail
354	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
355	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
356	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	PG	Symmetric (both sides)	Exposure to V-Stab 10% fail
357	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
358	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
359	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
360	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	TI	Asymmetric (either side)	Exposure to V-Stab 10% fail
361	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
362	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	TI	Asymmetric (either side)	Exposure to V-Stab 10% fail
363	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
364	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
365	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
366	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
367	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
368	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
369	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
370	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
371	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
372	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	TI	Symmetric (both sides)	Exposure to V-Stab 10% fail
373	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
374	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
375	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
376	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	None	Asymmetric (either side)	Exposure to V-Stab 10% fail
377	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
378	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	None	Asymmetric (either side)	Exposure to V-Stab 10% fail
379	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
380	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
381	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
382	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
383	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
384	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
385	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
386	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
387	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
388	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	None	Symmetric (both sides)	Exposure to V-Stab 10% fail
389	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to V-Stab 10% fail
390	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to V-Stab 10% fail
391	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	EG	Symmetric (both sides)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	Precipitation* *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	Sideslip (β) and Rudder Deflection (δ) ** In order of Priority: *None (0º, 0º), Max (7.5º, 30º: based on B757 report), TBD*	Temperature *Cold, Warm, Any*	Fluid *In order of Priority: PG, TI, EG, None*	Contamination Application *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
392	7	Fluid and Cont. (Other)	Other	δ = 0º, β = 0º	Cold	EG	Asymmetric (either side)	Exposure to HOT
393	7	Fluid and Cont. (Other)	Other	δ = 0º, β = 0º	Cold	PG	Symmetric (both sides)	Exposure to HOT
394	7	Fluid and Cont. (Other)	Other	δ = 0º, β = 0º	Cold	PG	Asymmetric (either side)	Exposure to HOT
395	7	Fluid and Cont. (Other)	Other	δ = 0º, β = 0º	Warm	EG	Symmetric (both sides)	Exposure to HOT
396	7	Fluid and Cont. (Other)	Other	δ = 0º, β = 0º	Warm	EG	Asymmetric (either side)	Exposure to HOT
397	7	Fluid and Cont. (Other)	Other	δ = 0º, β = 0º	Warm	PG	Symmetric (both sides)	Exposure to HOT
398	7	Fluid and Cont. (Other)	Other	δ = 0º, β = 0º	Warm	PG	Asymmetric (either side)	Exposure to HOT
399	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Cold	EG	Symmetric (both sides)	Exposure to HOT
400	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
401	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
402	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Cold	PG	Symmetric (both sides)	Exposure to HOT
403	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
404	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
405	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Warm	EG	Symmetric (both sides)	Exposure to HOT
406	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
407	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
408	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Warm	PG	Symmetric (both sides)	Exposure to HOT
409	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
410	7	Fluid and Cont. (Other)	Other	δ = TBDº, β = TBDº	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
411	7	Fluid and Cont. (Other)	Other	δ = -20º, β = -10º	Cold	EG	Symmetric (both sides)	Exposure to HOT
412	7	Fluid and Cont. (Other)	Other	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
413	7	Fluid and Cont. (Other)	Other	δ = -20º, β = -10º	Cold	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
414	7	Fluid and Cont. (Other)	Other	δ = -20º, β = -10º	Cold	PG	Symmetric (both sides)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
415	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
416	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
417	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	EG	Symmetric (both sides)	Exposure to HOT
418	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Into Wind)	Exposure to HOT
419	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	EG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
420	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	PG	Symmetric (both sides)	Exposure to HOT
421	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	PG	Asymmetric (Cont. Into Wind)	Exposure to HOT
422	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	PG	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
423	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	TI	Symmetric (both sides)	Exposure to HOT
424	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	TI	Asymmetric (either side)	Exposure to HOT
425	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	TI	Symmetric (both sides)	Exposure to HOT
426	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	TI	Asymmetric (either side)	Exposure to HOT
427	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	TI	Symmetric (both sides)	Exposure to HOT
428	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
429	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
430	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	TI	Symmetric (both sides)	Exposure to HOT
431	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
432	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
433	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	TI	Symmetric (both sides)	Exposure to HOT
434	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT
435	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
436	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	TI	Symmetric (both sides)	Exposure to HOT
437	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Into Wind)	Exposure to HOT

Table 3.2: Proposed Test Plan for Testing with the CRM V-Stab (cont'd)

Test #	Priority	Objective	**Precipitation*** *In Order of Priority: None, Snow, Freezing Rain, Other Other (i.e., IP)*	**Sideslip (β) and Rudder Deflection (δ) **** In order of Priority: *None (0°, 0°), Max (7.5°, 30°: based on B757 report), TBD*	**Temperature** *Cold, Warm, Any*	**Fluid** *In order of Priority: PG, TI, EG, None*	**Contamination Application** *Symmetric, Asymmetric (Either side), Asymmetric (Cont. Not Into Wind), Asymmetric (Cont. Into Wind), Tufts*	Comments
438	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	TI	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
439	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	None	Symmetric (both sides)	Exposure to HOT
440	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Cold	None	Asymmetric (either side)	Exposure to HOT
441	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	None	Symmetric (both sides)	Exposure to HOT
442	7	Fluid and Cont. (Other)	Other	δ = 0°, β = 0°	Warm	None	Asymmetric (either side)	Exposure to HOT
443	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	None	Symmetric (both sides)	Exposure to HOT
444	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
445	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
446	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	None	Symmetric (both sides)	Exposure to HOT
447	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
448	7	Fluid and Cont. (Other)	Other	δ = TBD°, β = TBD°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
449	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	None	Symmetric (both sides)	Exposure to HOT
450	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
451	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Cold	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT
452	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	None	Symmetric (both sides)	Exposure to HOT
453	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Into Wind)	Exposure to HOT
454	7	Fluid and Cont. (Other)	Other	δ = -20°, β = -10°	Warm	None	Asymmetric (Cont. Not Into Wind)	Exposure to HOT

4. DATA FORMS

The following data forms are required for the 2021-22 wind tunnel tests:

- Attachment 1: General Form;
- Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form;
- Attachment 3: Example Snow Dispensing Form;
- Attachment 4: Example Ice Pellet Dispensing Form;
- Attachment 5: Example Manual Freezing Rain/Rain Dispensing Form;
- Attachment 6: Visual Evaluation Rating Form;
- Attachment 7: General Form for Calibration Test;
- Attachment 8: Fluid Receipt Form (Electronic Form); and
- Attachment 9: Log of Fluid Sample Bottles.

When and how the data forms will be used is described throughout Section 5.

5. PROCEDURE

The following sections describe the tasks to be performed during each test conducted. It should be noted that some sections (i.e., fluid application and contamination application) will be omitted depending on the objective of the test.

A rating system based on aerodynamic and visual observation data has been developed for fluid and contamination tests, and will be filled out by the on-site experts when applicable. The overall rating will provide insight into the severity of the conditions observed. A test failure (failure to adequately shed the contaminated fluid at time of rotation) shall be determined by the on-site experts based on residual contamination.

5.1 Initial Test Conditions Survey

- Record ambient conditions of the test (Attachment 1: General Form); and
- Record wing temperature (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form).

5.2 Fluid Application (Pour)

- Apply a minimum of 7.5 L of anti-icing fluid over the test area (3.75 L per side). This accounts for the minimum of 1 L/m² and includes a 20 percent buffer for loss. Ideally fluid is sprayed using a motorized backpack sprayer as pouring on the vertical surface is not efficient;
- Record fluid application times and quantities (Attachment 1: General Form;
- Let fluid settle for 5 minutes;
- Measure fluid thickness at pre-determined locations on the wing (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Record wing temperature (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Measure fluid Brix value (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Photograph and videotape the appearance of the fluid on the wing; and
- Begin the time-lapse camera to gather photos of the precipitation application phase.

5.3 Application of Contamination

The precipitation systems used for typical ice pellet allowance time testing cannot be directly adapted to the CRM V-Stab. Instead, the following are available:

- Snow using the ice pellet dispensers and calibration data specific to the CRM (Attachment 3: Example Snow Dispensing Form);
- Ice pellets using the ice pellet dispensers and calibration data specific to the CRM (Attachment 4: Example Ice Pellet Dispensing Form);
- Rain or Freezing Rain using a garden sprayer and an 80 percent efficiency spray (20 percent overspray) based on the surface area of 3.1 m² per side (Attachment 5: Example Manual Freezing Rain/Rain Dispensing Form).

5.3.1 Snow and Ice Pellet Dispenser Calibration and Setup

Calibration work is being performed during the winter of 2021-22 with the purpose of obtaining the dispenser's distribution footprint for snow on a vertical surface. A series of tests will be performed in low wind conditions. These tests will be conducted using 336 collection pans in a vertical area 7 x 12 feet with effective openings measuring 6 in. x 6 in. Pre-measured amounts of snow will be dispersed over this area and the amount collected by each pan will be recorded. A distribution footprint of the dispenser will be attained and efficiency for the dispenser computed.

As this work is still ongoing at the time of writing this procedure, the exact location of the dispenser's vis-a-vis the CRM have yet to be finalized and therefore cannot be included. Upon completion of the calibration work, detailed instructions for dispensing the snow on the vertical stabilizer will be developed and provided to the team for training and execution.

5.3.2 Rain and Freezing Rain with a Motorized Garden Sprayer Setup

Rain or freezing rain will be applied using a garden sprayer. A mix of ice and water will be used to supply the freezing rain, and cold water will be used for rain. The amount of water dispensed will be calculated using an estimated 80 percent efficiency of the spray (20 percent overspray) based on the surface area of 3.1 m^2 per side. Based on the desired exposure time, the total amount of water required for the test can be determined. The total amount is then divided per 5 minutes and per side and tracked using a graduated sprayer container and validated by weighing before and after weights of the sprayer system full and empty. The application is done using an "S" pattern to provide adequate and even coverage.

5.4 Prior to Engines-On Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Measure fluid Brix value (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Record wing temperatures (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Record start time of test (Attachment 1: General Form); and
- Fill out visual evaluation rating form (Attachment 6: Visual Evaluation Rating Form).

Note: In order to minimize the measurement time post precipitation, temperature should be measured 5 minutes before the end of precipitation, thickness measured 3 minutes before the end of precipitation, and Brix measured when the precipitation *ends. Also, consideration has been given to reducing the number of measurements that are taken for this phase (i.e., locations 2 and 5 only).*

5.5 During Wind Tunnel Test

- Take still pictures and video the behaviour of the fluid on the wing during the takeoff run, capturing any movement of fluid/contamination;
- Fill out visual evaluation rating form at the time of rotation (Attachment 6: Visual Evaluation Rating Form); and
- Record wind tunnel operation start and stop times.

5.6 After the Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Measure fluid Brix value (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Record wing temperatures (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Observe and record the status of the fluid/contamination (Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form);
- Fill out visual evaluation rating form (Attachment 6: Visual Evaluation Rating Form);
- Obtain aerodynamic data (excel file) from NRC; and
- Update APS test log with pertinent information.

5.7 Fluid Sample Collection for Viscosity Testing

Two liters of each fluid to be tested are to be collected on the first day of testing. The fluid receipt form [Attachment 8: Fluid Receipt Form (Electronic Form)] should be completed indicating quantity of fluid and date received. Any samples extracted for viscosity purposes should be documented in the fluid receipt form [Attachment 8: Fluid Receipt Form (Electronic Form)]; however, an additional form (Attachment 9: Log of Fluid Sample Bottles) is available if required. A falling ball viscosity test should be performed on site to confirm that fluid viscosity is appropriate before testing.

5.8 At the End of Each Test Session

If required, APS personnel will collect the waste solution. At the end of the testing period, NRC will organize for a glycol recovery service provider to safely dispose of the waste glycol fluid.

5.9 Camera Setup

The camera setup will be investigated in advance of the testing in order to determine the best locations to position video or still cameras with the restrictions of space, lighting, and access windows. The setup will likely use a combination of Osmo cameras with viewing capabilities through a paired iPad© along with DSLR cameras to document fluid condition up close. The final positioning of the cameras and lighting should be documented.

In addition, a closed-circuit television (CCTV) camera system will be used to allow participants to view the tests remotely. The data from the CCTV system will be saved and used as a backup.

5.10 Demonstration of a Typical Wind Tunnel Test Sequence

Table 5.1 demonstrates a typical Wind Tunnel test sequence of activities, assuming the test starts at 08:00:00. Figure 5.1 demonstrates a typical wind tunnel run timeline.

Table 5.1: Typical Wind Tunnel Test

TIME	TASK
8:30:00	START OF TEST. ALL EQUIPMENT READY.
8:30:00	- Record test conditions.
8:35:00	- Prepare wing for fluid application (clean wing, etc.).
8:45:00	- Measure wing temperature.
	- Ensure clean wing for fluid application.
8:50:00	- Pour fluid over test area.
9:00:00	- Measure Brix, thickness, wing temperature.
	- Photograph test area.
9:05:00	- Apply contamination over test area. (i.e. 30 min).
9:35:00	- Measure Brix, thickness, wing temperature.
	- Photograph test area.
9:40:00	- Clear area and start wind tunnel.
9:55:00	- Wind tunnel stopped.
10:05:00	- Measure Brix, thickness, wing temperature.
	- Photograph test area.
	- Record test observations.
10:35:00	END OF TEST.

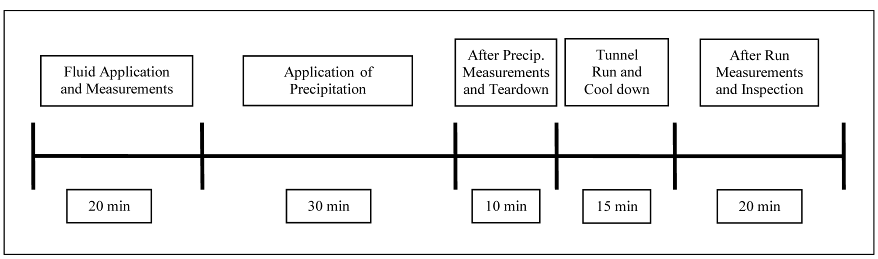


Figure 5.1: Typical Wind Tunnel Run Timeline

5.11 Procedures for Testing Objectives

Details for the testing objectives have been included in the following attachments:

- Attachment 10: Procedure – Calibration and Validation of Procedures;
- Attachment 11: Procedure – Vertical Surface Test Plan – Suggestions for Tuft Flow Visualization;
- Attachment 12: Procedure – Vertical Surface Test Plan – Suggestions for Boundary Layer Rake Tests; and
- Attachment 13: Procedure – Fluid Flow-Off Characterization.

6. EQUIPMENT

Equipment to be employed is shown in Table 6.1. As this testing is exploratory, additional equipment may be required and will be identified and acquired as necessary.

Table 6.1: Equipment List

EQUIPMENT	STATUS		EQUIPMENT	STATUS
General Support and Testing Equipment			**Camera Equipment**	
~~20L clean containers (if expecting totes)~~			DSLR cameras x3 + lenses etc. (2 suitcases)	
			Godox flashes x2	
~~Barrel Opener (if expecting barrels)~~			Manfroto arms and mounts suitcase	
~~Black Shelving Unit for rate pans (or plastic)~~			Osmo/GoPro Cameras + accessories	
Blow Horns x 2			Ipads x 2 for remote viewing Osmos	
Blue Protective Face Masks x 2 boxes			Remote camera system (See SM for details)	
Brixometer x 3			Photography laptop with mouse/charger	
Electrical tape x 2				
Exacto Knives x 2			**Ice Pellets Fabrication Equipment**	
Extension cords (power bars x 6 + reels x 4)			Adherence Probes Kit	
Eye protection x 10			Blenders x 12 in good condition	
Falling Ball Viscometer			Folding tables (2 large, 1 small)	
Fluid pouring pitchers x148			Ice bags	
Fluids (ORDER and SHIP to Ottawa)			Ice bags storage freezer x 3	
~~Fridge for personnel x1~~			Ice pellet box supports for railing x4	
Funnels (1 big + 1 small)			Ice Pellet control wires and boxes	
Gloves - black and yellow			Ice pellets dispersers x 12	
Gloves - cotton (a lot)			Sieves (solid base, 1.4 mm, 4 mm) x 2 each	
Gloves - latex (a lot)			Stands for ice pellets dispensing devices x 6	
Grid Section + Location docs			Ice pellets Styrofoam containers x40	
~~Hard water chemicals x 3 premixes~~			Measuring cups (1L + 1cup/smaller)	
Hand Sanitizer (x3 larger jugs/dispensers)			Sartorius 35KG scale	
~~Horse and tap for fluid barrel x all~~			Refrigerated Truck	
Pots and Sous Vide for Type I x 2			Rubber Mats x 4	
Inclinometer (yellow level) x 2			Wooden Spoons	
Isopropyl x 12				
Large and small tape measure			**Freezing Rain Equipment**	
Large Sharpies for Grid Section			Rates laptop (use BB's or bring an extra one)	
Long Ruler for marking wing x 2			NRC Freezing rain sprayer (NRC provided)	
Marker for waste x 2			Rubber suction feet for wooden boards x8	
Paper towel (blue shop towel) x 48			White plastic rate pans (4 sets)	
Protective yellow rubber clothing (all)			Wooden boards for rate pans (x4)	
Personal Clothing for APS YUL team				
~~Red Thermoses for Type III Transport~~			**Office Equipment**	
Sample bottles for viscosity (x6)			Laptops (MR, MR2, BB, CB) with accessories	
Sartorius Weigh Scale x 2			APS tuques x 10	
Scrapers x 5			Calculators x 3	
~~Shop Vac~~			Clip boards x 8	
Speed tape x 1 small			Data Forms	
Squeegees (5 small + 3 large floor)			Dry eraser markers	
Stop Watches x 4			Envelopes (9x12) x box	
Temperature probes: immersion x 3			File box x 2	
Temperature probes: surface x 3			Hard drive with all WT Photos	
Test Plate x 1			New blank SSD Hard Drives x 2	
Thermometer for Reefer Truck			Pencils + sharpies/markers	
Thickness Gauges (5 small, 5 big)			~~Projector for laptop~~	
Vise grip + rubber opener for containers			Scissors	
Walkie Talkies x 12			Small 90° aluminum ruler for wing	
~~Water (2 x 18L) for hard water~~			Test Procedures x 4, printer paper	
Whatmans Paper and conversion charts			YOW employee contracts	
			V-Stab Gear	
			Motorized backpack sprayer for Fluids/ZR x3	
			Calibration pans and stand (if needed)	
			Step ladders (use NRC's and buy if needed)	

7. FLUIDS

Mid-viscosity samples of both ethylene glycol and propylene glycol based Type IV fluids will be used in the wind tunnel tests as well as a propylene glycol based Type I fluid. Although the number of tests conducted will be determined based on the results obtained, the fluid quantities available are shown in Table 7.1. Fluid application will be performed using a motorized backpack sprayer (without the shearing nozzle) to reduce the quantity of fluid required during application.

Table 7.1: Fluid Available for CRM Wind Tunnel Tests

Company Name	Fluid Name	Type	Quantity (L)
Cryotech Deicing Technology	Polar Guard® Advance	PG - IV	300
Dow Chemical Company	UCAR™ Endurance EG106 De/Anti-Icing Fluid	EG - IV	300
Dow Chemical Company	UCAR™ PG ADF Concentrate	PG - I	100

8. PERSONNEL

Four APS staff members are required for the tests at the NRC IWT. Five additional persons will be required from Ottawa to assist with the preparation and application of fluids and contamination. One additional person from Ottawa will be required to coordinate the photography and videography.

