TP 15342E

TESTING OF ENDURANCE TIMES ON EXTENDED FLAPS AND SLATS

Prepared for the
Transportation Development Centre
In cooperation with
Transport Canada Civil Aviation
and the
Federal Aviation Administration
William J. Hughes Technical Center

Final Version 1.0
December 2016

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DOCUMENT ORIGIN AND APPROVAL RECORD

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March 27, 2017

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Un sommaire français se trouve avant la table des matières.

PREFACE

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

- To develop holdover time data for all newly-qualified de/anti-icing fluids and update and maintain the website for the holdover time guidelines;
- To evaluate fluid holdover times for snow at very cold temperatures close to -25°C;
- To conduct heavy snow research to determine the highest usable precipitation rate (HUPR) for which operations are permitted;
- To evaluate the effects of deploying flaps/slats, prior to takeoff, on fluid protection times;
- To conduct exploratory testing to evaluate fluid effectiveness and characterize contamination on high angle vertical surfaces;
- To conduct general and exploratory de/anti-icing research;
- To obtain full-scale operational documentation of anti-icing fluid flow-off, fluid freezing-in-flight, and residual fluid thickness;
- To conduct wind tunnel testing to support the development of the guidance material for operating in conditions mixed with ice pellets;
- To update the regression coefficient report with the newly-qualified de/anti-icing fluids; and
- To update the source documents used by Transport Canada and the Federal Aviation Administration for the maintenance and publication of the holdover time guidance material.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2015-16 are documented in five reports. The titles of the reports are as follows:

- TP 15338E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2015-16 Winter;
- TP 15339E Regression Coefficients and Equations Used to Develop the Winter 2016-17 Aircraft Ground Deicing Holdover Time Tables;
- TP 15340E Aircraft Ground Icing Research General Activities During the 2015-16 Winter;
- TP 15341E Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2015-16; and
- TP 15342E Testing of Endurance Times on Extended Flaps and Slats.

This report, TP 15432E describes research performed with the objective of evaluating the effect of deploying flaps and slats on the fluid endurance time.

This objective was met by conducting flat plate tests, airfoil tests, and a series of full-scale aircraft tests comparing fluid failure progression on an aircraft wing surface to flat plate test models. This testing was conducted at YMX airport with the support of UPS through the use of their A300 cargo aircraft for testing purposes. Complementary flat plate and airfoil model tests in natural snow conditions and in simulated freezing precipitation conditions were also conducted. In addition, Southwest Airlines (SWA) contracted directly with APS to conduct complementary comparative full-scale tests with two side-by-side B-737 aircraft at ALB airport to further support the full-scale work conducted at YMX.

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by Transport Canada with support from the Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, National Research Council Canada, and supporting members of the SAE International G-12 Aircraft Ground De-Icing Committee.

APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Yelyzaveta Asnytska, Brandon Auclair, Steven Baker, Stephanie Bendickson, Benjamin Bernier, Chloë Bernier, Trevor Butler, John D’Avirro, Jesse Dybka, Ben Falvo, Benjamin Guthrie, Michael Hawdur, Gabriel Maatouk, Philip Murphy, Matthew Pilling, Dany Posteraro, Marco Ruggi, Gordon Smith, David Youssef, and Nondas Zoitakis.

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

PROJECT ACKNOWLEDGEMENTS

APS would like to acknowledge Aéromag 2000, Aéroports de Montreal, Air Canada, Albany International Airport, Dow, LNT Solutions, Southwest Airlines, and UPS for their support during the full-scale testing and for their participation in the project planning process. APS would like to acknowledge James T. Riley and Timothy G. Smith from the Federal Aviation Administration who provided guidance in the preparation of this report.

Transport Canada | Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. TP 15342E	2. Project No. B14W	3. Recipient's Catalogue No.
4. Title and Subtitle Testing of Endurance Times on Extended Flaps and Slats		5. Publication Date December 2016
		6. Performing Organization Document No. CM2480.002
7. Author(s) Benjamin Bernier and Marco Ruggi		8. Transport Canada File No. 2450-BP-14
9. Performing Organization Name and Address APS Aviation Inc. 6700 Cote-de-Liesse, Suite 105 Montreal, Quebec H4T 2B5 Canada		10. PWGSC File No. TOR-4-37170
		11. PWGSC or Transport Canada Contract No. T8156-140243/001/TOR
12. Sponsoring Agency Name and Address Transportation Development Centre Transport Canada 330 Sparks St., 26th Floor Ottawa, Ontario K1A 0N5 Canada		13. Type of Publication and Period Covered Final
		14. Project Officer Antoine Lacroix

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

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

16. Abstract

Aircraft surfaces are well represented by the 10º flat plate for determination of fluid holdover times (HOT). However, flaps and slats in the deployed position can generate angles greater than 10º. These greater surface angles increase the precipitation catch factor of a surface and can cause the fluid to flow off more readily causing a potential for reductions to HOTs.

Wind tunnel research conducted in 2009-10 identified the issue when it was observed that anti-icing fluid applied to the thin high performance wing model with deployed flaps can quickly flow-off, resulting in a reduced fluid thickness layer, and consequently shortened fluid endurance times. As a result, preliminary guidance was issued, and a focused research plan was launched in 2010-11 that included flat plate testing. In 2011-12, based on industry feedback and cooperation, full-scale research was started with UPS and later with Southwest Airlines (through a separate contract) and Air Canada. In 2013-14 research looked at simulating the effects of rotation during taxi using flat plates, and evolved in 2014-15 to include airfoil models which were deemed more appropriate.

The full-scale data has shown a correlation with Type IV fluid between the inclined plates and the wing surfaces. In the extended configuration, the wing as a whole demonstrated earlier fluid failure as compared to the 10° plate; the shorter endurance times of the 20° simple plate better represented the expected fluid protection on the wings with extended flaps and slats. The flat plate data collected also showed a difference in the expected endurance time reductions on the simulated extended flaps and slats when using Type I versus Type IV fluids. Testing simulating aircraft rotation during taxi to the runway has indicated that adjusting for taxi orientation extends the fluid protection time. Further work is required to better understand how to incorporate these results into proper guidance.

17. Key Words Endurance Time, Holdover Time, Allowance Time, Flaps, Slats, Deployed Surfaces, Flat Plate, Airfoil, Full-Scale, A300, B737, A319, UPS, Southwest Airlines, Air Canada, Type I, Type II, Type III, Type IV, Taxi Orientation, Rotation During Taxi, Wind Tunnel	18. Distribution Statement Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication) Unclassified	20. Security Classification (of this page) Unclassified	21. Declassification (date)	22. No. of Pages xxii, 138 apps.	23. Price —

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. Nº de la publication de Transports Canada
TP 15341E

2. Nº de l'étude
B14W

3. Nº de catalogue du destinataire

4. Titre et sous-titre
Testing of Endurance Times on Extended Flaps and Slats

5. Date de la publication
Décembre 2016

6. Nº de document de l'organisme exécutant
CM2480.002

7. Auteur(s)
Benjamin Bernier et Marco Ruggi

8. Nº de dossier - Transports Canada
2450-BP-14

9. Nom et adresse de l'organisme exécutant
APS Aviation Inc.
6700 Cote-de-Liesse, Suite 105
Montreal, Québec
H4T 2B5
Canada

10. Nº de dossier - TPSGC
TOR-4-37170

11. Nº de contrat - TPSGC ou Transports Canada
T8156-140243/001/TOR

12. Nom et adresse de l'organisme parrain
Centre de développement des transports (CDT)
Transport Canada
330 Sparks St., 26th Floor
Ottawa, Ontario K1A 0N5
Canada

13. Genre de publication et période visée
Final

14. Agent de projet
Antoine Lacroix

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

Plusieurs rapports de recherche d'hivers antérieurs sur des essais de technologies de dégivrage et d'antigivrage ont été produits pour le compte de Transports Canada. Ils peuvent être obtenus du Centre de développement des transports (CDT). Plusieurs rapports ont été produits dans le cadre du programme de recherche de cet hiver. Leur objet est exposé à la préface. Les travaux décrits dans le présent rapport ont été en partie coparrainés par la Federal Aviation Administration (FAA).

16. Résumé

La plaque plane de 10º utilisée pour déterminer les durées d'efficacité (HOT) des liquides représente bien les surfaces d'aéronef. Cependant, les volets et les becs de bord d'attaque déployés peuvent produire des angles supérieurs à 10º. Ces angles de surface plus grands augmentent le facteur de capture de précipitation d'une surface et peuvent faire écouler le liquide plus facilement, ce qui peut réduire les durées d'efficacité.

Les recherches en soufflerie menées en 2009-2010 ont identifié le problème. Elles ont démontré que, lorsque appliqué sur une maquette d'aile haute performance mince avec volets déployés, le liquide antigivrage peut rapidement s'écouler, causant la réduction de l'épaisseur de la couche de liquide et, en conséquence, une diminution des temps d'endurance du liquide. Par conséquent, des lignes directrices préliminaires ont été émises et un plan de recherche ciblé a été amorcé en 2010-2011, y compris des essais sur plaque plane. En 2011-2012, avec la rétroaction et la coopération de l'industrie, des recherches à grande échelle ont été entreprises avec UPS et, plus tard, avec Southwest Airlines (en vertu d'un contrat distinct) et Air Canada. En 2013-2014, les recherches ont porté sur la simulation des effets du roulement durant la circulation au sol et sur des plaques planes, puis ont évolué en 2014-2015 avec des maquettes de surfaces portantes considérées plus appropriées.

Les données complètes ont démontré une corrélation des liquides de type IV entre les plaques inclinées et la surface des ailes. En configuration déployée, la perte d'efficacité du liquide sur l'ensemble de l'aile s'est produite plus tôt que sur la plaque de 10°. Les temps d'endurance plus courts de la plaque simple de 20° étaient plus représentatifs de la protection prévue du liquide sur les ailes dont les volets et les becs de bord d'attaque sont déployés. Les données sur les plaques planes ont également fait ressortir une différence dans les réductions prévues de temps d'endurance, lors de simulation de volets et de becs de bord d'attaque déployés, utilisant des liquides de type I plutôt que de type IV. Les simulations du roulement d'aéronefs durant la circulation au sol vers la piste ont démontré que l'ajustement de la direction de la circulation prolonge le temps de protection du liquide. Des travaux supplémentaires sont nécessaires pour mieux comprendre comment incorporer ces résultats à des lignes directrices appropriées.

17. Mots clés
Durée d'endurance, durée d'efficacité, marge de tolérance, volets, becs de bord d'attaque, surfaces déployées, plaque plane, surface portante, à grande échelle, A300, B737, A319, UPS, Southwest Airlines, Air Canada, type I, type II, type III, type IV, direction de la circulation au sol, roulement durant la circulation au sol, soufflerie.

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

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

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

21. Déclassification (date)

22. Nombre de pages
xxii, 138 ann.

23. Prix
—

CDT/TDC 79-005
Rev. 96

EXECUTIVE SUMMARY

Holdover times (HOT) for winter weather operations have been successfully used for years based on research and development using a 10 degree (10°) flat plate as a representative simulation of an aircraft wing. Aircraft surfaces using the 10° flat plate for determination of fluid HOT have been agreed upon by both industry and authorities and supported through technical standards by SAE International; this approach has been shown to work effectively. There are now a number of airline operators that deploy flaps and slats prior to the application of de/anti-icing fluids. Deploying the flaps and slats generates angles greater than 10° for those respective surfaces. These greater surface angles increase the precipitation catch factor of a surface and can cause the fluid to flow-off more readily which can potentially cause reductions in HOT.

Under contract to Transportation Development Centre (TDC), APS Aviation Inc. (APS) undertook a test program to evaluate de/anti-icing fluid endurance times on aircraft flaps and slats.

For the winter of 2010-11 both the Federal Aviation Administration (FAA) and Transport Canada provided guidance to operators for de/anti-icing with deployed flaps based on observations during testing conducted in the National Resource Council of Canada (NRC) Propulsion and Icing Wind Tunnel (PIWT) during the winter of 2009-10. It was observed that anti-icing fluid applied to a wing with deployed flaps can quickly flow-off, resulting in a reduced fluid thickness layer, and consequently shortened fluid endurance times. FAA mitigation strategies were initiated to compensate for that more rapid flow-off including a 50 percent HOT reduction if slats and flaps were deployed prior to anti-icing, to go into to effect in the winter of 2011-2012. Due to a lack of data to quantify actual endurance times on wings with deployed flaps, industry representatives requested that further testing be conducted to evaluate and potentially revise guidance material. The representatives expressed concern with how the issue would affect different wing configurations, risks associated with keeping flaps retracted until just prior to takeoff, and the 50 percent HOT reductions indicated by the FAA guidelines. Upon review of these issues, the FAA withdrew the 50 percent reduction strategy, and agreed to conduct further research with TC to better understand the effects of deploying flaps and slats. For the winter of 2011-12, the FAA issued changes to its guidance. The mitigation strategies were removed and replaced with more general guidance information along with a statement indicating that research was still continuing.

During the winter of 2010-11, standard aluminum test plates were used for comparative testing outdoors during natural snow conditions, and indoors in simulated freezing precipitation conditions. The plates were arranged so as to simulate: a simple/slotted flap (disconnection between main element and flap

surfaces), a nested/fowler flap (fluid feeding from wing to flap), and an extended slat (disconnection between main element and slat surfaces). The results of this work indicated potential reductions in holdover times for extended slat configurations as well as for simple/slotted flaps, the reduction increasing with respect to the angle of the surface simulating the flap or slat. The results were presented at the Berlin SAE International G-12 meeting in 2011, and the ensuing discussion included recommendations that full-scale validation using transport aircraft of the procedures and results be obtained. United Parcel Service (UPS) and Southwest Airlines (SWA) also expressed interest in supporting and participating in the full-scale testing initiatives.

During the winter of 2011-12, full-scale fluid endurance time comparison testing was conducted using the UPS A300 aircraft wing (including all surfaces such as flaps and slats) versus plates angled at 20º and 35º versus a standard 10º plate simulating both nested and simple flap and slat configurations. The goal of the research was full-scale evaluation of the flat plate results in collaboration with UPS and SWA. Due to a lack of suitable testing weather, the full complement of tests was not completed and the testing was set to continue during the winter of 2012-13. Consequently, no changes were made to the guidance material for the winter of 2012-13.

During the winter of 2012-13, further research was conducted with the goal of acquiring more data for full-scale evaluation of the flat plate results in collaboration with UPS and SWA. Due to limited winter testing opportunities, there were still outstanding full-scale tests to be completed at the end of the winter. Testing was scheduled to continue during the winter 2013-14, and in addition, testing with flat plate models was planned to simulate the effects of rotating the aircraft during taxi. Again, no changes were made to the guidance material issued during the winter of 2011-12.

During the winter of 2013-14 the full-scale tests were not completed due to lack of winter testing opportunities. However, new testing was conducted to simulate aircraft orientation with respect to the wind during taxi from the deicing bay to the runway. This testing was done with static 10º and 20º plates oriented at 0º, 90º, and 180º with respect to the wind, and also following a methodology using dynamic rotating of test plates with respect to the wind. The results indicated that adjusting for taxi orientation extended the 20º plate protection time, but the results were variable based on orientation direction sequence and ratios of time allotted in each direction.

For the winter of 2014-15, TC made no changes to its guidance material, however the FAA published additional holdover time and allowance time tables which included 10 percent reductions in the times in the standard holdover and allowance time tables. Additional testing with a full-scale wing model was recommended by TC/FAA and supported by industry representatives in order to develop a more thorough data base for evaluation.

During the winter of 2014-15 testing was planned with the UPS aircraft at Montreal-Mirabel International Airport (YMX), but was not accomplished due to limited opportunities. Complementary testing simulating aircraft orientation during taxi was accomplished with two airfoil models - a simple (single-element) airfoil and an airfoil retrofitted by SWA with flaps and slats - in natural and artificial conditions. In addition, flat plate research was continued to expand existing data sets, in order to provide greater substantiation for analysis and results using that data. No changes were made to the guidance material. Testing was planned to continue for 2015-16 according to the same methodologies.

The key objective of the 2015-16 work was to complete the outstanding tests planned with the UPS aircraft in YMX. Air Canada also offered access to an Airbus A319 to increase the testing windows of opportunity. One full-scale testing event was conducted with Air Canada. During the test event, the expected snowfall came mostly in the form of ice pellets. Nonetheless, airfoil testing was continued during the winter to further solidify the data set with more focus on the airfoil with the flaps and slats.

Test Results

The full-scale data has shown a correlation with Type IV fluid between the inclined plates and the wing surfaces. In the extended configuration, the wing as a whole demonstrated earlier fluid failure as compared to the 10º plate; the shorter endurance times of the 20º simple plate better represented the expected fluid protection on the wings with extended flaps and slats.

The flat plate data collected also showed a difference in the expected endurance time reductions on the extended flaps and slats when using Type I versus Type IV fluids. The Type I fluids were less susceptible to reductions in endurance times when tested on higher incline angles as compared to the Type IV, however this observation was not clearly demonstrated because of the limited Type I full-scale data collected.

Testing simulating aircraft rotation during taxi to the runway has indicated that adjusting for taxi orientation extends the fluid protection time. These results have been demonstrated on flat plates as well as with airfoil models. These results have been highly variable based on the type of taxi simulated and how much time is spent in the head, cross, or tail-wind orientations; the longer time spent in headwind orientation, the greater the decrease in fluid protection time.

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SOMMAIRE

Depuis de nombreuses années, des durées d'efficacité (HOT) sont utilisées avec succès pour les opérations hivernales, en fonction de recherche et développement utilisant une plaque plane de 10 degrés (10°) pour simuler une aile d'aéronef. L'utilisation de plaques planes de 10° pour établir les durées d'efficacité des liquides sur les surfaces d'aéronefs a reçu l'accord de l'industrie et des autorités et est appuyée par les normes techniques de SAE International. Cette approche s'est avérée efficace. À l'heure actuelle, un certain nombre d'exploitants de sociétés aériennes déploient les volets et les becs de bord d'attaque avant d'appliquer les liquides de dégivrage et d'antigivrage. Le déploiement des volets et des becs de bord d'attaque donne des angles supérieurs à 10° à ces surfaces respectives. Les angles plus marqués de ces surfaces augmentent le facteur de saisie des précipitations sur la surface et peuvent causer l'écoulement du liquide plus facilement et, en conséquence, une réduction possible des durées d'efficacité.

En vertu d'un contrat du Centre de développement des transports (TDC), APS Aviation Inc. (APS) a entrepris un programme d'essais pour évaluer les temps d'endurance des liquides de dégivrage et d'antigivrage sur les volets et les becs de bord d'attaque des aéronefs.

Pour l'hiver 2010-2011, la Federal Aviation Administration (FAA) et Transports Canada ont transmis aux exploitants des lignes directrices sur le dégivrage et l'antigivrage lorsque les volets sont déployés, en fonction d'observations lors d'essais menés à la soufflerie à propulsion à boucle ouverte et de givrage (SPBOG) du Conseil national de recherches du Canada (CNRC) durant l'hiver 2009-2010. On a alors pu observer que le liquide antigivrage appliqué sur une aile dont les volets sont déployés peut s'écouler rapidement, ce qui réduit l'épaisseur de la couche de liquide et, en conséquence, réduit les temps d'endurance du liquide. Des stratégies d'atténuation de la FAA, à mettre en vigueur à l'hiver 2011-2012, y compris une réduction de 50 pour cent des durées d'efficacité lorsque les becs de bord d'attaque et les volets étaient déployés avant l'antigivrage, ont été mises en place pour compenser pour cet écoulement plus rapide. En raison du manque de données pour mesurer les temps réels d'endurance sur les ailes dont les volets sont déployés, des représentants de l'industrie ont demandé la tenue d'essais additionnels pour évaluer et possiblement réviser les lignes directrices. Les représentants ont fait part d'inquiétudes au sujet des effets du problème sur les divers profils d'ailes, sur les risques associés au maintien des volets rentrés jusqu'avant le décollage et sur la réduction de 50 pour cent des durées d'efficacité spécifiée par les lignes directrices de la FAA. Après son examen de la question, la FAA a retiré la stratégie de réduction de 50 pour cent et a convenu de poursuivre les recherches avec TC pour mieux comprendre l'incidence du déploiement des volets et des becs de bord d'attaque. Pour l'hiver 2011-12, la

FAA a émis des changements à ses lignes directrices. Les stratégies d'atténuation ont été retirées et remplacées par de l'orientation de nature plus générale, accompagnée d'une déclaration à l'effet que les recherches se poursuivaient.

Durant l'hiver 2010-11, des plaques d'essai standard en aluminum ont servi à des essais comparatifs à l'extérieur dans des conditions de neige naturelle et, à l'intérieur, dans des conditions de précipitations verglaçantes simulées. Les plaques étaient disposées pour simuler : un volet à fente unique (déconnexion entre l'élément principal et les surfaces des volets), un volet Fowler encastré (le liquide s'écoule de l'aile au volet) et un volet déployé (déconnexion entre l'élément principal et les surfaces des volets). Les résultats de ces travaux ont indiqué des réductions possibles de durée d'efficacité dans des configurations de volets déployés et de volet à fente unique, la réduction augmentant avec l'angle de la surface simulant le volet ou le bec de bord d'attaque. Les résultats ont été présentés à la réunion G-12 de la SAE International à Berlin en 2011, et la discussion qui a suivi recommandait une validation intégrale avec des aéronefs de transport et la diffusion des résultats. Les sociétés United Parcel Service (UPS) et Southwest Airlines (SWA) ont également manifesté leur intérêt à appuyer et à participer aux projets d'essais complets.

Durant l'hiver 2011-2012, des essais comparatifs à grande échelle sur le temps d'endurance des liquides ont été menés, sur l'aile d'un A300 d'UPS (y compris sur toutes les surfaces, telles que les volets et les becs de bord d'attaque) comparativement à des plaques à des angles de 20º, de même que sur des plaques d'un angle de 35º comparativement à la norme de 10º, en simulant des configurations de volets et de becs de bord d'attaque encastrés et à fente unique. La recherche avait pour but de faire une évaluation intégrale des résultats sur plaque plane, avec la collaboration d'UPS et de SWA. En raison de l'absence de conditions météorologiques favorables aux essais, tous les essais n'ont pu être complétés et leur suite a été programmée pour l'hiver 2012-13. En conséquence, aucun changement n'a été apporté aux lignes directrices pour l'hiver 2012-13.

Durant l'hiver 2012-2013, des recherches supplémentaires ont été effectuées en collaboration avec UPS et SWA, dans le but d'obtenir davantage de données pour une évaluation complète des résultats sur plaque plane. En raison des opportunités limitées au cours de l'hiver, plusieurs essais à grande échelle restaient toujours à compléter à la fin de l'hiver. La suite des essais a été programmée pour l'hiver 2013-14 et, de plus, des modèles d'essais sur plaque plane ont été prévus, pour simuler le roulement des aéronefs durant la circulation au sol. Encore une fois, aucun changement n'a été apporté aux lignes directrices émises à l'hiver 2011-12.

Durant l'hiver 2013-2014 les essais à grande échelle n'ont pu être complétés en raison du manque d'opportunités d'essais hivernaux. Cependant, de nouveaux essais ont été effectués pour simuler la direction de l'aéronef par rapport au vent, durant la circulation entre la baie de dégivrage et la piste. Ces essais ont été menés avec des plaques statiques de 10º et de 20º, orientées 0º, 90º et 180º par rapport au vent, ainsi qu'avec une méthodologie de rotation dynamique des plaques d'essais par rapport au vent. Les résultats ont démontré que le réglage de la direction de la circulation prolonge le temps de protection de la plaque de 20º, mais les résultats variaient selon la séquence des changements de direction et les ratios de temps dans chaque direction.

Pour l'hiver 2014-2015, TC n'a apporté aucun changement à ses lignes directrices, mais la FAA a publié des tableaux additionnels de durées d'efficacité et de marges de tolérance qui comprenaient des réductions de 10 pour cent dans les durées d'efficacité et les marges de tolérance normales. Des essais additionnels avec un modèle d'aile grandeur nature ont été recommandés par TC et la FAA et appuyés par les représentants de l'industrie, afin d'élaborer une base de données plus complète à des fins d'évaluation.

Durant l'hiver 2014-15, des essais étaient prévus avec un aéronef d'UPS à l'Aéroport international de Montréal-Mirabel (YMX), mais n'ont pas eu lieu en raison d'opportunités limitées. Des essais supplémentaires simulant la direction d'aéronefs durant la circulation au sol ont été effectués, dans des condition naturelles et artificielles, avec deux modèles de surface portante – une surface simple (un seul élément) et une surface réaménagée par SWA avec des volets et des becs de bord d'attaque, dans des condition naturelles et artificielles. De plus, les recherches avec des plaques planes se sont poursuivies pour accroître les banques de données et fournir une meilleure corroboration pour utiliser les analyses et les résultats. Aucun changement n'a été apporté aux lignes directrices. La poursuite des essais en 2015-2016 était prévue, avec les mêmes méthodologies.

L'objectif principal des travaux de 2015-2016 était de terminer les essais en cours avec l'aéronef d'UPS à YMX. Air Canada a également offert un Airbus A319 afin d'augmenter les opportunités d'essais. Un essai à grande échelle a été tenu avec Air Canada. Au cours de cette activité, les chutes de neige prévues se sont surtout matérialisées sous forme de granules de glace. Néanmoins, des essais sur surfaces portantes se sont poursuivis durant l'hiver, afin de consolider davantage la banque de données, avec davantage d'emphase sur les surfaces dotées de volets et de becs de bord d'attaque.

Résultats des essais

L'ensemble des données a démontré une corrélation entre les liquides de Type IV appliqués sur des plaques inclinées et sur la surface des ailes. Dans la configuration déployée, l'ensemble de l'aile a affiché une perte plus rapide d'efficacité du liquide, comparativement à la plaque de 10º; les temps d'endurance plus courts de la plaque simple de 20º représentaient davantage la protection du liquide sur des ailes dont les volets et les becs de bord d'attaque étaient déployés.

Les données accumulées sur les plaques planes ont également démontré une différence dans la réduction du temps d'endurance prévu sur les volets et les becs de bord d'attaque déployés, lorsqu'on utilise des liquides de Type I plutôt que de Type IV. Les liquides de Type I étaient moins sujets à des réductions de temps d'endurance lorsque appliqués à des angles plus grands d'inclinaison, comparativement aux liquides de Type IV. Cette observation n'a cependant pas été clairement démontrée, car la collecte des données à grande échelle sur les liquides de Type I était limitée.

Les essais simulant le roulement d'aéronefs durant la circulation au sol vers la piste ont indiqué que l'ajustement de la direction prolonge la période de protection du liquide. Ces résultats ont été démontrés sur des plaques planes et sur des modèles de surfaces portantes. Ces résultats se sont avérés très variables, en fonction du type de circulation au sol simulée et du temps consacré à chacune des directions, soit face au vent, vent de travers ou vent arrière. Plus la circulation face au vent était longue, plus le temps de protection était réduit.

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GLOSSARY

APS	APS Aviation Inc.
CEF	Climatic Engineering Facility (NRC)
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
LOWV	Lowest On-Wing Viscosity
MSC	Meteorological Service of Canada
NRC	National Research Council Canada
OAT	Outside Air Temperature
PET	Pierre Elliott Trudeau International Airport (Montreal-Trudeau)
PIWT	Propulsion and Icing Wind Tunnel
ROGIDS	Remote On-Ground Ice Detection System
SWA	Southwest Airlines
TC	Transport Canada
TDC	Transportation Development Centre
UPS	United Parcel Service
YMX	Montréal-Mirabel International Airport

1. INTRODUCTION

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

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

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

1.1 Background

Aircraft surfaces are well represented by the 10º flat plate for determination of fluid holdover times (HOT). However, flaps and slats in the deployed position can generate angles greater than 10º. These greater surface angles increase the precipitation catch factor of a surface and can cause the fluid to flow-off more readily causing a potential for reductions to HOTs.

Early preliminary work was conducted during the winter of 1997-1998, and is documented in the TC report, TP 13318E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1997/98 Winter* (1). The series of tests were conducted at the NRC's Climatic Engineering Facility (CEF) in Ottawa to determine the effect of plate slope variation on the holdover time of Type IV fluids.