Table 8.1 demonstrates the personnel required and their associated tasks.

Fluid and contamination applications will be performed by APS/YOW personnel at the NRC IWT. NRC personnel will operate the NRC wind tunnel.

Table 8.1: Personnel List

Wind Tunnel Personnel List	
Person	**Responsibility**
John D'Avirro (JD)	Director (participating remotely)
Marco Ruggi (MR)	Lead Engineer and Project Coordinator
Chloë Bernier (CB)	Data documentation (forms, logs, camera setup, etc.) / Ice Manufacturing Manager
Benjamin Bernier (BB)	Data Collection / Fluid Manager (inventory and application) / YOW Pers. Manager
YOW Personnel	
Photo 1	Photography / Camera Documentation
Steve Baker (STB)	Fluids / Ice Manufacturing / Dispensing / General Support
YOW 1	Fluids / Ice Manufacturing / Dispensing
YOW 2	Fluids / Ice Manufacturing / Dispensing
YOW 3	Fluids / Ice Manufacturing / Dispensing
YOW 4	Ice Manufacturing

NRC Aerospace Research Centre Contacts

- Catherine Clark: (613) 990-6796; and
- Cory Bates: (613) 913-9720.

9. SAFETY

- A safety briefing will be done on the first day of testing;
- COVID-19 mitigation procedures will be in place;
- Personnel should be familiar with NRC emergency procedures i.e., DO NOT CALL 9-1-1, instead call the NRC Emergency Center as they will contact and direct the necessary services;
- All personnel must be familiar with the Material Safety Data Sheets (MSDS) for fluids;
- Prior to operating the wind tunnel, loose objects should be removed from the vicinity;
- When wind tunnel is operating, ensure that ear plugs are worn if necessary and personnel keep safe distances;
- When working on ladders, ensure equipment is stable;
- CSA approved footwear and appropriate clothing for frigid temperatures are to be worn by all personnel;
- Caution should be taken when walking in the test section due to slippery floors, and dripping fluid from the wing section;
- If fluid comes into contact with skin, rinse hands under running water;
- If fluid comes into contact with eyes, flush with the portable eye wash station; and
- Personnel must ensure they follow the protocols for working extended hours.

Separate guidelines related to COVID-19 mitigation strategies will be communicated to staff prior to the start of any activities.

Personnel must operate in accordance with the “Testing Safety Recommendations” and must follow the protocols for “Extended Work Hours Protocol for APS Personnel.” These documents are included in the “APS Office Policies & Procedures,” which is made available to all APS staff.

Attachment 1: General Form

GENERAL FORM (EVERY TEST)

DATE: ____________ FLUID APPLIED: ____________ RUN # (Plan #): ____________

AIR TEMPERATURE (°C) BEFORE TEST: ____________ AIR TEMPERATURE (°C) AFTER TEST: ____________

TUNNEL TEMPERATURE (°C) BEFORE TEST: ____________ TUNNEL TEMPERATURE (°C) AFTER TEST: ____________

WIND TUNNEL START TIME: ____________ PROJECTED SPEED (S/KTS): ____________

EFFECTIVE SIDE SLIP ANGLE (°) ____________ EXTRA RUN INFO: ____________

RUDDER DEFLECTION ANGLE (°) ____________

☐ Check if additional notes provided on a separate sheet

FLUID APPLICATION

Actual start time: ____________ Actual End Time: ____________

Fluid Brix: ____________ Amount of Fluid (L): ____________

Fluid Temperature (°C): ____________ Fluid Application Method: POUR

ICE PELLETS APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Ice Pellets Applied (g/dm²/h): ____________ Ice Pellets Size (mm): 1.4 - 4.0 mm

Exposure Time: ____________

Total IP Required per Dispenser: ____________

FREEZING RAIN/DRIZZLE APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Precipitation Applied (g/dm²/h): ____________ Droplet Size (mm): ____________

Exposure Time: ____________ Needle: ____________

Flow: ____________

Pressure ____________

SNOW APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Snow Applied (g/dm²/h): ____________ Snow Size (mm): <1.4 mm

Exposure Time: ____________ Method: ☐ Dispenser ☐ Sieve

Total SN Required per Dispenser: ____________

COMMENTS ____________

MEASUREMENTS BY: ____________ **HANDWRITTEN BY:** ____________

Attachment 2: Wing Temperature, Fluid Thickness and Fluid Brix Form

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: ______________________ Run: ______________

WING TEMPERATURE (Taken From NRC Logger)

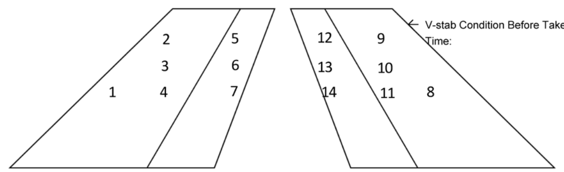
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3				
10				
Time:				

FLUID BRIX

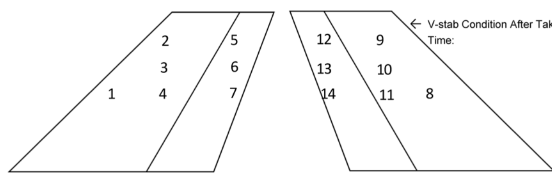
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3			
10			
Time:			

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
Time:			



V-stab Condition Before Takeoff
Time:



V-stab Condition After Takeoff
Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ______________________________

OBSERVER: ______________________

Attachment 3: Example Snow Dispensing Form

Snow Order Data Form for Dispensing on Vertical Stabilizer

Date: ____________________

Precipitation Type: Snow

Target Rate: 25 g/dm²/h

Duration: 15 minutes

Indicates fields to be manipulated

Snow needed per 5 minutes

In each position 417 g

In each Dispensor 2501 g

Snow needed for entire test

In each Dispensor 7503 g
(or if only doing 1 side)

Total Amount for Entire Test (both sides) 15005 g

Original Avg Rate 10 g/dm²/h

Original Rate Duration 5 minutes

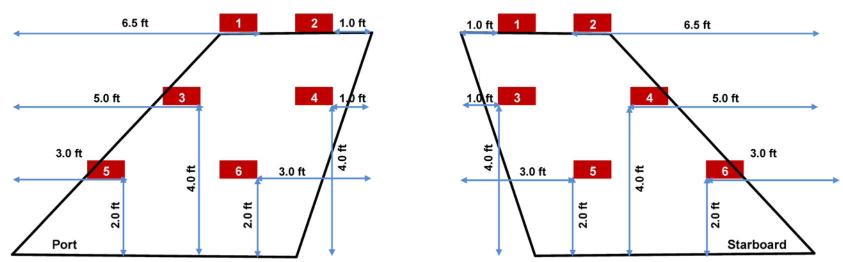
Original Snow Per Position 167 g/dm²/h

Expected Footprint of Snow

	1ft		2ft		3ft		4ft		5ft		6ft		7ft		8ft		9ft		10ft	
8ft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7ft	0	0	0	0	0	0	0	0	0	1	2	5	7	6	5	6	7	6	3	1
	0	0	0	0	0	0	0	0	2	11	14	17	20	28	27	20	20	18	13	4
6ft	0	0	0	0	0	0	0	2	6	11	8	9	12	18	15	11	10	8	8	5
	0	0	0	0	0	0	1	3	7	10	5	7	10	14	8	7	6	4	5	4
5ft	0	0	0	0	0	0	1	5	11	14	9	7	8	10	7	9	10	9	5	3
	0	0	0	0	0	2	11	15	19	23	20	16	10	19	18	19	20	19	15	5
4ft	0	0	0	0	2	6	11	9	9	11	9	12	13	18	11	9	8	8	9	5
	0	0	0	1	3	7	11	5	5	5	5	8	11	15	7	6	4	4	4	4
3ft	0	0	1	3	8	12	13	6	3	3	6	11	14	15	7	3	2	2	2	2
	0	2	11	14	18	21	22	15	8	15	16	20	23	23	16	6	4	2	2	1
2ft	2	6	11	8	8	9	11	11	11	15	10	10	11	12	10	6	4	2	2	1
	3	7	10	4	4	4	5	8	10	13	6	6	5	5	5	4	3	2	2	0
1ft	3	5	7	3	2	3	3	5	7	9	4	3	3	3	3	2	2	1	1	0
	2	3	5	2	2	1	2	4	4	5	3	2	2	2	2	1	1	1	1	0

	1ft		2ft		3ft		4ft		5ft		6ft		7ft		8ft		9ft		10ft	
8ft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7ft	0	1	2	5	7	6	5	6	7	6	3	1	0	0	0	0	0	0	0	0
	2	11	14	17	20	28	27	20	20	18	13	4	3	1	0	0	0	0	0	0
6ft	6	11	8	9	12	18	15	11	10	8	8	5	3	1	0	0	0	0	0	0
	7	10	5	7	10	14	8	7	6	4	5	4	2	1	1	0	0	0	0	0
5ft	5	8	6	10	14	15	7	4	4	5	8	9	7	4	1	0	0	0	0	0
	5	15	16	19	22	23	17	8	15	16	18	19	18	14	5	3	1	0	0	0
4ft	8	14	9	9	10	12	12	11	15	10	9	8	8	8	5	3	1	0	0	0
	8	12	5	5	5	6	8	11	14	6	5	4	3	4	3	2	1	1	0	0
3ft	6	8	3	2	4	6	11	13	15	7	3	3	4	8	8	7	4	1	0	0
	4	5	3	4	12	16	20	22	23	16	8	14	16	18	19	18	14	5	3	1
2ft	3	5	4	7	12	9	10	10	12	12	12	15	9	8	8	8	8	5	3	1
	1	2	4	7	11	5	5	5	6	8	11	13	6	5	4	3	4	3	2	1
1ft	1	2	3	5	8	3	2	3	4	5	7	9	4	3	2	2	2	2	1	1
	1	1	2	3	5	2	2	2	3	4	4	5	3	2	1	1	2	1	1	1

Dispenser Locations



Attachment 4: Example Ice Pellet Dispensing Form

Ice Pellet Order Data Form for Dispensing on Vertical Stabilizer

Date: ____________________

Precipitation Type: Ice Pellets

Target Rate:	25	g/dm²/h
Duration:	190	minutes

Indicates fields to be manipulated

Ice Pellets needed per 5 minutes

In each position	265	g
In each Dispensor	1590	g

IP needed for entire test

In each Dispensor (or if only doing 1 side)	60420	g
Total Amount for Entire Test (both sides)	120840	g

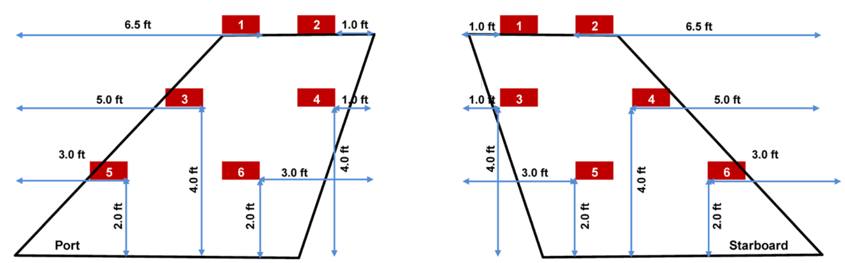
Original Avg Rate	25	g/dm²/h
Original Rate Duration	5	minutes
Original IP Per Position	265	g/dm²/h

Expected Footprint of Ice Pellets

		1ft		2ft		3ft		4ft		5ft		6ft		7ft		8ft		9ft		10ft
8ft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7ft	0	0	0	0	0	0	0	0	0	2	6	11	9	7	7	11	9	5	1	-1
	0	0	0	0	0	0	0	2	10	32	35	36	44	63	56	37	35	30	21	4
6ft	0	0	0	0	0	0	2	14	30	24	16	22	38	31	25	17	13	9	12	9
	0	0	0	0	0	0	9	27	41	17	15	30	44	20	11	9	9	8	6	7
5ft	0	0	0	0	0	0	12	34	56	23	20	30	47	17	12	15	14	10	5	4
	0	0	0	0	2	10	40	56	69	43	40	47	50	44	39	36	37	33	24	6
4ft	0	0	0	2	14	30	30	31	33	17	19	44	67	41	19	10	10	11	14	11
	0	0	0	9	27	41	19	13	14	7	17	40	57	27	13	7	4	5	7	7
3ft	0	0	2	17	39	54	21	9	8	6	21	45	63	25	9	4	3	2	3	3
	2	10	32	42	55	69	41	30	19	38	47	60	74	44	27	8	3	3	2	2
2ft	14	30	24	20	25	32	22	32	44	33	26	31	36	21	17	13	8	4	2	1
	27	41	17	9	11	14	17	33	47	23	14	14	14	8	7	7	6	5	2	0
1ft	28	45	14	6	7	8	15	30	47	18	9	9	8	5	3	2	4	3	3	0
	21	35	9	4	5	6	12	24	36	11	6	7	7	5	3	2	1	2	2	1

		1ft		2ft		3ft		4ft		5ft		6ft		7ft		8ft		9ft		10ft
8ft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7ft	0	2	6	11	9	7	7	11	9	5	1	-1	0	0	0	0	0	0	0	0
	10	32	35	36	44	63	56	37	35	30	21	4	1	0	0	0	0	0	0	0
6ft	30	24	16	22	38	31	25	17	13	9	12	9	5	1	0	0	0	0	0	0
	41	17	15	30	44	20	11	9	9	8	6	7	5	4	1	0	0	0	0	0
5ft	45	15	20	41	56	21	6	4	7	11	15	13	9	4	2	0	0	0	0	0
	45	42	45	57	71	41	28	16	36	38	37	36	32	23	5	1	0	0	0	0
4ft	56	34	22	27	34	22	29	42	33	18	10	9	9	13	10	5	1	0	0	0
	51	21	10	12	14	18	34	48	23	12	7	4	4	5	6	5	4	1	0	0
3ft	51	16	6	7	10	21	42	56	24	8	5	4	8	13	12	9	4	2	0	0
	39	12	8	15	39	47	58	71	41	29	18	36	37	35	35	32	23	5	1	0
2ft	28	14	19	36	29	24	27	34	22	30	43	32	17	9	8	9	13	10	5	1
	10	13	28	42	17	10	12	14	17	33	48	23	12	6	4	4	5	6	5	4
1ft	6	13	29	45	14	6	7	8	15	31	48	18	7	5	2	2	2	2	3	3
	4	10	23	35	9	5	5	7	12	24	37	11	4	4	3	2	2	1	1	1

Dispenser Locations



APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Final Version 1.0/V-Stab Wind Tunnel 2021-22 Final Version 1.1.docx
Final Version 1.1, August 22

40

Attachment 5: Example Manual Freezing Rain/Rain Dispensing Form

Precipitation Type	Manual ZR/R

Date	

Run #	

* ***Field to be manipulated***

Target Rate	**25**	**g/dm^2/h**
Duration	**20**	**minutes**

Surface Area x2 sides	620	dm²
Efficiency of Spray	80%	%

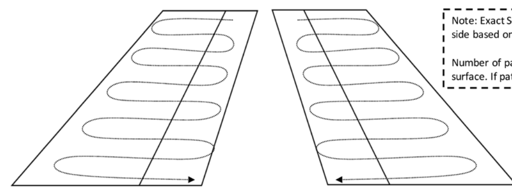
Water needed per 5 minutes

Sprayed per 5 -min (L)	1.6

Water needed for entire test

Total Water (L)	6.5

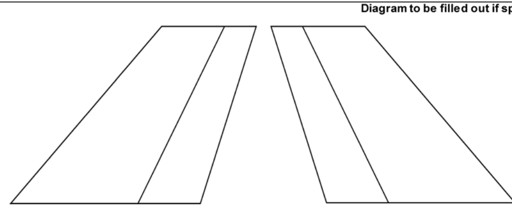
1. Enter "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Water Needed for Entire Test" in Litres in the backpack sprayer (use ice bath if needing freezing rain)
5. Spray in a continual "S" pattern on the port side of the wing, and then continue onto the starboard side. Stop once the required amount per 5-min is reached.
6. Repeat step 5 for the desired duration of the test.



Note: Exact S-pattern to be determined on site. Expect 10 passes per side based on what was done for Piper model.

Number of passes should be enough to evenly cover the wing surface. If patter is different, it should be documented on this form.

Diagram to be filled out if spray patter is different than above.



Attachment 6: Visual Evaluation Rating Form

VISUAL EVALUATION RATING OF CONDITION OF WING

Date: ____________________ Run Number: _______

Ratings:
1 - Contamination is not very visible, fluid still clean.
2 - Contamination is visible, but lots of fluid still present
3 - Contamination is visible, spots of bridging contamination
4 - Contamination is visible, lots of dry bridging present
5 - Contamination is visible, adherence of contamination

Note: Ratings can include decimals i.e. 1.4 or 3.5

Before Take-off Run

Area	Visual Severity Rating (1-5)		
	Port	Stbd	
Leading Edge			*>3 = Review, >3.5=Bad*
Trailing Edge			*>3 = Review, >3.5=Bad*
Rudder			*>4 = Review, >4.5=Bad*

At Rotation

Area	Visual Severity Rating (1-5)	
	Port	Stbd
Leading Edge		
Trailing Edge		
Rudder		

>1= Review >1.5 = Bad

Expected Lift Loss (%) *>5.4 = Review* *>9.2 = Bad*

After Take-off Run

Area	Visual Severity Rating (1-5)	
	Port	Stbd
Leading Edge		
Trailing Edge		
Rudder		

Additional Observations: ____________________

____

____

OBSERVER: ____________________

Attachment 7: General Form for Calibration Test

GENERAL FORM (EVERY CALIBRATION TEST)

DATE: ______________________ RUN # (Plan #): ______________

OJECTIVE: ☐ Tuft Tests ☐ Boundary Layer Rake

AIR TEMPERATURE (°C) BEFORE TEST: ________ AIR TEMPERATURE (°C) AFTER TEST: ________

TUNNEL TEMPERATURE (°C) BEFORE TEST: ________ TUNNEL TEMPERATURE (°C) AFTER TEST: ________

WIND TUNNEL START TIME: ________ EFFECTIVE SIDE SLIP ANGLE (°): ________

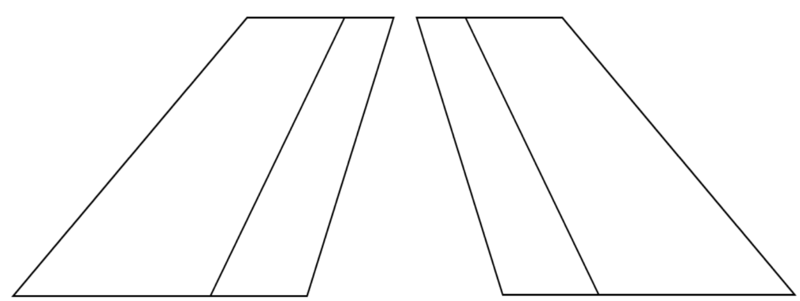
WIND TUNNEL END TIME: ________ RUDDER DEFLECTION ANGLE (°): ________

PROJECTED SPEED (S/KTS): ________

TUFTS APPLIED: Y / N TUFT DETAILS: ______________________

☐ Full Wing ☐ Partial Wing (describe) ______________________

BOUNDARY LAYER RAKE: Y / N RAKE DETAILS: ______________________



COMMENTS :

HANDWRITTEN BY:

☐ Check if further details are available behind this sheet

APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Final Version 1.0/V-Stab Wind Tunnel 2021-22 Final Version 1.1.docx
Final Version 1.1, August 22

43

Attachment 8: Fluid Receipt Form (Electronic Form)

FORM 1

GENERAL FORM FOR RECEIVING FLUID

Receiving Location: APS Site Other: ______________ **Date of Receipt:** ____________________

Fluid Characteristics: Type: ___________ Colour: ____________ **Date of Production:** ____________________

Manufacturer: ____________________________________ **Batch #:** ____________________

Fluid Name: ____________________________________ **Project Task:** ____________________

Fluid Quantities / Fluid Brix / Falling Ball Info:

Fluid Dilution: ____________	Fluid Dilution: ____________	Fluid Dilution: ____________
Fluid Code: ____________	Fluid Code: ____________	Fluid Code: ____________
Fluid Quantity: ____ x ____ L = ____ L	Fluid Quantity: ____ x ____ L = ____ L	Fluid Quantity: ____ x ____ L = ____ L
Fluid Brix: ______°	Fluid Brix: ______°	Fluid Brix: ______°
Falling Ball Time: ___:___:___ (mm:ss:cs)	Falling Ball Time: ___:___:___ (mm:ss:cs)	Falling Ball Time: ___:___:___ (mm:ss:cs)
Falling Ball Temp: _____°C	Falling Ball Temp: _____°C	Falling Ball Temp: _____°C
Sample from Container #: _____ of _____	Sample from Container #: _____ of _____	Sample from Container #: _____ of _____

Sample Collection:

HOT Fluids: Extract 4 L 100 / 75 / 50 and 2 L Type I
Other Fluids: Extract 3 L 100 / 75 / 50 / Type I

Sample Distribution:

Viscosity:	2 L 100 / 75 / 50	to third party and in-house for testing
WSET:	1 L 100 / 75 / 50 / Type I	to AMIL for WSET (HOT samples only)
Office:	1 L 100 / 75 / 50 / Type I	to be retained in office

Photo Documentation: (take photos of all that apply)

Palette (as received)	100/0 MFR Fluid Label	75/25 MFR Fluid Label	50/50 MFR Fluid Label	Type I MFR Fluid Label

Additional Info/Notes: (additional information included on fluid containers, paperwork received, etc.)