Standard holdover time tests with test surfaces set at a 10° slope were compared to test surfaces with increased slopes, mainly at 11° and 12°. It was noted that these very small increments in plate slope had a significant effect on the holdover time of a given fluid. When tests were performed on plates with an increase of 1° or 2° in plate inclination from the standard 10º plate, for every 1° increase in slope resulting holdover times could be decreased over the standard tests by as much as 10 percent.

During the winter of 2009-10, testing was conducted in the NRC PIWT with a thin high performance wing configured with a hinged flap set to 20º. Testing results, primarily with mixed ice pellet conditions, indicated early failure on the flap in deployed position compared to the rest of the wing. The flap was observed to fail faster than the main wing section, with a failure time 40 percent less than the main wing. The results also showed that a contaminated flap could cause a significant degradation in aerodynamic performance; aerodynamic performance improved when the hinged flap was up (retracted) during the contamination period (see TC Interim report, *Wind Tunnel Research to Support the Development of Ice Pellet Allowance Time Tables Winter 2009-10*) (2).

For the winter of 2010-11 both the FAA and Transport Canada provided guidance to operators for de/anti-icing with deployed flaps based on observations during testing conducted in the NRC Wind Tunnel during the winter of 2009-10. As an option, Transport Canada recommended delaying slat/flap deployment until just prior to takeoff, or deploying the devices prior to de/anti-icing so that the surfaces under these devices are treated. With the second option, the holdover time would be reduced due to the steeper angles of the slat/flap in the deployed configuration. The FAA recommended the following mitigation strategy options to be implemented no later than October 1, 2011:

- Delay flap extension to just before takeoff;
- Reduce published HOTs by 50 percent; or
- Conduct a pre-takeoff inspection if more than 50 percent of the holdover time (HOT) has elapsed.

Anti-icing fluid applied to a wing with deployed flaps can quickly flow-off, resulting in a reduced fluid thickness layer, and consequently shortened fluid endurance times. Due to a lack of data to quantify actual endurance times on wings with deployed flaps, industry representatives requested that further testing be conducted to evaluate and potentially revise guidance material. The industry representatives expressed concern with how the issue would affect different wing configurations, risks associated with keeping flaps retracted until just prior to takeoff, and the 50 percent HOT reductions indicated by FAA guidelines.

It was recommended by industry representatives and supported by TC and FAA that flat plate testing be conducted to support the previous research and to investigate the effect of different representative angles for flaps and slats, and different configurations (i.e. nested/fowler flap vs. simple or slotted flap) on fluid endurance times.

During the winter of 2010-11, standard aluminum test plates were used for comparative testing outdoors during natural snow conditions, and indoors in simulated freezing precipitation conditions. Angles of the plates were increased to simulate different flap and slat configurations. Angles of 20° and 35° were selected based on typical flap and slat settings used at takeoff, this data were determined based on reference diagrams and information obtained from Airbus, TC, FAA, US Airways, and NRC. The plates were arranged so as to simulate: a simple/slotted flap (disconnection between main element and flap surfaces), a nested/fowler flap (fluid feeding from wing to flap), and an extended slat (disconnection between main element and slat surfaces). The results of this work indicated potential reductions in holdover times for extended slat configurations as well as for simple/slotted flaps; this reduction increased with respect to the angle of the surface simulating the flap or slat.

The results were presented at the Berlin SAE International G-12 meeting in 2011, and the ensuing discussion included recommendations that full-scale validation using transport aircraft of the procedures and results be obtained. UPS and Southwest Airlines (SWA) also expressed interest in supporting and participating in the full-scale testing initiatives.

For the winter of 2011-12 the FAA issued changes to their guidance. The mitigation strategies were removed and replaced with more general guidance information along with a statement indicating that research work was still continuing. TC only issued a small editorial change to the guidance material previously published.

During the winter of 2011-12, full-scale fluid endurance time comparison testing was conducted using the UPS A300 aircraft wing (including all surfaces such as flaps and slats) versus plates angled at 20° and 35° versus a standard 10° plate simulating both nested and simple flap and slat configurations. The goal of the research was full-scale evaluation of the flat plate results in collaboration and cooperation with UPS and SWA. Due to a lack of suitable testing weather, the full complement of tests was not completed and the testing was set to continue during the winter of 2012-13. Consequently, no major changes were made to the guidance material previously published.

During the winter of 2012-13, further research was conducted with the goal of acquiring more data for full-scale evaluation of the flat plate results, also in collaboration and cooperation with UPS and SWA. Due to limited testing opportunities, there were still outstanding full-scale tests to be completed at the end of the winter. Testing was scheduled to continue during the winter 2013-14, and in addition, testing with flat plate models was planned to simulate the effects of rotating the aircraft during taxi. Again, no changes were made to the guidance material originally issued during the winter of 2011-12.

During the winter of 2013-14 again, the full-scale tests were not completed due to lack of winter testing opportunities. However, new testing was conducted to simulate aircraft orientation with respect to the wind during taxi from the deicing bay to the runway This testing was done with static 10º and 20º plates oriented at 0º, 90º, and 180º with respect to the wind, and also following a methodology using dynamic rotating of test plates with respect to the wind. The results indicated that adjusting for taxi orientation extended the 20º plate protection time, but varied with orientation direction sequence and ratios of allotted direction times. For the winter of 2014-15, TC made no changes to its guidance material, however, the FAA published additional holdover time and allowance time tables which included 10 percent reductions in the times in the standard holdover and allowance time tables. Additional testing with a full-scale wing model was recommended by TC/FAA and supported by industry representatives in order to develop a more thorough data base for evaluation

During the winter of 2014-15 testing was planned with UPS aircraft at Montreal Mirabel International Airport (YMX), but was not accomplished due to limited opportunities. However, complementary testing simulating aircraft orientation during taxi was accomplished with two airfoil models - a simple (single-element) airfoil and an airfoil retrofitted by SWA with flaps and slats - in natural and artificial conditions. In addition, flat plate research was continued to expand existing data sets, in order to provide greater substantiation to analysis and results using that data. No changes were made to the guidance material. Testing was planned to continue for 2015-16 according to the same methodologies.

The key objective of the 2015-16 work was to complete the outstanding tests planned with the UPS aircraft in YMX. Air Canada also offered access to their Airbus A319 to increase the testing windows of opportunity. One full-scale testing event was conducted with Air Canada. During the test event, the expected snowfall came mostly in the form of ice pellets. Airfoil testing was continued during the winter to further solidify the data set with more focus on the airfoil with the flaps and slats. TC issued changes to their guidance to be in line with FAA, however further discussion and likely additional testing are expected to continue into 2016-17.

1.2 Objective

The objective of this multi-year project has been to investigate the effect of different representative flap and slat configurations on de/anti-icing fluid endurance times. This has been achieved by observing the failure propagation on flat plates mounted at 10°, 20º, and 35º in both simple and nested configurations, on airfoil models with and without flap and slat devices, and by correlating the results to the failure observed on full-scale aircraft wing surfaces (flaps, slats, and main wing) configured to representative takeoff positions.

As a secondary objective, a comparison of fluid failure on the main wing versus the horizontal stabilizer was undertaken.

For the winter of 2015-16, the sections of the TDC work statement pertaining to the work described in this report are provided in Appendix A.

1.3 Report Format

The following list provides short descriptions of the main sections of this report:

a) Section 2 provides a description of the methodology used to carry out the tests;
b) Section 3 provides the 2010-11 to 2015-16 testing data logs;
c) Section 4 summarizes the flat plate testing results;
d) Section 5 summarizes the full-scale aircraft testing results;
e) Section 6 summarizes the taxi orientation testing with test plates and airfoils; and
f) Section 7 presents the conclusions.

Note: the results and analysis of the 2010-11 to 2015-16 testing have been included in this report, therefore this report is a stand-alone report of the work conducted to date. Previous interim versions of this report should be disregarded as this report is now contains all relevant and current information. Additional testing was also conducted as part of a separate contract with Southwest Airlines (SWA), the details of which have been included in a separate report issued to SWA *"Test Report: Full-Scale Evaluation of Fluid Failure On Extended Flaps and Slats – August 2013".* For analysis purposes, some final values from this testing have been included as part of this report.

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2. METHODOLOGY

This section describes the overall approach, test parameters and experimental procedures followed during the 2010-11 to 2015-16 projects.

APS measurement instruments and test equipment are calibrated and verified on an annual basis. This calibration is carried out according to a calibration plan derived from approved ISO 9001:2008 standards, and developed internally by APS.

2.1 Test Facilities

The following sections describe the different testing facilities used to conduct the various tests.

2.1.1 APS Montreal P.E.T. Airport Test Site

Fluid endurance time testing during natural snow conditions was conducted by APS personnel at the APS test site (Photo 2.1 and Photo 2.2) located at the Pierre Elliott Trudeau International Airport (P.E,T, Montreal-Trudeau) in Montreal. The location of the test site is shown on the plan view of the airport in Figure 2.1.

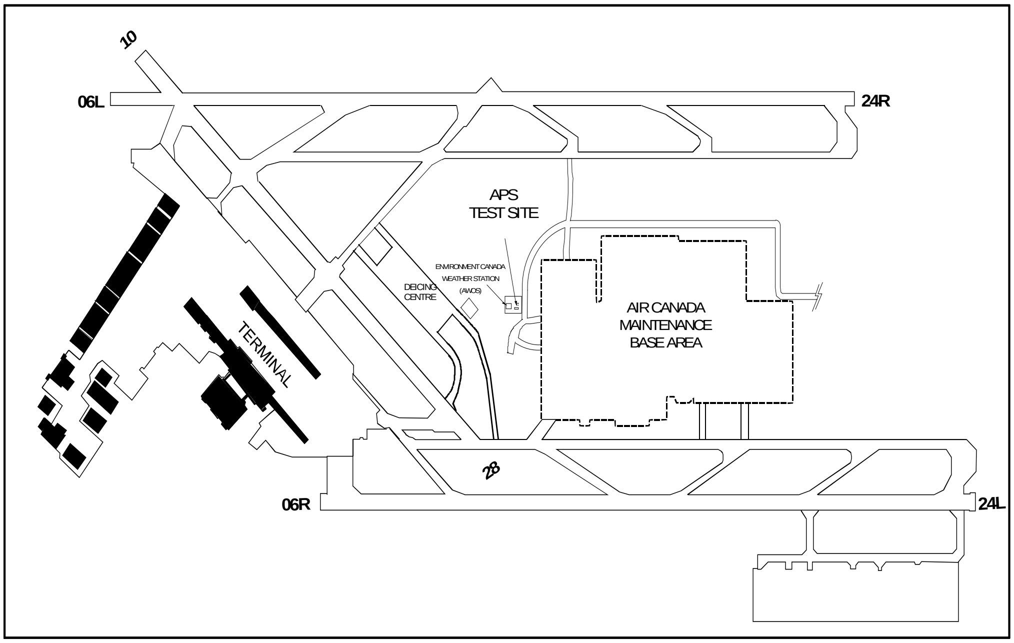


Figure 2.1 Plan View of APS Montreal-Trudeau Airport Test Site

2.1.2 NRC Climatic Engineering Facility

To obtain the necessary fluid endurance time data for the freezing precipitation conditions, testing was carried out by APS personnel at the NRC CEF (Photo 2.3) using a sprayer assembly (Photo 2.4) to simulate the required freezing precipitation conditions. Figure 2.2 provides a schematic of the NRC Uplands campus showing the location of the U-88/U-89 facility.

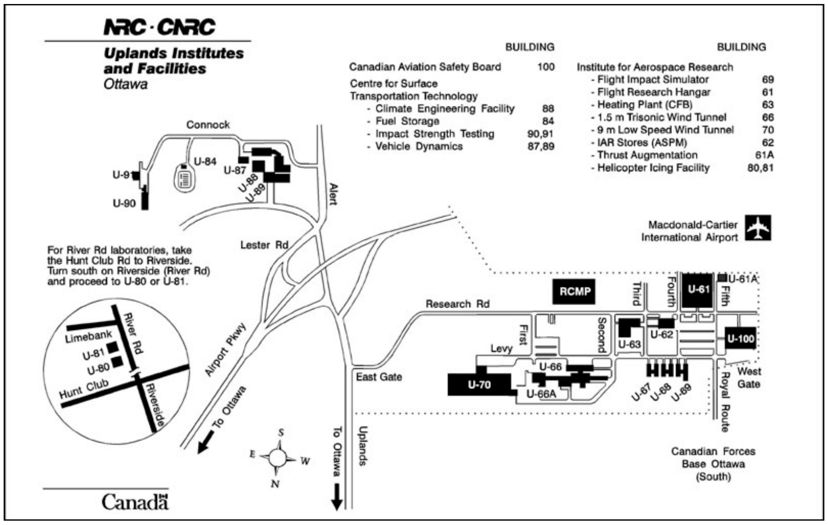


Figure 2.2: Schematic of NRC Uplands Campus

2.1.3 UPS YMX Gateway Test Site

Full-scale aircraft testing was conducted during natural snow conditions at the UPS YMX Gateway (Photo 2.5) located at the Montreal-Mirabel International Airport in Mirabel, Quebec. Testing was conducted by APS personnel with the support of UPS and Aéromag 2000. The location of the test site is shown on the plan view of the airport in Figure 2.3.

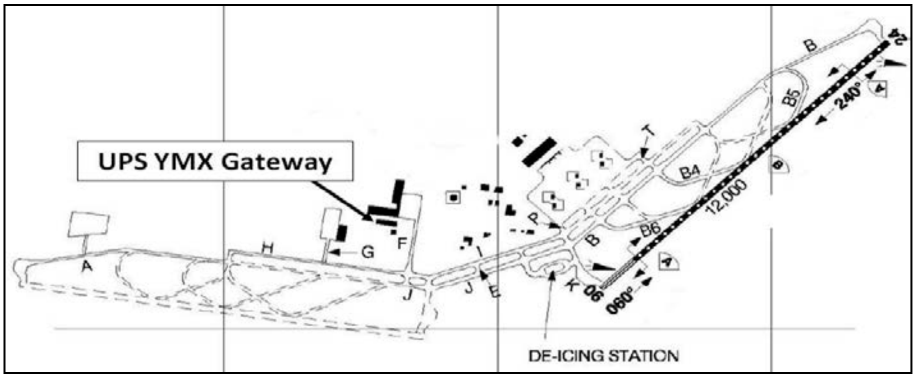


Figure 2.3: Plan View of UPS YMX Gateway Test Site

2.1.4 Air Canada YUL Aéromag 2000 Deicing Center Test Site

Full-scale testing with an Air Canada aircraft was conducted during natural snow conditions at the Aéromag 2000 Deicing center (Photo 2.5) located at the P.E.T. International Airport in Montreal, Quebec. Testing was conducted by APS personnel with the support of Air Canada and Aéromag 2000. The location of the test site is shown on the plan view of the airport in Figure 2.4.

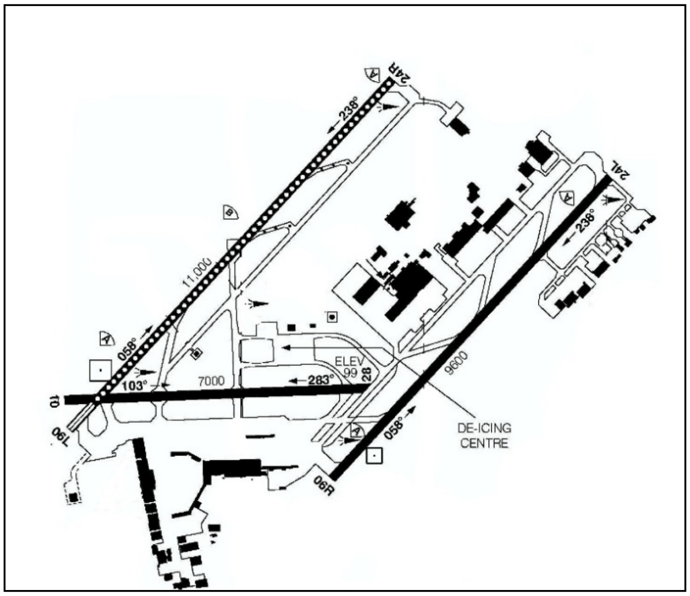


Figure 2.4: Plan View YUL Aéromag 2000 Deicing Center Test Site

2.2 Details on Flaps and Slats Configurations

The following sections provide information on flaps and slats configurations and how they apply to the test methods.

2.2.1 Information Obtained from Industry Consultations

In order to develop a flat plate testing protocol representative of common carrier aircraft, APS contacted airframe manufacturers to obtain information regarding flap and slat configurations during takeoff. Due to the confidential nature of the information acquired, the actual emails and documents have not been included in this report, but they are summarized below. Based on schematic drawings provided by and conversations with the airframe manufacturers, the following general conclusions were reached and were used as the basis of the testing.

Flaps

- Aircraft flap angle is referenced with the bottom surface of the flap with respect to the normal;
- The top surface of the flap can have an increase in angle between 10-20 degrees with respect to the bottom of the flap i.e. a flap set to an angle of 20° will result in a slope of 30-40° on the top surface of the flap;
- Typical aircraft configuration settings during takeoff will result in flap angles of 15-40°;
- A simple flap (no overlap from main body of wing) will not have fluid feeding i.e. no extra fluid will flow over the surface;
- A nested flap will have fluid feeding from the main body of the wing on the flap. The gap distance of the overlap could be approximately 4 cm;
- Some operators deploy flaps immediately after de/anti-icing; and
- Figure 2.5 shows the two schematics of flap configurations used as the basis for the test methodology.

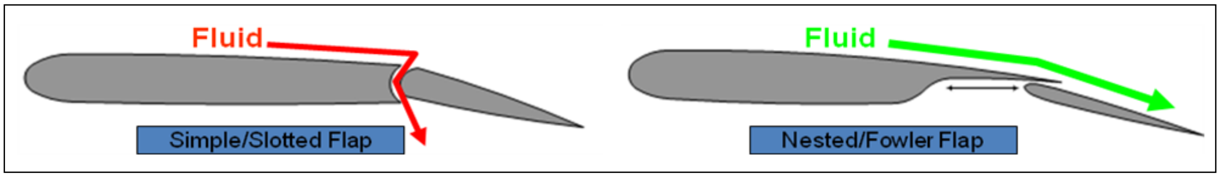


Figure 2.5: Simplified Flap Configurations

Slats

- Slats are typically deployed in conjunction with the flaps; by default, deploying flaps results in deploying slats;
- A deployed slat results in a physical disconnect between the main wing body and the top of the slat. This disconnect will allow fluid flowing from the main wing to pass underneath the slat, resulting in no fluid feeding to the slat;
- Slats are curved surfaces, therefore determining a representative angle using flat plates is difficult, however the aft half of the slat is typically flatter. In a deployed configuration, this top aft half portion could see angles of 20-40°;
- The gap between the slat and the main body of the wing could be up to 0.15 cm for lower slat settings, and up to 2 cm for higher slat settings; and
- Figure 2.6 shows a typical slat in extended and retracted configurations.

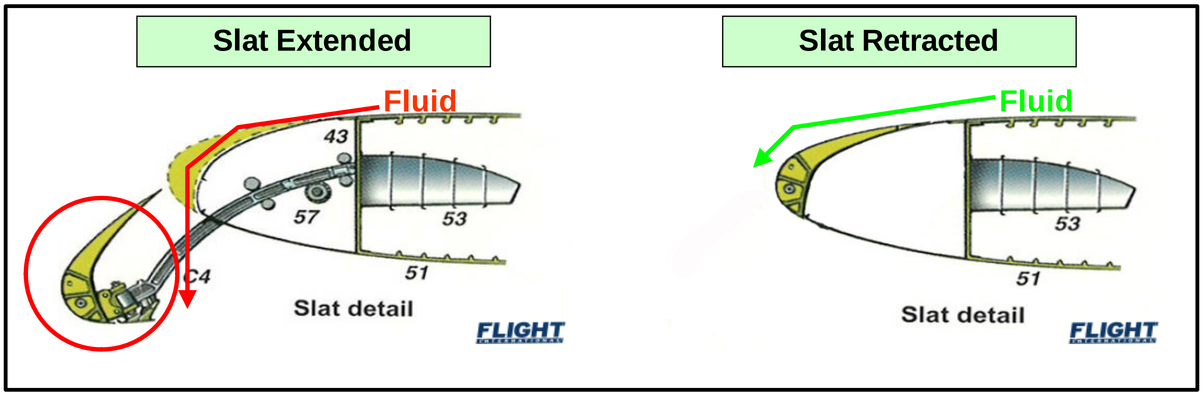


Figure 2.6: Slat Configurations

Based on this information, the 20° and 35° plates in simple and nested configuration were selected as generic models able to represent a wide range of aircraft and takeoff configurations.

2.2.2 Flap and Slat Angle Data Recorded During Full-Scale Tests

For the UPS, Air Canada, and SWA tests, the aircraft designated for full-scale testing was configured for testing purposes at the start of the testing day. The actual angles of the flap and slat surfaces in the designated test section were measured using an inclinometer; the typical measurement locations are shown in Figure 2.7. A summary of the data actually collected is shown in Table 2.1.

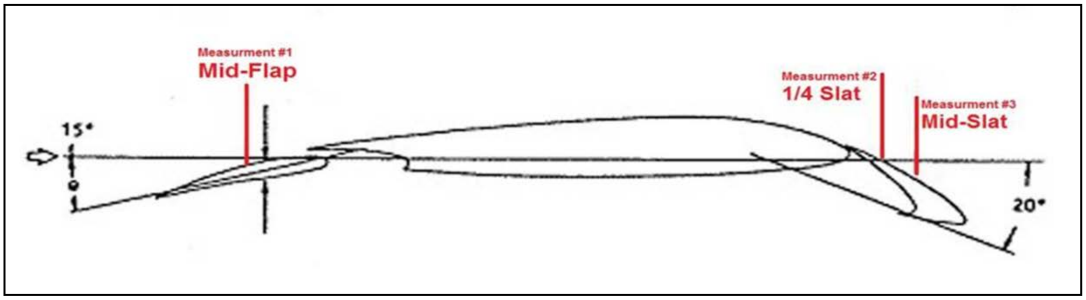


Figure 2.7: Flap and Slat Top Surface Angle Measurements

Table 2.1: Summary of Flap and Slat Angle Data Recorded During Full-Scale Tests

Run #	Fluid / Orientation	Aircraft	Flap/Slat Setting	Measured Mid Flap Angle (°)	Measured Mid Slat Angle (°)
SWA 1	TIV / Head Wind	B737	Flap 5	18 / 32 (multi-element)	24
SWA 2	TIV / Head Wind	B737	Flap 5	18 / 32 (multi-element)	24
2	TIV / Head Wind	A300	15/20	21	22
3	TIV / Head Wind	A300	15/20	21	22
4	TIV / Head Wind	A300	15/20	22	20
5*	TI / Head Wind	A300	15/20	22	20
6	TI / Tail Wind	A300	15/20	21	22
7*	TIV / Tail Wind	A300	15/20	21	22
8	TIV / Tail Wind	A300	15/20	21	22
9	TI / Tail Wind	A300	15/20	21	22
10	TIV / Tail Wind	A319	1+F 18/10	24	27
11	TIV / Tail Wind	A319	1+F 18/10	24	27
SWA 1	TIV / Head Wind	B737	RETRACTED	14	7
SWA 2	TIV / Head Wind	B737	RETRACTED	14	7

2.2.3 Early Fluid Failure on Extended Versus Retracted Flaps and Slats

A diagram illustrating the early fluid failure phenomenon is provided in Figure 2.8. The retracted configuration demonstrates normal fluid coverage over the entire wing since there is no disconnect in the top surface. The extended configuration demonstrates that while there is normal coverage on the main wing element, the extended flap exhibits accelerated fluid flow-off due to the increased angle that is somewhat offset by the fluid feeding or dripping off from the main wing element. On the extended slat, the accelerated fluid flow-off is caused by the increased angle, however due to the disconnect of the surfaces and lack of overlap from the main wing, there is no fluid feeding or dripping to offset this accelerated fluid flow-off. These differences lead to earlier fluid failure on the extended configuration as compared to the retracted configuration.

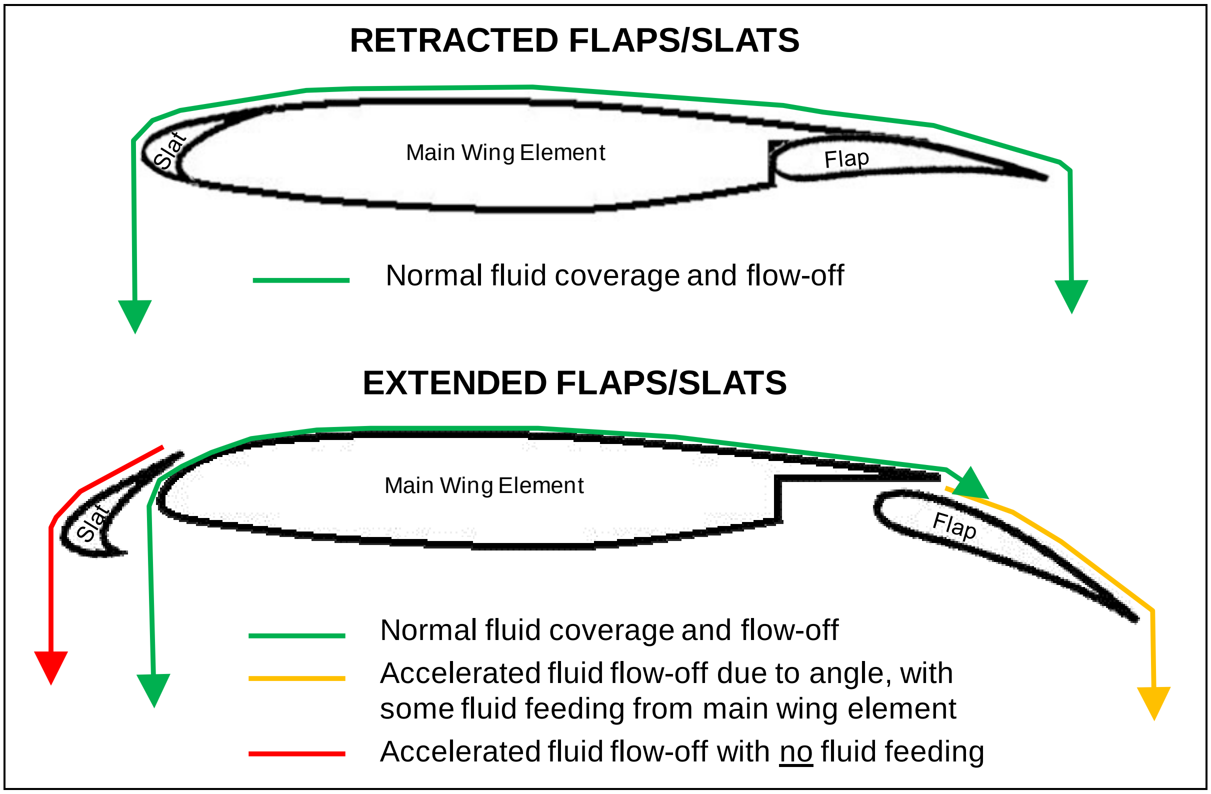


Figure 2.8: Early Fluid Failure on Flaps and Slats Diagram

2.3 Test Methodology

The test methodologies used to conduct the various flap and slat tests are summarized in the following sections; details can be found in in the appendices. The methodologies are separated into six sections based on individual objectives:

- Natural Snow Flat Plate Testing Setup;
- Indoor Freezing Precipitation Flat Plate Testing Setup;
- Natural Snow Testing of Rotating Flat Plates Setup (Taxi Orientation Testing);
- Airfoil Testing Setup (Taxi Orientation Testing);
- UPS YMX Full-Scale Aircraft Testing Setup; and
- Air Canada YUL Full-Scale Aircraft Testing Setup.

2.3.1 Natural Snow Flat Plate Testing Setup

A total of seven standard aluminum test plates were used for this testing. The baseline plate was positioned at 10° (in some cases a duplicate test was also conducted and the average of the results was used to provide a more robust baseline), two plates simulating slats or simple hinged flaps were positioned at

20° and 35°, and four plates simulating nested flaps were positioned at 20° and 35° with an overlapping 10° plate. Tests were conducted in natural snow conditions using standard holdover time testing procedures.

Figure 2.9 and Photo 2.6 demonstrate the test setup. It should be noted that in some cases, the overlapping 10° plates were used as the baseline plates in order to streamline testing. The detailed test procedure used for these tests during the 2010-11 to 2015-16 winters can be found in Appendix B.