Received by: ______________________ **Date:** ______________________ **Verified by:** ______________________

Fluid Receipt Form (Oct 2018)

Attachment 9: Log of Fluid Sample Bottles

Date of Extraction	*Fluid and Dilution*	*Batch #*	*Sample Source (i.e., drum)*	*Falling Ball Fluid Temp (°C)*	*Falling Ball Time (sec)*	*Comments*

Attachment 10: Procedure – Calibration and Validation of Procedures

Background

As the work with the vertical stabilizer is exploratory, and this CRM model has never been tested before, it is important to validate the testing procedures to ensure safety, reliability, and repeatability.

Objective

Validate the testing procedures to ensure safety, reliability, and repeatability.

Methodology

- Simulate and validate testing procedures related to:
  - Safety measures when operating around the model and at heights if necessary;
  - Application of fluids;
  - Application of contamination, and calibration as required;
  - Equipment reliability during "wind on" tests;
  - Repeatability of data collected;
  - Physical evaluation of model to ensure robustness of installation; and
  - Other procedural elements identified on site.

Test Plan

One day of testing is planned.

Attachment 11: Procedure – Vertical Surface Test Plan – Suggestions for Tuft Flow Visualization

Section originally written by: Andy Broeren for Piper Seneca II model in 2019 and modified by APS in 2021 for the CRM model

Background

Here are some suggestions for conducting flow visualization on the CRM vertical tail model in the NRC 3m x 6m wind tunnel.

Tuft Layout

The exact layout of the tufts will be determined on site with the direction of the test team, however the following are general guidelines:

- Target two rows of tufts on rudder, and 3 rows of tufts on the main element.
- On the rudder locate the tufts closer to 60 and 90% of the chord.
- On the main element, locate the tufts closer 40, 60 and 90% of the chord.
- Add partial strips if appropriate.
- Use same layout on each side (suction and pressure surfaces)

Objective

Objective for Tuft Flow Visualization

- The objective for these tests is to check for highly three-dimensional and/or separated flow over the vertical tail including the rudder and on the splitter plate. Highly 3D and/or separated flow will be indicated by tufts that are not nicely aligned with the flow stream direction.
- It is important to apply tufts to both the suction and pressure surfaces as this will provide a nice comparison or contrast in the flow visualization images. For example, one would assume that the flow on the pressure surface should be free of highly 3D and/or separated flow. These tuft images can then be easily compared or contrasted to the suction side which might show some evidence of highly 3D or separated flow.

Methodology

Suggested Procedure

1. Set δ_r = 0 deg. and β = 0 deg.
2. Set tunnel to desired speed (e.g. 100 knots).
3. Photograph tufts.
4. Set rudder to δ_r = 0 deg. Set side slip β = -10 deg and increase to β = +10 deg in 2 deg increments.
5. Repeat step 4 decreasing rudder angle by 5 deg increments up to δ_r = -20 deg
6. Repeat step 4 with rudder δ_r = +10 deg to verify symmetry
7. Check for highly 3D and/or separated flow.

Test Plan

One day of testing is planned.

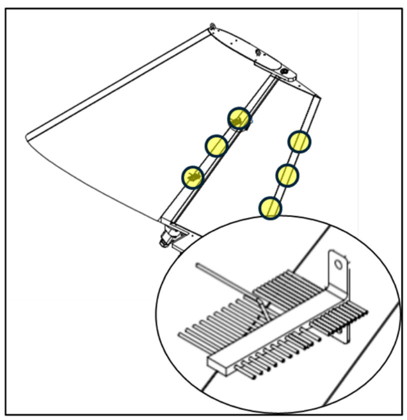
Attachment 12: Procedure – Vertical Surface Test Plan – Suggestions for Boundary Layer Rake Tests

Objective

To conduct testing with the objective of collecting pressure data with a boundary layer rake that will characterize boundary layer separations.

Boundary Layer Rake Layout

- 3 boundary layer rakes available for aerodynamic characterization work:
- Pre-drilled mounting points exist on CRM
  - 3 mounting points on trailing edge of main element
  - 3 mounting points on trailing edge of rudder
  - Approx. 1/4, 1/2 and 3/4 span
  - Note: boundary layer rakes are not permanently installed and will be removed for fluid tests.



Methodology

Suggested Procedure

1. Set $\delta_r = 0$ deg. and $\beta = 0$ deg.

2. Set tunnel to desired speed (e.g. 100 knots).
3. Set rudder to δ_r = 0 deg. Set side slip β = -10 deg and increase to β = +10 deg in 2 deg increments.
4. Repeat step 4 decreasing rudder angle by 5 deg increments up to δ_r = -20 deg
5. Repeat step 4 with rudder δ_r = +10 deg to verify symmetry
6. Check for highly 3D and/or separated flow.

Test Plan

2 days of testing are planned.

Attachment 13: Procedure – Fluid Flow-Off Characterization

Background

The overall aerodynamic impact of contaminated fluid on vertical surfaces has yet to be fully understood. This data will then be used by aircraft manufacturers to better understand the expected impacts on their specific aircraft types.

Objective

The objective of this testing is to conduct aerodynamic testing with a vertical stabilizer to document contaminated fluid flow-off on a vertical stabilizer.

Methodology

- Conduct testing with clean fluids to understand the baseline fluid flow-off performance;
- Conduct testing with fluid contaminated with simulated snow and compare the fluid flow-off performance to the clean fluid performance;
- Record visual observations, video, photography, and manually collected data; and
- Adjust testing plan accordingly based on results obtained.

Test Plan

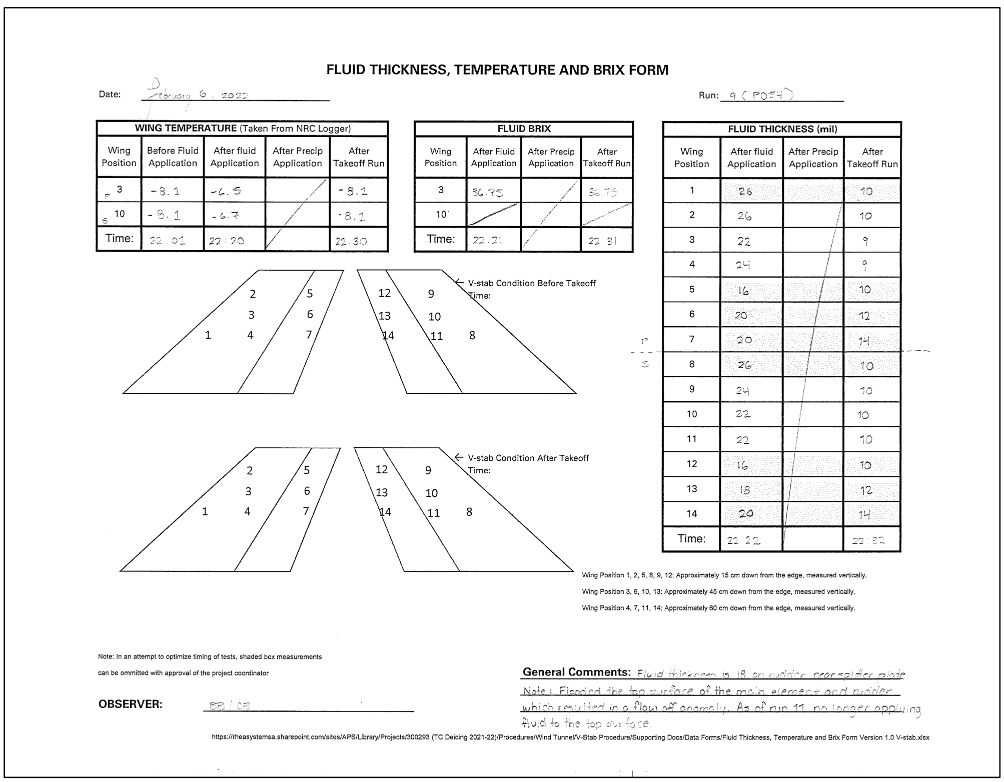
Five days of testing are planned.

APPENDIX C

CRM TESTING 2021-22 FLUID THICKNESS, TEMPERATURE, AND BRIX DATA FORMS

No Data Available

Figure C1: Runs #1-8



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 6, 2022

Run: 9 (P054)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
P 3	-8.1	-6.5		-8.1
S 10	-8.1	-6.7		-8.1
Time:	22:01	22:20		22:30

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.75		36.75
10			
Time:	22:21		22:31

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	26		10
2	26		10
3	22		9
4	24		9
5	16		10
6	20		12
7	20		14
8	26		10
9	24		10
10	22		10
11	22		10
12	16		10
13	18		12
14	20		14
Time:	22:22		22:32

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

OBSERVER: BB / CB

General Comments: Fluid thickness is 18 on rudder near splitter plate. Note: Flooded the top surface of the main element and rudder which resulted in a flow off anomaly. As of run 11, no longer applying fluid to the top surface.

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C2: Run # 9

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

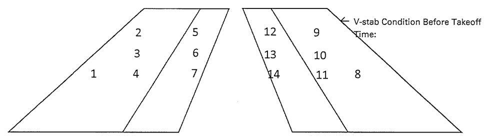
Date: February 6, 2022

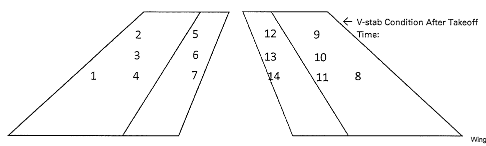
Run: 10 (POS6)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-6.7	-5.9		-8.1
10	-6.6	-6.4		-8.1
Time:	22:54	23:11		23:22

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.75		37.0
10			
Time:	23:12		23:28

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	26		11
2	26		9
3	24		10
4	26		9
5	18		10
6	24		14
7	22		22
8	28		10
9	24		10
10	26		10
11	26		11
12	14		9
13	26		10
14	22		10
Time:	23:13		23:24





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: Flooded the top flat surface of the main element and rudder which resulted in a flow off anomaly. As of run 11 no longer applying fluid to top surface.

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C3: Run # 10

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

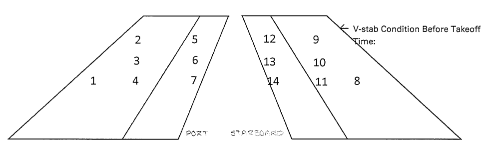
Date: February 7, 2022

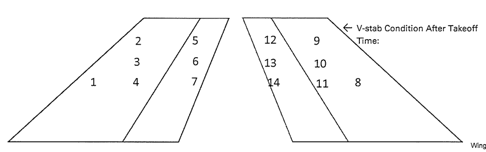
Run: 11 (POS6)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3 P	-7.4	-6.7		-8.0
10 S	-7.5	-6.7		-8.0
Time:	23:40	23:56		00:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.75		37.0
10			
Time:	23:57		00:08

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	16		7
2	14		5
3	16		7
4	18		5
5	11		8
6	16		16
7	18		12
8	14		7
9	10		7
10	16		8
11	16		9
12	11		8
13	12		8
14	16		9
Time:	23:58		00:09





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C4: Run # 11

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

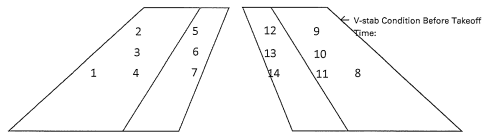
Date: February 7, 2022

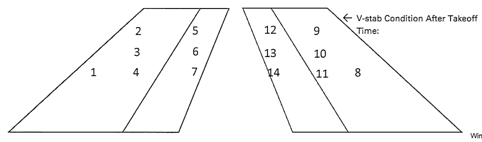
Run: 12 (POS4)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-7.4	-6.3	/	-7.7
10	-7.4	-6.2	/	-7.6
Time:	00:19	00:36	/	00:46

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.75	/	37.0
10	/	/	/
Time:	00:37	/	00:47

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14	/	6
2	12	/	5
3	14	/	8
4	20	/	8
5	12	/	8
6	20	/	8
7	16	/	12
8	12	/	5
9	11	/	4
10	22	/	10
11	20	/	8
12	11	/	8
13	14	/	10
14	18	/	12
Time:	00:38	/	00:48





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C5: Run # 12

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

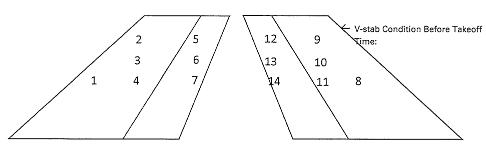
Date: February 7, 2022

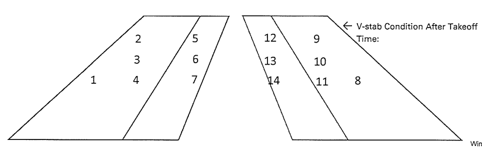
Run: 13 (POS6)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-7.1	-6.1	/	-7.7
10	-7.0	-6.2	/	-7.7
Time:	1:01	1:17	/	1:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.5	/	37.25
10	/	/	/
Time:	1:18	/	1:29

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14	/	5
2	14	/	4
3	18	/	6
4	22	/	6
5	12	/	10
6	18	/	16
7	20	/	14
8	12	/	5
9	11	/	3
10	16	/	9
11	18	/	9
12	11	/	6
13	16	/	7
14	16	/	8
Time:	1:19		1:30





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: FT ~ 20 at bottom of rudder port side

OBSERVER: BB / CB

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Figure C6: Run # 13

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

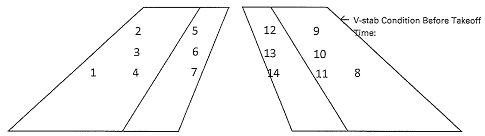
Date: February 7, 2022

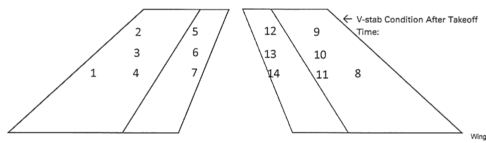
Run: 14 (P05R)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-6.7	-6.0		-7.2
10	-6.9	-6.2		-7.0
Time:	1:41	1:58		2:08

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.75		37.25
10			
Time:	1:59		2:09

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14		5
2	12		6
3	16		8
4	20		10
5	11		10
6	16		11
7	16		14
8	14		6
9	11		5
10	18		10
11	18		11
12	11		5
13	14		4
14	16		6
Time:	2:00		2:10





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: FT is 24 at the bottom of the rudder near splitter plate.

OBSERVER: BB / CR

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Figure C7: Run # 14

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

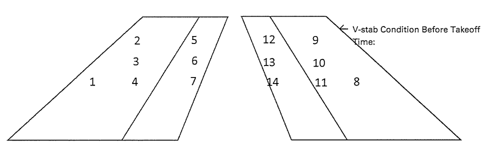
Date: February 7, 2022

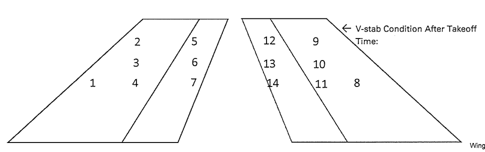
Run: 15 (P06G)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-6.7	-5.6		-7.3
10	-6.5	-5.9		-7.2
Time:	2:44	3:02		3:10

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		33.25
10			
Time:	3:03		3:11

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	24		6
2	18		8
3	24		10
4	22		10
5	14		11
6	20		12
7	18		10
8	18		6
9	18		12
10	22		12
11	18		8
12	12		10
13	20		10
14	18		11
Time:	3:04		3:12





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CR

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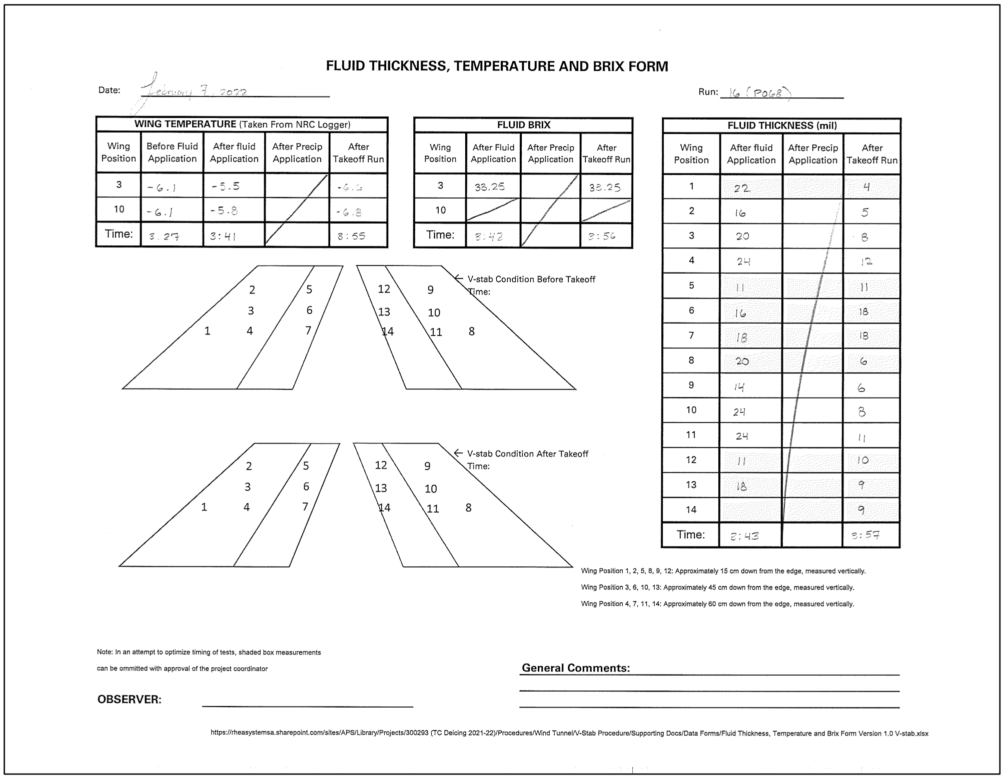
Figure C8: Run # 15