In the winter of 2013-14, an additional 15° plate was added to the setup.

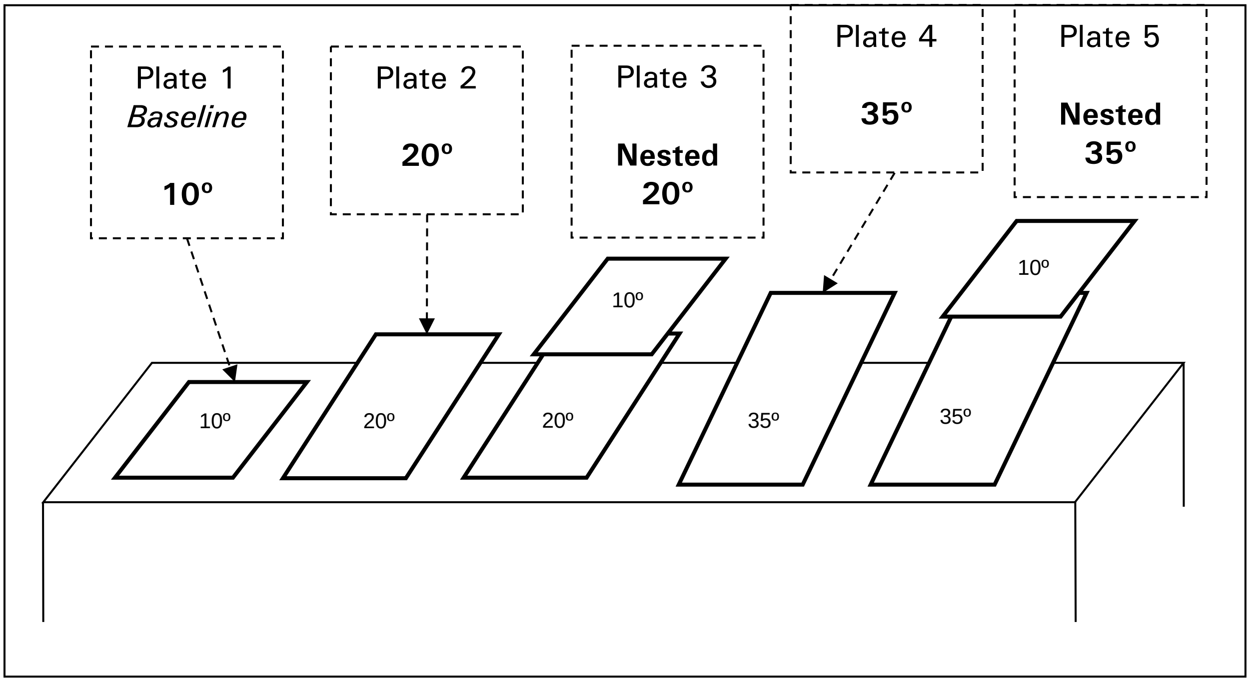


Figure 2.9: Outdoor Flat Plate Test Set Up

2.3.2 Indoor Freezing Precipitation Flat Plate Testing Setup

Testing with nested and non-nested plates indicated that non-nested (simple) plates have greater reduction in holdover times; therefore, the nested plates were of lower priority for the indoor testing starting in 2012-13. Each comparative test included a baseline plate inclined to a 10° slope and two non-nested plates simulating slats or simple hinged flaps inclined to a 20° and 35° slope. Figure 2.10 and Photo 2.7 demonstrate the test setup (previous 2010-11 testing with nested and non-nested plates used a setup similar to Figure 2.9). Tests were conducted in freezing drizzle and freezing fog using standard holdover time testing procedures. The detailed test procedures used for the indoor tests can be found in Appendix C; the procedure was relatively unchanged for 2013-14 onwards.

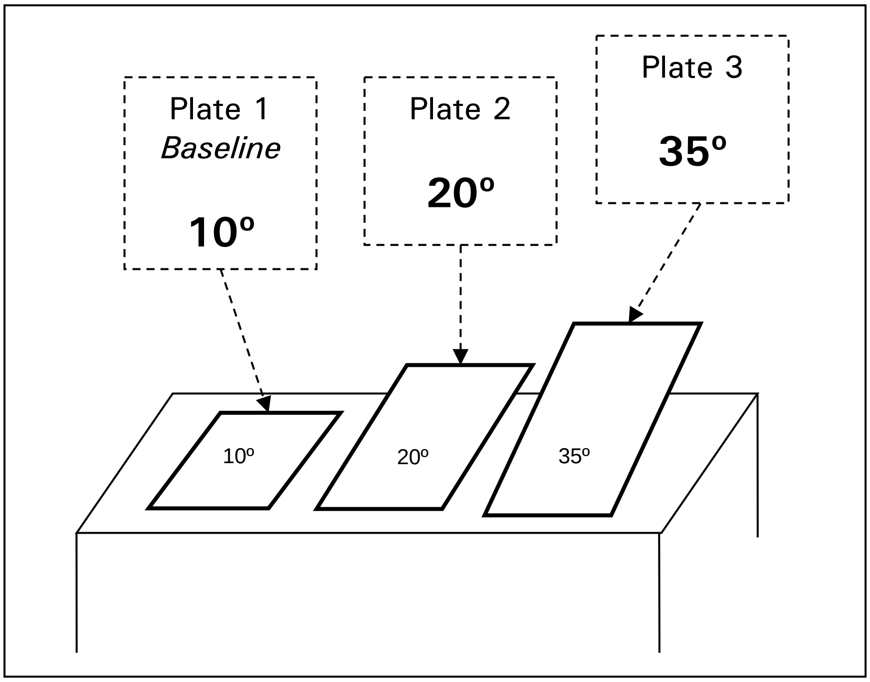


Figure 2.10: Indoor Simulated Freezing Precipitation Testing Setup

2.3.3 Natural Snow Testing of Rotating Flat Plates Setup (Taxi Orientation Testing)

Discussions with industry representatives have indicated that the changing aircraft direction relative to the wind direction during taxi could result in an increase to the protection time of deployed slats and flaps, as they may be shielded from the wind during a segment of the taxi. This shielding is only a factor for deployed slats and flaps; it is not a factor for retracted slats or flaps due to the increased angle of the surface which results in a higher catch factor. This effect is not significant on retracted surfaces with shallower angles. It was suggested that this shielding could help compensate for otherwise reduced protection times when operating with deployed flaps and slats. To investigate effect of wind direction, static cross-wind, and tail 10º and 20º plates with a rate pan were added to the head wind setup; a 20º simple plate provided the best representation of aircraft data with flaps/slats extended and the 10º plate provided a baseline reference to the HOT's. An additional set of dynamic rotating 10º and 20º plates with a rate pan were included to the setup.

The first setup consisted of a rotating stand that was manually turned. The stand was rotated at pre-determined angles and intervals throughout the test. The timing of rotation was established from past research and data collected by Southwest Airlines. A rate measurement was also incorporated into this stand, which rotated accordingly. Figure 2.11 depicts this setup.

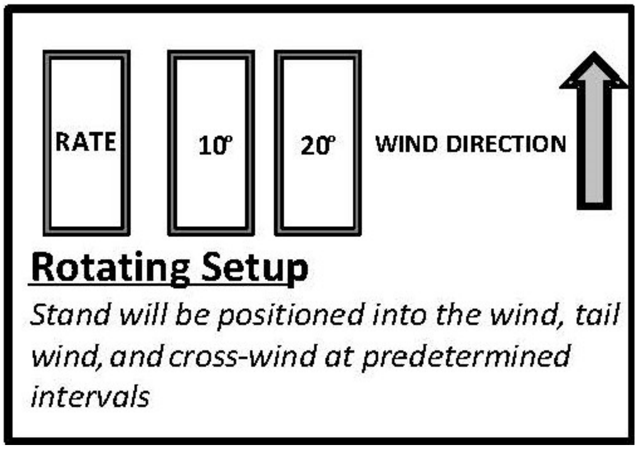


Figure 2.11: Rotating Setup

The static setup consisted of a cross formation design that involved three stands. Test stands were placed in a cross formation allowing simultaneous testing of headwind (0º to the wind), crosswind (90º to the wind) and tailwind (180º to the wind). Each stand had associated rate measurements. Figure 2.12 depicts this setup. Photo 2.8 shows the setup including both the rotating setup and the cross formation setup. Details of these procedures are included in Appendix B.

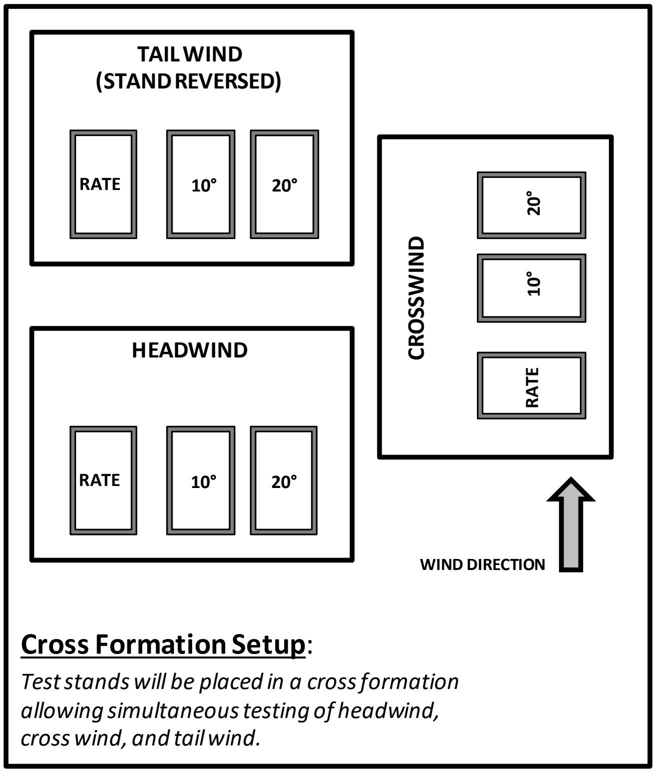


Figure 2.12: Cross Formation Setup

2.3.4 Airfoil Testing Setup (Taxi Orientation Testing)

TC currently owns two Fokker F28 (F28) airfoil models. One of these models was retrofitted by Southwest Airlines in 2014-15 to have a slat and flaps modeled after the Boeing 737; the second F28 model was left un-modified (referred to as the simple airfoil). The airfoils were able to rotate during testing to simulate an aircraft taxi. During testing, the timing of the rotation was selected to best represent an aircraft taxiing from the deicing bay to the runway; the rotation profiles used were based on actual aircraft data collected by Southwest Airlines. Photo 2.12 and Figure 2.13 demonstrates the setup used. Photo 2.9 and Photo 2.10 show the outdoor and indoor testing setups.

As testing progressed and results showed consistent trends, the setup was minimized to include the 10º and 20º head wind plates along with the airfoil with flaps and slats only.

Details of these procedures are included in Appendix B. Some limited testing was also conducted in simulated freezing precipitation conditions and the details of these procedures are included in Appendix C.

2.3.5 UPS YMX Full-Scale Aircraft Testing Setup

During each natural snow test the A300 aircraft was oriented with the nose into the wind for head wind tests or with the tail into the wind for tail wind tests and the flaps and slats were set to the highest takeoff configuration (this was specific to the test objectives). The flat plates (10º, 20º, and 35º) and test stand were positioned into the wind as per the flat plate test procedure. A two-step fluid application was performed on the aircraft wing test section (the middle 1/3 section of wing as shown in Photo 2.11) using) using Type I (XL54) followed by Type IV (EG 106 Neat). Simultaneously with the application of the Type IV fluid to the wing section, the same sample of Type IV (EG 106 Neat) from the deicing truck was manually poured from containers and applied onto plates The same outdoor plate testing setup described in Subsection 2.3.1 was also used for this testing. The pattern of fluid failure on the wing and plates was monitored, recorded, and compared. Figure 2.14 demonstrates the test setup for a head wind orientation. The detailed test procedure used for these tests can be found in Appendix D.

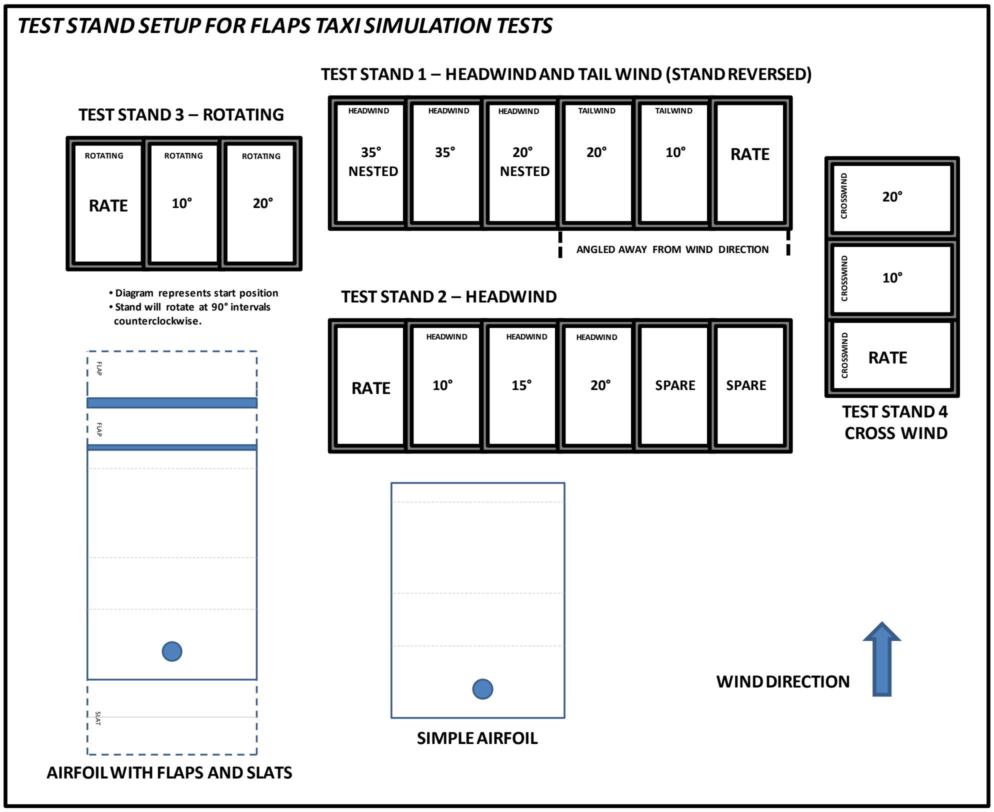


Figure 2.13: Airfoil Testing Setup

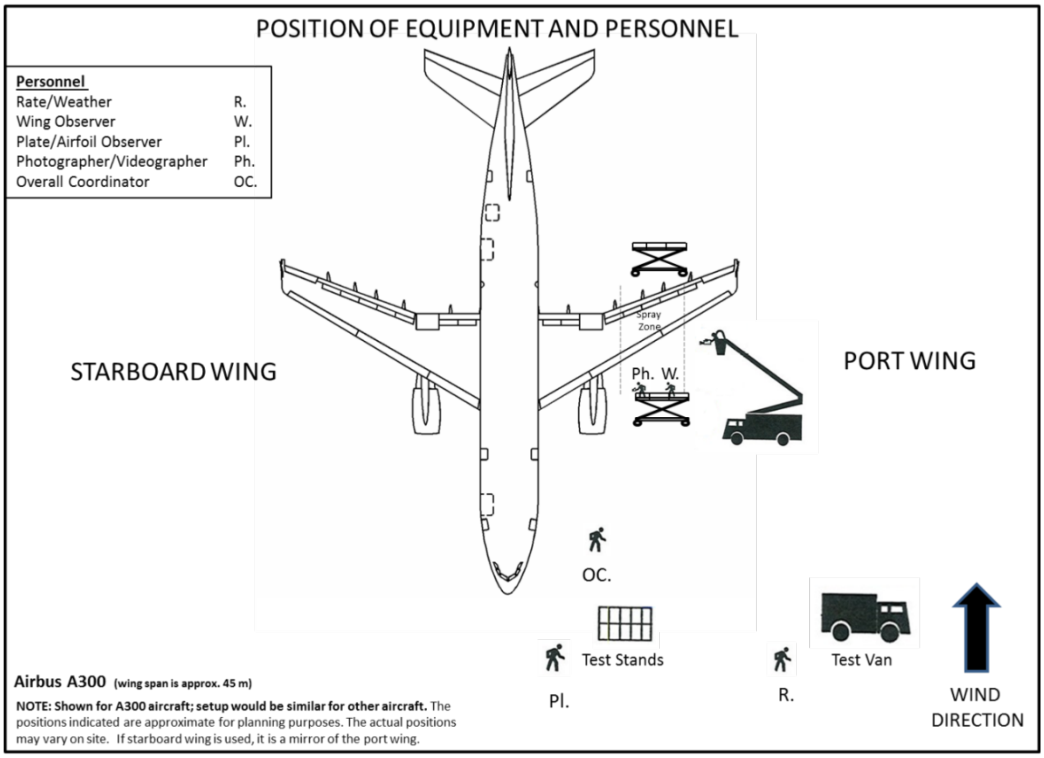


Figure 2.14: UPS YMX Full-Scale Testing Setup

2.3.6 Air Canada YUL Full-Scale Aircraft Testing Setup

During one natural snow test the A319 aircraft was oriented with the tail into the wind and the flaps and slats were set to the typical takeoff configuration. The flat plates (10º, 20º, and 35º) and test stand were positioned into the wind as per the flat plate test procedure. A two-step fluid application was performed on the aircraft full wing test section using Type I (XL54) followed by Type IV (EG 106 Neat). Simultaneously with the application of the Type IV fluid to the wing section, the same sample of Type IV (EG 106 Neat) from the deicing truck was manually poured from containers and applied onto plates The same outdoor plate testing setup described in Subsection 2.3.1 was also used for this testing. The pattern of fluid failure on the wing and plates was monitored, recorded, and compared. Figure 2.15 demonstrates the test setup for a head wind orientation. The detailed test procedure used for these tests can be found in Appendix D.

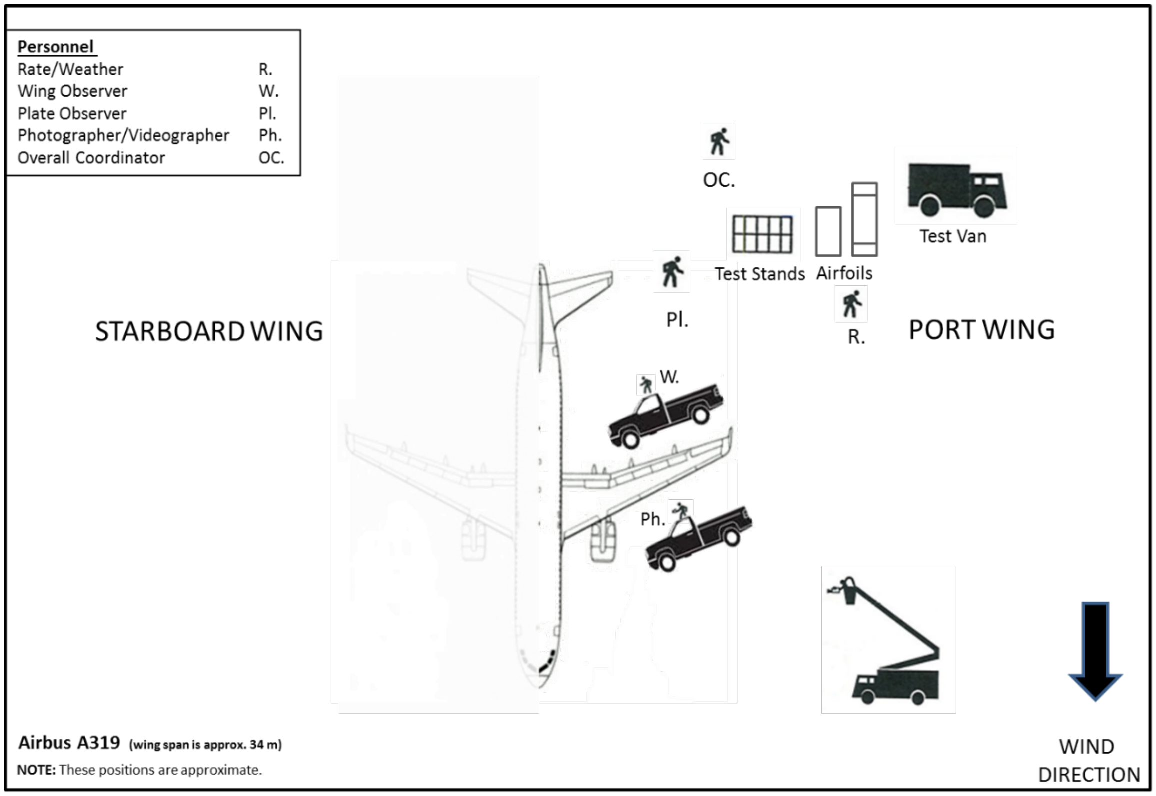


Figure 2.15: Air Canada YUL Full-Scale Testing Setup

2.4 Adjustment of Endurance Times to Compensate for Variation in Precipitation Rates

During natural snow conditions, the precipitation rate will fluctuate over the course of a test. When conducting comparative tests, it is necessary to adjust the measured endurance times to compensate for variations in precipitation rates. This is done by adjusting the measured endurance time for each test by a linear ratio determined by the average rate of precipitation measured over course of each individual test as compared to the average rate during the baseline test. The endurance times were adjusted based on a linear relationship in the following formula:

$$\text{Adjusted Endurance Time} = \text{Actual Endurance Time} \times \frac{\text{Rate of Precip}}{\text{Avg Rate of Precip of Baseline Test(s)}}$$

An example of this calculation is shown in Table 2.2.

Table 2.2: Example of Normalization of Endurance Times to Compensate for Variation in Precipitation Rates

TEST #	SURFACE	Start Time (Local)	Fail Time (Local)	ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	ADJUSTED ENDURANCE TIME CALCULATION	ADJUSTED ENDURANCE TIME (MIN)
Baseline 1	10° (Baseline)	1:15:00	3:09:15	114.3	19.1	=19.1/19.1x114.3	114.3
2	20° Simple	1:16:00	1:48:00	32.0	26.0	=26.0/19.1x32.0	43.6
3	35° Simple	1:17:00	1:33:20	16.3	25.7	=25.7/19.1x16.3	22.0
4	Slatted Airfoil	1:17:45	2:41:30	83.8	17.4	=17.4/19.1x83.8	76.3
5	A-319	1:14:30	1:55:00	40.5	24.1	=24.1/19.1x40.5	51.1

2.5 Data Forms

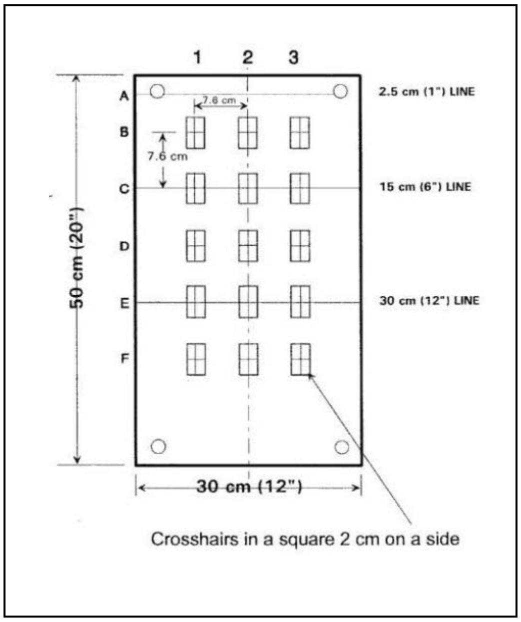
The data forms used for the various test objectives are provided for the respective procedures described in Appendices B, C, and D.

2.6 Equipment

The test equipment for standard HOT testing was used to conduct the flap and slat evaluation and are described for the respective procedures in Appendices B, C, and D. The following subsections briefly describe some of the equipment used.

2.6.1 Test Plate Surfaces

Flat plate endurance time testing was conducted using standard aluminum test plates. These test plates were positioned in different configurations using specially manufactured aluminum stands to achieve the desired angles. A schematic of a test plate is shown in Figure 2.16.



Crosshairs in a square 2 cm on a side

Figure 2.16: Schematic of Standard Holdover Time Test Plate

2.6.2 Fokker F28 Airfoil

TC currently owns two F28 airfoil models. One of these models was retrofitted by Southwest Airlines in 2014-15 to have a slat and flaps modelled after the Boeing 737; the second F28 model was left un-modified (referred to as the simple airfoil). The airfoils were able to be rotated during testing to simulate an aircraft taxi. The modified airfoil measured 2.8 meters (9 feet 2 inches) length, 0.8 meters (2 feet 8 inches) width, and the leading gap size was 0.2 mm (0.007 inches). Photo 2.12 shows the progress of the Southwest Airlines modification to the airfoil.

2.6.3 UPS A300 Aircraft

The aircraft used for testing was an Airbus A300, wide-body jet, operated by UPS. At the time of conducting the tests, the aircraft was configured for cargo operations and was in active service. A three-view diagram of the A300 aircraft has been included in Figure 2.17. The wing span is 45 m (147 ft.) and the overall length is 54 m (177 ft.). The A300 aircraft is fitted with both leading edge and trailing edge moveable devices.

2.6.4 Air Canada A319 Aircraft

The aircraft used for testing was an Airbus A319, narrow-body jet, operated by Air Canada. At the time of conducting the tests, the aircraft was configured for passenger operations and was in active service. A three-view diagram of the A320 aircraft has been included in Figure 2.18; the A319 is a shortened version of this aircraft. The wing span is 34 m (112 ft.) and the overall length is 34 m (112 ft.). The A319 aircraft is fitted with both leading edge and trailing edge moveable devices.

2.6.5 Wet Film Thickness Gauge

Wet film fluid thickness measurements were recorded during endurance time tests. Figure 2.19 shows the schematic of the wet film thickness gauges.