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 7, 2022 Run: 16 (P068)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-6.1	-5.5		-6.6
10	-6.1	-5.8		-6.8
Time:	3:27	3:41		3:55

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.25		33.25
10			
Time:	3:42		3:56

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	22		4
2	16		5
3	20		8
4	24		12
5	11		11
6	16		18
7	18		18
8	20		6
9	14		6
10	24		8
11	24		11
12	11		10
13	18		9
14			9
Time:	3:43		3:57

V-stab Condition Before Takeoff Time:

V-stab Condition After Takeoff Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER:

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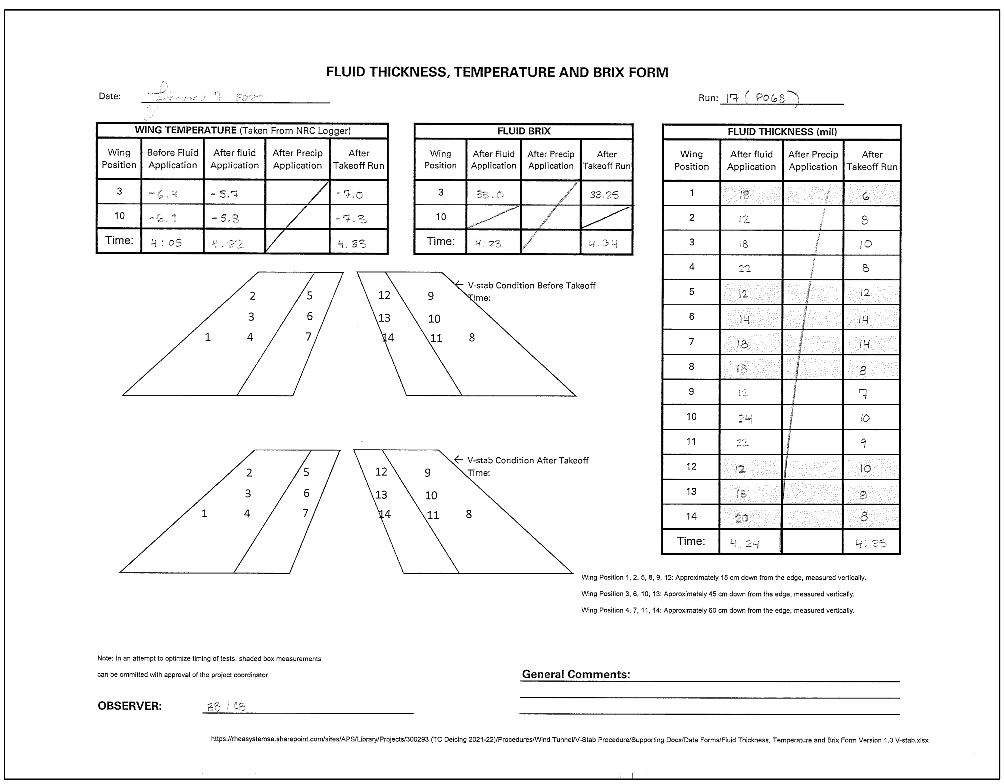
Figure C9: Run # 16



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 7, 2022 Run: 17 (P068)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-6.4	-5.7		-7.0
10	-6.1	-5.8		-7.3
Time:	4:05	4:22		4:33

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		33.25
10			
Time:	4:23		4:34

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	18		6
2	12		8
3	18		10
4	22		8
5	12		12
6	14		14
7	18		14
8	18		8
9	12		7
10	24		10
11	22		9
12	12		10
13	18		8
14	20		8
Time:	4:24		4:35

V-stab Condition Before Takeoff Time:

V-stab Condition After Takeoff Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BS / CB

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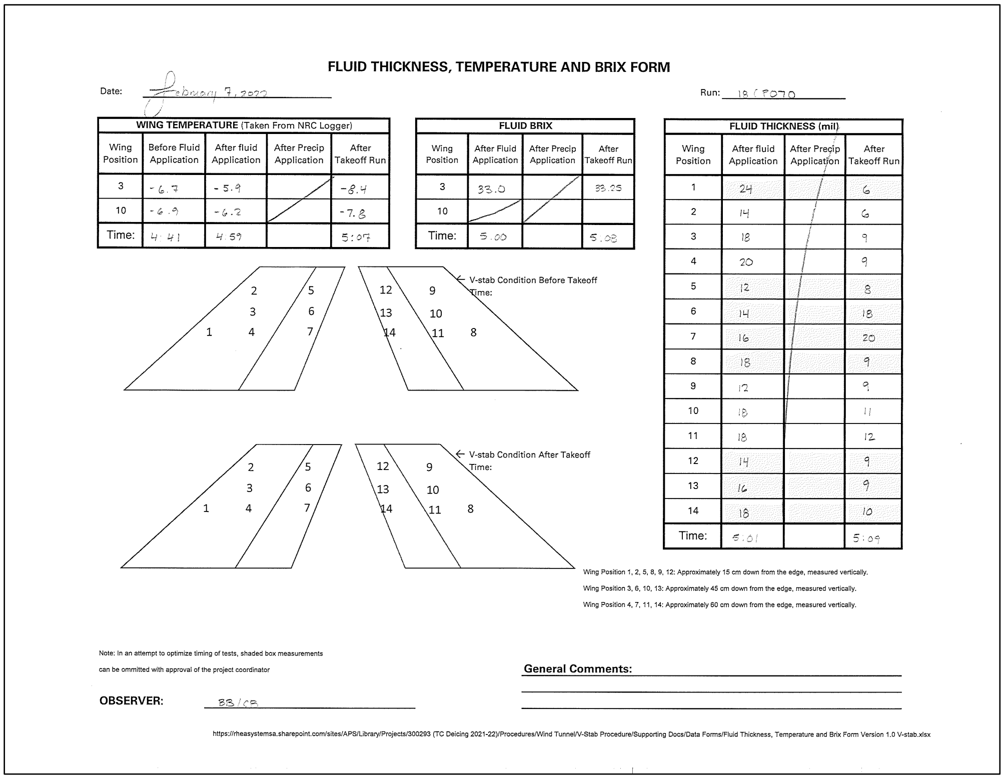
Figure C10: Run # 17



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 7, 2022

Run: 18 (P070

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-6.7	-5.9		-8.4
10	-6.9	-6.2		-7.8
Time:	4:41	4:59		5:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		33.25
10			
Time:	5.00		5.08

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	24		6
2	14		6
3	18		9
4	20		9
5	12		8
6	14		18
7	16		20
8	18		9
9	12		9
10	18		11
11	18		12
12	14		9
13	16		9
14	18		10
Time:	5:01		5:09

← V-stab Condition Before Takeoff
Time:

← V-stab Condition After Takeoff
Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

OBSERVER: BB/CB

General Comments:

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Figure C11: Run # 18

No Data Available

Figure C12: Run # 19

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

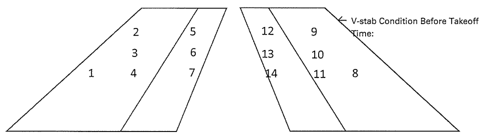
Date: February 7, 2022

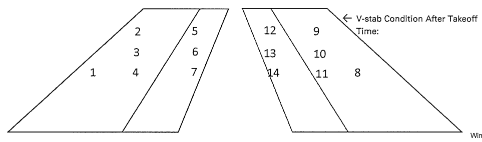
Run: 20 (P070)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-2.6	-1.7		-3.6
10	-2.6	-1.9		-3.2
Time:	21:33	21:50		22:01

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.25		33.05
10			
Time:	21:51		22:02

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	12		7
2	12		5
3	20		10
4	20		10
5	18		10
6	16		20
7	20		22
8	16		9
9	14		7
10	22		12
11	22		11
12	14		9
13	20		10
14	18		10
Time:	21:52		22:03





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C13: Run # 20

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

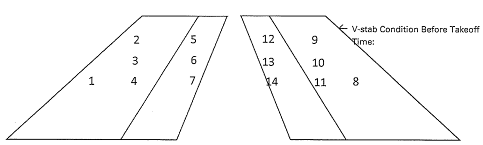
Date: February 7, 2022

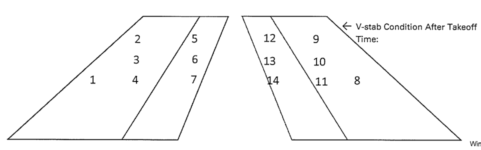
Run: 21 (P060)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-1.0	3.2		-1.2
10	-0.5	3.3		-1.1
Time:	22:25	22:41		22:52

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	30.5		39.0
10			
Time:	22:42		22:53

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	1		2
2	1		< 1
3	1		< 1
4	3		< 1
5	1		< 1
6	2		< 1
7	2		< 1
8	1		1
9	2		< 1
10	1		1
11	1		1
12	1		< 1
13	1		< 1
14	1		2
Time:	22:43		22:54





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

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Figure C14: Run # 21

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

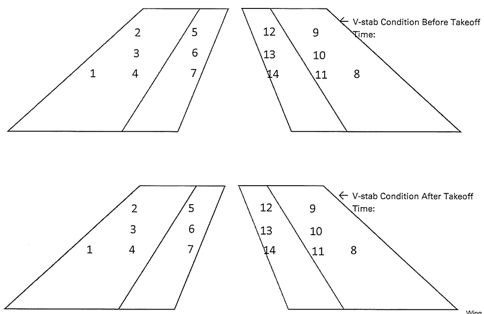
Date: February 7, 2022

Run: 22 (P062)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-1.3	2.3		-1.5
10	-1.3	2.2		-1.3
Time:	23:27	23:40		23:51

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	24.5		46.0
10			
Time:	23 40		23:52

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	2		< 1
2	1		< 1
3	2		< 1
4	2		< 1
5	< 1		< 1
6	2		1
7	2		1
8	1		< 1
9	1		1
10	2		2
11	2		1
12	1		1
13	1		1
14	2		< 1
Time:	23:40		23:53



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C15: Run # 22

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

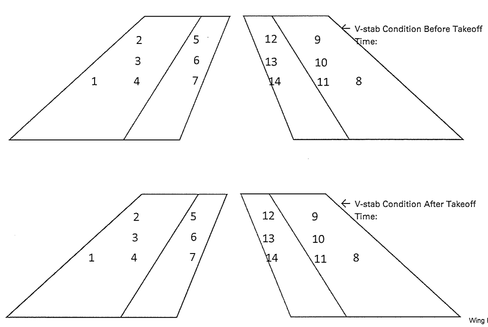
Date: February 8, 2022

Run: 23 (P062)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-0.9	3.9		-1.2
10	-0.7	4.1		-1.1
Time:	00:01	00:13		00:22

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.0		46.0
10	25.5		
Time:	00:14		00 23

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	3		< 1
2	1		< 1
3	2		< 1
4	3		< 1
5	1		2
6	3		2
7	2		1
8	2		< 1
9	1		< 1
10	2		2
11	2		1
12	1		< 1
13	1		< 1
14	2		< 1
Time:	00:15		00:24



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

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Figure C16: Run # 23

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

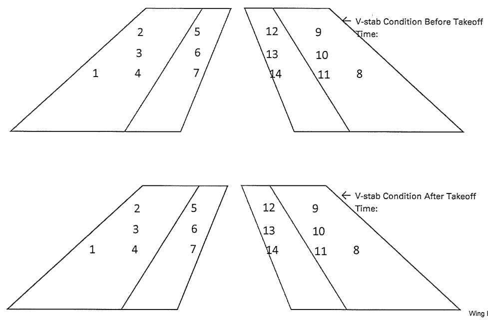
Date: February 8 2022

Run: 24 (P064)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-0.9	3.4		-2.2
10	-0.4	8.3		-1.4
Time:	00:32	00:43		00:53

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	31.75		44.0
10			
Time:	00:44		00:54

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	2		< 1
2	1		1
3	2		< 1
4	3		2
5	< 1		1
6	2		3
7	2		2
8	2		< 1
9	1		< 1
10	2		2
11	2		1
12	1		< 1
13	1		< 1
14	1		< 1
Time:	00.45		00.53



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

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Figure C17: Run # 24

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

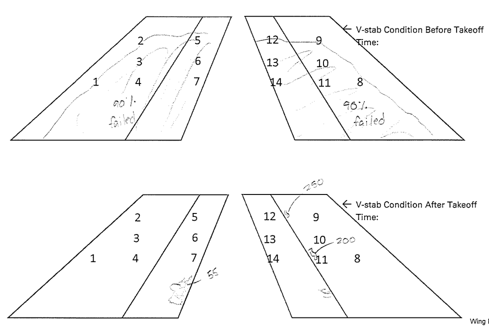
Date: February 8, 2022

Run: 25 (P174)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-1.9	-1.5	-2.7	-2.4
10	-1.9	-1.8	-2.7	-2.5
Time:	1:15	1:33	2 26	2 56

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0	6.0	dry
10		5.25	dry
Time:	1:34	2:27	2 57

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	20	slush 45	< 1
2	18	slush 50	< 1
3	18	slush 45	< 1
4	24	slush 30	< 1
5	12	slush 40	< 1
6	20	slush 40	1
7	22	slush 26	2
8	14	slush 28	< 1
9	14	slush 35	< 1
10	16	slush 45	< 1
11	22	slush 50	< 1
12	12	slush 30	< 1
13	20	slush 35	< 1
14	24	slush 30	< 1
Time:	1:35	2:28	2 58



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C18: Run # 25

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

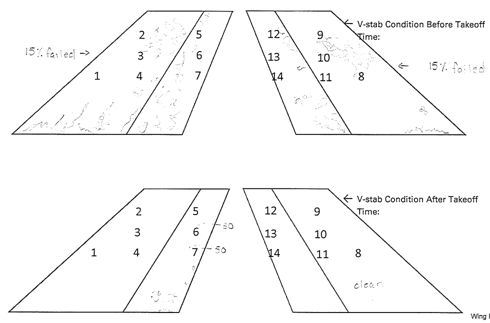
Date: February 8, 2022

Run: 26 (P110)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-2.4	-1.4	-4.2	-3.2
10	-2.3	-1.7	-4.3	-3.4
Time:	3:07	3:27	3:48	4:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0	20.75	26.5
10		18.0	23.5
Time:	3:28	3:49	4:05

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	22	7	4
2	18	3	3
3	18	slush 30	1
4	28	slush 45	3
5	14	2	1
6	16	slush 30	1
7	24	3	1
8	22	4	1
9	12	3	4
10	18	7	< 1
11	24	4	< 1
12	10	5	< 1
13	16	slush 26	< 1
14	22	7	< 1
Time:	3:29	3:50	4:06



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CS

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C19: Run # 26

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

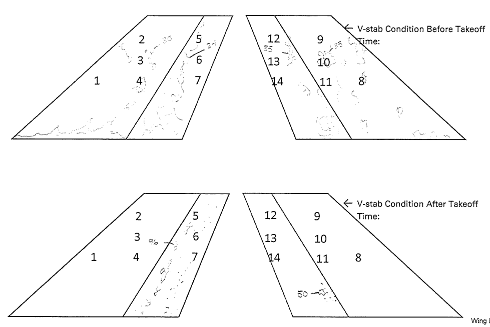
Date: February 8, 2022

Run: 27 (P116)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-3.3	-2.0	-5.6	-4.8
10	-3.4	-2.1	-5.2	-4.7
Time:	4:16	4:34	4:53	5:08

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.75	17.25	23.0
10		15.75	17.75
Time:	4:35	4:54	5:09

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	20	5	< 1
2	20	4	3
3	20	5	< 1
4	24	2	< 1
5	14	7	2
6	16	4	5
7	26	3	4
8	16	4	5
9	14	3	< 1
10	16	7	2
11	24	6	1
12	12	8	< 1
13	18	5	< 1
14	22	3	1
Time:	4:36	4:55	5:10



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

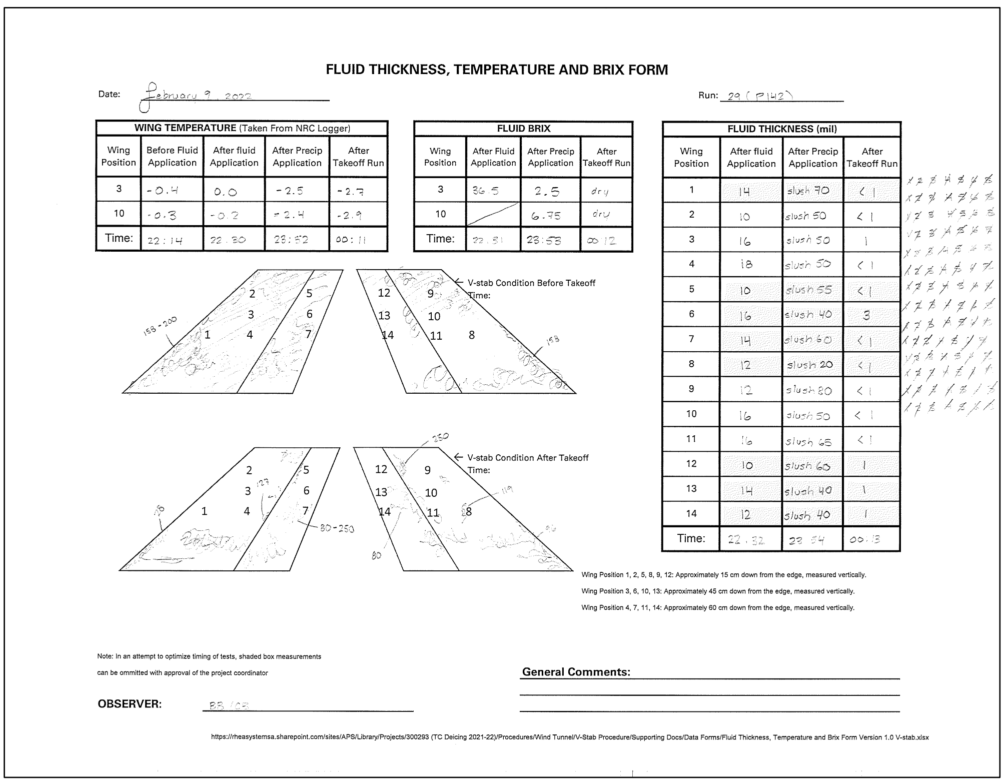
OBSERVER: BB / CS

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C20: Run # 27

No Data Available

Figure C21: Run # 28



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 9, 2022

Run: 29 (P142)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-0.4	0.0	-2.5	-2.7
10	-0.3	-0.2	-2.4	-2.9
Time:	22:14	22:30	23:52	00:11

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.5	2.5	dry
10		6.75	dry
Time:	22:31	23:53	00:12

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14	slush 70	< 1
2	10	slush 50	< 1
3	16	slush 50	1
4	18	slush 50	< 1
5	10	slush 55	< 1
6	16	slush 40	3
7	14	slush 60	< 1
8	12	slush 20	< 1
9	12	slush 80	< 1
10	16	slush 50	< 1
11	16	slush 65	< 1
12	10	slush 60	1
13	14	slush 40	1
14	12	slush 40	1
Time:	22:32	23:54	00:13

V-stab Condition Before Takeoff
Time:

V-stab Condition After Takeoff
Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C22: Run # 29