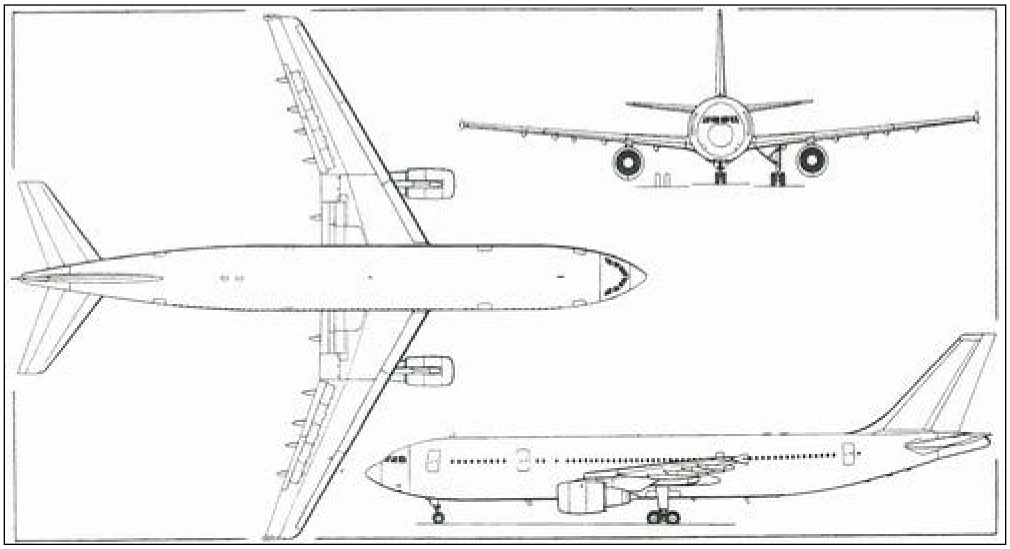


Figure 2.17: Schematic of A300 Aircraft

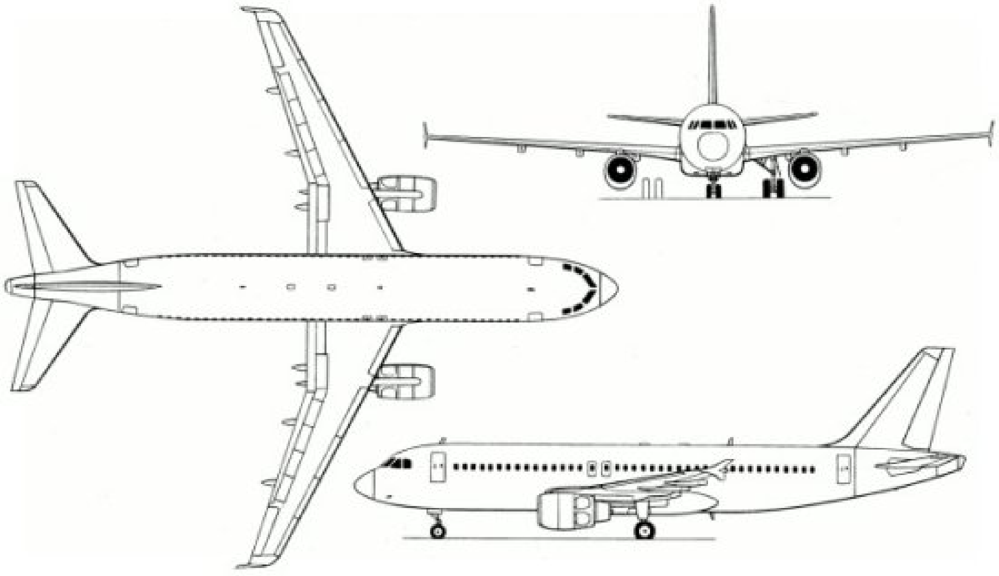
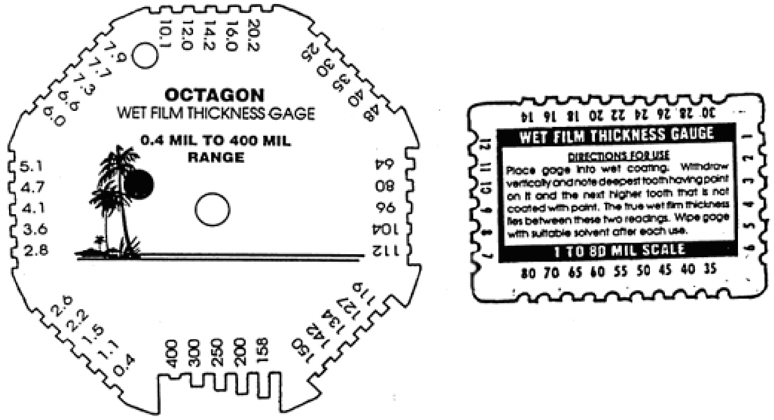


Figure 2.18: Schematic of A320 Aircraft (A319 is shortened version of A320)



DIRECTIONS FOR USE

Place gage into wet coating. Withdraw vertically and note deepest tooth having paint on it and the next higher tooth that is not coated with paint. The true wet film thickness lies between these two readings. Wipe gage with suitable solvent after each use.

Figure 2.19: Wet Film Thickness Gauges

2.6.6 Brixometer

Brix measurements provided data relevant to the fluid concentration; measuring Brix monitors fluid dilution. Figure 2.20 shows the schematic of a hand-held Brixometer which measures refractive index.

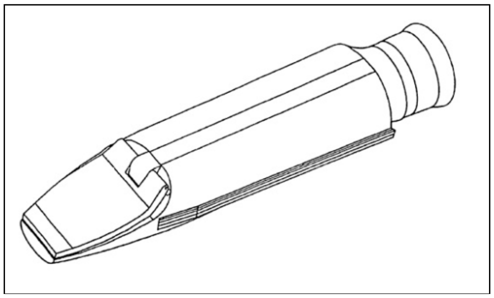


Figure 2.20: Hand-Held Brixometer

2.6.7 ROGIDS Camera Systems

Arrangements were made during the winter of 2012-13 with a manufacturer of a remote on-ground ice detection system (ROGIDS) to test the system in conjunction with the flaps/slats full-scale testing, however this testing was not completed as the manufacturer was not available during the testing events. This testing was to be supported by TC/FAA and through the cooperation of UPS and SWA and would aim at collecting full-scale operational test data to further support the development of ROGIDS technology.

2.7 Video and Photo Equipment

Canon Digital Rebel XTi still cameras were used to obtain high-resolution photographs of the testing. The cameras were fitted with a 24-105 mm lens to allow both wide angle and zoom capabilities, as well as an 18-55 mm lens which is a more general purpose lens.

In addition, some short HD videos were taken with a GoPro Hero video camera. The GoPro Hero video camera is encased in a heavy duty plastic housing which is waterproof and shockproof and is ideal for working in outdoor conditions.

Select photos with descriptions have been included in Appendix E with captions describing general setup and methodology. A full set of low resolution thumbnail photos has been included in a tile mosaic form in Appendix F for reference purpose. Higher resolution photos are available on the APS server and can be made available upon request.

2.8 Fluids

Various commercial and research fluids were used for flat plate testing. Commercial fluids were typically in the mid-production range viscosity whereas research fluid was typically closer to the LOWV. Fluids used were for comparative testing as indicated in Section 3 in the individual test logs, and therefore, the individual fluid performance was not relevant to this research.

For the full-scale UPS (YMX) and Air Canada (YUL) testing, fluid was provided by Aéromag 2000 and was mid-production range viscosity. A summary of the viscosity measurements of the samples taken is provided in Table 2.3.

The viscosity of the fluids used for airfoil testing is included in the log (see Table 3.3).

Table 2.3: Summary of YMX Full-Scale Dow UCAR EG106 100/0 Fluid Sample Viscosities

Date	Sample Origin	Viscosity (cP)*
24-Feb-12	Truck Tank	33,993
24-Feb-12	Sprayed Sample (into bucket)	33,393
01-Mar-12	Truck Tank	35,962
01-Mar-12	Sprayed Sample (into bucket)	33,793
19-Mar-13	Truck Tank	28,994
19-Mar-13	Sprayed Sample (into bucket)	26,394
2-Mar-16	Truck Tank	39,700
2-Mar-16	Sprayed Sample (into bucket)	38,600

*Measured using SC4-31/13R small sample adapter 10 mL 0°C 0.3 r/min 10 minutes 0 seconds.

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Photo 2.1: APS Test Site - View from Test Pad

Photo 2.2: APS Test Site - View from Trailer

Photo 2.3: Inside View of NRC Climate Engineering Facility

Photo 2.4: Sprayer Assembly Used to Produce Fine Droplets

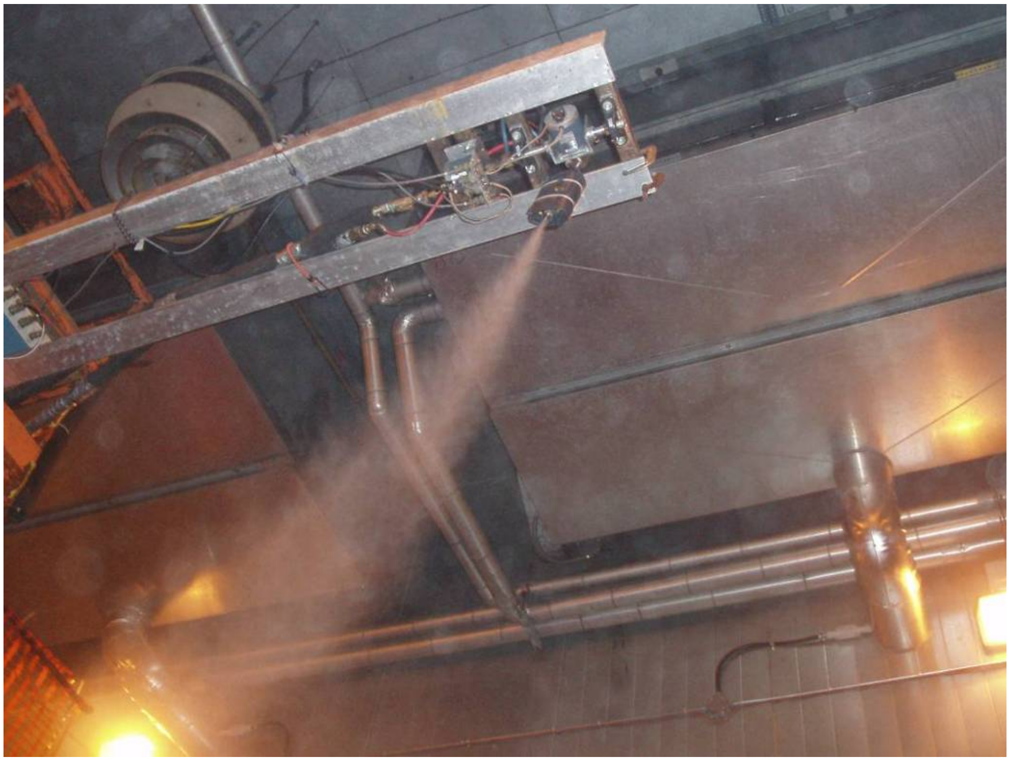


Photo 2.5: UPS YMX Gateway (View from Sorting Centre)

Photo 2.6: Natural Snow Test Setup (10° plate not shown)

Photo 2.7: Indoor Test Setup (10° plate not shown)

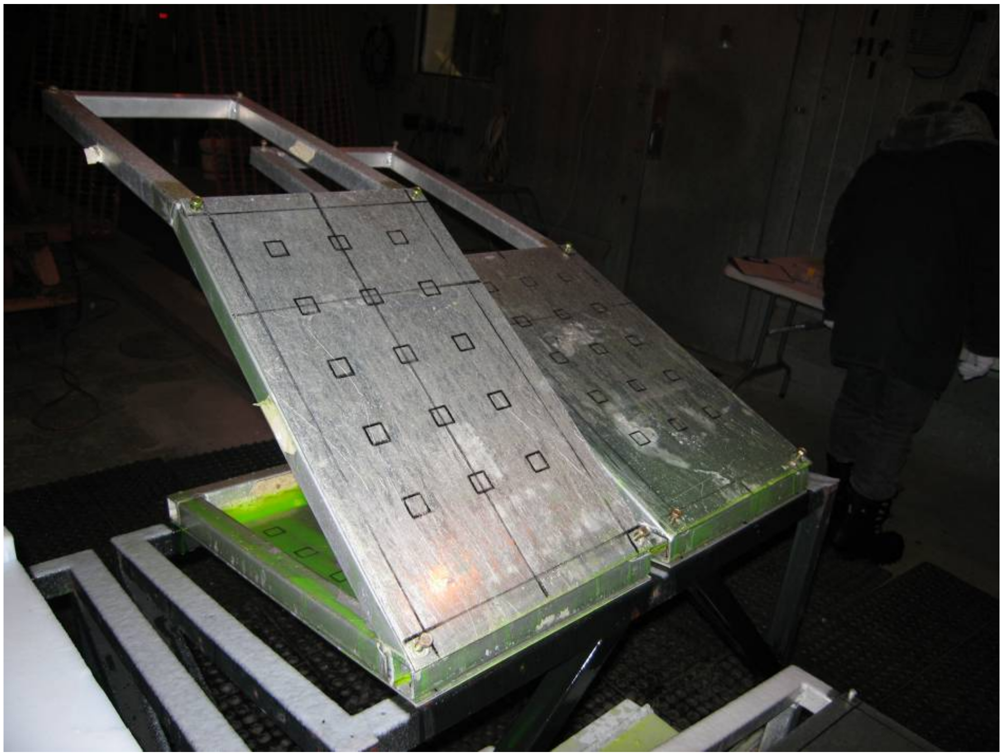


Photo 2.8: Outdoor Rotating Snow Testing Setup

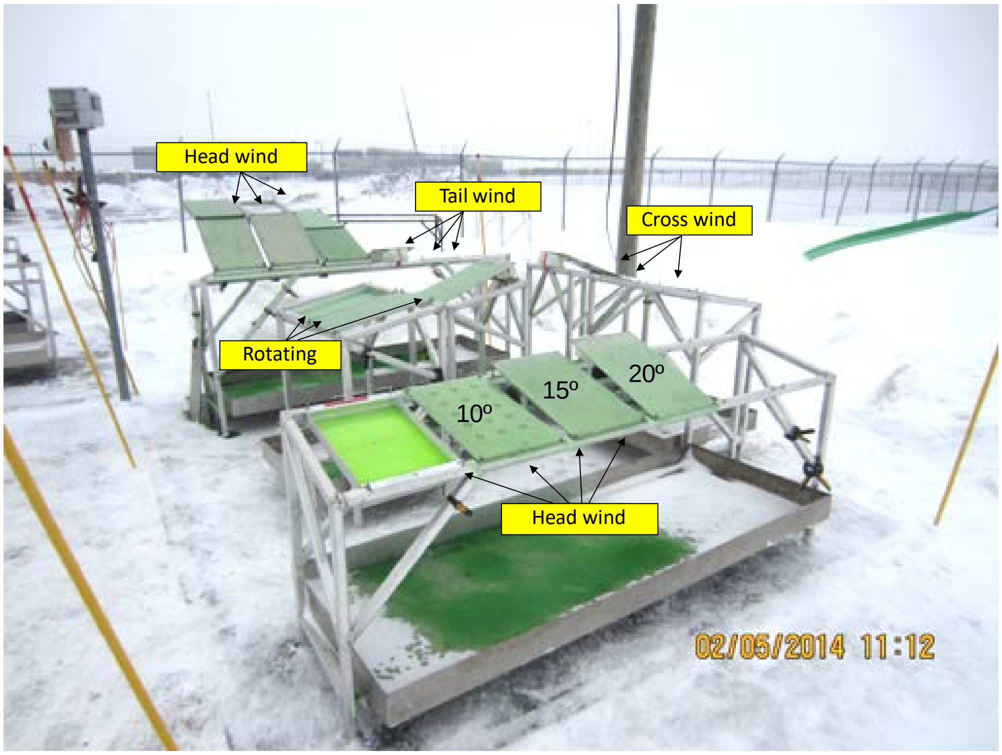


Photo 2.9: Outdoor Airfoil Testing Setup

Photo 2.10: Indoor Airfoil Testing Setup with Winglet

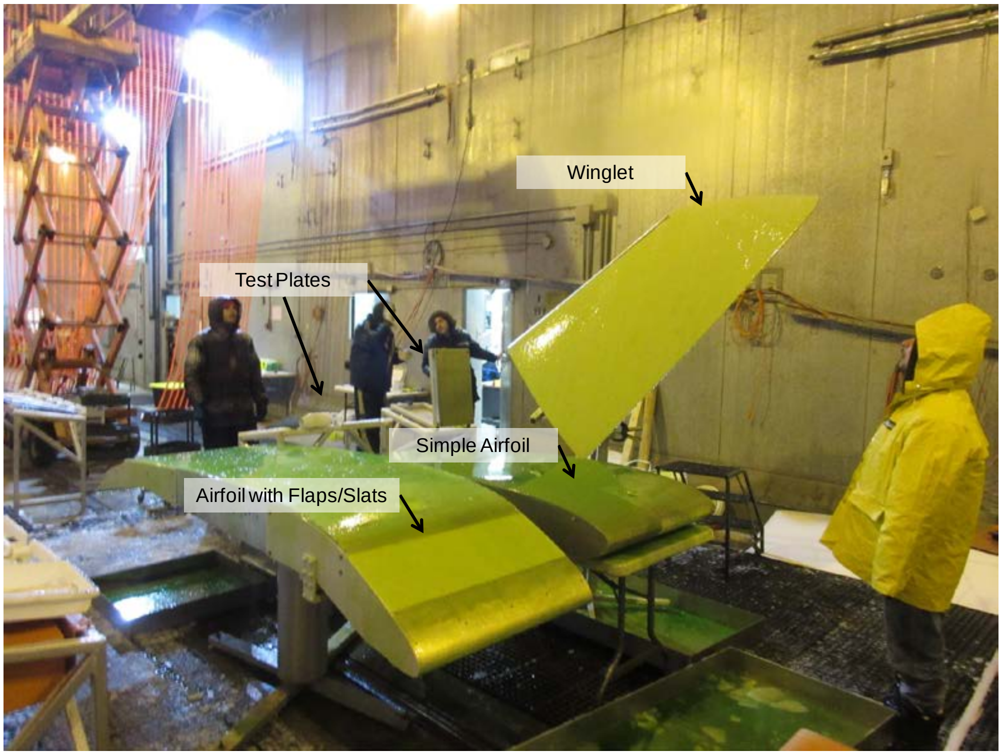
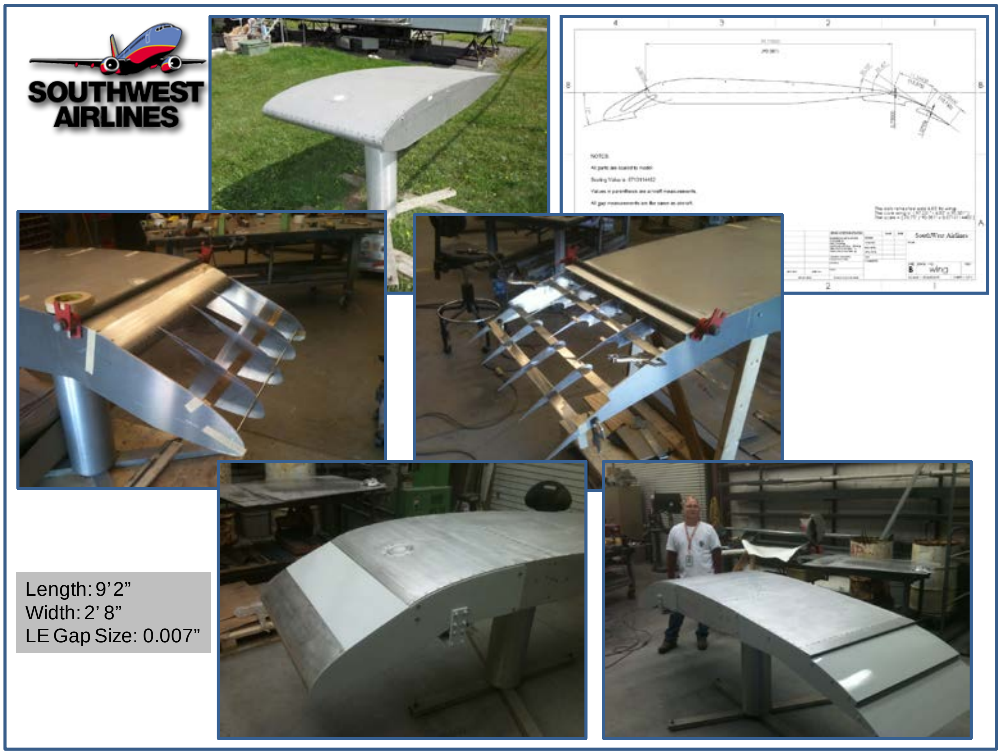


Photo 2.11: A300 Spray Area (Mid 1/3 of Wing)

Photo 2.12: Fokker F28 Airfoil Modification to Incorporate B737 Flap and Slat



Length: 9’2”
Width: 2’ 8”
LE Gap Size: 0.007”

3. TESTING DATA AND LOGS

In this section, the flat plate testing data collected during the winter of 2015-16 is presented. In addition, the flat plate data collected from 2010-11 to 2014-15 has also been included to maintain continuity in the analysis. This report contains all the data collected to date, and therefore future reports should add to this data set.

3.1 Flat Plate Testing Log

The data collected during the winters from 2010-11 to 2014-15 are presented in Table 3.1 which provide relevant information for each set of comparative flat plate tests, as well as final values used for the data analysis.

Note: The log of the full-scale aircraft tests has been included in Subsection 3.2.

During each test, the endurance times recorded were adjusted based on the rate of precipitation measured during each of the individual tests of a comparative data set; the adjustment was made to match the baseline test average rate of precipitation. The same general methodology was used for adjusting the failure times observed on the wing surfaces. Additional details on how the adjustment was made can be found in Subsection 2.4.

It should be noted that in the winter of 2013-14, an additional column, “Stand Orientation”, was included in the log specifying the plate orientation. This change resulted from natural snow testing performed to simulate taxi orientation. “Head” wind orientation tests are the standard tests with the plates oriented into the wind. The “cross” and “tail” are oriented 90º and 180º to the wind, respectively. The “rotating” designation is for tests simulating taxi from the deicing bay to the runway; the timing was established from past research and data collected by Southwest Airlines. These tests were also applicable for the airfoil tests (a duplicate, separate log of the airfoil tests has been included in Table 3.3). More details and data are also discussed in Section 4.

3.2 Full-Scale Testing Log

The log presented in Table 3.2 provides a summary of the full-scale tests conducted at YMX in conjunction with UPS during the winters of 2011-12 and 2012-13, and the full-scale tests conducted at YUL in conjunction with Air Canada during the winter of 2015-16; no testing was completed in 2013-14 or 2014-15 due to lack of appropriate weather conditions for testing. It should be noted that these tests are also included in Table 3.1; however have been repeated in Table 3.2 (along with calculated grouping averages) for ease of reference. More details and data are also discussed in Section 5.

3.3 Airfoil Testing Log

The log presented in Table 3.3 provides a summary of the airfoil tests conducted at YUL and at the NRC CEF during the winter of 2014-15. It should be noted that these tests are also included in Table 3.1; however have been repeated in Table 3.3 (along with calculated grouping averages) for ease of reference. More details and data are also discussed in Section 6.

Table 3.1: Flat Plate Testing Log for All Winters

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE ($g/dm^2/h$)	OAT (°C)
1	2010-11	13-Feb-11	SN 1	Snow	PET	IV	Dow EG106	100%	HEAD	10°	124.1	124.1	5.9	-5.6
	2010-11	13-Feb-11	SN 2	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	76.7	100.2	7.7	-5.6
	2010-11	13-Feb-11	SN 3	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	40.8	35.4	5.1	-5.6
	2010-11	13-Feb-11	SN 4	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	29.3	40.1	8.0	-5.6
2	2010-11	25-Feb-11	SN 5	Snow	PET	IV	Dow EG106	100%	HEAD	10°	127.5	127.5	10.8	-3.9
	2010-11	25-Feb-11	SN 6	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	43.0	58.4	14.7	-3.9
	2010-11	25-Feb-11	SN 7	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	56.8	41.9	8.0	-3.9
	2010-11	25-Feb-11	SN 8	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	22.2	34.1	16.7	-3.9
	2010-11	25-Feb-11	SN 9	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	23.5	26.8	12.3	-3.9
	2010-11	25-Feb-11	SN 10	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	34.3	21.9	6.9	-3.9
	2010-11	25-Feb-11	SN 11	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	24.7	22.3	9.8	-3.9
3	2010-11	25-Feb-11	SN 12	Snow	PET	IV	Launch	100%	HEAD	10°	151.1	151.1	6.0	-3.9
	2010-11	25-Feb-11	SN 13	Snow	PET	IV	Launch	100%	HEAD	20º Simple	145.6	149.0	6.2	-3.9
	2010-11	25-Feb-11	SN 14	Snow	PET	IV	Launch	100%	HEAD	35° Simple	87.0	87.4	6.1	-3.9
4	2010-11	28-Feb-11	SN 15	Snow	PET	IV	Launch	100%	HEAD	10°	94.2	94.2	17.4	0.3
	2010-11	28-Feb-11	SN 16	Snow	PET	IV	Launch	100%	HEAD	20º Simple	73.3	65.0	15.4	0.3
	2010-11	28-Feb-11	SN 17	Snow	PET	IV	Launch	100%	HEAD	35° Simple	54.5	48.2	15.4	0.3

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
5	2010-11	28-Feb-11	SN 18	Snow	PET	IV	HV1	50%	HEAD	10°	16.6	16.6	15.6	0.3
	2010-11	28-Feb-11	SN 19	Snow	PET	IV	HV1	50%	HEAD	20º Simple	6.9	8.3	18.7	0.3
	2010-11	28-Feb-11	SN 20	Snow	PET	IV	HV1	50%	HEAD	35° Simple	5.2	6.8	20.5	0.3
	2010-11	28-Feb-11	SN 21	Snow	PET	IV	HV1	50%	HEAD	35° Simple	12.2	10.3	13.2	0.3
6	2010-11	28-Feb-11	SN 22	Snow	PET	IV	Dow EG106	100%	HEAD	10°	126.5	126.5	16.6	0.6
	2010-11	28-Feb-11	SN 23	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	46.3	37.5	13.4	0.6
	2010-11	28-Feb-11	SN 24	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	46.8	38.7	13.7	0.6
7	2010-11	27-Feb-11	SN 25	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	163.7	163.7	3.7	-10.3
	2010-11	27-Feb-11	SN 26	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	96.4	116.8	4.4	-10.3
	2010-11	27-Feb-11	SN 27	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	72.0	84.4	4.3	-10.3
	2010-11	27-Feb-11	SN 28	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	112.7	84.0	2.7	-10.3
8	2010-11	6-Mar-11	SN 29	Snow	PET	IV	LV2	75%	HEAD	10°	102.3	102.3	10.9	-2.3
	2010-11	6-Mar-11	SN 30	Snow	PET	IV	LV2	75%	HEAD	20º Simple	51.8	55.7	11.8	-2.3
	2010-11	6-Mar-11	SN 31	Snow	PET	IV	LV2	75%	HEAD	35° Simple	30.1	31.9	11.6	-2.3
	2010-11	6-Mar-11	SN 32	Snow	PET	IV	LV2	75%	HEAD	35° Simple	32.5	34.1	11.5	-7.6
9	2010-11	7-Mar-11	SN 33	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	98.1	98.1	15.6	-7.6
	2010-11	7-Mar-11	SN 34	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	46.6	37.0	12.4	-7.6

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
9 cont'd	2010-11	7-Mar-11	SN 35	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	26.1	16.4	9.8	-7.6
	2010-11	7-Mar-11	SN 36	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	17.5	21.0	18.7	-7.6
10	2010-11	7-Mar-11	SN 37	Snow	PET	IV	Launch	100%	HEAD	10°	59.0	59.0	14.1	-7.6
	2010-11	7-Mar-11	SN 38	Snow	PET	IV	Launch	100%	HEAD	35° Simple	22.5	29.1	18.2	-7.6
	2010-11	7-Mar-11	SN 39	Snow	PET	IV	Launch	100%	HEAD	35° Simple	23.8	18.6	11.0	-7.6
11	2010-11	7-Mar-11	SN 40	Snow	PET	IV	Dow EG106	100%	HEAD	10°	57.8	57.8	16.4	-7.6
	2010-11	7-Mar-11	SN 41	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	24.5	23.8	16.0	-7.6
	2010-11	7-Mar-11	SN 42	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	16.3	13.7	13.8	-7.6
	2010-11	7-Mar-11	SN 43	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	10.8	14.4	21.7	-7.6
12	2010-11	11-Mar-11	SN 44	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	121.0	121.0	9.7	-0.1
	2010-11	11-Mar-11	SN 45	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	85.9	63.0	7.1	-0.1
	2010-11	11-Mar-11	SN 46	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	56.7	37.5	6.4	-0.1
	2010-11	11-Mar-11	SN 47	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	39.9	46.8	11.4	-0.1
13	2010-11	11-Mar-11	SN 48	Snow	PET	IV	Launch	100%	HEAD	10°	132.1	132.1	17.1	-0.1
	2010-11	11-Mar-11	SN 49	Snow	PET	IV	Launch	100%	HEAD	20º Simple	66.6	72.3	18.6	-0.1
	2010-11	11-Mar-11	SN 50	Snow	PET	IV	Launch	100%	HEAD	35° Simple	50.6	46.0	15.6	-0.1
	2010-11	11-Mar-11	SN 51	Snow	PET	IV	Launch	100%	HEAD	35° Simple	45.1	50.7	19.2	-0.1

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE $(g/dm^2/h)$	OAT (°C)
14	2010-11	11-Mar-11	SN 52	Snow	PET	IV	Dow EG106	100%	HEAD	10°	88.8	88.8	4.4	-0.1
	2010-11	11-Mar-11	SN 53	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	63.0	61.0	4.2	-0.1
	2010-11	11-Mar-11	SN 54	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	24.6	54.1	9.7	-0.1
15	2010-11	11-Mar-11	SN 56	Snow	PET	IV	HV1	75%	HEAD	10°	50.3	50.3	17.6	-0.1
	2010-11	11-Mar-11	SN 57	Snow	PET	IV	HV1	75%	HEAD	20º Simple	27.7	29.2	18.5	-0.1
	2010-11	11-Mar-11	SN 58	Snow	PET	IV	HV1	75%	HEAD	35° Simple	18.8	19.7	18.4	-0.1
16	2010-11	21-Mar-11	SN 59	Snow	PET	IV	Dow EG106	100%	HEAD	10°	79.5	79.5	23.7	0.3
	2010-11	21-Mar-11	SN 60	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	29.0	40.0	32.8	0.3
	2010-11	21-Mar-11	SN 61	Snow	PET	IV	Dow EG106	100%	HEAD	35° Nested	76.8	77.5	23.9	0.3
17	2010-11	6-Apr-11	ZP 1	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	10°	109.8	109.8	5.0	-10.0
	2010-11	6-Apr-11	ZP 2	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	20º Nested	98.5	106.4	5.4	-10.0
18	2010-11	6-Apr-11	ZP 3	Freezing Drizzle	NRC	IV	ABC-S Plus	100%	HEAD	10°	32.2	32.2	14.5	-10.0
	2010-11	6-Apr-11	ZP 4	Freezing Drizzle	NRC	IV	ABC-S Plus	100%	HEAD	35° Simple	42.1	40.3	13.9	-10.0
	2010-11	6-Apr-11	ZP 5	Freezing Drizzle	NRC	IV	ABC-S Plus	100%	HEAD	35° Nested	55.3	51.4	13.5	-10.0
19	2010-11	6-Apr-11	ZP 6	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	10°	67.6	67.6	12.8	-10.0
	2010-11	6-Apr-11	ZP 7	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	35° Simple	23.1	23.6	13.1	-10.0
	2010-11	6-Apr-11	ZP 8	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	35° Nested	47.0	47.4	12.9	-10.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE $(g/dm^2/h)$	OAT (°C)
20	2010-11	6-Apr-11	ZP 9	Light Freezing Rain	NRC	IV	ABC-S Plus	75%	HEAD	10°	29.6	29.6	23.6	-10.0
	2010-11	6-Apr-11	ZP 10	Light Freezing Rain	NRC	IV	ABC-S Plus	75%	HEAD	35° Simple	12.0	12.4	24.4	-10.0
	2010-11	6-Apr-11	ZP 11	Light Freezing Rain	NRC	IV	ABC-S Plus	75%	HEAD	35° Nested	29.1	29.7	24.1	-10.0
21	2010-11	7-Apr-11	ZP 12	Light Freezing Rain	NRC	IV	Launch	100%	HEAD	10°	84.2	84.2	24.7	-3.0
	2010-11	7-Apr-11	ZP 13	Light Freezing Rain	NRC	IV	Launch	100%	HEAD	20º Simple	42.7	41.5	24.0	-3.0
	2010-11	7-Apr-11	ZP 14	Light Freezing Rain	NRC	IV	Launch	100%	HEAD	20º Nested	83.2	81.9	24.3	-3.0
22	2010-11	7-Apr-11	ZP 15	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	10°	74.0	74.0	12.6	-3.0
	2010-11	7-Apr-11	ZP 16	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	35° Simple	34.6	32.7	11.9	-3.0
	2010-11	7-Apr-11	ZP 17	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	35° Nested	79.8	79.8	12.6	-3.0
23	2010-11	7-Apr-11	ZP 18	Freezing Drizzle	NRC	IV	LV2	100%	HEAD	10°	87.5	87.5	13.3	-3.0
	2010-11	7-Apr-11	ZP 19	Freezing Drizzle	NRC	IV	LV2	100%	HEAD	35° Simple	32.0	33.7	14.0	-3.0
	2010-11	7-Apr-11	ZP 20	Freezing Drizzle	NRC	IV	LV2	100%	HEAD	35° Nested	64.3	68.2	14.1	-3.0
24A	2010-11	8-Apr-11	ZP 21	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	10°	176.3	176.3	5.4	-3.0
	2010-11	8-Apr-11	ZP 22	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	20º Simple	103.3	101.4	5.3	-3.0
	2010-11	8-Apr-11	ZP 23	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	20º Nested	123.6	119.0	5.2	-3.0
24B	2010-11	8-Apr-11	ZP 24	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	10°	176.3	176.3	5.4	-3.0
	2010-11	8-Apr-11	ZP 25	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	35° Simple	77.0	79.8	5.6	-3.0
	2010-11	8-Apr-11	ZP 26	Freezing Drizzle	NRC	IV	HV1	100%	HEAD	35° Nested	194.6	205.4	5.7	-3.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
25	2010-11	11-Apr-11	ZP 27	Freezing Fog	NRC	IV	Launch	100%	HEAD	10°	53.7	53.7	4.3	-14.0
	2010-11	11-Apr-11	ZP 28	Freezing Fog	NRC	IV	Launch	100%	HEAD	35° Simple	35.1	36.7	4.5	-14.0
	2010-11	11-Apr-11	ZP 29	Freezing Fog	NRC	IV	Launch	100%	HEAD	35° Nested	67.6	64.5	4.1	-14.0
26	2010-11	11-Apr-11	ZP 30	Freezing Fog	NRC	IV	ABC-S Plus	100%	HEAD	10°	44.0	44.0	5.0	-25.0
	2010-11	11-Apr-11	ZP 31	Freezing Fog	NRC	IV	ABC-S Plus	100%	HEAD	35° Simple	32.3	29.1	4.5	-25.0
	2010-11	11-Apr-11	ZP 32	Freezing Fog	NRC	IV	ABC-S Plus	100%	HEAD	35° Nested	65.9	60.6	4.6	-25.0
27	2010-11	11-Apr-11	ZP 33	Freezing Fog	NRC	IV	Dow EG106	100%	HEAD	10°	72.4	72.4	1.9	-25.0
	2010-11	11-Apr-11	ZP 34	Freezing Fog	NRC	IV	Dow EG106	100%	HEAD	20º Simple	89.7	66.1	1.4	-25.0
	2010-11	11-Apr-11	ZP 35	Freezing Fog	NRC	IV	Dow EG106	100%	HEAD	20º Nested	90.9	71.8	1.5	-25.0
28	2010-11	11-Apr-11	ZP 36	Freezing Fog	NRC	IV	ABAX AD-49	100%	HEAD	10°	66.7	66.7	1.9	-14.0
	2010-11	11-Apr-11	ZP 37	Freezing Fog	NRC	IV	ABAX AD-49	100%	HEAD	35° Simple	44.2	41.9	1.8	-14.0
	2010-11	11-Apr-11	ZP 38	Freezing Fog	NRC	IV	ABAX AD-49	100%	HEAD	35° Nested	83.7	83.7	1.9	-14.0
29	2010-11	12-Apr-11	ZP 39	Freezing Fog	NRC	IV	HV1	50%	HEAD	10°	86.7	86.7	1.9	-3.0
	2010-11	12-Apr-11	ZP 40	Freezing Fog	NRC	IV	HV1	50%	HEAD	20º Simple	43.9	41.6	1.8	-3.0
30	2010-11	12-Apr-11	ZP 41	Freezing Fog	NRC	IV	LV2	50%	HEAD	10°	46.5	46.5	5.3	-3.0
	2010-11	12-Apr-11	ZP 42	Freezing Fog	NRC	IV	LV2	50%	HEAD	35° Simple	17.7	16.7	5.0	-3.0
	2010-11	12-Apr-11	ZP 43	Freezing Fog	NRC	IV	LV2	50%	HEAD	35° Nested	39.2	33.3	4.5	-3.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
31	2011-12	17-Jan-12	SN 62 SN 63	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	121.5	121.5	11.9	-3.8
	2011-12	17-Jan-12	SN 64	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	60.3	55.7	11.0	-3.8
	2011-12	17-Jan-12	SN 65	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	59.7	65.2	13.0	-3.8
	2011-12	17-Jan-12	SN 66	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Nested	122.2	123.3	12.0	-3.8
	2011-12	17-Jan-12	SN 67	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	31.9	29.2	10.9	-3.8
	2011-12	17-Jan-12	SN 68	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	31.5	35.2	13.3	-3.8
	2011-12	17-Jan-12	SN 69	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	35.1	32.2	10.9	-3.8
	2011-12	17-Jan-12	SN 70	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Nested	123.5	123.5	11.9	-3.8
32	2011-12	26-Jan-12	SN 71 SN 72	Snow	PET	IV	ABC-S Plus	75%	HEAD	10°	154.8	154.8	7.4	-5.6
	2011-12	26-Jan-12	SN 73	Snow	PET	IV	ABC-S Plus	75%	HEAD	20º Simple	82.2	75.0	6.7	-5.6
	2011-12	26-Jan-12	SN 74	Snow	PET	IV	ABC-S Plus	75%	HEAD	20º Simple	69.0	74.2	7.9	-5.6
	2011-12	26-Jan-12	SN 75	Snow	PET	IV	ABC-S Plus	75%	HEAD	20º Nested	150.7	147.6	7.2	-5.6
	2011-12	26-Jan-12	SN 76	Snow	PET	IV	ABC-S Plus	75%	HEAD	35° Simple	50.6	44.7	6.5	-5.6
	2011-12	26-Jan-12	SN 77	Snow	PET	IV	ABC-S Plus	75%	HEAD	35° Simple	48.9	43.9	6.6	-5.6
	2011-12	26-Jan-12	SN 78	Snow	PET	IV	ABC-S Plus	75%	HEAD	35° Nested	133.5	119.9	6.6	-5.6
33	2011-12	3-Mar-12	SN 80	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	63.6	63.6	18.8	-0.1
	2011-12	3-Mar-12	SN 81	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	20.8	18.6	16.8	-0.1

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
33 cont'd	2011-12	3-Mar-12	SN 83	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Nested	73.3	77.2	19.8	-0.1
	2011-12	3-Mar-12	SN 84	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	11.3	9.2	15.3	-0.1
	2011-12	3-Mar-12	SN 85	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Nested	32.8	30.2	17.3	-0.1
34	2011-12	24-Feb-12	SN86 SN87 SN88 SN89	Snow	YMX	IV	Dow EG106	100%	HEAD	10°	89.4	89.4	15.2	-1.2
	2011-12	24-Feb-12	SN 90	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Simple	50.3	38.4	11.6	-1.2
	2011-12	24-Feb-12	SN 91	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Simple	35.9	47.5	20.1	-1.2
	2011-12	24-Feb-12	SN 92	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Nested	93.3	95.1	15.5	-1.2
	2011-12	24-Feb-12	SN 93	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	34.0	20.6	9.2	-1.2
	2011-12	24-Feb-12	SN 94	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	21.0	23.9	17.3	-1.2
	2011-12	24-Feb-12	SN 95	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	18.8	24.5	19.8	-1.2
	2011-12	24-Feb-12	SN 96	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Nested	92.2	93.4	15.4	-1.2
	2011-12	24-Feb-12	FS2	Snow	YMX	IV	Dow EG106	100%	HEAD	A-300	65.7	55.7	12.9	-1.2
35	2011-12	24-Feb-12	SN97 SN98 SN99	Snow	YMX	IV	Dow EG106	100%	HEAD	10°	58.7	58.7	30.5	-0.7
	2011-12	24-Feb-12	SN 100	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Simple	26.0	23.8	27.9	-0.7
	2011-12	24-Feb-12	SN 101	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Nested	38.8	36.1	28.4	-0.7
	2011-12	24-Feb-12	SN 102	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	12.4	13.1	32.1	-0.7
	2011-12	24-Feb-12	SN 103	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Nested	37.8	34.6	27.9	-0.7

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
35 cont'd	2011-12	24-Feb-12	FS3	Snow	YMX	IV	Dow EG106	100%	HEAD	A-300	37.0	33.7	27.8	-0.7
36	2011-12	1-Mar-12	SN104 SN105 SN106 SN107	Snow	YMX	IV	Dow EG106	100%	HEAD	10°	133.0	133.0	9.7	-7.5
	2011-12	1-Mar-12	SN 108	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Simple	50.3	63.8	12.3	-7.5
	2011-12	1-Mar-12	SN 109	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Simple	50.8	37.7	7.2	-7.5
	2011-12	1-Mar-12	SN 110	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Nested	134.1	135.5	9.8	-7.5
	2011-12	1-Mar-12	SN 111	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	30.4	46.4	14.8	-7.5
	2011-12	1-Mar-12	SN 112	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	27.7	24.0	8.4	-7.5
	2011-12	1-Mar-12	SN 113	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Nested	124.8	126.0	9.8	-7.5
	2011-12	1-Mar-12	FS4	Snow	YMX	IV	Dow EG106	100%	HEAD	A-300	85.6	91.8	10.4	-7.5
37	2011-12	1-Mar-12	SN 114	Snow	YMX	I	Type I EG	38%	HEAD	10°	13.9	13.9	4.1	-6.9
	2011-12	1-Mar-12	SN 115	Snow	YMX	I	Type I EG	38%	HEAD	20º Simple	11.0	11.0	4.1	-6.9
	2011-12	1-Mar-12	SN 116	Snow	YMX	I	Type I EG	38%	HEAD	35° Simple	7.7	7.9	4.2	-6.9
	2011-12	1-Mar-12	FS5	Snow	YMX	I	Type I EG	38%	HEAD	A-300	49.0	35.9	3.0	-6.9
38	2011-12	22-Mar-12	ZP 44	Freezing Drizzle	NRC	III	2031 - HOT	100%	HEAD	10°	22.0	22.0	5.4	-3.0
	2011-12	22-Mar-12	ZP 45	Freezing Drizzle	NRC	III	2031 - HOT	100%	HEAD	20º Simple	12.5	13.0	5.6	-3.0
	2011-12	22-Mar-12	ZP 46	Freezing Drizzle	NRC	III	2031 - HOT	100%	HEAD	35° Simple	14.5	15.0	5.6	-3.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
39	2011-12	21-Mar-12	ZP 47	Freezing Drizzle	NRC	III	2031 - HOT	75%	HEAD	10°	14.9	14.9	5.1	-10.0
	2011-12	21-Mar-12	ZP 48	Freezing Drizzle	NRC	III	2031 - HOT	75%	HEAD	20º Simple	11.0	12.1	5.6	-10.0
	2011-12	21-Mar-12	ZP 49	Freezing Drizzle	NRC	III	2031 - HOT	75%	HEAD	35° Simple	12.0	12.7	5.4	-10.0
40	2011-12	21-Mar-12	ZP50 ZP51	Freezing Drizzle	NRC	I	F1	Conc.	HEAD	10°	6.8	6.8	13.5	-10.0
	2011-12	21-Mar-12	ZP 52	Freezing Drizzle	NRC	I	F1	Conc.	HEAD	20º Simple	6.2	6.3	13.8	-10.0
	2011-12	21-Mar-12	ZP 53	Freezing Drizzle	NRC	I	F1	Conc.	HEAD	35° Simple	5.8	6.0	13.8	-10.0
41	2011-12	27-Mar-12	ZP 54	Freezing Fog	NRC	III	2031 - HOT	50%	HEAD	10°	28.5	28.5	1.5	-3.0
	2011-12	27-Mar-12	ZP 55	Freezing Fog	NRC	III	2031 - HOT	50%	HEAD	20º Simple	21.1	19.7	1.4	-3.0
	2011-12	27-Mar-12	ZP 56	Freezing Fog	NRC	III	2031 - HOT	50%	HEAD	35° Simple	19.1	17.8	1.4	-3.0
42	2012-13	10-Dec-12	SN 115	Snow	PET	I	Octaflo EF	22.50	HEAD	10°	3.4	3.4	30.1	-4.8
	2012-13	10-Dec-12	SN 116	Snow	PET	I	Octaflo EF	22.50	HEAD	20º Simple	2.5	2.3	27.7	-4.8
	2012-13	10-Dec-12	SN 117	Snow	PET	I	Octaflo EF	22.50	HEAD	35° Simple	2.8	3.1	33.1	-4.8
43	2012-13	10-Dec-12	SN 118	Snow	PET	I	Octaflo EF	22.50	HEAD	10°	2.6	2.6	53.7	-4.8
	2012-13	10-Dec-12	SN 119	Snow	PET	I	Octaflo EF	22.50	HEAD	20º Simple	2.3	2.3	54.4	-4.8
	2012-13	10-Dec-12	SN 120	Snow	PET	I	Octaflo EF	22.50	HEAD	35° Simple	2.0	2.0	55.5	-4.8
44	2012-13	10-Dec-12	SN 121	Snow	PET	I	Octaflo EF	22.50	HEAD	10°	4.0	4.0	15.6	-4.2
	2012-13	10-Dec-12	SN 122	Snow	PET	I	Octaflo EF	22.50	HEAD	20º Simple	3.9	3.9	15.6	-4.2

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
44 cont'd	2012-13	10-Dec-12	SN 123	Snow	PET	I	Octaflo EF	22.50	HEAD	35° Simple	4.0	4.0	15.8	-4.2
45	2012-13	16-Dec-12	SN 124	Snow	PET	I	Octaflo EF	22.50	HEAD	10°	6.0	6.0	8.3	-5.9
	2012-13	16-Dec-12	SN 125	Snow	PET	I	Octaflo EF	22.50	HEAD	20º Simple	5.0	5.1	8.4	-5.9
	2012-13	16-Dec-12	SN 126	Snow	PET	I	Octaflo EF	22.50	HEAD	35° Simple	4.8	5.0	8.6	-5.9
46	2012-13	16-Dec-12	SN 127	Snow	PET	I	Octaflo EF	22.50	HEAD	10°	7.0	7.0	6.1	-5.9
	2012-13	16-Dec-12	SN 128	Snow	PET	I	Octaflo EF	22.50	HEAD	20º Simple	5.2	5.2	6.1	-5.9
	2012-13	16-Dec-12	SN 129	Snow	PET	I	Octaflo EF	22.50	HEAD	35° Simple	4.8	4.8	6.0	-5.9
47	2012-13	27-Dec-13	SN 130	Snow	PET	I	Octaflo EF	24.00	HEAD	10°	2.8	2.8	64.0	-6.2
	2012-13	27-Dec-13	SN 131	Snow	PET	I	Octaflo EF	24.00	HEAD	20º Simple	2.0	2.0	64.0	-6.2
	2012-13	27-Dec-13	SN 132	Snow	PET	I	Octaflo EF	24.00	HEAD	35° Simple	1.7	1.7	64.0	-6.2
48	2012-13	27-Dec-13	SN 133	Snow	PET	I	Octaflo EF	24.00	HEAD	10°	2.6	2.6	57.5	-5.3
	2012-13	27-Dec-13	SN 134	Snow	PET	I	Octaflo EF	24.00	HEAD	20º Simple	2.1	2.1	57.9	-5.3
	2012-13	27-Dec-13	SN 135	Snow	PET	I	Octaflo EF	24.00	HEAD	35° Simple	1.6	1.6	58.6	-5.3
49	2012-13	29-Dec-13	SN 136	Snow	PET	I	Octaflo EF	26.50	HEAD	10°	13.2	13.2	2.0	-9.2
	2012-13	29-Dec-13	SN 137	Snow	PET	I	Octaflo EF	26.50	HEAD	20º Simple	10.7	10.7	2.0	-9.2
	2012-13	29-Dec-13	SN 138	Snow	PET	I	Octaflo EF	26.50	HEAD	35° Simple	9.8	9.8	2.0	-9.2
50	2012-13	3-Jan-13	SN 139	Snow	PET	I	Octaflo EF	n/a	HEAD	10°	6.8	6.8	3.5	-13.8

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
50 cont'd	2012-13	3-Jan-13	SN 140	Snow	PET	I	Octaflo EF	n/a	HEAD	20º Simple	6.6	6.6	3.5	-13.8
	2012-13	3-Jan-13	SN 141	Snow	PET	I	Octaflo EF	n/a	HEAD	35° Simple	5.4	5.4	3.5	-13.8
51	2012-13	6-Jan-13	SN 142	Snow	PET	I	Octaflo EF	27.00	HEAD	10°	41.1	41.1	1.0	-10.3
	2012-13	6-Jan-13	SN 143	Snow	PET	I	Octaflo EF	27.00	HEAD	20º Simple	36.0	36.0	1.0	-10.3
	2012-13	6-Jan-13	SN 144	Snow	PET	I	Octaflo EF	27.00	HEAD	35° Simple	33.3	33.3	1.0	-10.3
52	2012-13	19-Jan-13	SN 145	Snow	PET	I	Octaflo EF	24.00	HEAD	10°	8.7	8.7	8.8	-6.4
	2012-13	19-Jan-13	SN 146	Snow	PET	I	Octaflo EF	24.00	HEAD	20º Simple	6.1	6.1	8.8	-6.4
	2012-13	19-Jan-13	SN 147	Snow	PET	I	Octaflo EF	24.00	HEAD	35° Simple	6.4	6.3	8.7	-6.4
53	2012-13	19-Jan-13	SN 148	Snow	PET	I	Octaflo EF	24.00	HEAD	10°	8.0	8.0	8.7	-6.0
	2012-13	19-Jan-13	SN 149	Snow	PET	I	Octaflo EF	24.00	HEAD	20º Simple	5.8	5.8	8.7	-6.0
	2012-13	19-Jan-13	SN 150	Snow	PET	I	Octaflo EF	24.00	HEAD	35° Simple	5.3	5.3	8.7	-6.0
54	2012-13	10-Apr-13	ZP 57	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	10°	15.7	15.7	5.5	-3.0
	2012-13	10-Apr-13	ZP 58	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	20º Simple	17.5	19.0	6.0	-3.0
	2012-13	10-Apr-13	ZP 59	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	35° Simple	16.3	17.2	5.8	-3.0
55	2012-13	9-Apr-13	ZP60 ZP61 ZP62	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	10°	8.5	8.5	6.1	-10.0
	2012-13	9-Apr-13	ZP 63	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	20º Simple	7.6	7.5	6.0	-10.0
	2012-13	9-Apr-13	ZP 64	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	35° Simple	7.3	7.3	6.1	-10.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
55 cont'd	2012-13	9-Apr-13	ZP 65	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	20º Nested	8.5	8.3	6.0	-10.0
	2012-13	9-Apr-13	ZP 66	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	35° Nested	9.7	9.6	6.0	-10.0
56	2012-13	8-Apr-13	ZP 67	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	10°	5.4	5.4	13.4	-10.0
	2012-13	8-Apr-13	ZP 68	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	20º Simple	5.9	6.1	13.8	-10.0
	2012-13	8-Apr-13	ZP 69	Freezing Drizzle	NRC	I	Octaflo EF	27.00	HEAD	35° Simple	5.3	5.1	12.9	-10.0
57	2012-13	4-Apr-13	ZP 70	Freezing Fog	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	10°	11.5	11.5	5.0	-3.0
	2012-13	4-Apr-13	ZP 71	Freezing Fog	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	20º Simple	11.7	11.9	5.1	-3.0
	2012-13	4-Apr-13	ZP 72	Freezing Fog	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	35° Simple	10.7	10.7	5.0	-3.0
58	2012-13	10-Apr-13	ZP73 ZP74 ZP75	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	10°	14.2	14.2	13.9	-3.0
	2012-13	10-Apr-13	ZP 76	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	20º Simple	12.0	12.0	13.9	-3.0
	2012-13	10-Apr-13	ZP 77	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	35° Simple	11.9	11.9	13.9	-3.0
	2012-13	10-Apr-13	ZP 78	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	20º Nested	15.6	15.6	13.9	-3.0
	2012-13	10-Apr-13	ZP 79	Freezing Drizzle	NRC	I	Octaflo EF	21.25	HEAD	35° Nested	15.7	15.7	13.9	-3.0
59	2012-13	8-Apr-13	ZP 80	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	10°	5.0	5.0	24.8	-10.0
	2012-13	8-Apr-13	ZP 81	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	20º Simple	4.7	4.8	25.1	-10.0
	2012-13	8-Apr-13	ZP 82	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	35° Simple	4.4	4.4	25.2	-10.0
60	2012-13	27-Feb-13	SN 151	Snow	YMX	I	Type I EG	25.00	HEAD	10°	57.1	57.1	7.7	1.1

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE ($g/dm^2/h$)	OAT (°C)
60 cont'd	2012-13	27-Feb-13	SN 152	Snow	YMX	I	Type I EG	25.00	HEAD	20º Simple	33.7	25.8	5.9	0.8
	2012-13	27-Feb-13	SN 153	Snow	YMX	I	Type I EG	25.00	HEAD	35° Simple	18.0	9.8	4.2	0.8
	2012-13	27-Feb-13	FS6	Snow	YMX	I	Type I EG	25.00	TAIL	A-300	23.9	15.4	5.0	0.8
61	2012-13	19-Mar-13	SN154 SN155	Snow	YMX	IV	Dow EG106	100%	HEAD	10°	73.1	73.1	21.4	-4.2
	2012-13	19-Mar-13	SN 156	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Simple	34.4	29.4	18.3	-4.2
	2012-13	19-Mar-13	SN 157	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	11.7	11.6	21.3	-4.1
	2012-13	19-Mar-13	SN 158	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Nested	54.7	49.3	19.3	-4.2
	2012-13	19-Mar-13	SN 159	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Nested	41.7	36.1	18.5	-4.2
	2012-13	19-Mar-13	FS7	Snow	YMX	IV	Dow EG106	100%	TAIL	A-300	12.5	17.4	29.8	-4.1
62	2012-13	19-Mar-13	SN160 SN161 SN162 SN163	Snow	YMX	IV	Dow EG106	100%	HEAD	10°	103.7	103.7	10.0	-3.7
	2012-13	19-Mar-13	SN 164	Snow	YMX	IV	Dow EG106	100%	HEAD	20º Simple	49.1	52.1	10.6	-3.9
	2012-13	19-Mar-13	SN 165	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Simple	35.5	23.7	6.7	-3.9
	2012-13	19-Mar-13	SN 166	Snow	YMX	IV	Dow EG106	100%	HEAD	35° Nested	48.2	46.9	9.7	-3.9
	2012-13	19-Mar-13	FS8	Snow	YMX	IV	Dow EG106	100%	TAIL	A-300	68.5	76.2	11.1	-3.7
63	2012-13	19-Mar-13	SN 167	Snow	YMX	I	Type I EG	24.75	HEAD	10°	16.3	16.3	9.4	-3.4
	2012-13	19-Mar-13	SN 168	Snow	YMX	I	Type I EG	24.75	HEAD	20º Simple	17.9	18.0	9.4	-3.4
	2012-13	19-Mar-13	SN 169	Snow	YMX	I	Type I EG	24.75	HEAD	35° Simple	7.0	7.4	10.0	-3.4