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

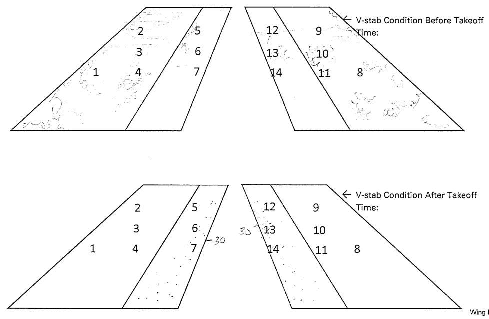
Date: February 9, 2022

Run: 30 (P073)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-3.7	-2.1	-6.8	-3.5
10	-3.0	-2.1	-6.8	-3.6
Time:	00:34	00:48	1:10	1:29

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.5	12.0	13.5
10		20.5	13.25
Time:	00:49	1:11	1:30

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14	slush96	1
2	11	slush 60	2
3	14	slush 80	3
4	20	26	4
5	10	7	3
6	12	26	4
7	16	26	2
8	14	24	3
9	12	slush 40	2
10	20	slush 65	2
11	16	slush 60	3
12	10	8	5
13	16	4	2
14	18	20	2
Time:	00:50	1.12	1.31



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C23: Run # 30

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

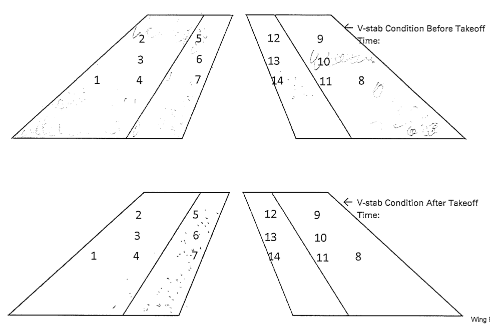
Date: February 9, 2022

Run: 31 (P078)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-3.9	-2.6	-7.3	-4.7
10	-3.8	-2.7	-7.4	-4.8
Time:	1:40	1:54	2:16	2:30

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.75	18.25	14.25
10		18.0	15.0
Time:	1:55	2:17	2:31

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14	slush 70	3
2	12	slush 50	5
3	16	slush 65	3
4	20	slush 70	4
5	10	6	2
6	12	26	4
7	14	26	2
8	12	24	2
9	8	slush 40	2
10	12	slush 45	4
11	16	slush 50	3
12	10	10	2
13	16	26	4
14	16	28	12
Time:	1:56	2:18	2:32



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C24: Run # 31

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

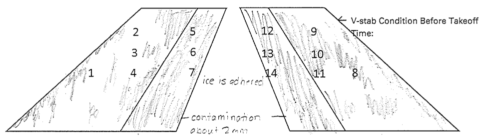
Date: February 9, 2022

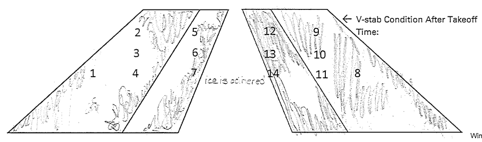
Run: 32 (P280)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	-4.0	-2.9	0.4	-4.6
10	-4.1	-2.9	0.5	-4.5
Time:	3:01	3:15	4:38	4:52

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.5	ice	ice
10	/	ice	ice
Time:	3:16	4:39	4:53

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	18	ice	ice
2	11	ice	ice
3	22	ice	ice
4	20	ice	ice
5	10	ice	ice
6	14	ice	ice
7	16	ice	ice
8	18	ice	ice
9	10	ice	ice
10	20	ice	ice
11	18	ice	ice
12	10	ice	ice
13	16	ice	ice
14	16	ice	ice
Time:	3:17	4:40	4:54





Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C25: Run # 32

No Data Available

Figure C26: Run # 33

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

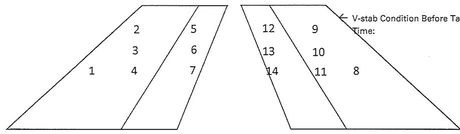
Date: February 9, 2022

Run: 34 (P058)

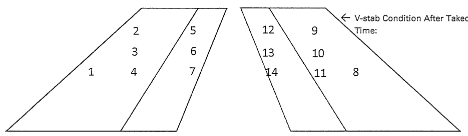
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.7	1.3		0.3
10	0.7	1.0		0.3
Time:	21:29	21:45		21:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.75		36.5
10			
Time:	21:46		21:58

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	12		8
2	16		4
3	16		9
4	16		9
5	10		9
6	14		12
7	16		11
8	16		5
9	16		9
10	18		7
11	22		8
12	14		4
13	16		7
14	18		7
Time:	21:47		21:59



← V-stab Condition Before Takeoff
Time:



← V-stab Condition After Takeoff
Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C27: Run # 34

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

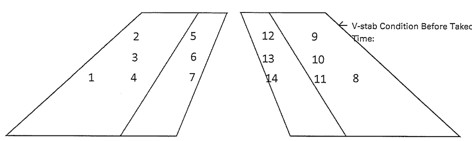
Date: February 9, 2022

Run: 35 (P070)

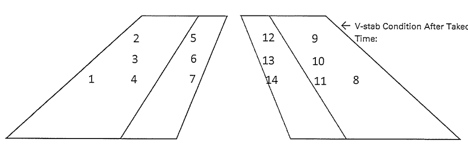
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.4	1.1		n/a
10	0.5	0.9		n/a
Time:	22:16	22:33		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		n/a
10			n/a
Time:	22:33		

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	20		n/a
2	14		n/a
3	24		n/a
4	24		n/a
5	16		n/a
6	20		n/a
7	22		n/a
8	22		n/a
9	16		n/a
10	20		n/a
11	26		n/a
12	20		n/a
13	24		n/a
14	26		n/a
Time:	22:33		



← V-stab Condition Before Takeoff
Time:



← V-stab Condition After Takeoff
Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: no post measurements wing rotated back to 0° while tunnel was still running

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C28: Run # 35

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

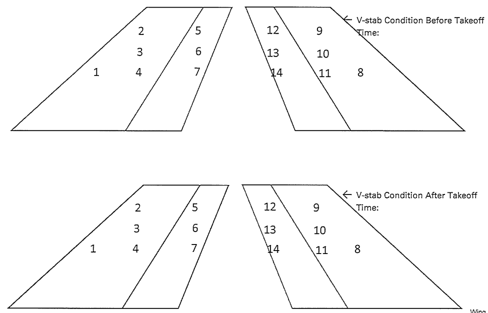
Date: February 9, 2022

Run: 36 (P070)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.6	1.0		0.4
10	0.7	0.9		0.4
Time:	22:51	23:08		23:18

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		32.25
10			
Time:	23:09		23:19

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14		6
2	16		6
3	22		10
4	24		9
5	12		11
6	22		24
7	20		24
8	18		10
9	22		8
10	24		9
11	24		11
12	22		6
13	22		9
14	24		10
Time:	23:10		23:20



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C29: Run # 36

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

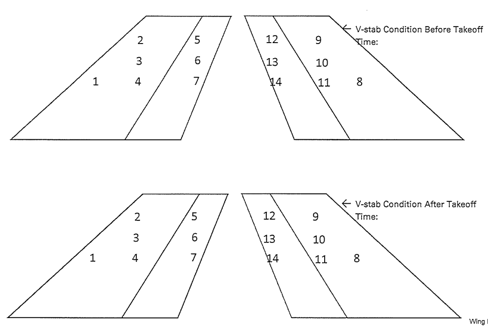
Date: February 9, 2022

Run: 37 (EI)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.6	1.1		0.3
10	0.8	0.9		0.2
Time:	23:29	23:45		00:01

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.75		32.25
10			
Time:	23:46		00:02

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	14		6
2	14		8
3	18		9
4	26		10
5	12		20
6	18		30
7	26		30
8	18		n/a
9	22		4
10	22		7
11	28		11
12	20		10
13	24		10
14	24		9
Time:	23:47		00:03



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C30: Run # 37

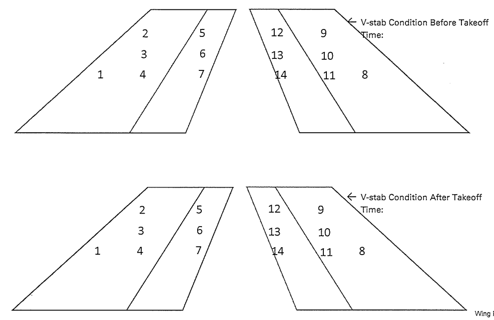
FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 10 2022 Run: 38 (E2)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.5	1.4		0.9
10	0.6	1.2		0.7
Time:	00.26	00:44		00:58

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		32.5
10			
Time:	00 45		00:59

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	16		5
2	14		8
3	22		9
4	24		10
5	12		12
6	22		24
7	22		24
8	24		7
9	20		8
10	26		10
11	26		11
12	20		8
13	24		12
14	26		12
Time:	00:46		01:00



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: RB / CR

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C31: Run # 38

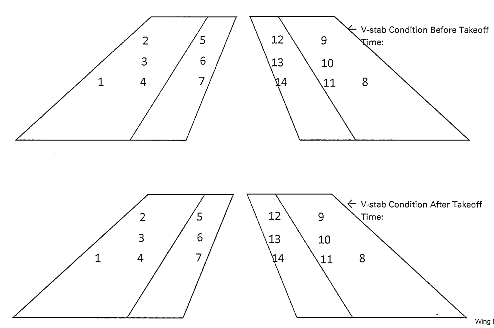
FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 10, 2022 Run: 39 (E3)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.7	0.6		0.3
10	0.8	1.1		0.8
Time:	1:10	1:24		1:36

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	clean		clean
10	33.0		32.5
Time:	1:25		1:37

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	clean		7
2	clean		6
3	clean		clean
4	clean		clean
5	clean		10
6	clean		12
7	clean		20
8	18		12
9	14		9
10	18		14
11	26		18
12	18		10
13	24		10
14	26		12
Time:	1:26		1:38



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

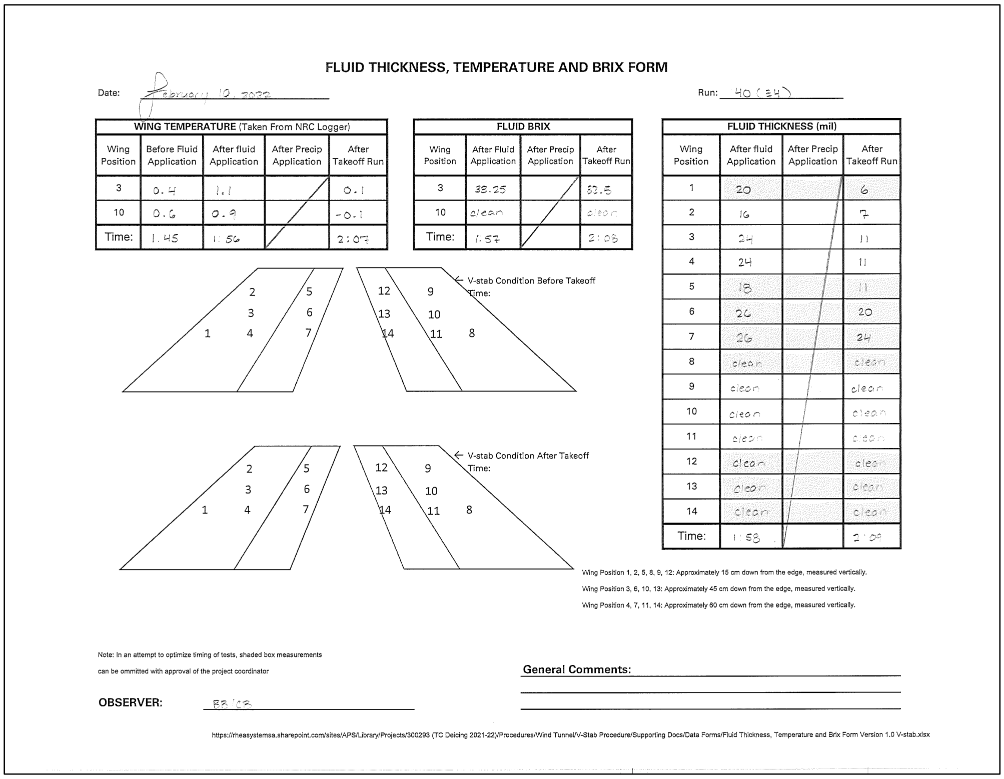
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: RB / CR

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C32: Run # 39



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 10, 2022 Run: 40 (E4)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.4	1.1		0.1
10	0.6	0.9		-0.1
Time:	1:45	1:56		2:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.25		32.5
10	clean		clean
Time:	1:57		2:08

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	20		6
2	16		7
3	24		11
4	24		11
5	18		11
6	26		20
7	26		24
8	clean		clean
9	clean		clean
10	clean		clean
11	clean		clean
12	clean		clean
13	clean		clean
14	clean		clean
Time:	1:58		2:09

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

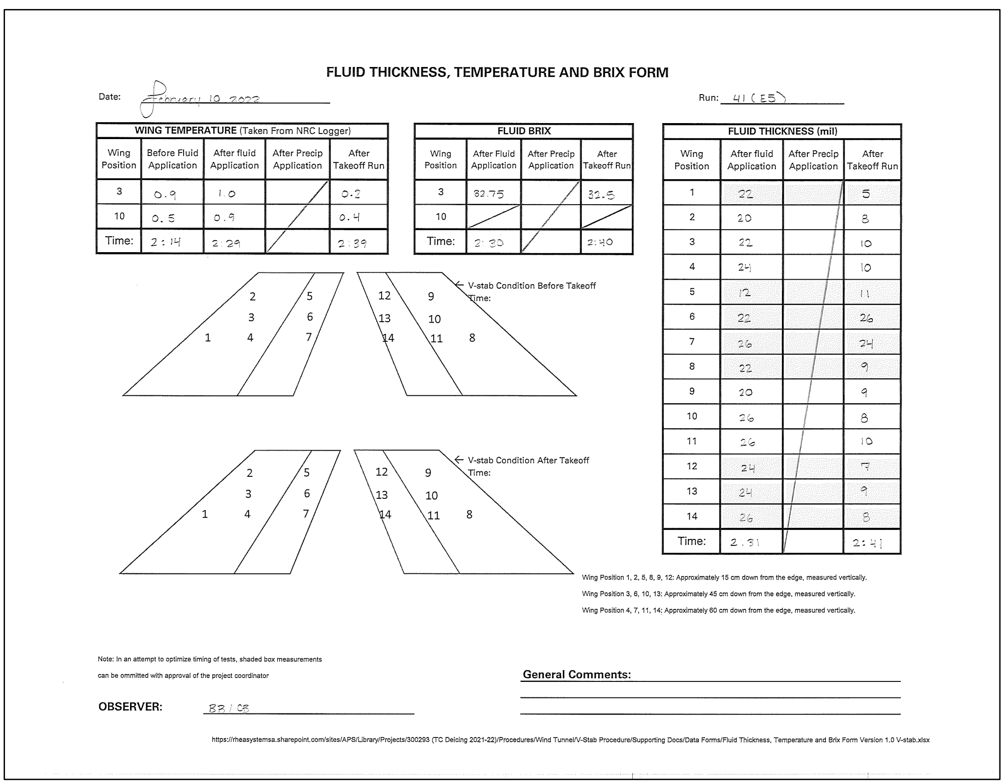
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C33: Run # 40



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 10, 2022 Run: 41 (E5)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.9	1.0		0.2
10	0.5	0.9		0.4
Time:	2:14	2:29		2:39

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.75		32.5
10			
Time:	2:30		2:40

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	22		5
2	20		8
3	22		10
4	24		10
5	12		11
6	22		26
7	26		24
8	22		9
9	20		9
10	26		8
11	26		10
12	24		7
13	24		9
14	26		8
Time:	2:31		2:41

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C34: Run # 41

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

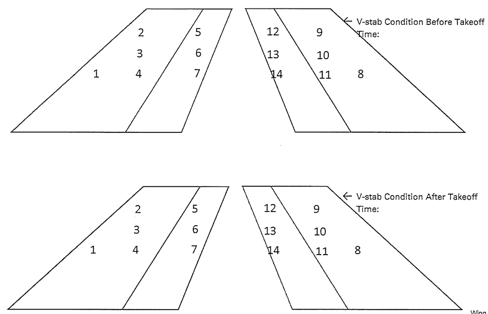
Date: February 10, 2022

Run: 42 (E6)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.7	1.5		0.9
10	0.7	1.2		0.9
Time:	2:49	3:06		3:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.75		32.75
10			
Time:	3:07		3:16

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	24		8
2	18		7
3	22		8
4	28		10
5	16		22
6	26		24
7	26		26
8	22		7
9	16		9
10	26		10
11	26		11
12	24		9
13	26		10
14	28		12
Time:	3:08		3:17



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: RB / CR

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C35: Run # 42

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

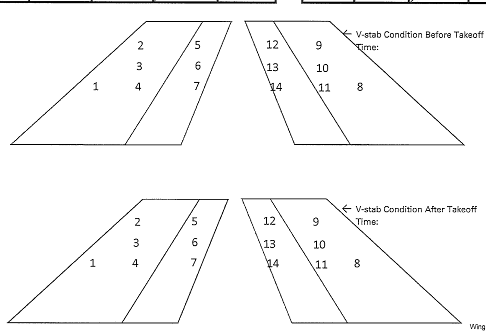
Date: February 10, 2022

Run: 43 (E7)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.8	0.7		0.4
10	0.9	1.2		0.7
Time:	3:27	3:39		3:47

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.5		32.25
10			
Time:	3:40		3:48

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	clean		clean
2	clean		clean
3	clean		clean
4	clean		clean
5	clean		18
6	clean		20
7	clean		20
8	20		7
9	16		12
10	22		12
11	26		12
12	20		10
13	24		11
14	28		11
Time:	3:41		3:49



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: RB / CR

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C36: Run # 43

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

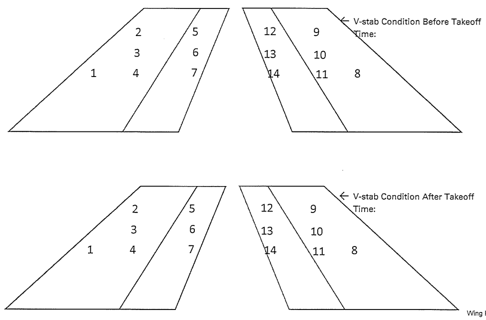
Date: February 10, 2022

Run: 44 (E8)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	1.1	1.0		0.6
10	1.2	1.5		0.7
Time:	4:05	4:15		4:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3			
10	36.75		37.0
Time:	4:16		4:29

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	clean		clean
2	clean		clean
3	clean		clean
4	clean		clean
5	clean		12
6	clean		11
7	clean		10
8	14		3
9	14		7
10	18		8
11	24		8
12	22		6
13	22		8
14	24		8
Time:	4:17		4:30



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C37: Run # 44

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

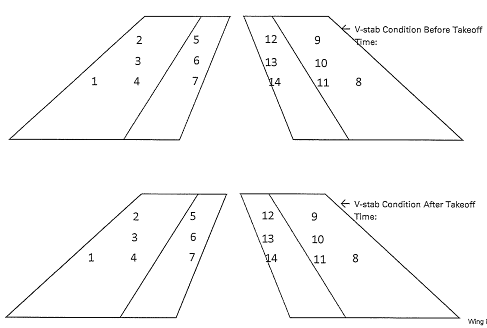
Date: February 10, 2022

Run: 45 (E9)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	0.9	0.9		0.3
10	0.9	1.1		0.5
Time:	4:39	4:48		4:56

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	clean		clean
10	36.75		37.0
Time:	4:49		4:57

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	clean		clean
2	clean		clean
3	clean		clean
4	clean		clean
5	clean		12
6	clean		22
7			18
8	16		7
9	12		10
10	20		10
11	24		11
12	11		7
13	22		6
14	22		7
Time:	4:50		4:58



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

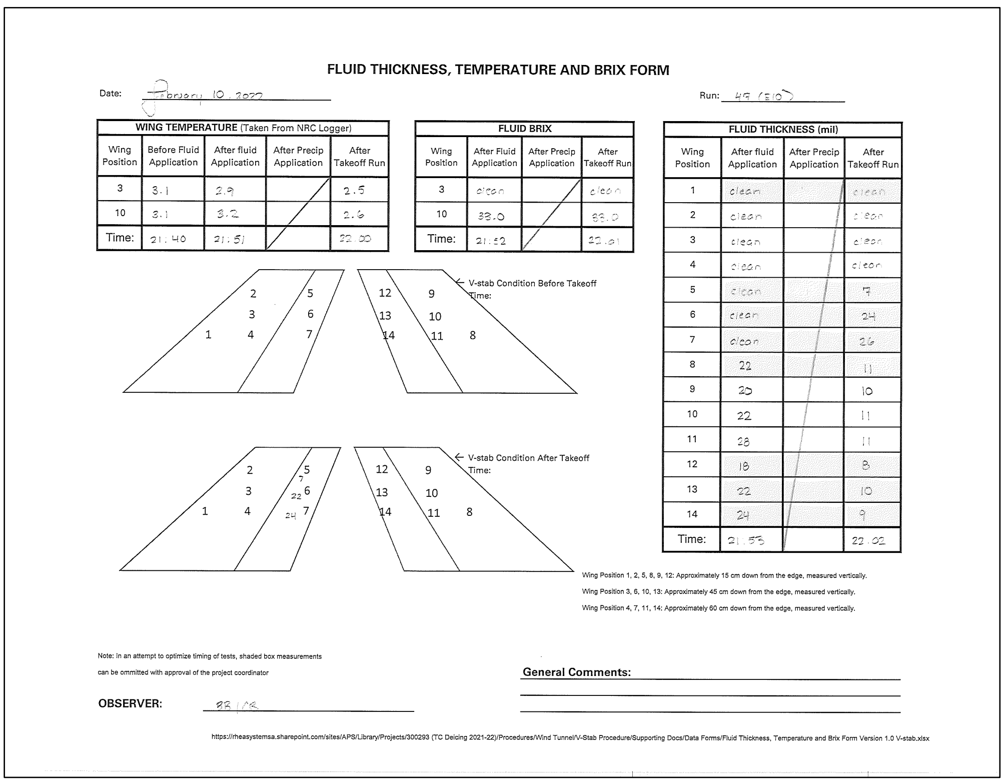
OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C38: Run # 45

No Data Available

Figure C39: Run # 46



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 10, 2022

Run: 47 (E10)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	3.1	2.9		2.5
10	3.1	3.2		2.6
Time:	21:40	21:51		22:00

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	clean		clean
10	33.0		33.0
Time:	21:52		22:01

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	clean		clean
2	clean		clean
3	clean		clean
4	clean		clean
5	clean		7
6	clean		24
7	clean		26
8	22		11
9	20		10
10	22		11
11	28		11
12	18		8
13	22		10
14	24		9
Time:	21:53		22:02

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.

Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.

Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

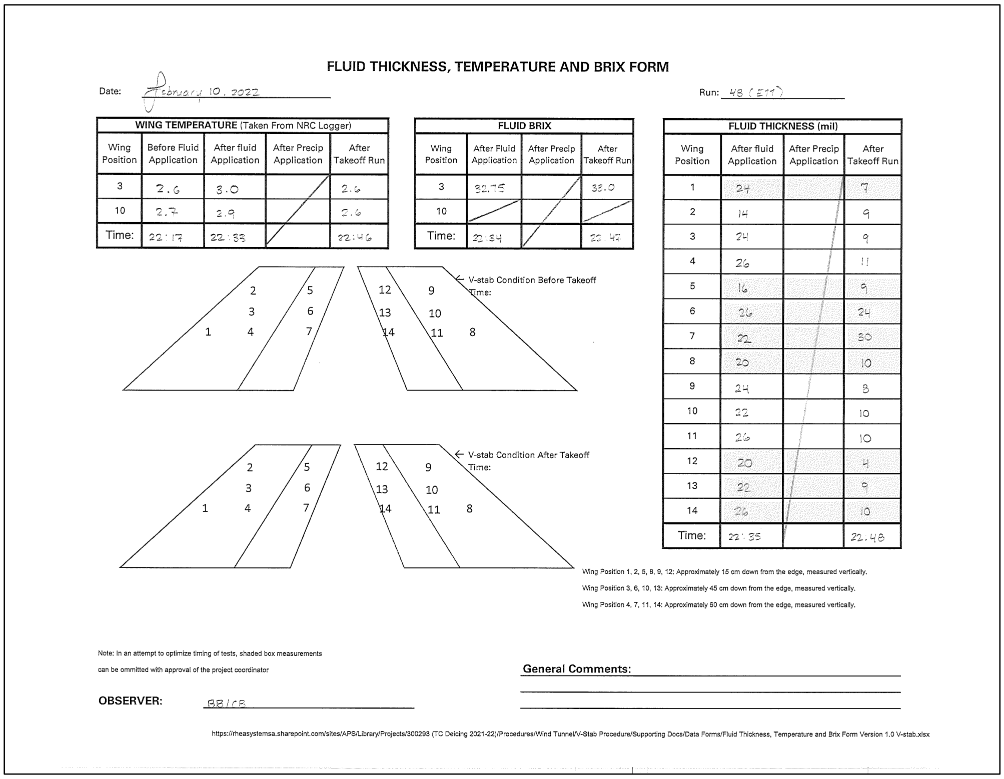
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CR

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C40: Run # 47



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 10, 2022

Run: 48 (E11)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	2.6	3.0		2.6
10	2.7	2.9		2.6
Time:	22:17	22:33		22:46

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.75		33.0
10			
Time:	22:34		22:47

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	24		7
2	14		9
3	24		9
4	26		11
5	16		9
6	26		24
7	22		30
8	20		10
9	24		8
10	22		10
11	26		10
12	20		4
13	22		9
14	26		10
Time:	22:35		22:48

V-stab Condition Before Takeoff
Time:

V-stab Condition After Takeoff
Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

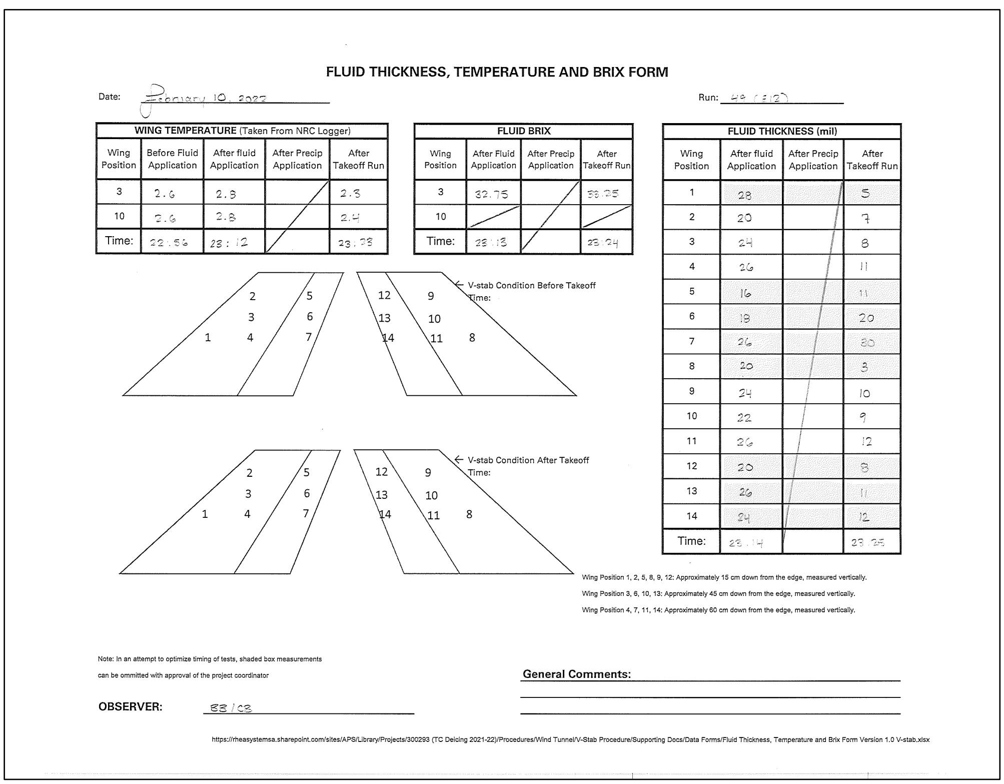
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C41: Run # 48



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 10, 2022

Run: 49 (E12)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	2.6	2.8		2.3
10	2.6	2.8		2.4
Time:	22:56	23:12		23:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.75		33.25
10			
Time:	23:13		23:24

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	28		5
2	20		7
3	24		8
4	26		11
5	16		11
6	18		20
7	26		30
8	20		3
9	24		10
10	22		9
11	26		12
12	20		8
13	26		11
14	24		12
Time:	23:14		23:25

V-stab Condition Before Takeoff
Time:

V-stab Condition After Takeoff
Time:

Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C42: Run # 49

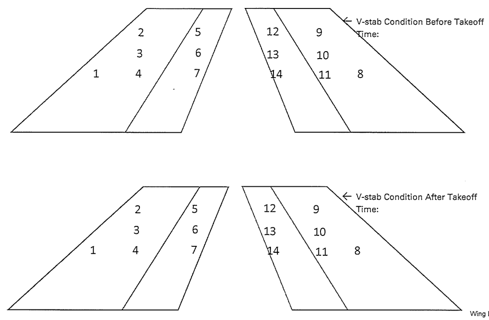
FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 11, 2022 Run: 50 (E13)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	2.3	2.2		1.9
10	2.4	2.1		2.0
Time:	23:37	23:53		00:03

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	32.75		34.25
10			
Time:	23:54		00:04

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	22		4
2	20		7
3	26		10
4	26		11
5	18		11
6	24		22
7	28		24
8	18		8
9	16		7
10	22		9
11	26		10
12	22		5
13	20		9
14	24		10
Time:	23:55		00:05



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C43: Run # 50

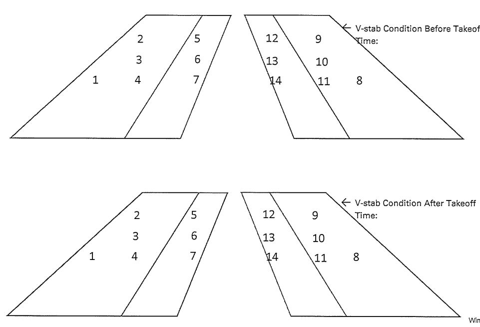
FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 11, 2022 Run: 51 (E14)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	1.9	2.1		1.5
10	1.9	2.1		1.8
Time:	00:16	00:32		00:42

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		34.0
10			
Time:	00:33		00:43

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	24		4
2	16		3
3	20		5
4	24		7
5	14		8
6	20		20
7	22		30
8	16		7
9	16		5
10	18		8
11	20		10
12	18		4
13	20		8
14	24		10
Time:	00:34		00:44



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB/CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C44: Run # 51

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

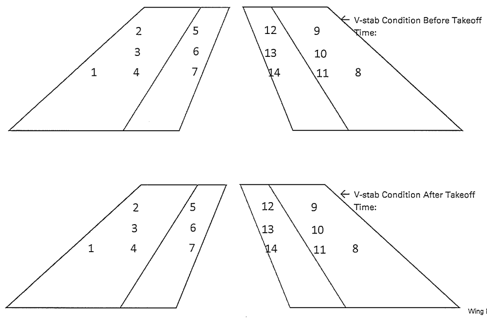
Date: February 11, 2022

Run: 52 (E15)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	2.0	2.2		1.4
10	2.0	2.1		1.4
Time:	1:00	1:15		1:24

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	33.0		34.0
10			
Time:	1:16		1:25

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	24		8
2	22		11
3	22		9
4	22		11
5	20		14
6	22		24
7	24		26
8	20		8
9	16		11
10	22		11
11	26		16
12	14		12
13	22		16
14	24		20
Time:	1:17		1:26



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: [illegible]

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C45: Run # 52

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

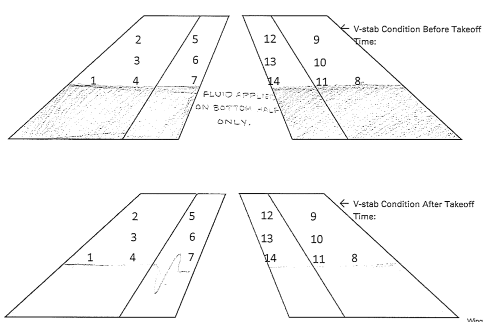
Date: February 11, 2022

Run: 53 (E16)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	2.0	2.0		1.5
10	2.0	2.0		1.7
Time:	1:39	1:54		2:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	clean		clean
10	clean		clean
Time:	1:54		2:04

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	clean		clean
2	clean		clean
3	clean		clean
4	clean		clean
5	clean		clean
6	clean		clean
7	clean		clean
8	clean		clean
9	clean		clean
10	clean		clean
11	clean		clean
12	clean		clean
13	clean		clean
14	clean		clean
Time:	1:54		2:04



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: [illegible]

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C46: Run # 53

No Data Available

Figure C47: Run # 54

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

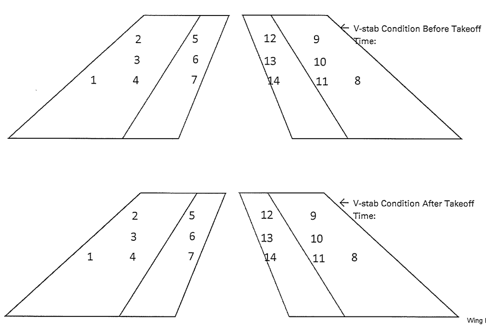
Date: February 11, 2022

Run: 55 (E18)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
3	2.0	2.3		1.8
10	2.0	2.2		1.7
Time:	2:37	2:50		3:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
3	36.25		37.0
10			
Time:	2:51		3:05

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	12		3
2	10		4
3	12		5
4	14		5
5	10		12
6	12		12
7	12		12
8	10		2
9	12		5
10	12		4
11	14		8
12	10		4
13	12		4
14	16		7
Time:	2:52		3:06



Wing Position 1, 2, 5, 8, 9, 12: Approximately 15 cm down from the edge, measured vertically.
Wing Position 3, 6, 10, 13: Approximately 45 cm down from the edge, measured vertically.
Wing Position 4, 7, 11, 14: Approximately 60 cm down from the edge, measured vertically.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: BB / CB

https://rheasystemsa.sharepoint.com/sites/APS/Library/Projects/300293 (TC Deicing 2021-22)/Procedures/Wind Tunnel/V-Stab Procedure/Supporting Docs/Data Forms/Fluid Thickness, Temperature and Brix Form Version 1.0 V-stab.xlsx