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
63 cont'd	2012-13	19-Mar-13	FS9	Snow	YMX	I	Type I EG	24.75	TAIL	A-300	3.0	3.4	10.6	-3.4
64	2013-14	26-Nov-13	SN170 SN171 SN172	Snow	PET	III-C	2031	100%	HEAD	10°	74.5	74.5	2.3	0.1
	2013-14	26-Nov-13	SN173	Snow	PET	III-C	2031	100%	HEAD	35° Nested	90.1	99.5	2.5	0.1
	2013-14	26-Nov-13	SN174	Snow	PET	III-C	2031	100%	HEAD	35° Simple	71.8	66.5	2.1	0.1
	2013-14	26-Nov-13	SN175	Snow	PET	III-C	2031	100%	HEAD	20º Nested	95.1	108.7	2.6	0.1
	2013-14	26-Nov-13	SN176	Snow	PET	III-C	2031	100%	TAIL	10°	93.0	104.7	2.6	0.1
	2013-14	26-Nov-13	SN177	Snow	PET	III-C	2031	100%	TAIL	20º Simple	77.5	76.8	2.3	0.1
	2013-14	26-Nov-13	SN178	Snow	PET	III-C	2031	100%	HEAD	15° Simple	76.0	74.0	2.2	0.1
	2013-14	26-Nov-13	SN179	Snow	PET	III-C	2031	100%	HEAD	20º Simple	71.7	66.4	2.1	0.1
	2013-14	26-Nov-13	SN180	Snow	PET	III-C	2031	100%	ROTATING	10°	86.0	92.0	2.5	0.1
	2013-14	26-Nov-13	SN181	Snow	PET	III-C	2031	100%	ROTATING	20º Simple	72.1	66.8	2.1	0.1
	2013-14	26-Nov-13	SN182	Snow	PET	III-C	2031	100%	CROSS	10°	92.2	103.5	2.6	0.1
	2013-14	26-Nov-13	SN183	Snow	PET	III-C	2031	100%	CROSS	20º Simple	73.9	70.0	2.2	0.1
65	2013-14	9-Dec-13	SN184 SN185 SN186	Snow	PET	IV	Dow EG106	100%	HEAD	10°	87.0	87.0	13.5	-5.0
	2013-14	9-Dec-13	SN187	Snow	PET	IV	Dow EG106	100%	HEAD	35° Nested	75.8	60.1	10.7	-5.0
	2013-14	9-Dec-13	SN188	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	38.0	25.3	9.0	-5.0
	2013-14	9-Dec-13	SN189	Snow	PET	IV	Dow EG106	100%	HEAD	20º Nested	76.5	63.3	11.1	-5.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
65 cont'd	2013-14	9-Dec-13	SN190	Snow	PET	IV	Dow EG106	100%	TAIL	10°	104.7	128.3	16.5	-5.0
	2013-14	9-Dec-13	SN191	Snow	PET	IV	Dow EG106	100%	TAIL	20º Simple	76.0	63.0	11.2	-5.0
	2013-14	9-Dec-13	SN192	Snow	PET	IV	Dow EG106	100%	HEAD	15° Simple	72.9	58.6	10.8	-5.0
	2013-14	9-Dec-13	SN193	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	60.6	44.3	9.9	-5.0
	2013-14	9-Dec-13	SN194	Snow	PET	IV	Dow EG106	100%	ROTATING	10°	84.3	86.3	13.8	-5.0
	2013-14	9-Dec-13	SN195	Snow	PET	IV	Dow EG106	100%	ROTATING	20º Simple	65.8	51.1	10.4	-5.0
	2013-14	9-Dec-13	SN196	Snow	PET	IV	Dow EG106	100%	CROSS	10°	99.1	118.4	16.1	-5.0
	2013-14	9-Dec-13	SN197	Snow	PET	IV	Dow EG106	100%	CROSS	20º Simple	62.2	46.1	10.0	-5.0
66	2013-14	9-Dec-13	SN198 SN199 SN200	Snow	PET	IV	Dow EG106	100%	HEAD	10°	78.7	78.7	15.2	-4.9
	2013-14	9-Dec-13	SN201	Snow	PET	IV	Dow EG106	100%	HEAD	35° Nested	74.7	77.3	15.7	-4.9
	2013-14	9-Dec-13	SN202	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	26.2	31.7	18.4	-4.9
	2013-14	9-Dec-13	SN203	Snow	PET	IV	Dow EG106	100%	HEAD	20º Nested	73.0	76.2	15.9	-4.9
	2013-14	9-Dec-13	SN204	Snow	PET	IV	Dow EG106	100%	TAIL	10°	106.9	93.3	13.3	-4.9
	2013-14	9-Dec-13	SN205	Snow	PET	IV	Dow EG106	100%	TAIL	20º Simple	60.1	69.5	17.6	-4.9
	2013-14	9-Dec-13	SN206	Snow	PET	IV	Dow EG106	100%	HEAD	15° Simple	51.1	61.9	18.4	-4.9
	2013-14	9-Dec-13	SN207	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	38.8	49.3	19.3	-4.9
	2013-14	9-Dec-13	SN208	Snow	PET	IV	Dow EG106	100%	ROTATING	10°	64.8	70.3	16.5	-4.9

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
66 cont'd	2013-14	9-Dec-13	SN209	Snow	PET	IV	Dow EG106	100%	ROTATING	20º Simple	36.5	46.3	19.3	-4.9
	2013-14	9-Dec-13	SN210	Snow	PET	IV	Dow EG106	100%	CROSS	10°	98.4	88.3	13.6	-4.9
	2013-14	9-Dec-13	SN211	Snow	PET	IV	Dow EG106	100%	CROSS	20º Simple	49.2	59.9	18.5	-4.9
67	2013-14	14-Dec-13	SN212 SN213 SN 214	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	56.3	56.3	6.4	-17.0
	2013-14	14-Dec-13	SN215	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Nested	37.3	30.2	5.2	-17.0
	2013-14	14-Dec-13	SN216	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	26.5	20.6	5.0	-17.0
	2013-14	14-Dec-13	SN217	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Nested	48.3	42.9	5.6	-17.0
	2013-14	14-Dec-13	SN218	Snow	PET	IV	ABC-S Plus	100%	TAIL	10°	191.7	332.7	11.0	-17.0
	2013-14	14-Dec-13	SN219	Snow	PET	IV	ABC-S Plus	100%	TAIL	20º Simple	102.4	196.3	12.2	-17.0
	2013-14	14-Dec-13	SN220	Snow	PET	IV	ABC-S Plus	100%	HEAD	15° Simple	54.8	54.9	6.4	-17.0
	2013-14	14-Dec-13	SN221	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	49.5	44.8	5.8	-17.0
	2013-14	14-Dec-13	SN222	Snow	PET	IV	ABC-S Plus	100%	ROTATING	10°	58.7	68.0	7.4	-17.0
	2013-14	14-Dec-13	SN223	Snow	PET	IV	ABC-S Plus	100%	ROTATING	20º Simple	54.4	56.6	6.6	-17.0
	2013-14	14-Dec-13	SN224	Snow	PET	IV	ABC-S Plus	100%	CROSS	10°	74.2	130.8	11.2	-17.0
	2013-14	14-Dec-13	SN225	Snow	PET	IV	ABC-S Plus	100%	CROSS	20º Simple	67.9	106.4	10.0	-17.0
68	2013-14	15-Dec-13	SN226 SN227 SN228	Snow	PET	IV	Dow EG106	100%	HEAD	10°	64.2	64.2	20.1	-15.0
	2013-14	15-Dec-13	SN229	Snow	PET	IV	Dow EG106	100%	HEAD	35° Nested	22.5	23.0	20.5	-15.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
68 cont'd	2013-14	15-Dec-13	SN230	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	12.9	13.5	21.0	-15.0
	2013-14	15-Dec-13	SN231	Snow	PET	IV	Dow EG106	100%	HEAD	20º Nested	35.2	35.4	20.2	-15.0
	2013-14	15-Dec-13	SN232	Snow	PET	IV	Dow EG106	100%	TAIL	10°	142.0	127.7	18.1	-15.0
	2013-14	15-Dec-13	SN233	Snow	PET	IV	Dow EG106	100%	TAIL	20º Simple	141.8	127.5	18.1	-15.0
	2013-14	15-Dec-13	SN234	Snow	PET	IV	Dow EG106	100%	HEAD	15° Simple	44.2	43.7	19.9	-15.0
	2013-14	15-Dec-13	SN235	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	29.5	29.5	20.1	-15.0
	2013-14	15-Dec-13	SN236	Snow	PET	IV	Dow EG106	100%	ROTATING	10°	54.2	54.7	20.3	-15.0
	2013-14	15-Dec-13	SN237	Snow	PET	IV	Dow EG106	100%	ROTATING	20º Simple	30.9	30.9	20.1	-15.0
	2013-14	15-Dec-13	SN238	Snow	PET	IV	Dow EG106	100%	CROSS	10°	92.5	91.3	19.8	-15.0
	2013-14	15-Dec-13	SN239	Snow	PET	IV	Dow EG106	100%	CROSS	20º Simple	58.3	59.0	20.4	-15.0
69	2013-14	20-Dec-13	SN240 SN241 SN242	Snow	PET	IV	Dow EG106	100%	HEAD	10°	91.4	91.4	10.8	-7.0
	2013-14	20-Dec-13	SN243	Snow	PET	IV	Dow EG106	100%	HEAD	35° Nested	50.5	52.5	11.2	-7.0
	2013-14	20-Dec-13	SN244	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	28.8	27.9	10.5	-7.0
	2013-14	20-Dec-13	SN245	Snow	PET	IV	Dow EG106	100%	HEAD	20º Nested	67.8	71.7	11.4	-7.0
	2013-14	20-Dec-13	SN246	Snow	PET	IV	Dow EG106	100%	TAIL	10°	376.2	172.4	5.0	-7.0
	2013-14	20-Dec-13	SN247	Snow	PET	IV	Dow EG106	100%	TAIL	20º Simple	208.8	215.7	11.2	-7.0
	2013-14	20-Dec-13	SN248	Snow	PET	IV	Dow EG106	100%	HEAD	15° Simple	59.5	63.6	11.5	-7.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
69 cont'd	2013-14	20-Dec-13	SN249	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	44.3	47.4	11.5	-7.0
	2013-14	20-Dec-13	SN250	Snow	PET	IV	Dow EG106	100%	ROTATING	10°	85.0	87.0	11.1	-7.0
	2013-14	20-Dec-13	SN251	Snow	PET	IV	Dow EG106	100%	ROTATING	20º Simple	52.7	56.4	11.6	-7.0
	2013-14	20-Dec-13	SN252	Snow	PET	IV	Dow EG106	100%	CROSS	10°	108.4	103.8	10.4	-7.0
	2013-14	20-Dec-13	SN253	Snow	PET	IV	Dow EG106	100%	CROSS	20º Simple	61.1	65.1	11.5	-7.0
70	2013-14	20-Dec-13	SN254 SN255 SN256	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	123.3	123.3	8.7	-8.0
	2013-14	20-Dec-13	SN257	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Nested	31.1	43.3	12.1	-8.0
	2013-14	20-Dec-13	SN258	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	28.6	39.0	11.9	-8.0
	2013-14	20-Dec-13	SN259	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Nested	41.2	61.2	12.9	-8.0
	2013-14	20-Dec-13	SN260	Snow	PET	IV	ABC-S Plus	100%	TAIL	10°	208.1	78.9	3.3	-8.0
	2013-14	20-Dec-13	SN261	Snow	PET	IV	ABC-S Plus	100%	TAIL	20º Simple	208.4	79.3	3.3	-8.0
	2013-14	20-Dec-13	SN262	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	36.5	53.3	12.7	-8.0
	2013-14	20-Dec-13	SN263	Snow	PET	IV	ABC-S Plus	100%	ROTATING	10°	81.2	103.3	11.1	-8.0
	2013-14	20-Dec-13	SN264	Snow	PET	IV	ABC-S Plus	100%	ROTATING	20º Simple	37.9	55.9	12.8	-8.0
	2013-14	20-Dec-13	SN265	Snow	PET	IV	ABC-S Plus	100%	CROSS	10°	184.6	134.1	6.3	-8.0
	2013-14	20-Dec-13	SN266	Snow	PET	IV	ABC-S Plus	100%	CROSS	20º Simple	61.3	89.7	12.7	-8.0
71	2013-14	1-Feb-14	SN267 SN268 SN269	Snow	PET	IV	ABAX AD-49	100%	HEAD	10°	165.0	165.0	5.6	-0.1

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
71 cont'd	2013-14	1-Feb-14	SN270	Snow	PET	IV	ABAX AD-49	100%	HEAD	35° Nested	53.7	76.5	8.0	-0.1
	2013-14	1-Feb-14	SN271	Snow	PET	IV	ABAX AD-49	100%	HEAD	35° Simple	40.4	56.2	7.8	-0.1
	2013-14	1-Feb-14	SN272	Snow	PET	IV	ABAX AD-49	100%	HEAD	20º Nested	192.8	188.6	5.5	-0.1
	2013-14	1-Feb-14	SN273	Snow	PET	IV	ABAX AD-49	100%	TAIL	10°	179.5	189.7	5.9	-0.1
	2013-14	1-Feb-14	SN274	Snow	PET	IV	ABAX AD-49	100%	TAIL	20º Simple	199.1	243.9	6.9	-0.1
	2013-14	1-Feb-14	SN275	Snow	PET	IV	ABAX AD-49	100%	HEAD	15° Simple	113.6	112.6	5.6	-0.1
	2013-14	1-Feb-14	SN276	Snow	PET	IV	ABAX AD-49	100%	HEAD	20º Simple	93.3	96.6	5.8	-0.1
	2013-14	1-Feb-14	SN277	Snow	PET	IV	ABAX AD-49	100%	ROTATING	10°	180.8	194.6	6.0	-0.1
	2013-14	1-Feb-14	SN278	Snow	PET	IV	ABAX AD-49	100%	ROTATING	20º Simple	96.5	99.4	5.8	-0.1
	2013-14	1-Feb-14	SN279	Snow	PET	IV	ABAX AD-49	100%	CROSS	10°	172.6	177.2	5.8	4.5
	2013-14	1-Feb-14	SN280	Snow	PET	IV	ABAX AD-49	100%	CROSS	20º Simple	103.3	104.9	5.7	-0.1
72	2013-14	1-Feb-14	SN281 SN282 SN283	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	83.0	83.0	21.1	-1.4
	2013-14	1-Feb-14	SN284	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Nested	62.5	60.4	20.4	-1.4
	2013-14	1-Feb-14	SN285	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	29.0	28.9	21.0	-1.4
	2013-14	1-Feb-14	SN286	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Nested	78.1	76.6	20.7	-1.4
	2013-14	1-Feb-14	SN287	Snow	PET	IV	ABC-S Plus	100%	TAIL	10°	89.7	91.5	21.5	-1.4
	2013-14	1-Feb-14	SN288	Snow	PET	IV	ABC-S Plus	100%	TAIL	20º Simple	117.3	129.4	23.3	-1.4

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
72 cont'd	2013-14	1-Feb-14	SN289	Snow	PET	IV	ABC-S Plus	100%	HEAD	15° Simple	61.4	59.4	20.4	-1.4
	2013-14	1-Feb-14	SN290	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	49.1	47.2	20.3	-1.4
	2013-14	1-Feb-14	SN291	Snow	PET	IV	ABC-S Plus	100%	ROTATING	10°	115.7	127.9	23.3	-1.4
	2013-14	1-Feb-14	SN292	Snow	PET	IV	ABC-S Plus	100%	ROTATING	20º Simple	53.2	51.3	20.3	-1.4
	2013-14	1-Feb-14	SN293	Snow	PET	IV	ABC-S Plus	100%	CROSS	10°	90.8	93.5	21.7	-1.4
	2013-14	1-Feb-14	SN294	Snow	PET	IV	ABC-S Plus	100%	CROSS	20º Simple	56.4	54.4	20.4	-1.4
73	2013-14	1-Feb-14	SN295 SN296 SN297	Snow	PET	IV	Dow EG106	100%	HEAD	10°	80.8	80.8	11.5	-4.0
	2013-14	1-Feb-14	SN298	Snow	PET	IV	Dow EG106	100%	HEAD	35° Nested	95.5	100.7	12.1	-4.0
	2013-14	1-Feb-14	SN299	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	30.2	27.2	10.3	-4.0
	2013-14	1-Feb-14	SN300	Snow	PET	IV	Dow EG106	100%	HEAD	20º Nested	100.5	109.6	12.5	-4.0
	2013-14	1-Feb-14	SN301	Snow	PET	IV	Dow EG106	100%	TAIL	10°	65.3	62.3	10.9	-4.0
	2013-14	1-Feb-14	SN302	Snow	PET	IV	Dow EG106	100%	TAIL	20º Simple	86.0	87.9	11.7	-4.0
	2013-14	1-Feb-14	SN303	Snow	PET	IV	Dow EG106	100%	HEAD	15° Simple	60.2	56.9	10.8	-4.0
	2013-14	1-Feb-14	SN304	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	47.1	43.9	10.7	-4.0
	2013-14	1-Feb-14	SN305	Snow	PET	IV	Dow EG106	100%	ROTATING	10°	83.9	85.7	11.7	-4.0
	2013-14	1-Feb-14	SN306	Snow	PET	IV	Dow EG106	100%	ROTATING	20º Simple	54.3	50.9	10.7	-4.0
	2013-14	1-Feb-14	SN307	Snow	PET	IV	Dow EG106	100%	CROSS	10°	83.1	84.4	11.6	-4.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
73 cont'd	2013-14	1-Feb-14	SN308	Snow	PET	IV	Dow EG106	100%	CROSS	20º Simple	48.2	44.8	10.6	-4.0
74	2013-14	5-Feb-14	SN309 SN310 SN311	Snow	PET	IV	Polar Guard Advance	100%	HEAD	10°	227.4	227.4	4.8	-9.0
	2013-14	5-Feb-14	SN312	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Nested	130.5	119.0	4.4	-9.0
	2013-14	5-Feb-14	SN313	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Simple	89.1	77.0	4.2	-9.0
	2013-14	5-Feb-14	SN314	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Nested	167.4	167.4	4.8	-9.0
	2013-14	5-Feb-14	SN315	Snow	PET	IV	Polar Guard Advance	100%	TAIL	10°	443.9	548.4	5.9	-9.0
	2013-14	5-Feb-14	SN316	Snow	PET	IV	Polar Guard Advance	100%	TAIL	20º Simple	340.6	430.0	6.1	-9.0
	2013-14	5-Feb-14	SN317	Snow	PET	IV	Polar Guard Advance	100%	HEAD	15° Simple	151.5	149.6	4.7	-9.0
	2013-14	5-Feb-14	SN318	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Simple	121.8	111.4	4.4	-9.0
	2013-14	5-Feb-14	SN319	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	10°	316.5	378.5	5.7	-9.0
	2013-14	5-Feb-14	SN320	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	20º Simple	216.7	213.6	4.7	-9.0
	2013-14	5-Feb-14	SN321	Snow	PET	IV	Polar Guard Advance	100%	CROSS	10°	246.7	247.7	4.8	-9.0
	2013-14	5-Feb-14	SN322	Snow	PET	IV	Polar Guard Advance	100%	CROSS	20º Simple	169.5	171.3	4.9	-9.0
75	2013-14	13-Feb-14	SN323 SN324 SN325	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	125.0	125.0	8.1	-7.0
	2013-14	13-Feb-14	SN326	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Nested	52.5	36.1	5.6	-7.0
	2013-14	13-Feb-14	SN327	Snow	PET	IV	ABC-S Plus	100%	HEAD	35° Simple	42.1	26.1	5.0	-7.0
	2013-14	13-Feb-14	SN328	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Nested	57.4	43.7	6.2	-7.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
75 cont'd	2013-14	13-Feb-14	SN329	Snow	PET	IV	ABC-S Plus	100%	TAIL	10°	300.1	424.9	11.5	-7.0
	2013-14	13-Feb-14	SN330	Snow	PET	IV	ABC-S Plus	100%	TAIL	20º Simple	299.7	424.8	11.5	-7.0
	2013-14	13-Feb-14	SN331	Snow	PET	IV	ABC-S Plus	100%	HEAD	15° Simple	79.7	76.4	7.8	-7.0
	2013-14	13-Feb-14	SN332	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	67.0	58.5	7.1	-7.0
	2013-14	13-Feb-14	SN333	Snow	PET	IV	ABC-S Plus	100%	ROTATING	10°	287.8	406.2	11.4	-7.0
	2013-14	13-Feb-14	SN334	Snow	PET	IV	ABC-S Plus	100%	ROTATING	20º Simple	235.4	311.0	10.7	-7.0
	2013-14	13-Feb-14	SN335	Snow	PET	IV	ABC-S Plus	100%	CROSS	10°	188.3	216.4	9.3	-7.0
	2013-14	13-Feb-14	SN336	Snow	PET	IV	ABC-S Plus	100%	CROSS	20º Simple	97.7	97.4	8.1	-7.0
76	2013-14	9-Mar-14	SN333	Snow	PET	III	2031 - HOT	100%	HEAD	10°	23.0	23.0	8.6	-5.7
	2013-14	9-Mar-14	SN334	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	17.8	16.7	8.1	-5.7
77A	2013-14	12-Mar-14	SN335 SN336 SN337	Snow	PET	IV	Polar Guard Advance	100%	HEAD	10°	172.6	172.6	16.9	-10.2
	2013-14	12-Mar-14	SN338	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Nested	55.8	49.1	14.9	-9.8
	2013-14	12-Mar-14	SN339	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Simple	34.2	28.3	14.0	-9.8
	2013-14	12-Mar-14	SN340	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Nested	79.9	70.7	15.0	-9.8
	2013-14	12-Mar-14	SN341	Snow	PET	IV	Polar Guard Advance	100%	TAIL	10°	719.6	795.3	18.7	-10.3
	2013-14	12-Mar-14	SN342	Snow	PET	IV	Polar Guard Advance	100%	TAIL	20º Simple	424.2	468.9	18.7	-10.7
	2013-14	12-Mar-14	SN343	Snow	PET	IV	Polar Guard Advance	100%	HEAD	15° Simple	96.9	88.9	15.5	-10.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
77A cont'd	2013-14	12-Mar-14	SN344	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Simple	87.7	77.0	14.9	-10.0
	2013-14	12-Mar-14	SN345	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	10°	216.1	233.2	18.3	-10.3
	2013-14	12-Mar-14	SN346	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	20º Simple	174.1	176.1	17.1	-10.2
	2013-14	12-Mar-14	SN347	Snow	PET	IV	Polar Guard Advance	100%	CROSS	10°	258.4	302.4	19.8	-10.3
	2013-14	12-Mar-14	SN348	Snow	PET	IV	Polar Guard Advance	100%	CROSS	20º Simple	216.3	232.7	18.2	-10.3
77B	2013-14	12-Mar-14	SN349 SN350 SN351	Snow	PET	IV	Polar Guard Advance	100%	HEAD	10°	162.5	162.5	14.4	-11.8
	2013-14	12-Mar-14	SN351	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Nested	75.1	76.8	14.7	-11.4
	2013-14	12-Mar-14	SN352	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Simple	37.8	34.9	13.3	-11.4
	2013-14	12-Mar-14	SN353	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Nested	76.7	78.5	14.7	-11.4
	2013-14	12-Mar-14	SN354	Snow	PET	IV	Polar Guard Advance	100%	HEAD	15° Simple	123.3	125.0	14.6	-11.6
	2013-14	12-Mar-14	SN355	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Simple	87.6	90.6	14.9	-11.4
	2013-14	12-Mar-14	SN356	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	10°	268.3	251.3	13.5	-11.0
	2013-14	12-Mar-14	SN357	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	20º Simple	175.6	173.8	14.3	-11.8
	2013-14	12-Mar-14	SN358	Snow	PET	IV	Polar Guard Advance	100%	CROSS	10°	256.3	240.3	13.5	-11.0
	2013-14	12-Mar-14	SN359	Snow	PET	IV	Polar Guard Advance	100%	CROSS	20º Simple	187.8	186.5	14.3	-11
78	2013-14	12-Mar-14	SN360	Snow	PET	III	2031 - HOT	100%	HEAD	10°	6.3	6.3	26.5	-10.7
	2013-14	12-Mar-14	SN361	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	4.5	4.5	26.5	-10.7

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
79	2013-14	12-Mar-14	SN362	Snow	PET	I	Octaflo EF	100%	HEAD	10°	7.3	7.3	11.9	-11.3
	2013-14	12-Mar-14	SN363	Snow	PET	I	Octaflo EF	100%	HEAD	20º Simple	5.0	5.0	11.9	-11.3
80	2013-14	12-Mar-14	SN364	Snow	PET	III	2031 - HOT	100%	HEAD	10°	14.0	14.0	19.6	-10.9
	2013-14	12-Mar-14	SN365	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	5.3	5.8	21.5	-10.9
81	2013-14	12-Mar-14	SN366	Snow	PET	III	2031 - HOT	100%	HEAD	10°	24.1	24.1	14.0	-12.0
	2013-14	12-Mar-14	SN367	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	9.5	9.9	14.6	-12.0
82	2013-14	12-Mar-14	SN368	Snow	PET	I	Octaflo EF	100%	HEAD	10°	9.2	9.2	7.4	-9.0
	2013-14	12-Mar-14	SN369	Snow	PET	I	Octaflo EF	100%	HEAD	20º Simple	7.8	7.6	7.2	-9.0
83	2013-14	12-Mar-14	SN370	Snow	PET	III	2031 - HOT	100%	HEAD	10°	18.7	18.7	13.4	-10.1
	2013-14	12-Mar-14	SN371	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	10.0	10.8	14.5	-10.1
84	2013-14	12-Mar-14	SN372	Snow	PET	III	2031 - HOT	100%	HEAD	10°	20.9	20.9	17.6	-10.4
	2013-14	12-Mar-14	SN373	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	10.7	11.1	18.1	-10.4
85	2013-14	22-Mar-14	SN374	Snow	PET	III	2031 - HOT	75%	HEAD	10°	18.8	18.8	13.3	-3.0
	2013-14	22-Mar-14	SN375	Snow	PET	III	2031 - HOT	75%	HEAD	20º Simple	15.8	15.8	13.3	-3.0
86	2013-14	19-Mar-14	ZP 83	Light Freezing Rain	NRC	II	LNT P250-2	50%	HEAD	10°	23.0	23.0	12.8	-3.0
	2013-14	19-Mar-14	ZP 84	Light Freezing Rain	NRC	II	LNT P250-2	50%	HEAD	20º Simple	13.7	12.7	11.9	-3.0
	2013-14	19-Mar-14	ZP 85	Light Freezing Rain	NRC	II	LNT P250-2	50%	HEAD	35° Simple	13.3	12.4	12.0	-3.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE ($g/dm^2/h$)	OAT (°C)
87	2013-14	20-Mar-14	ZP 86	Light Freezing Rain	NRC	IV	Newave FCY 9311	75%	HEAD	10°	41.1	41.1	5.0	-10.0
	2013-14	20-Mar-14	ZP 87	Light Freezing Rain	NRC	IV	Newave FCY 9311	75%	HEAD	20º Simple	21.0	23.1	5.5	-10.0
	2013-14	20-Mar-14	ZP 88	Light Freezing Rain	NRC	IV	Newave FCY 9311	75%	HEAD	35° Simple	21.6	23.4	5.4	-10.0
88	2013-14	20-Mar-14	ZP 89	Light Freezing Rain	NRC	I	Octaflo EF	27.00	HEAD	10°	8.4	8.4	5.7	-10.0
	2013-14	20-Mar-14	ZP 90	Light Freezing Rain	NRC	I	Octaflo EF	27.00	HEAD	20º Simple	6.7	6.5	5.5	-10.0
	2013-14	20-Mar-14	ZP 91	Light Freezing Rain	NRC	I	Octaflo EF	27.00	HEAD	35° Simple	6.5	6.2	5.4	-10.0
89	2013-14	20-Mar-14	ZP 92	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	10°	12.8	12.8	13.1	-10.0
	2013-14	20-Mar-14	ZP 93	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	20º Simple	10.2	9.9	12.8	-10.0
	2013-14	20-Mar-14	ZP 94	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	35° Simple	9.6	9.5	13.0	-10.0
90	2013-14	20-Mar-14	ZP 95	Light Freezing Rain	NRC	I	Octaflo EF	22.90	HEAD	10°	5.3	5.3	26.2	-10.0
	2013-14	20-Mar-14	ZP 96	Light Freezing Rain	NRC	I	Octaflo EF	22.90	HEAD	20º Simple	6.2	6.3	26.5	-10.0
	2013-14	20-Mar-14	ZP 97	Light Freezing Rain	NRC	I	Octaflo EF	22.90	HEAD	35° Simple	6.7	6.7	26.1	-10.0
91	2013-14	20-Mar-14	ZP 98	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	10°	6.5	6.5	26.2	-10.0
	2013-14	20-Mar-14	ZP 99	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	20º Simple	5.0	5.1	26.5	-10.0
	2013-14	20-Mar-14	ZP 100	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	35° Simple	5.1	5.1	26.1	-10.0
92	2013-14	21-Mar-14	ZP 101	Light Freezing Rain	NRC	II	Flight	75%	HEAD	10°	39.3	39.3	24.1	-3.0
	2013-14	21-Mar-14	ZP 102	Light Freezing Rain	NRC	II	Flight	75%	HEAD	20º Simple	31.0	30.4	23.6	-3.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
92 cotn'd	2013-14	21-Mar-14	ZP 103	Light Freezing Rain	NRC	II	Flight	75%	HEAD	35° Simple	21.0	22.3	25.6	-3.0
93	2013-14	21-Mar-14	ZP 104	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	21.25	HEAD	10°	11.0	11.0	24.1	-3.0
	2013-14	21-Mar-14	ZP 105	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	21.25	HEAD	20º Simple	10.9	10.6	23.6	-3.0
	2013-14	21-Mar-14	ZP 106	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	21.25	HEAD	35° Simple	9.9	10.5	25.6	-3.0
94	2013-14	25-Mar-14	ZP 107	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	10°	11.1	11.1	4.9	-3.0
	2013-14	25-Mar-14	ZP 108	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	20º Simple	10.9	11.5	5.2	-3.0
	2013-14	25-Mar-14	ZP 109	Light Freezing Rain	NRC	I	Dow UCAR ADF (EG)	17.60	HEAD	35° Simple	9.9	10.9	5.4	-3.0
95	2013-14	25-Mar-14	ZP 110	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	10°	25.6	25.6	4.9	-3.0
	2013-14	25-Mar-14	ZP 111	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	20º Simple	18.4	19.6	5.2	-3.0
	2013-14	25-Mar-14	ZP 112	Light Freezing Rain	NRC	III	2031 - HOT	100%	HEAD	35° Simple	15.7	17.2	5.4	-3.0
96	2014-15	2-Dec-14	SN376	Snow	PET	III-C	ALLCLEAR CB2	100%	HEAD	10°	22.5	22.5	27.9	-9.0
	2014-15	2-Dec-14	SN377	Snow	PET	III-C	ALLCLEAR CB2	100%	HEAD	20º Simple	12.7	13.2	29.1	-9.0
97	2014-15	2-Dec-14	SN378	Snow	PET	I	Octaflo EF	10 deg buff	HEAD	10°	6.5	6.5	12.5	-9.0
	2014-15	2-Dec-14	SN379	Snow	PET	I	Octaflo EF	10 deg buff	HEAD	20º Simple	5.3	5.2	12.2	-9.0
98	2014-15	5-Dec-14	SN380	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	10°	48.1	48.1	10.6	-6.6
	2014-15	5-Dec-14	SN381	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	20º Simple	30.8	20.5	7.1	-6.6
99	2014-15	9-Dec-14	SN382	Snow	PET	III-C	2031	100%	HEAD	10°	54.0	54.0	3.3	-2.9