Figure C48: Run # 55

APPENDIX D

SUMMARY OF FLUID THICKNESS DATA

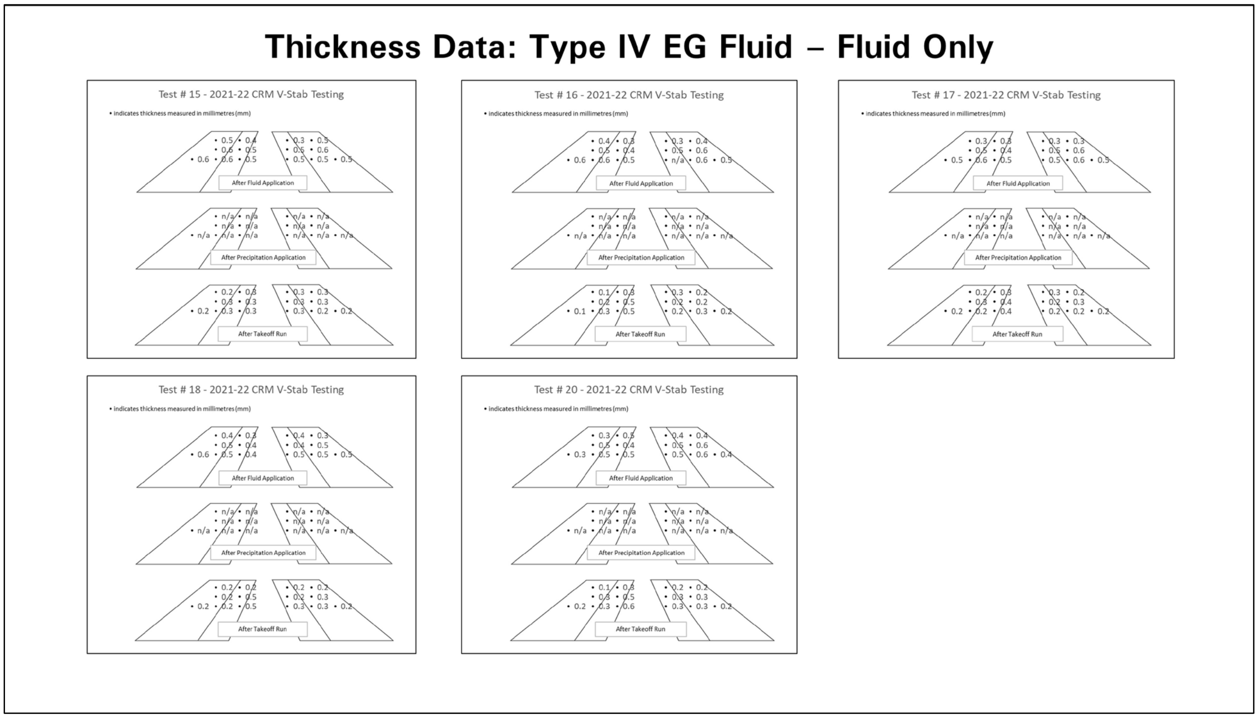


Figure 1: Thickness Data: Type IV EG Fluid – Fluid Only

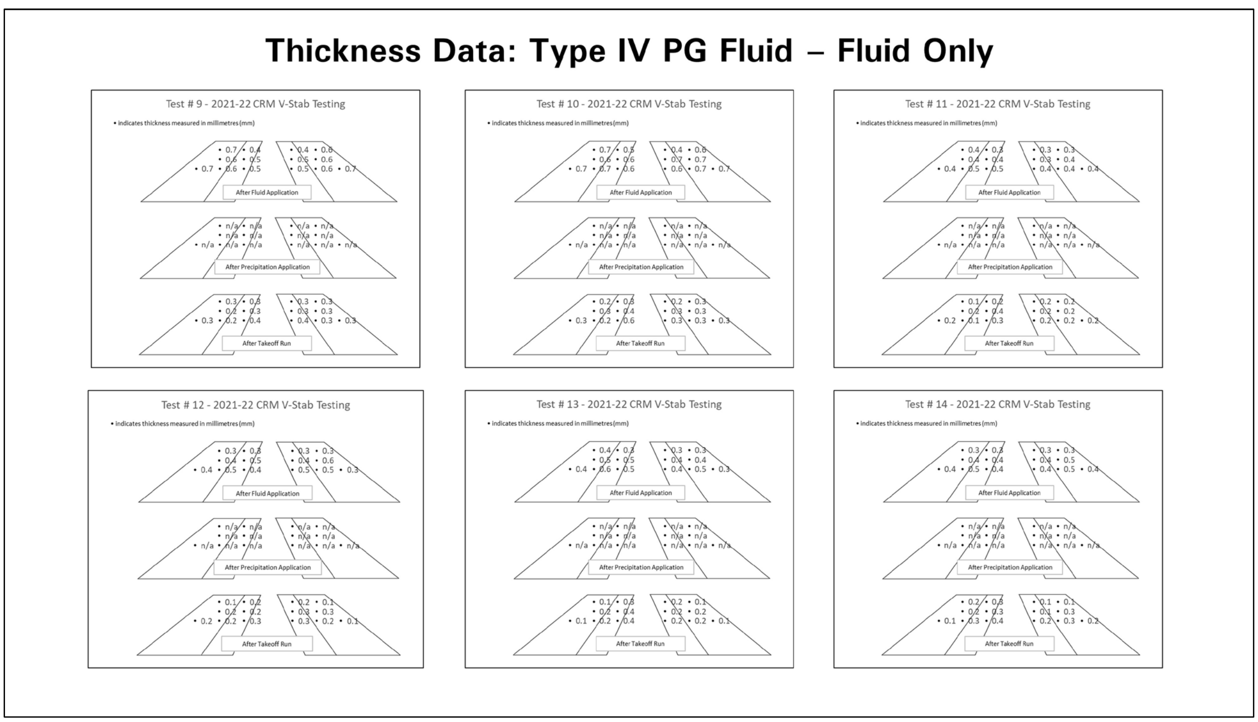


Figure 2: Thickness Data: Type IV PG Fluid – Fluid Only

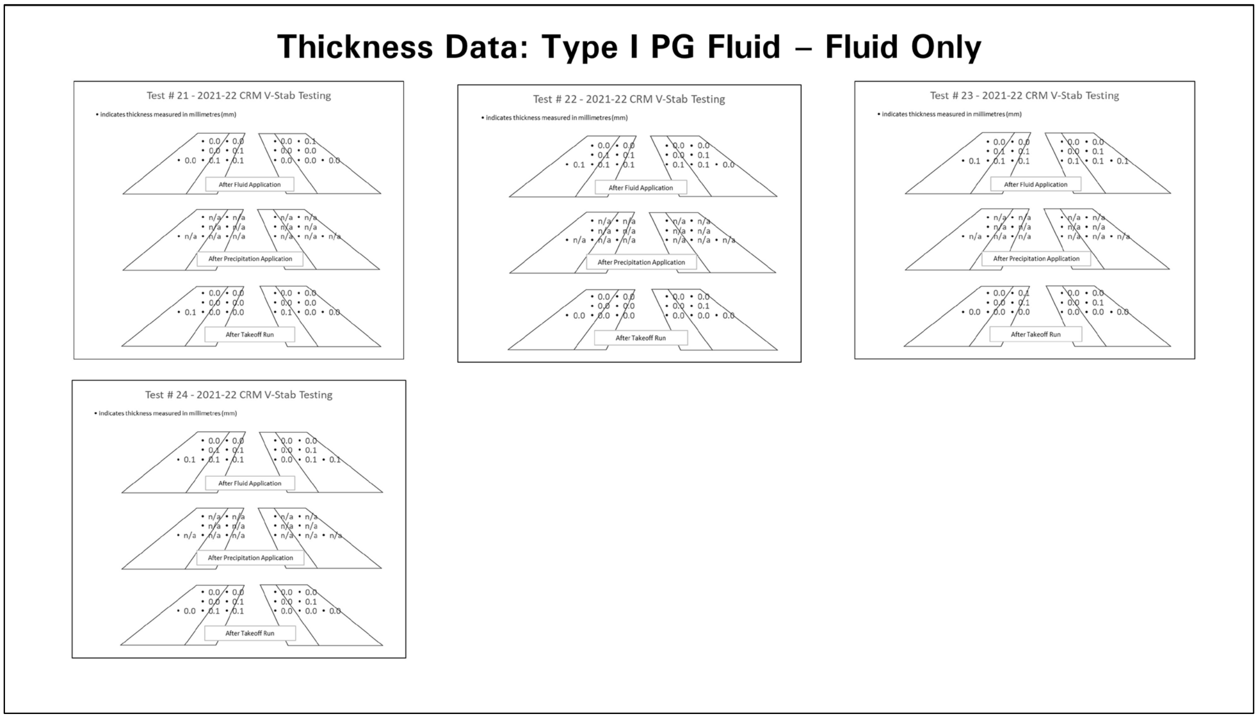


Figure 3: Thickness Data: Type I PG Fluid – Fluid Only

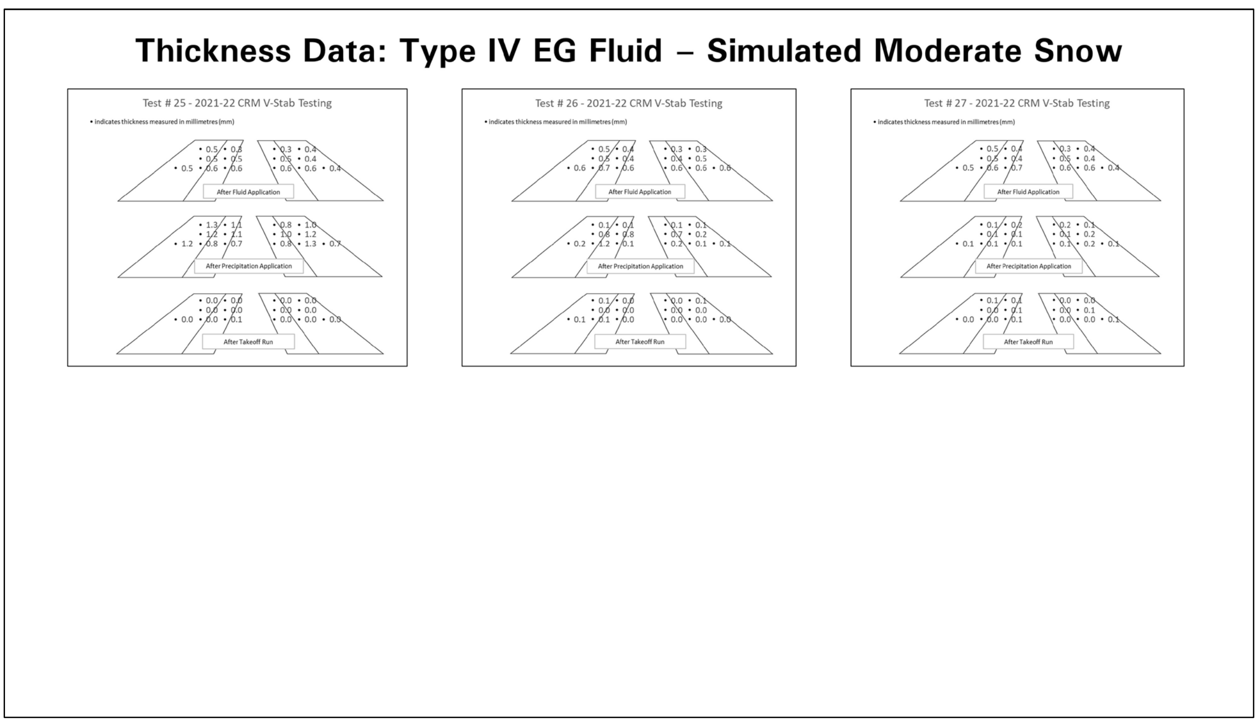


Figure 4: Thickness Data: Type IV EG Fluid – Simulated Moderate Snow

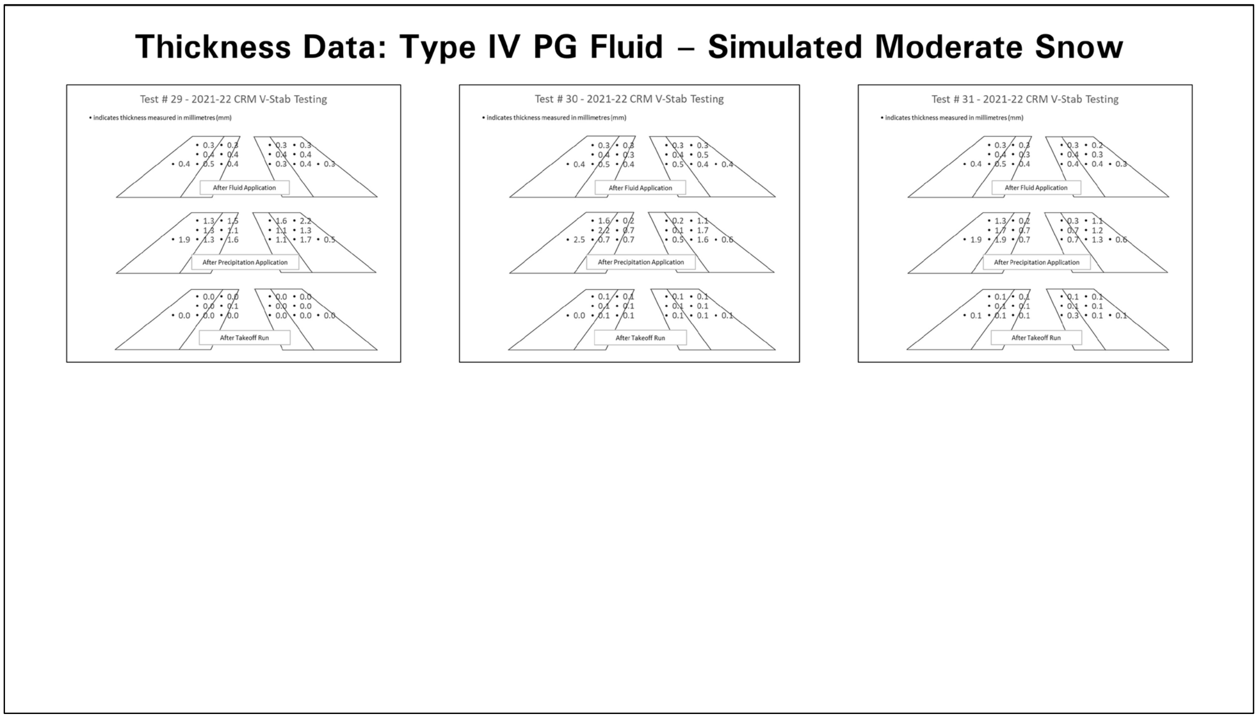


Figure 5: Thickness Data: Type IV PG Fluid – Simulated Moderate Snow

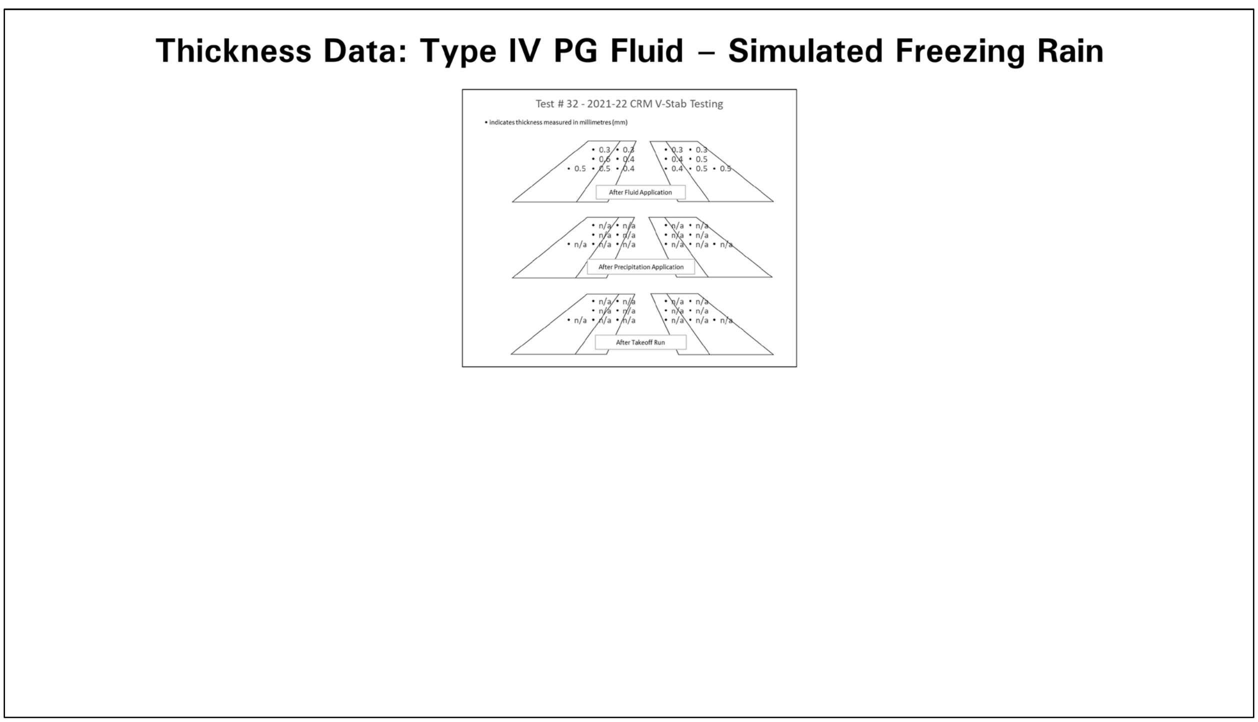


Figure 6: Thickness Data: Type IV PG Fluid – Simulated Freezing Rain

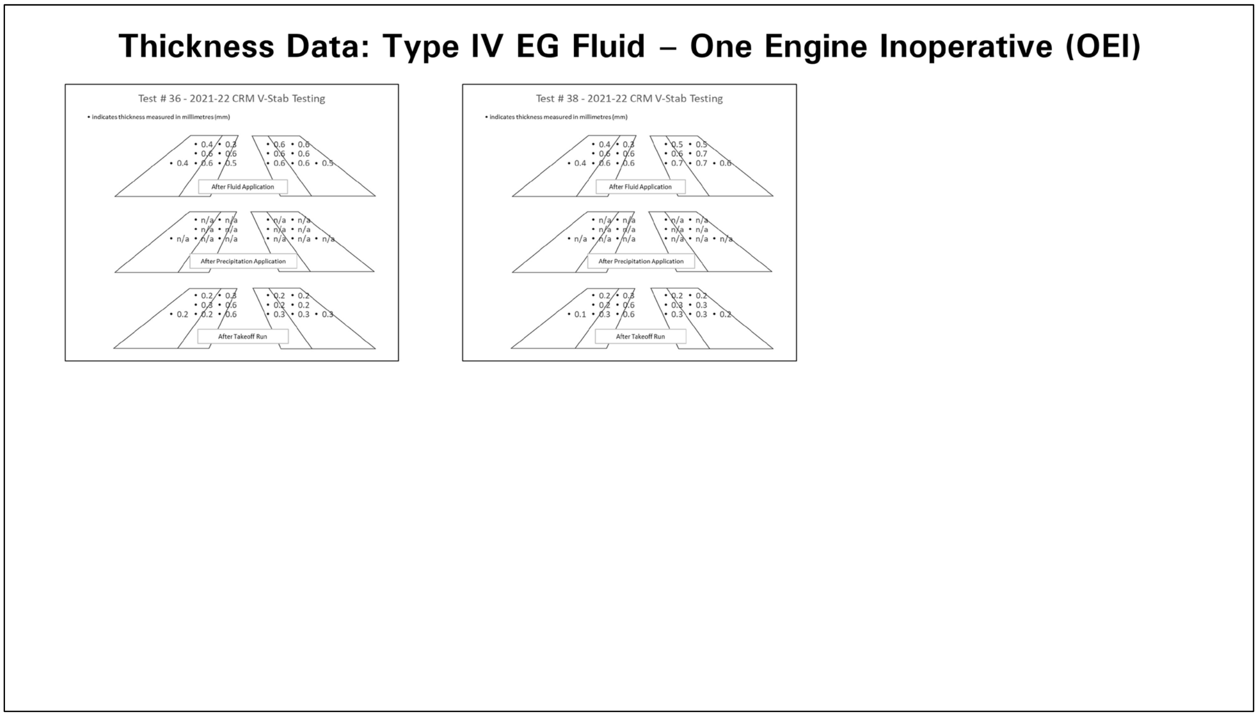


Figure 7: Thickness Data: Type IV EG Fluid – One Engine Inoperative (OEI)

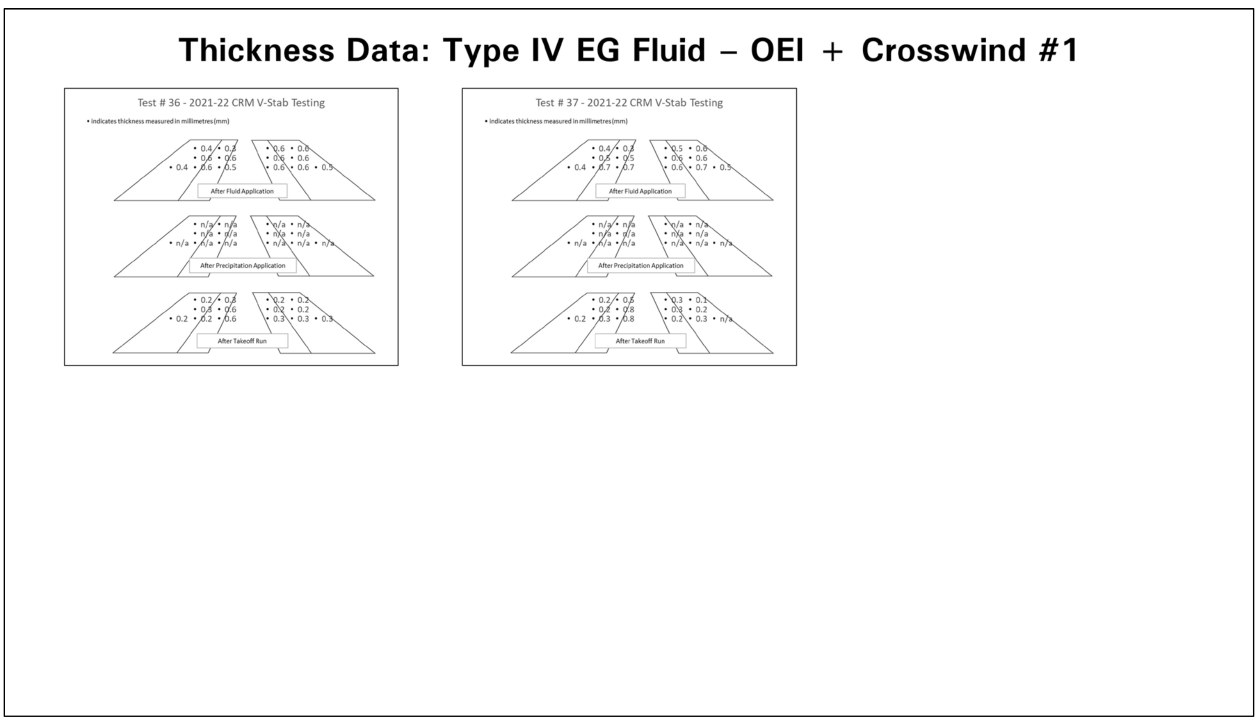
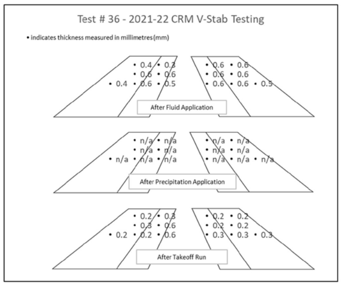