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
99 cont'd	2014-15	9-Dec-14	SN383	Snow	PET	III-C	2031	100%	HEAD	20º Simple	28.4	26.0	3.0	-3.0
	2014-15	9-Dec-14	SNX1	Snow	PET	III-C	2031	100%	ROTATING	Slatted Airfoil	39.8	37.6	3.1	-2.9
100	2014-15	9-Dec-14	SN384	Snow	PET	III-C	2031	100%	HEAD	10°	28.6	28.6	8.2	-2.6
	2014-15	9-Dec-14	SN385	Snow	PET	III-C	2031	100%	HEAD	20º Simple	20.1	19.3	7.9	-2.8
	2014-15	9-Dec-14	SNX2	Snow	PET	III-C	2031	100%	ROTATING	Slatted Airfoil	22.8	22.0	7.9	-2.6
101	2014-15	9-Dec-14	SN386	Snow	PET	III-C	2031	100%	HEAD	10°	70.4	70.4	2.5	-1.8
	2014-15	9-Dec-14	SN387	Snow	PET	III-C	2031	100%	HEAD	20º Simple	52.0	62.1	3.0	-1.8
	2014-15	9-Dec-14	SNX3	Snow	PET	III-C	2031	100%	ROTATING	Slatted Airfoil	63.4	70.2	2.8	-1.8
102	2014-15	9-Dec-14	SN388	Snow	PET	IV	Dow EG106	100%	HEAD	10°	129.4	129.4	8.2	-0.9
	2014-15	9-Dec-14	SN389	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	65.1	54.4	6.9	-1.1
	2014-15	9-Dec-14	SNX4	Snow	PET	IV	Dow EG106	100%	ROTATING	Slatted Airfoil	133.0	133.0	8.2	-0.9
103	2014-15	10-Dec-14	SN390	Snow	PET	IV	Dow EG106	100%	HEAD	10°	83.5	83.5	20.8	-0.2
	2014-15	10-Dec-14	SN391	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	25.5	32.5	26.5	-0.2
	2014-15	10-Dec-14	SNX5	Snow	PET	IV	Dow EG106	100%	ROTATING	Slatted Airfoil	84.0	84.1	20.8	-0.2
104	2014-15	3-Jan-15	SN392	Snow	PET	III	2031 - HOT	75%	HEAD	10°	13.8	13.8	7.7	-12.7
	2014-15	3-Jan-15	SN393	Snow	PET	III	2031 - HOT	75%	HEAD	20º Simple	8.8	8.6	7.5	-12.7
105	2014-15	3-Jan-15	SN394	Snow	PET	III	2031 - HOT	75%	HEAD	10°	4.4	4.4	43.2	-11.2

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
105 cont'd	2014-15	3-Jan-15	SN395	Snow	PET	III	2031 - HOT	75%	HEAD	20º Simple	3.3	3.0	40.3	-11.2
106	2014-15	3-Jan-15	SN396	Snow	PET	III-C	MP III 2031	75%	HEAD	10°	18.0	18.0	18.6	-9.4
	2014-15	3-Jan-15	SN397	Snow	PET	III-C	MP III 2031	75%	HEAD	20º Simple	9.5	9.5	18.7	-9.4
107	2014-15	9-Jan-15	SN398 (x3)	Snow	PET	IV	Dow EG106	100%	HEAD	10°	125.8	125.8	7.2	-9.6
	2014-15	9-Jan-15	SN399	Snow	PET	IV	Dow EG106	100%	HEAD	15° Simple	74.1	80.2	7.8	-9.6
	2014-15	9-Jan-15	SN400	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	50.3	58.1	8.4	-9.6
	2014-15	9-Jan-15	SN401	Snow	PET	IV	Dow EG106	100%	HEAD	35° Nested	83.8	90.8	7.8	-9.6
	2014-15	9-Jan-15	SN402	Snow	PET	IV	Dow EG106	100%	HEAD	35° Simple	25.5	33.9	9.6	-9.6
	2014-15	9-Jan-15	SN403	Snow	PET	IV	Dow EG106	100%	HEAD	20º Nested	82.1	88.7	7.8	-9.6
	2014-15	9-Jan-15	SN404	Snow	PET	IV	Dow EG106	100%	TAIL	10°	141.7	142.1	7.3	-9.6
	2014-15	9-Jan-15	SN405	Snow	PET	IV	Dow EG106	100%	TAIL	20º Simple	85.8	92.7	7.8	-9.6
	2014-15	9-Jan-15	SN406	Snow	PET	IV	Dow EG106	100%	CROSS	10°	119.5	119.8	7.3	-9.6
	2014-15	9-Jan-15	SN407	Snow	PET	IV	Dow EG106	100%	CROSS	20º Simple	61.1	67.9	8.0	-9.6
	2014-15	9-Jan-15	SN408	Snow	PET	IV	Dow EG106	100%	ROTATING	10°	130.7	131.0	7.3	-9.6
	2014-15	9-Jan-15	SN409	Snow	PET	IV	Dow EG106	100%	ROTATING	20º Simple	55.3	63.0	8.2	-9.6
	2014-15	9-Jan-15	SN410	Snow	PET	IV	Dow EG106	100%	ROTATING	Simple Airfoil	145.5	145.3	7.2	-9.6
	2014-15	9-Jan-15	SN411	Snow	PET	IV	Dow EG106	100%	ROTATING	Slatted Airfoil	83.0	89.9	7.8	-9.6

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm^2/h)	OAT (°C)
108	2014-15	15-Jan-15	SN412 (x3)	Snow	PET	IV	Newave FCY 9311	75%	HEAD	10°	109.5	109.5	2.0	-4.8
	2014-15	15-Jan-15	SN413	Snow	PET	IV	Newave FCY 9311	75%	HEAD	15° Simple	98.7	78.3	1.6	-4.8
	2014-15	15-Jan-15	SN414	Snow	PET	IV	Newave FCY 9311	75%	HEAD	20º Simple	93.4	64.9	1.4	-4.8
	2014-15	15-Jan-15	SN415	Snow	PET	IV	Newave FCY 9311	75%	HEAD	35° Nested	88.5	48.4	1.1	-4.8
	2014-15	15-Jan-15	SN416	Snow	PET	IV	Newave FCY 9311	75%	HEAD	35° Simple	78.1	29.2	0.8	-4.8
	2014-15	15-Jan-15	SN417	Snow	PET	IV	Newave FCY 9311	75%	HEAD	20º Nested	118.3	128.7	2.2	-4.8
	2014-15	15-Jan-15	SN418	Snow	PET	IV	Newave FCY 9311	75%	TAIL	10°	196.0	310.9	3.2	-4.6
	2014-15	15-Jan-15	SN419	Snow	PET	IV	Newave FCY 9311	75%	TAIL	20º Simple	203.5	330.8	3.3	-4.6
	2014-15	15-Jan-15	SN420	Snow	PET	IV	Newave FCY 9311	75%	CROSS	10°	122.5	151.5	2.5	-4.8
	2014-15	15-Jan-15	SN421	Snow	PET	IV	Newave FCY 9311	75%	CROSS	20º Simple	112.6	116.5	2.1	-4.8
	2014-15	15-Jan-15	SN422	Snow	PET	IV	Newave FCY 9311	75%	ROTATING	10°	140.0	185.5	2.7	-4.6
	2014-15	15-Jan-15	SN423	Snow	PET	IV	Newave FCY 9311	75%	ROTATING	20º Simple	119.9	150.0	2.5	-4.8
	2014-15	15-Jan-15	SN424	Snow	PET	IV	Newave FCY 9311	75%	ROTATING	Simple Airfoil	220.6	374.9	3.5	-4.4
	2014-15	15-Jan-15	SN425	Snow	PET	IV	Newave FCY 9311	75%	ROTATING	Slatted Airfoil	103.2	88.9	1.8	-4.8
109	2014-15	16-Jan-15	SN426	Snow	PET	III-C	MP III 2031	75%	HEAD	10°	22.9	22.9	4.1	-4.8
	2014-15	16-Jan-15	SN427	Snow	PET	III-C	MP III 2031	75%	HEAD	20º Simple	14.7	15.4	4.4	-4.8
110	2014-15	18-Jan-15	SN428 (x3)	Snow	PET	IV	Polar Guard Advance	100%	HEAD	10°	N/A	N/A	6.1	-1.7

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
110 cont'd	2014-15	18-Jan-15	SN429	Snow	PET	IV	Polar Guard Advance	100%	HEAD	15° Simple	147.7	N/A	8.0	-1.5
	2014-15	18-Jan-15	SN430	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Simple	133.5	N/A	8.3	-1.5
	2014-15	18-Jan-15	SN431	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Nested	224.2	N/A	6.0	-1.7
	2014-15	18-Jan-15	SN432	Snow	PET	IV	Polar Guard Advance	100%	HEAD	35° Simple	57.3	N/A	12.8	-1.4
	2014-15	18-Jan-15	SN433	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Nested	222.8	N/A	6.0	-1.7
	2014-15	18-Jan-15	SN434	Snow	PET	IV	Polar Guard Advance	100%	TAIL	10°	222.8	N/A	6.0	-1.7
	2014-15	18-Jan-15	SN435	Snow	PET	IV	Polar Guard Advance	100%	TAIL	20º Simple	142.0	N/A	8.0	-1.4
	2014-15	18-Jan-15	SN436	Snow	PET	IV	Polar Guard Advance	100%	CROSS	10°	226.7	N/A	6.1	-1.7
	2014-15	18-Jan-15	SN437	Snow	PET	IV	Polar Guard Advance	100%	CROSS	20º Simple	131.8	N/A	8.5	-1.4
	2014-15	18-Jan-15	SN438	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	10°	226.4	N/A	6.1	-1.7
	2014-15	18-Jan-15	SN439	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	20º Simple	134.3	N/A	8.4	-1.4
	2014-15	18-Jan-15	SN440	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	Simple Airfoil (no fail)	N/A	N/A	6.0	-1.7
	2014-15	18-Jan-15	SN441	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	Slatted Airfoil	N/A	N/A	6.0	-1.7
111	2014-15	2-Feb-15	SN442	Snow	PET	IV	Dow EG106	100%	HEAD	10°	73.8	73.8	8.4	-22.2
	2014-15	2-Feb-15	SN443	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	45.3	44.3	8.2	-22.2
	2014-15	2-Feb-15	SN444	Snow	PET	IV	Dow EG106	100%	ROTATING	Slatted Airfoil	79.6	77.8	8.2	-22.2
112	2014-15	2-Feb-15	SN445	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	10°	63.2	63.2	7.5	-22.3

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
112 cont'd	2014-15	2-Feb-15	SN446	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	20º Simple	36.9	35.6	7.3	-22.3
113	2014-15	2-Feb-15	SN447	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	10°	69.6	69.6	8.4	-21.9
	2014-15	2-Feb-15	SN448	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	20º Simple	30.1	29.6	8.3	-21.9
	2014-15	2-Feb-15	SN449	Snow	PET	IV	Clariant Max Flight 04	100%	ROTATING	Slatted Airfoil	67.6	67.9	8.5	-21.9
114	2014-15	2-Feb-15	SN450	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	10°	103.5	103.5	8.0	-21.6
	2014-15	2-Feb-15	SN451	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	20º Simple	53.9	49.5	7.3	-21.3
115	2014-15	2-Feb-15	SN452	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	10°	84.0	84.0	9.3	-21.0
	2014-15	2-Feb-15	SN453	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	20º Simple	39.5	38.1	9.0	-21.0
	2014-15	2-Feb-15	SN454	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	Slatted Airfoil	47.3	44.9	8.8	-21.0
116	2014-15	2-Feb-15	SN455	Snow	PET	IV	Dow EG106	100%	HEAD	10°	108.0	108.0	7.4	-20.1
	2014-15	2-Feb-15	SN456	Snow	PET	IV	Dow EG106	100%	HEAD	20º Simple	60.5	57.9	7.1	-20.1
	2014-15	2-Feb-15	SN457	Snow	PET	IV	Dow EG106	100%	ROTATING	Slatted Airfoil	129.3	130.8	7.5	-19.6
117	2014-15	2-Feb-15	SN458	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	10°	103.3	103.3	7.3	-19.6
	2014-15	2-Feb-15	SN459	Snow	PET	III-C	ALLCLEAR CB4	100%	HEAD	20º Simple	53.7	50.8	6.9	-20.1
118	2014-15	4-Feb-15	SN460	Snow	PET	III	2031 - HOT	75%	HEAD	10°	48.7	48.7	1.7	-5.8
	2014-15	4-Feb-15	SN461	Snow	PET	III	2031 - HOT	75%	HEAD	20º Simple	49.6	50.2	1.7	-5.8
119	2014-15	4-Feb-15	SN462	Snow	PET	III-C	MP III 2031	75%	HEAD	10°	46.2	46.2	1.8	-5.8

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
119 cont'd	2014-15	4-Feb-15	SN463	Snow	PET	III-C	MP III 2031	75%	HEAD	20º Simple	40.0	36.0	1.6	-5.9
120	2014-15	4-Feb-15	SN464	Snow	PET	III	2031 - HOT	100%	HEAD	10°	109.1	109.1	2.6	-5.6
	2014-15	4-Feb-15	SN465	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	109.8	109.8	2.6	-5.6
121	2014-15	4-Feb-15	SN466	Snow	PET	III-C	MP III 2031	100%	HEAD	10°	60.3	60.3	2.7	-5.5
	2014-15	4-Feb-15	SN467	Snow	PET	III-C	MP III 2031	100%	HEAD	20º Simple	42.5	42.0	2.7	-5.5
122	2014-15	4-Feb-15	SN468	Snow	PET	III	2031 - HOT	100%	HEAD	10°	75.7	75.7	1.6	-4.9
	2014-15	4-Feb-15	SN469	Snow	PET	III	2031 - HOT	100%	HEAD	20º Simple	69.5	69.1	1.6	-4.9
123	2014-15	4-Feb-15	SN470	Snow	PET	III-C	MP III 2031	100%	HEAD	10°	81.3	81.3	1.5	-4.9
	2014-15	4-Feb-15	SN471	Snow	PET	III-C	MP III 2031	100%	HEAD	20º Simple	66.6	58.2	1.3	-4.9
124	2014-15	4-Feb-15	SN472	Snow	PET	II	Kilfrost P2586	75%	HEAD	10°	65.2	65.2	3.6	-4.5
	2014-15	4-Feb-15	SN473	Snow	PET	II	Kilfrost P2586	75%	HEAD	20º Simple	39.0	42.6	3.9	-4.5
	2014-15	4-Feb-15	SN474	Snow	PET	II	Kilfrost P2586	75%	ROTATING	Slatted Airfoil	62.0	61.7	3.6	-4.5
125	2014-15	4-Feb-15	SN475	Snow	PET	IV	Polar Guard Advance	75%	HEAD	10°	232.0	232.0	4.7	-5.3
	2014-15	4-Feb-15	SN476	Snow	PET	IV	Polar Guard Advance	75%	HEAD	20º Simple	148.3	165.5	5.3	-4.9
	2014-15	4-Feb-15	SN477	Snow	PET	IV	Polar Guard Advance	75%	ROTATING	Slatted Airfoil	224.0	224.0	4.7	-5.3
126	2014-15	4-Feb-15	SN478	Snow	PET	II	Kilfrost P2586	75%	HEAD	10°	61.5	61.5	4.0	-7.3
	2014-15	4-Feb-15	SN479	Snow	PET	II	Kilfrost P2586	75%	HEAD	20º Simple	39.4	34.6	3.5	-7.2

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
127	2014-15	8-Feb-15	SN480	Snow	PET	I	Octaflo EF	31.50	HEAD	10°	6.8	6.8	9.3	-16.7
	2014-15	8-Feb-15	SN481	Snow	PET	I	Octaflo EF	31.50	HEAD	20º Simple	4.8	4.8	9.3	-16.7
	2014-15	8-Feb-15	SN482	Snow	PET	I	Octaflo EF	31.50	ROTATING	Slatted Airfoil	4.3	4.3	9.3	-16.7
128	2014-15	8-Feb-15	SN483	Snow	PET	I	Octaflo EF	31.50	HEAD	10°	8.8	8.8	7.3	-15.9
	2014-15	8-Feb-15	SN484	Snow	PET	I	Octaflo EF	31.50	HEAD	20º Simple	7.5	6.8	6.7	-15.9
	2014-15	8-Feb-15	SN485	Snow	PET	I	Octaflo EF	31.50	ROTATING	Slatted Airfoil	6.9	6.6	7.1	-15.9
129	2014-15	8-Feb-15	SN486	Snow	PET	I	Octaflo EF	31.50	HEAD	10°	14.3	14.3	5.5	-15.5
	2014-15	8-Feb-15	SN487	Snow	PET	I	Octaflo EF	31.50	HEAD	20º Simple	10.5	10.5	5.5	-15.5
	2014-15	8-Feb-15	SN488	Snow	PET	I	Octaflo EF	31.50	ROTATING	Slatted Airfoil	10.8	10.8	5.5	-15.5
130	2014-15	11-Feb-15	SN489	Snow	PET	III-C	MP III 2031	75%	HEAD	10°	15.3	15.3	2.3	-12.3
	2014-15	11-Feb-15	SN490	Snow	PET	III-C	MP III 2031	75%	HEAD	20º Simple	13.3	13.0	2.2	-12.3
131	2014-15	11-Feb-15	SN491	Snow	PET	II	Newave FCY-2 BIO+	75%	HEAD	10°	19.3	19.3	6.9	-12.4
	2014-15	11-Feb-15	SN492	Snow	PET	II	Newave FCY-2 BIO+	75%	HEAD	20º Simple	10.0	11.0	7.5	-2.4
132	2014-15	11-Feb-15	SN493	Snow	PET	I	Octaflo EF	28.50	HEAD	10°	11.6	11.6	4.9	-12.4
	2014-15	11-Feb-15	SN494	Snow	PET	I	Octaflo EF	28.50	HEAD	20º Simple	8.1	6.6	4.0	-12.4
133	2014-15	11-Feb-15	SN495	Snow	PET	II	LNT P250	75%	HEAD	10°	101.3	101.3	3.8	-12.4
	2014-15	11-Feb-15	SN496	Snow	PET	II	LNT P250	75%	HEAD	20º Simple	24.6	50.3	7.8	-12.4

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
134	2014-15	12-Feb-15	SN497	Snow	PET	I	Defrost ECO I	25.25	HEAD	10°	16.8	16.8	2.2	-12.4
	2014-15	12-Feb-15	SN498	Snow	PET	I	Defrost ECO I	25.25	HEAD	20º Simple	13.8	13.8	2.2	-12.4
135	2014-15	14-Feb-15	SN499	Snow	PET	II	Newave FCY-2 BIO+	100%	HEAD	10°	251.9	251.9	0.9	-16.2
	2014-15	14-Feb-15	SN500	Snow	PET	II	Newave FCY-2 BIO+	100%	HEAD	20º Simple	123.5	151.6	1.1	-16.6
136	2014-15	21-Feb-15	SN501	Snow	PET	IV	ABAX AD-49	100%	HEAD	10°	95.3	95.3	6.0	-8.5
	2014-15	21-Feb-15	SN502	Snow	PET	IV	ABAX AD-49	100%	HEAD	20º Simple	73.5	67.1	5.5	-8.8
	2014-15	21-Feb-15	SN503	Snow	PET	IV	ABAX AD-49	100%	ROTATING	Slatted Airfoil	93.0	91.1	5.9	-8.5
137	2014-15	21-Feb-15	SN504	Snow	PET	IV	Polar Guard Advance	100%	HEAD	10°	177.7	177.7	3.7	-8.2
	2014-15	21-Feb-15	SN505	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Simple	162.5	169.1	3.8	-8.2
	2014-15	21-Feb-15	SN506	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	Slatted Airfoil	179.0	179.5	3.7	-8.2
138	2014-15	21-Feb-15	SN507	Snow	PET	II	Kilfrost P2586	75%	HEAD	10°	79.9	79.9	3.3	-8.6
	2014-15	21-Feb-15	SN508	Snow	PET	II	Kilfrost P2586	75%	HEAD	20º Simple	42.2	47.1	3.7	-7.9
139	2014-15	3-Mar-15	SN509	Snow	PET	IV	Launch	50%	HEAD	10°	17.5	17.5	14.3	-5.5
	2014-15	3-Mar-15	SN510	Snow	PET	IV	Launch	50%	HEAD	20º Simple	8.9	9.0	14.5	-5.5
	2014-15	3-Mar-15	SN511	Snow	PET	IV	Launch	50%	HEAD	Slatted Airfoil	12.7	12.9	14.6	-5.5
140	2014-15	3-Mar-15	SN512	Snow	PET	III	MP III 2031	75%	HEAD	10°	5.9	5.9	35.4	-5.9
	2014-15	3-Mar-15	SN513	Snow	PET	III	MP III 2031	75%	HEAD	20º Simple	3.8	4.0	37.2	-5.9

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
140 cont'd	2014-15	3-Mar-15	SN514	Snow	PET	III-C	MP III 2031	75%	ROTATING	Slatted Airfoil	5.5	5.4	34.7	-5.9
141	2014-15	3-Mar-15	SN515	Snow	PET	IV	Clariant Max Flight 04	50%	HEAD	10°	40.2	40.2	7.5	-5.8
	2014-15	3-Mar-15	SN516	Snow	PET	IV	Clariant Max Flight 04	50%	HEAD	20º Simple	14.0	16.9	9.1	-5.8
142	2014-15	3-Mar-15	SN517	Snow	PET	IV	Launch Plus	50%	HEAD	10°	3.8	3.8	43.2	-5.7
	2014-15	3-Mar-15	SN518	Snow	PET	IV	Launch Plus	50%	HEAD	20º Simple	2.6	2.3	39.2	-5.7
143	2014-15	3-Mar-15	SN519	Snow	PET	II	LNT P250	75%	HEAD	10°	42.8	42.8	14.3	-5.5
	2014-15	3-Mar-15	SN520	Snow	PET	II	LNT P250	75%	HEAD	20º Simple	35.8	30.2	12.1	-5.5
144	2014-15	3-Mar-15	SN521	Snow	PET	II	Kilfrost P2595	75%	HEAD	10°	85.2	85.2	6.2	-5.0
	2014-15	3-Mar-15	SN522	Snow	PET	II	Kilfrost P2595	75%	HEAD	20º Simple	41.7	46.2	6.8	-5.1
145	2014-15	3-Mar-15	SN523	Snow	PET	III	MP III 2031	50%	HEAD	10°	12.5	12.5	5.2	-4.9
	2014-15	3-Mar-15	SN524	Snow	PET	III	MP III 2031	50%	HEAD	20º Simple	8.8	9.0	5.3	-4.9
	2014-15	3-Mar-15	SN525	Snow	PET	III-C	MP III 2031	50%	ROTATING	Slatted Airfoil	9.1	9.5	5.4	-4.9
146	2014-15	27-Mar-15	ZP113	Light Freezing Rain	NRC	III	MP III 2031	100%	HEAD	10°	13.5	13.5	13.2	-3.0
	2014-15	27-Mar-15	ZP114	Light Freezing Rain	NRC	III	MP III 2031	100%	HEAD	20º Simple	11.1	10.8	12.9	-3.0
147	2014-15	27-Mar-15	ZP115	Light Freezing Rain	NRC	III	AllClear CB1-PB8000A	100%	HEAD	10°	23.7	23.7	25.1	-3.0
	2014-15	27-Mar-15	ZP116	Light Freezing Rain	NRC	III	AllClear CB1-PB8000A	100%	HEAD	20º Simple	17.4	16.7	24.1	-3.0
148	2014-15	26-Mar-15	ZP117	Light Freezing Rain	NRC	II	Newave FCY-2 BIO+	100%	HEAD	10°	29.0	29.0	13.2	-10.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
148 cont'd	2014-15	26-Mar-15	ZP118	Light Freezing Rain	NRC	II	Newave FCY-2 BIO+	100%	HEAD	20º Simple	15.2	15.8	13.7	-10.0
149	2014-15	26-Mar-15	ZP119	Light Freezing Rain	NRC	IV	ECO-SHIELD	100%	HEAD	10°	26.5	26.5	24.3	-10.0
	2014-15	26-Mar-15	ZP120	Light Freezing Rain	NRC	IV	ECO-SHIELD	100%	HEAD	20º Simple	18.8	18.9	24.5	-10.0
150	2014-15	25-Mar-15	ZP121	Freezing Drizzle	NRC	III	MP III 2031	75%	HEAD	10°	12.0	12.0	12.0	-3.0
	2014-15	25-Mar-15	ZP122	Freezing Drizzle	NRC	III	MP III 2031	75%	HEAD	20º Simple	9.6	9.6	12.0	-3.0
151	2014-15	27-Mar-15	ZP123	Freezing Drizzle	NRC	III	MP III 2031	75%	HEAD	10°	12.8	12.8	5.7	-10.0
	2014-15	27-Mar-15	ZP124	Freezing Drizzle	NRC	III	MP III 2031	75%	HEAD	20º Simple	9.9	9.9	5.7	-10.0
152	2014-15	26-Mar-15	ZP125	Freezing Drizzle	NRC	II	Kilfrost P2595	100%	HEAD	10°	26.0	26.0	13.5	-10.0
	2014-15	26-Mar-15	ZP126	Freezing Drizzle	NRC	II	Kilfrost P2595	100%	HEAD	20º Simple	15.8	15.1	12.9	-10.0
153	2014-15	26-Mar-15	ZP127	Freezing Drizzle	NRC	III	MP III 2031	75%	HEAD	10°	7.3	7.3	13.9	-10.0
	2014-15	26-Mar-15	ZP128	Freezing Drizzle	NRC	III	MP III 2031	75%	HEAD	20º Simple	4.9	5.0	14.1	-10.0
154	2014-15	31-Mar-15	ZP129	Freezing Fog	NRC	III	2031 - HOT	100%	HEAD	10°	21.4	21.4	4.7	-3.0
	2014-15	31-Mar-15	ZP130	Freezing Fog	NRC	III	2031 - HOT	100%	HEAD	20º Simple	16.5	17.5	5.0	-3.0
155	2014-15	31-Mar-15	ZP131	Freezing Fog	NRC	III	AllClear CB1-PB8000A	100%	HEAD	10°	61.4	61.4	5.1	-10.0
	2014-15	31-Mar-15	ZP132	Freezing Fog	NRC	III	AllClear CB1-PB8000A	100%	HEAD	20º Simple	37.2	38.7	5.3	-10.0
156	2014-15	26-Mar-15	ZP133	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	10°	81.5	81.5	11.8	-10.0
	2014-15	26-Mar-15	ZP134	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	20º Simple	49.7	49.7	11.8	-10.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
156 cont'd	2014-15	26-Mar-15	ZP135	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	Slatted Airfoil	64.3	64.3	11.8	-10.0
	2014-15	26-Mar-15	ZP136	Light Freezing Rain	NRC	IV	Dow EG106	100%	HEAD	Simple Airfoil	52.9	52.9	11.8	-10.0
157	2014-15	26-Mar-15	ZP137	Light Freezing Rain	NRC	I	Clariant MP I 1938 ECO	Premix	HEAD	10°	6.6	6.6	11.8	-10.0
	2014-15	26-Mar-15	ZP138	Light Freezing Rain	NRC	I	Clariant MP I 1938 ECO	Premix	HEAD	20º Simple	5.1	5.1	11.8	-10.0
	2014-15	26-Mar-15	ZP139	Light Freezing Rain	NRC	I	Clariant MP I 1938 ECO	Premix	HEAD	Slatted Airfoil	4.8	4.8	11.8	-10.0
	2014-15	26-Mar-15	ZP140	Light Freezing Rain	NRC	I	Clariant MP I 1938 ECO	27.5	HEAD	Simple Airfoil	11.1	11.1	11.8	-10.0
158	2014-15	26-Mar-15	ZP141	Light Freezing Rain	NRC	IV	ABAX AD-49	100%	HEAD	10°	23.0	23.0	24.5	-10.0
	2014-15	26-Mar-15	ZP142	Light Freezing Rain	NRC	IV	ABAX AD-49	100%	HEAD	20º Simple	19.5	19.5	24.5	-10.0
	2014-15	26-Mar-15	ZP143	Light Freezing Rain	NRC	IV	ABAX AD-49	100%	HEAD	Slatted Airfoil	20.9	20.9	24.5	-10.0
	2014-15	26-Mar-15	ZP144	Light Freezing Rain	NRC	IV	ABAX AD-49	100%	HEAD	Simple Airfoil	26.7	26.7	24.5	-10.0
159	2014-15	25-Mar-15	ZP145	Freezing Drizzle	NRC	IV	Newave FCY 9311	50%	HEAD	10°	20.5	20.5	5.3	-3.0
	2014-15	25-Mar-15	ZP146	Freezing Drizzle	NRC	IV	Newave FCY 9311	100%	HEAD	20º Simple	6.8	6.8	5.3	-3.0
	2014-15	25-Mar-15	ZP147	Freezing Drizzle	NRC	IV	Newave FCY 9311	50%	HEAD	Slatted Airfoil	19.0	19.0	5.3	-3.0
	2014-15	25-Mar-15	ZP148	Freezing Drizzle	NRC	IV	Newave FCY 9311	50%	HEAD	Simple Airfoil	55.0	55.0	5.3	-3.0
160	2014-15	25-Mar-15	ZP149	Freezing Drizzle	NRC	IV	ABC-S Plus	75%	HEAD	10°	52.0	52.0	14.7	-3.0
	2014-15	25-Mar-15	ZP150	Freezing Drizzle	NRC	IV	ABC-S Plus	75%	HEAD	20º Simple	23.0	23.0	14.7	-3.0
	2014-15	25-Mar-15	ZP151	Freezing Drizzle	NRC	IV	ABC-S Plus	75%	HEAD	Slatted Airfoil	33.5	33.5	14.7	-3.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
160 cont'd	2014-15	25-Mar-15	ZP152	Freezing Drizzle	NRC	IV	ABC-S Plus	75%	HEAD	Simple Airfoil	56.0	56.0	14.7	-3.0
161	2015-16	27-Dec-15	SN526	Snow	PET	IV	Launch	100%	HEAD	10°	97.2	97.2	24.3	-0.1
	2015-16	27-Dec-15	SN527	Snow	PET	IV	Launch	100%	HEAD	20º Simple	61.0	54.8	21.8	0.0
	2015-16	27-Dec-15	SN528	Snow	PET	IV	Launch	100%	ROTATING	Slatted Airfoil	99.3	98.5	24.1	-0.1
	2015-16	27-Dec-15	SN529	Snow	PET	IV	Launch	100%	ROTATING	Simple Airfoil (no fail)	N/A	N/A	N/A	-0.1
162	2015-16	29-Dec-15	SN530	Snow	PET	IV	Polar Guard Advance	100%	HEAD	10°	25.6	25.6	31.8	-11.6
	2015-16	29-Dec-15	SN531	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Simple	19.6	18.4	30.0	-11.6
	2015-16	29-Dec-15	SN532	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	Slatted Airfoil	29.1	29.5	32.3	-11.6
163	2015-16	29-Dec-15	SN533	Snow	PET	II	ABC-Ice Clear II	75%	HEAD	10°	11.3	11.3	27.0	-10.6
	2015-16	29-Dec-15	SN534	Snow	PET	II	ABC-Ice Clear II	75%	HEAD	20º Simple	5.2	5.2	27.4	-10.6
	2015-16	29-Dec-15	SN535	Snow	PET	II	ABC-Ice Clear II	75%	ROTATING	Slatted Airfoil	14.9	14.7	26.6	-10.6
164	2015-16	29-Dec-15	SN536	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	80.0	80.0	22.1	-8.5
	2015-16	29-Dec-15	SN537	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	36.6	36.5	22.0	-8.6
	2015-16	29-Dec-15	SN538	Snow	PET	IV	ABC-S Plus	100%	ROTATING	Slatted Airfoil	81.8	82.2	22.2	-8.3
	2015-16	29-Dec-15	SN539	Snow	PET	IV	ABC-S Plus	100%	ROTATING	Simple Airfoil	161.5	165.9	22.7	-8.1
165	2015-16	29-Dec-15	SN540	Snow	PET	I	Cryotech Polar Plus	26.0	HEAD	10°	3.2	3.2	15.7	-8.1
	2015-16	29-Dec-15	SN541	Snow	PET	I	Cryotech Polar Plus	26.0	HEAD	20º Simple	2.7	2.7	15.7	-8.1