Figure 8: Thickness Data: Type IV EG Fluid – OEI + Crosswind #1

Thickness Data: Type IV EG Fluid – OEI + Crosswind #2



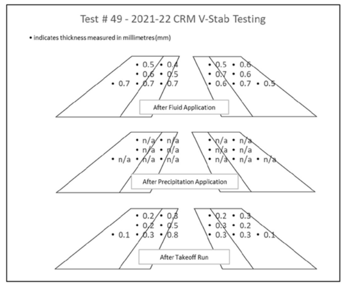
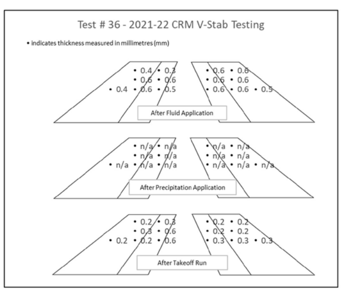


Figure 9: Thickness Data: Type IV EG Fluid – OEI + Crosswind #2

Thickness Data: Type IV EG Fluid – OEI + Crosswind #2 @115 Kts



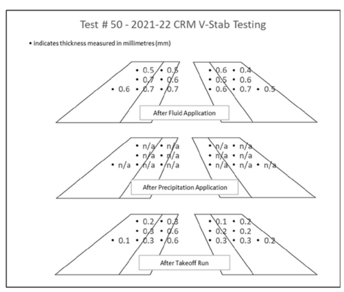
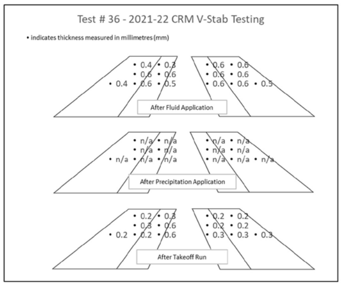


Figure 10: Thickness Data: Type IV EG Fluid – OEI + Crosswind #2 @115kts

Thickness Data: Type IV EG Fluid – OEI + Crosswind #2 @115kts



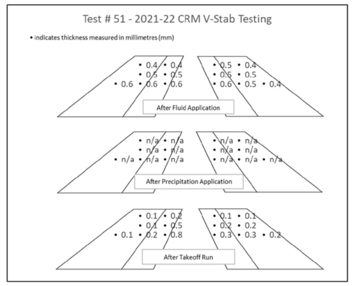
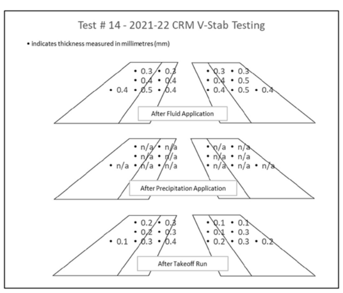


Figure 11: Thickness Data: Type IV EG Fluid – OEI + Crosswind #2 @115kts

Thickness Data: Type IV PG Fluid – OEI + Crosswind #1



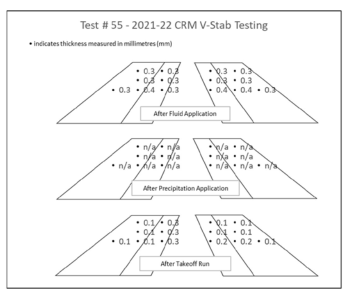


Figure 12: Thickness Data: Type IV PG Fluid – OEI + Crosswind #1

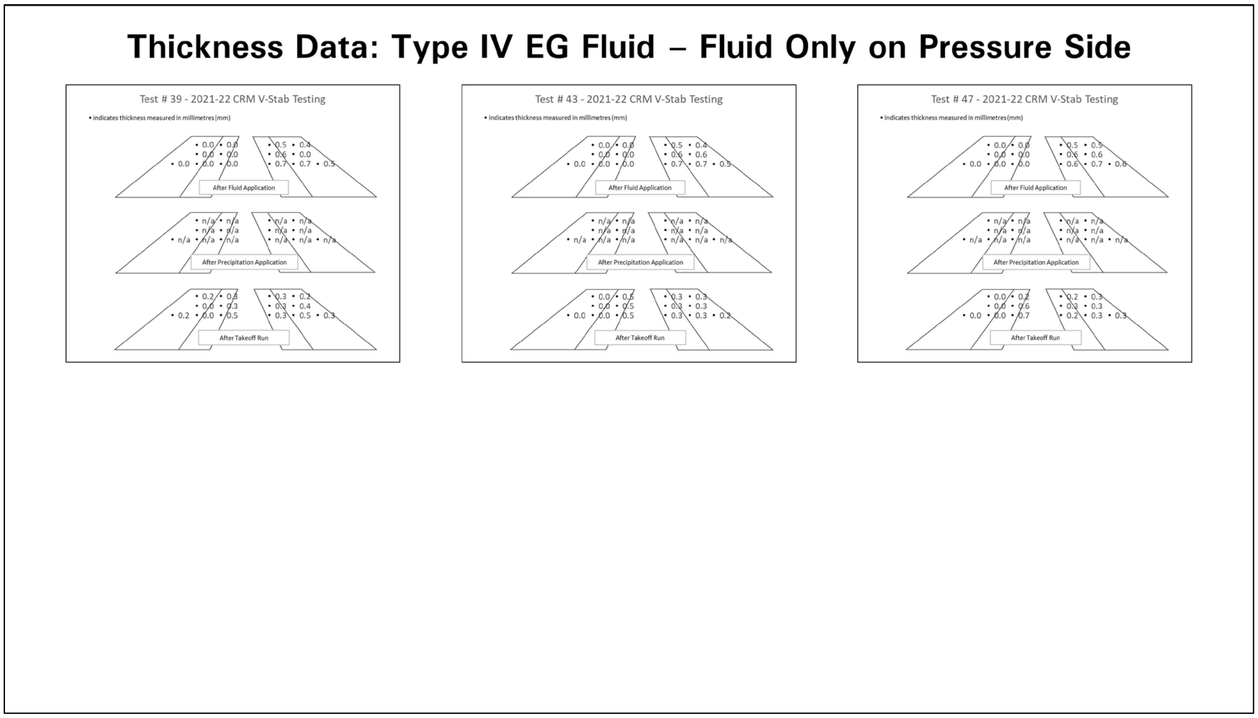


Figure 13: Thickness Data: Type IV EG Fluid – Fluid Only on Pressure Side

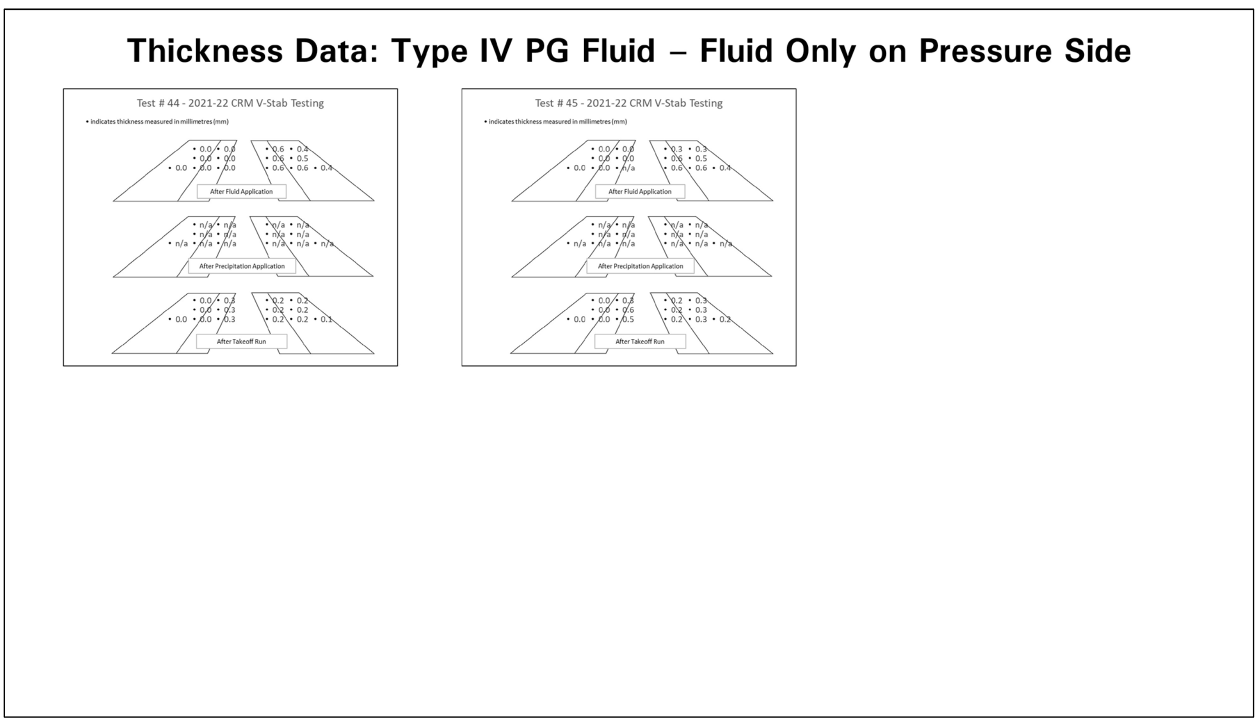


Figure 14: Thickness Data: Type IV PG Fluid – Fluid Only on Pressure Side

Thickness Data: Type IV EG Fluid – Fluid Only on Suction Side

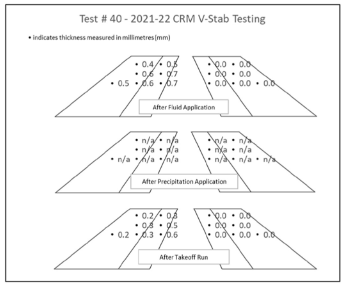
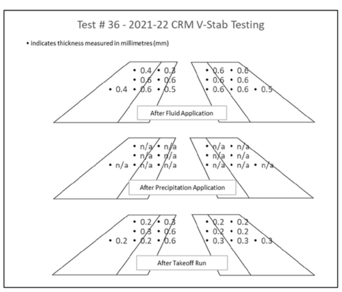


Figure 15: Thickness Data: Type IV EG Fluid – Fluid Only on Suction Side

Thickness Data: Type IV EG Fluid – Fluid only on Bottom Half



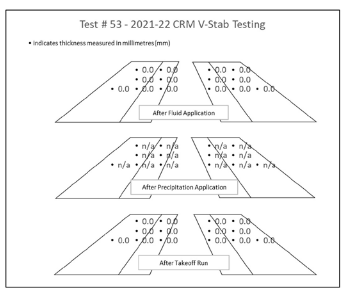


Figure 16: Thickness Data: Type IV EG Fluid – Fluid Only on Bottom Half

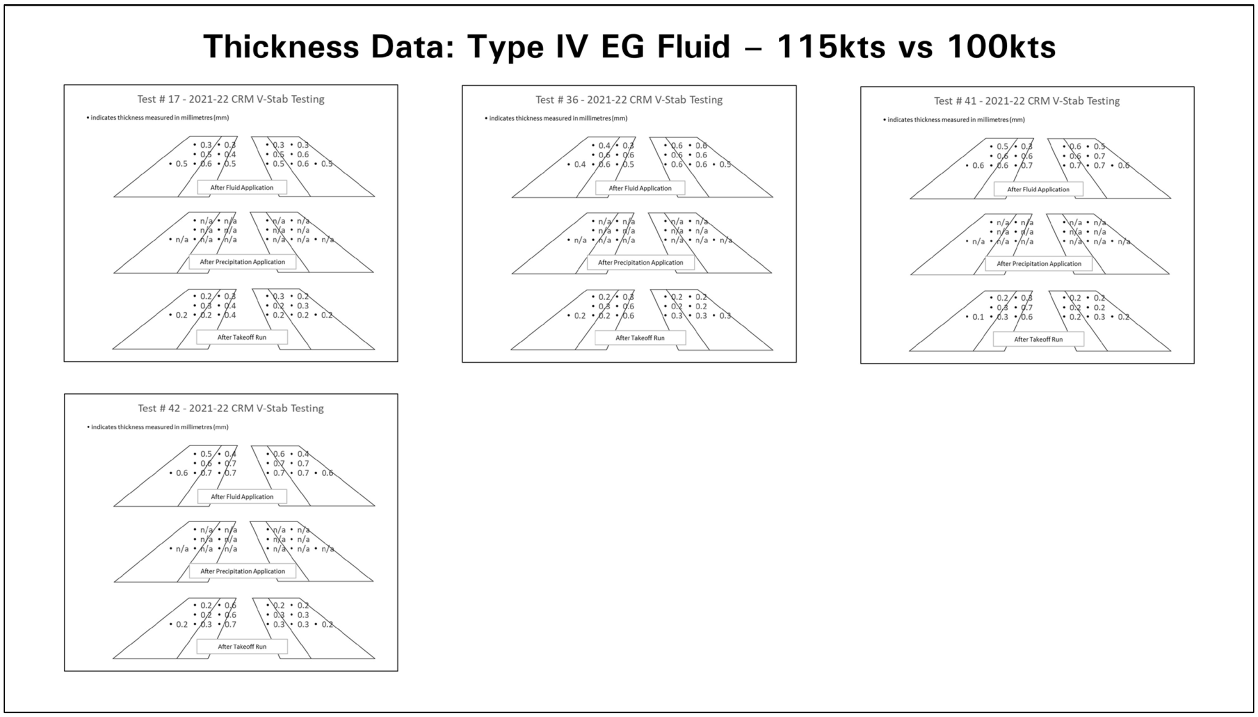


Figure 17: Thickness Data: Type IV EG Fluid – 115kts vs 100kts

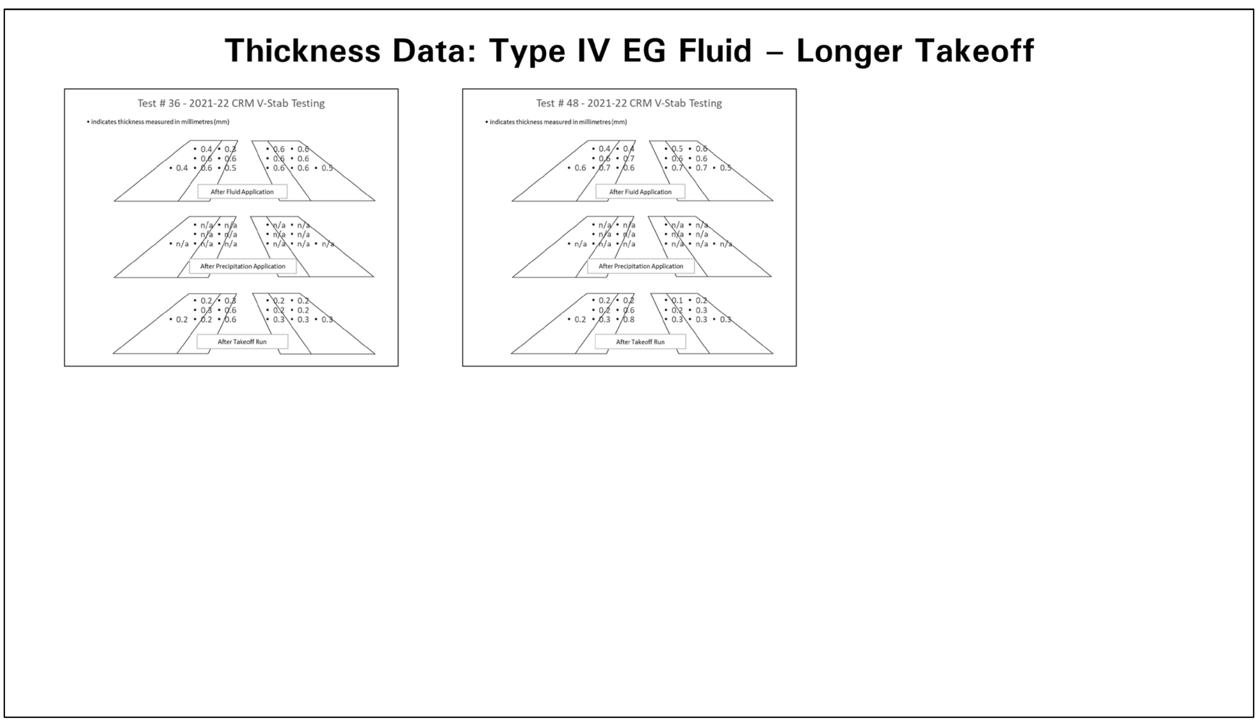


Figure 18: Thickness Data: Type IV EG Fluid – Longer Takeoff

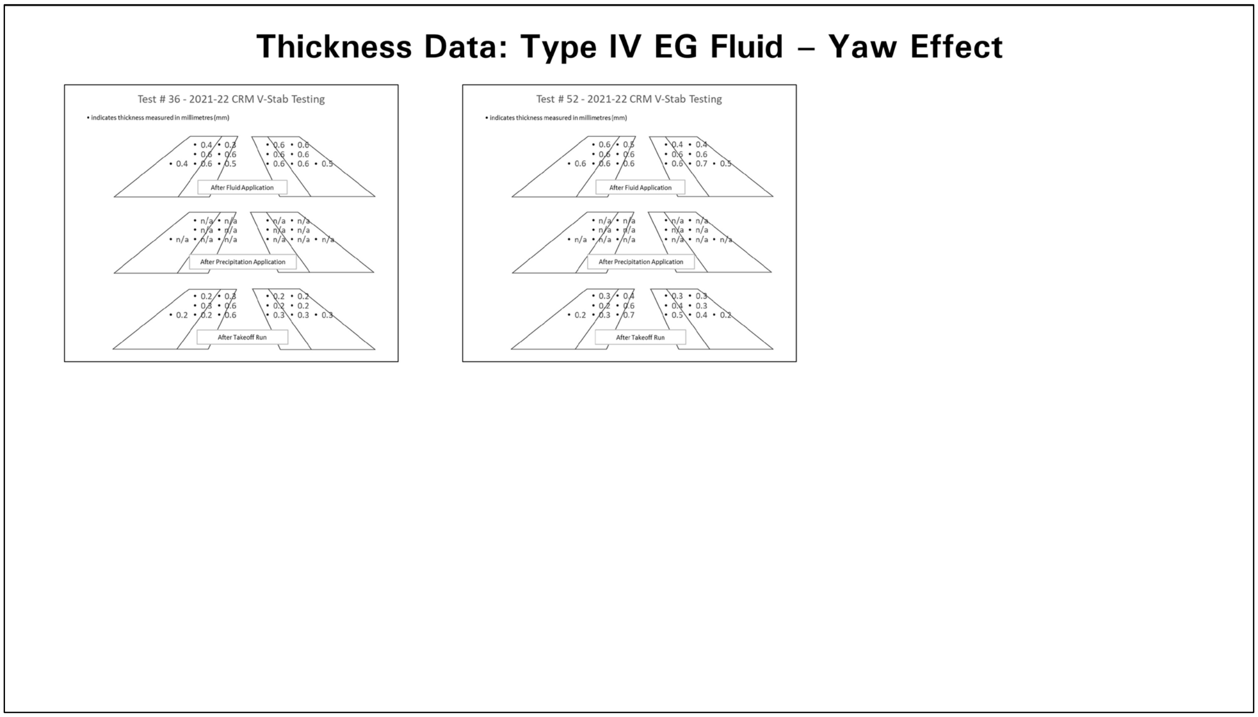


Figure 19: Thickness Data: Type IV EG Fluid – Yaw Effect