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
165 cont'd	2015-16	29-Dec-15	SN542	Snow	PET	I	Cryotech Polar Plus	26.0	ROTATING	Slatted Airfoil	4.2	4.2	15.7	-8.1
166	2015-16	29-Dec-15	SN543	Snow	PET	I	Cryotech Polar Plus	27.5	HEAD	10°	2.5	2.5	29.1	-8.4
	2015-16	29-Dec-15	SN544	Snow	PET	I	Cryotech Polar Plus	27.5	HEAD	20º Simple	2.0	2.0	29.5	-8.4
	2015-16	29-Dec-15	SN545	Snow	PET	I	Cryotech Polar Plus	27.5	ROTATING	Slatted Airfoil	2.5	2.4	27.5	-8.4
167	2015-16	29-Dec-15	SN546	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	10°	N/A	N/A	4.9	-8.4
	2015-16	29-Dec-15	SN547	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	20º Simple	N/A	N/A	5.0	-8.4
	2015-16	29-Dec-15	SN548	Snow	PET	IV	Clariant Max Flight 04	100%	ROTATING	Slatted Airfoil	N/A	N/A	5.0	-8.3
168	2015-16	2-Jan-16	SN549	Snow	PET	II	Newave FCY-2 BIO+	50%	HEAD	10°	14.3	14.3	9.9	-0.6
	2015-16	2-Jan-16	SN550	Snow	PET	II	Newave FCY-2 BIO+	50%	HEAD	20º Simple	8.1	8.9	11.0	-0.6
	2015-16	2-Jan-16	SN551	Snow	PET	II	Newave FCY-2 BIO+	50%	ROTATING	Slatted Airfoil	12.3	12.8	10.3	-0.6
169	2015-16	3-Jan-16	SN552	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	10°	284.8	284.8	5.7	-0.8
	2015-16	3-Jan-16	SN553	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	20º Simple	176.0	140.8	4.5	-1.0
	2015-16	3-Jan-16	SN554	Snow	PET	IV	Clariant Max Flight 04	100%	ROTATING	Slatted Airfoil	N/A	N/A	N/A	-0.7
170	2015-16	12-Jan-16	SN555	Snow	PET	II	ABC-Ice Clear II	75%	HEAD	10°	175.2	175.2	1.3	-4.8
	2015-16	12-Jan-16	SN556	Snow	PET	II	ABC-Ice Clear II	75%	HEAD	20º Simple	149.0	105.9	0.9	-4.9
	2015-16	12-Jan-16	SN557	Snow	PET	II	ABC-Ice Clear II	75%	ROTATING	Slatted Airfoil	150.4	108.1	0.9	-4.9
171	2015-16	12-Jan-16	SN558	Snow	PET	III-C	AeroClear MAX	100%	HEAD	10°	88.5	88.5	2.3	-4.4

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
171 cont'd	2015-16	12-Jan-16	SN559	Snow	PET	III-C	AeroClear MAX	100%	HEAD	20º Simple	40.1	63.9	3.6	-4.6
	2015-16	12-Jan-16	SN560	Snow	PET	III-C	AeroClear MAX	100%	ROTATING	Slatted Airfoil	89.5	90.3	2.3	-4.4
172	2015-16	3-Feb-16	SN561	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	188.0	188.0	11.4	-4.7
	2015-16	3-Feb-16	SN562	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	148.6	53.9	4.2	-4.8
	2015-16	3-Feb-16	SN563	Snow	PET	IV	ABC-S Plus	100%	ROTATING	Slatted Airfoil	166.0	103.0	7.1	-4.8
173	2015-16	9-Feb-16	SN564	Snow	PET	I	Octaflo EF	25.0	HEAD	10°	19.3	19.3	0.9	-8.2
	2015-16	9-Feb-16	SN565	Snow	PET	I	Octaflo EF	25.0	HEAD	20º Simple	13.8	13.1	0.8	-8.1
	2015-16	9-Feb-16	SN566	Snow	PET	I	Octaflo EF	25.0	ROTATING	Slatted Airfoil	15.3	14.4	0.8	-8.1
174	2015-16	12-Feb-16	SN567	Snow	PET	I	AllClear E-188	23.0	HEAD	10°	6.0	6.0	11.6	-7.1
	2015-16	12-Feb-16	SN568	Snow	PET	I	AllClear E-188	23.0	HEAD	20º Simple	5.8	5.7	11.5	-7.1
	2015-16	12-Feb-16	SN569	Snow	PET	I	AllClear E-188	23.0	ROTATING	Slatted Airfoil	3.8	3.8	11.5	-7.1
	2015-16	12-Feb-16	SN570	Snow	PET	I	AllClear E-188	23.0	ROTATING	Simple Airfoil	7.5	7.3	11.2	-7.1
175	2015-16	12-Feb-16	SN571	Snow	PET	I	AllClear E-188	23.0	HEAD	10°	11.3	11.3	6.4	-6.3
	2015-16	12-Feb-16	SN572	Snow	PET	I	AllClear E-188	23.0	HEAD	20º Simple	8.1	8.6	6.8	-6.7
	2015-16	12-Feb-16	SN573	Snow	PET	I	AllClear E-188	23.0	ROTATING	Slatted Airfoil	4.1	5.5	8.7	-6.7
	2015-16	12-Feb-16	SN574	Snow	PET	I	AllClear E-188	23.0	ROTATING	Simple Airfoil	14.7	14.5	6.3	-6.3
176	2015-16	12-Feb-16	SN575	Snow	PET	I	AllClear E-188	18.0	HEAD	10°	52.7	52.7	0.6	-6.8

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
176 cont'd	2015-16	12-Feb-16	SN576	Snow	PET	I	AllClear E-188	18.0	HEAD	20º Simple	50.6	50.6	0.6	-6.7
	2015-16	12-Feb-16	SN577	Snow	PET	I	AllClear E-188	18.0	ROTATING	Slatted Airfoil	7.4	15.8	1.3	-6.7
	2015-16	12-Feb-16	SN578	Snow	PET	I	AllClear E-188	18.0	ROTATING	Simple Airfoil	52.8	54.5	0.6	-6.7
177	2015-16	16-Feb-16	SN579	Snow	PET	IV	Polar Guard Advance	100%	HEAD	10°	60.8	60.8	14.4	-6.6
	2015-16	16-Feb-16	SN580	Snow	PET	IV	Polar Guard Advance	100%	HEAD	20º Simple	46.3	46.6	14.6	-6.3
	2015-16	16-Feb-16	SN581	Snow	PET	IV	Polar Guard Advance	100%	ROTATING	Slatted Airfoil	59.3	59.3	14.4	-6.5
178	2015-16	16-Feb-16	SN582	Snow	PET	IV	ABC-S Plus	100%	HEAD	10°	90.8	90.8	11.7	-7.2
	2015-16	16-Feb-16	SN583	Snow	PET	IV	ABC-S Plus	100%	HEAD	20º Simple	52.0	41.6	9.3	-7.3
	2015-16	16-Feb-16	SN584	Snow	PET	IV	ABC-S Plus	100%	ROTATING	Slatted Airfoil	92.5	92.4	11.7	-7.2
179	2015-16	16-Feb-16	SN585	Snow	PET	IV	LNT E450	100%	HEAD	10°	70.5	70.5	33.2	-6.3
	2015-16	16-Feb-16	SN586	Snow	PET	IV	LNT E450	100%	HEAD	20º Simple	16.0	18.2	37.7	-6.5
	2015-16	16-Feb-16	SN587	Snow	PET	IV	LNT E450	100%	ROTATING	Slatted Airfoil	41.5	40.3	32.3	-6.4
180	2015-16	19-Feb-16	SN588	Snow	PET	III-C	AeroClear MAX	100%	HEAD	10°	8.9	8.9	55.3	-0.2
	2015-16	19-Feb-16	SN589	Snow	PET	III-C	AeroClear MAX	100%	HEAD	20º Simple	5.5	6.1	60.9	-0.2
	2015-16	19-Feb-16	SN590	Snow	PET	III-C	AeroClear MAX	100%	ROTATING	Slatted Airfoil	8.7	9.1	57.9	-0.2
181	2015-16	19-Feb-16	SN591	Snow	PET	IV	LAUNCH PLUS	50%	HEAD	10°	6.2	6.2	55.4	-0.3
	2015-16	19-Feb-16	SN592	Snow	PET	IV	LAUNCH PLUS	50%	HEAD	20º Simple	4.7	4.6	54.1	-0.2

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
181 cont'd	2015-16	19-Feb-16	SN593	Snow	PET	IV	LAUNCH PLUS	50%	ROTATING	Slatted Airfoil	5.5	5.3	53.5	-0.2
182	2015-16	19-Feb-16	SN594	Snow	PET	IV	Launch	100%	HEAD	10°	N/A	N/A	3.9	0.0
	2015-16	19-Feb-16	SN595	Snow	PET	IV	Launch	100%	HEAD	20º Simple	112.3	N/A	8.7	-0.7
	2015-16	19-Feb-16	SN596	Snow	PET	IV	Launch	100%	ROTATING	Slatted Airfoil	N/A	N/A	4.0	0.0
183	2015-16	24-Feb-16	SN597	Snow	PET	II	Newave FCY-2 BIO+	75%	HEAD	10°	118.6	118.6	2.9	-3.7
	2015-16	24-Feb-16	SN598	Snow	PET	II	Newave FCY-2 BIO+	75%	HEAD	20º Simple	99.8	63.9	1.9	-3.7
	2015-16	24-Feb-16	SN599	Snow	PET	II	Newave FCY-2 BIO+	75%	ROTATING	Slatted Airfoil	110.8	90.6	2.4	-3.7
184	2015-16	24-Feb-16	SN600	Snow	PET	II	Newave FCY-2 BIO+	75%	HEAD	10°	58.3	58.3	6.1	-3.1
	2015-16	24-Feb-16	SN601	Snow	PET	II	Newave FCY-2 BIO+	75%	HEAD	20º Simple	31.8	37.2	7.2	-3.4
	2015-16	24-Feb-16	SN602	Snow	PET	II	Newave FCY-2 BIO+	75%	ROTATING	Slatted Airfoil	50.3	53.9	6.6	-3.1
185	2015-16	24-Feb-16	SN603	Snow	PET	III-C	MP III 2031	100%	HEAD	10°	20.3	20.3	21.3	-1.4
	2015-16	24-Feb-16	SN604	Snow	PET	III-C	MP III 2031	100%	HEAD	20º Simple	13.8	12.4	19.3	-1.4
	2015-16	24-Feb-16	SN605	Snow	PET	III-C	MP III 2031	100%	ROTATING	Slatted Airfoil	19.0	18.4	20.6	-1.4
186	2015-16	24-Feb-16	SN606	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	10°	152.9	152.9	25.0	-1.1
	2015-16	24-Feb-16	SN607	Snow	PET	IV	Clariant Max Flight 04	100%	HEAD	20º Simple	67.5	65.7	24.3	-1.2
	2015-16	24-Feb-16	SN608	Snow	PET	IV	Clariant Max Flight 04	100%	ROTATING	Slatted Airfoil	N/A	N/A	25.1	-1.1
187	2015-16	2-Mar-16	SN609	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	10°	114.3	114.3	19.1	-10.1

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
187 cont'd	2015-16	2-Mar-16	SN610	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	20º Simple	32.0	43.6	26.0	-10.3
	2015-16	2-Mar-16	SN611	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	20º Nested	N/A	N/A	18.3	-10.2
	2015-16	2-Mar-16	SN612	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	35° Simple	16.3	22.0	25.7	-10.3
	2015-16	2-Mar-16	SN613	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	35° Nested	63.8	59.2	17.7	-10.2
	2015-16	2-Mar-16	SN614	Snow	YUL-Aeromag	IV	Dow EG106	100%	TAIL	Slatted Airfoil	83.8	76.3	17.4	-10.2
	2015-16	2-Mar-16	FS10	Snow	YUL-Aeromag	IV	Dow EG106	100%	TAIL	A-319	38.5	48.7	24.1	-10.3
188	2015-16	2-Mar-16	SN616	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	10°	91.0	91.0	18.8	-9.8
	2015-16	2-Mar-16	SN617	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	20º Simple	35.5	36.0	19.0	-9.9
	2015-16	2-Mar-16	SN618	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	20º Nested	N/A	N/A	18.6	-9.8
	2015-16	2-Mar-16	SN619	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	35° Simple	17.3	17.9	19.5	-9.9
	2015-16	2-Mar-16	SN620	Snow	YUL-Aeromag	IV	Dow EG106	100%	HEAD	35° Nested	N/A	N/A	18.7	-9.8
	2015-16	2-Mar-16	SN621	Snow	YUL-Aeromag	IV	Dow EG106	100%	TAIL	Slatted Airfoil	62.3	61.1	18.4	-9.8
	2015-16	2-Mar-16	FS11	Snow	YUL-Aeromag	IV	Dow EG106	100%	TAIL	A-319	64.0	64.0	18.8	-9.8
189	2015-16	24-Mar-16	SN623	Snow	PET	I	LNT E188	19.5	HEAD	10°	16.0	16.0	5.7	-5.7
	2015-16	24-Mar-16	SN624	Snow	PET	I	LNT E188	19.5	HEAD	20º Simple	9.6	9.0	5.4	-5.7
	2015-16	24-Mar-16	SN625	Snow	PET	I	LNT E188	19.5	ROTATING	Slatted Airfoil	7.3	6.4	5.1	-5.7
190	2015-16	24-Mar-16	SN626	Snow	PET	I	LNT E188	19.0	HEAD	10°	9.4	9.4	8.2	-5.4

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
190 cont'd	2015-16	24-Mar-16	SN627	Snow	PET	I	LNT E188	19.0	HEAD	20º Simple	6.0	5.8	7.9	-5.4
	2015-16	24-Mar-16	SN628	Snow	PET	I	LNT E188	19.0	ROTATING	Slatted Airfoil	4.2	3.9	7.6	-5.4
191	2015-16	24-Mar-16	SN629	Snow	PET	I	LNT E188	19.5	HEAD	10°	6.7	6.7	15.7	-5.7
	2015-16	24-Mar-16	SN630	Snow	PET	I	LNT E188	19.5	HEAD	20º Simple	4.2	3.8	14.2	-5.7
	2015-16	24-Mar-16	SN631	Snow	PET	I	LNT E188	19.5	ROTATING	Slatted Airfoil	5.2	4.6	13.9	-5.7
192	2015-16	24-Mar-16	SN632	Snow	PET	IV	Launch	100%	HEAD	10°	127.0	127.0	22.3	-5.2
	2015-16	24-Mar-16	SN633	Snow	PET	IV	Launch	100%	HEAD	20º Simple	42.8	34.5	18.0	-5.1
	2015-16	24-Mar-16	SN634	Snow	PET	IV	Launch	100%	ROTATING	Slatted Airfoil	99.5	84.4	18.9	-5.2
193	2015-16	8-Apr-16	ZP153	Light Freezing Rain	NRC	IV	Clariant Max Flight 04	100%	HEAD	10°	20.4	20.4	26.6	-10.0
	2015-16	8-Apr-16	ZP154	Light Freezing Rain	NRC	IV	Clariant Max Flight 04	100%	HEAD	20º Simple	23.8	23.8	26.6	-10.0
	2015-16	8-Apr-16	ZP155	Light Freezing Rain	NRC	IV	Clariant Max Flight 04	100%	HEAD	Slatted Airfoil	27.8	27.8	26.6	-10.0
194	2015-16	8-Apr-16	ZP156	Light Freezing Rain	NRC	IV	ABC-S Plus	75%	HEAD	10°	26.7	26.7	12.8	-10.0
	2015-16	8-Apr-16	ZP157	Light Freezing Rain	NRC	IV	ABC-S Plus	75%	HEAD	20º Simple	20.8	20.8	12.8	-10.0
	2015-16	8-Apr-16	ZP158	Light Freezing Rain	NRC	IV	ABC-S Plus	75%	HEAD	Slatted Airfoil	21.3	21.3	12.8	-10.0
195	2015-16	8-Apr-16	ZP159	Light Freezing Rain	NRC	I	LNT E188	23.0	HEAD	10°	4.5	4.5	12.8	-10.0
	2015-16	8-Apr-16	ZP160	Light Freezing Rain	NRC	I	LNT E188	23.0	HEAD	20º Simple	4.5	4.5	12.8	-10.0
	2015-16	8-Apr-16	ZP161	Light Freezing Rain	NRC	I	LNT E188	23.0	HEAD	Slatted Airfoil	3.5	3.5	12.8	-10.0

Table 3.1: Flat Plate Testing Log for All Winters (cont'd)

RUN	YEAR	DATE	TEST #	CONDITION	SITE	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	SURFACE	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	PRECIP RATE (g/dm²/h)	OAT (°C)
196	2015-16	8-Apr-16	ZP162	Freezing Drizzle	NRC	IV	ABAX AD-49	50%	HEAD	10°	21.4	21.4	5.8	-3.0
	2015-16	8-Apr-16	ZP163	Freezing Drizzle	NRC	IV	ABAX AD-49	50%	HEAD	20º Simple	18.0	18.0	5.8	-3.0
	2015-16	8-Apr-16	ZP164	Freezing Drizzle	NRC	IV	ABAX AD-49	50%	HEAD	Slatted Airfoil	26.0	26.0	5.8	-3.0
197	2015-16	8-Apr-16	ZP165	Freezing Drizzle	NRC	II	ABC-Ice Clear II	100%	HEAD	10°	39.8	39.8	13.6	-3.0
	2015-16	8-Apr-16	ZP166	Freezing Drizzle	NRC	II	ABC-Ice Clear II	100%	HEAD	20º Simple	24.6	24.6	13.6	-3.0
	2015-16	8-Apr-16	ZP167	Freezing Drizzle	NRC	II	ABC-Ice Clear II	100%	HEAD	Slatted Airfoil	36.3	36.3	13.6	-3.0
198	2015-16	8-Apr-16	ZP168	Freezing Drizzle	NRC	I	LNT E188	18.75	HEAD	10°	9.0	9.0	13.6	-3.0
	2015-16	8-Apr-16	ZP169	Freezing Drizzle	NRC	I	LNT E188	18.75	HEAD	20º Simple	8.6	8.6	13.6	-3.0
	2015-16	8-Apr-16	ZP170	Freezing Drizzle	NRC	I	LNT E188	18.75	HEAD	Slatted Airfoil	12.4	12.4	13.6	-3.0

Table 3.2 : Summary Full-Scale Aircraft Testing Log

Run #	Year	Date	First Step Fluid	Second Step Fluid	AVG OAT (°C)	AVG Rate (g/dm²/h)	AVG Wind (km/h)	Slat/Flap Config	Comments
1	2011-12	24-Feb-12	DOW ADF Type I EG	DOW EG106	-1	n/a	19	15/20	Dry Run, no precip
2	2011-12	24-Feb-12	DOW ADF Type I EG	DOW EG106	-1.2	12.9	19	15/20	Head wind, max slat/flap config
3	2011-12	24-Feb-12	DOW ADF Type I EG	DOW EG106	-0.7	27.8	19	15/20	Head wind, max slat/flap config
4	2011-12	01-Mar-12	DOW ADF Type I EG	DOW EG106	-7.5	10.4	23	15/20	Head wind, max slat/flap config
5	2011-12	01-Mar-12	DOW ADF Type I EG	DOW ADF Type I EG	-6.9	3.0	23	15/20	Head wind, max slat/flap config, sprayed tail also
6	2012-13	27-Feb-13	DOW ADF Type I EG	DOW ADF Type I EG	0.8	5.0	22	15/20	Tail wind, max slat/flap config.
7	2012-13	19-Mar-13	DOW ADF Type I EG	DOW EG106	-4.1	29.8	12	15/20	Tail wind, max slat/flap config.
8	2012-13	19-Mar-13	DOW ADF Type I EG	DOW EG106	-3.7	11.1	9	15/20	Head wind, max slat/flap config, sprayed tail also
9	2012-13	19-Mar-13	DOW ADF Type I EG	DOW ADF Type I EG	-3.4	10.6	6	15/20	Tail wind, max slat/flap config.
10	2015-16	2-Mar-16	LNT E188	DOW EG106	-10.3	24.1	47	18/10	Mostly Ice Pellets mixed with snow.
11	2015-16	2-Mar-16	LNT E188	DOW EG106	-9.8	18.8	46	18/10	Mostly Ice Pellets mixed with snow.

Note: No testing was completed in 2013-14 due to lack of appropriate testing weather opportunities. Southwest Airlines tests not included in the test log.

Table 3.3: Airfoil Testing Log

Test Surface	Test #	Year	Fluid Name	Fluid Type	Dilution	Fluid Batch	Measured Viscosity (cP)	Date of Viscosity Test	Viscosity Test Method	Listed LOWV	Ratio (Measured Visc. / LOWV)	Rotation Profile	Adjusted Airfoil Endurance Time (min)	Adjusted 10° Headwind Endurance Time Ratio (%)	Rate (g/dm²/h)	OAT (°C)	Wind Speed (km/h)	Average Adjusted 10° HW ET Ratio By Grouping (%)
Slatted Airfoil (Snow)	SN449	2014-15	MaxFlight 04	IV	100/0	U49E001966	11658	Jan-13	MAN	5540	2.10	C40%,T40%,H20%	67.9	98%	8.5	-21.9	35.7	88%
	SN503	2014-15	AD-49	IV	100/0	WT.12.13.AD-49	13200	Feb-16	MAN	12150	1.09		91.1	96%	5.9	-8.5	13.0	
	SN514	2014-15	MP III 2031	III-C	75/25	6V4 0159/2012	72	May-12	MAN	86	0.84		5.4	91%	34.7	-5.9	28.0	
	SN525	2014-15	MP III 2031	III-C	50/50	6V4 0159/2012	16	May-12	MAN	16	1.00		9.5	76%	5.4	-4.9	28.0	
	SNX2	2014-15	MP III 2031	III-C	100/0	USHA035996	554	Jan-14	MAN	120	4.62		22.0	77%	7.9	-2.6	21.0	
	SNX4	2014-15	EG106	IV	100/0	1J0201GKDR	3979	Jan-13	AIR	2230	1.78		133.0	103%	8.2	-0.9	31.7	
	SN528	2015-16	Launch	IV	100/0	USHA039555	13997	Jan-13	AIR/MAN	7550	1.85		98.5	101%	24.1	-0.1	23.1	
	SN557	2015-16	ABC-Ice Clear II	II	75/25	X/1/2/15	5660	Mar-15	AIR/MAN	5660	1.00		108.1	62%	0.9	-4.9	26.1	
	SN563	2015-16	ABC-S Plus	IV	100/0	B/13/12/11	19,396	Jan-12	MAN	17900	1.08		103.0	55%	7.1	-4.8	25.5	
	SN581	2015-16	Polar Guard Advance	IV	100/0	13342	15200	Jan-13	MAN	4400	3.45		59.3	98%	14.4	-6.5	15.8	
	SN584	2015-16	ABC-S Plus	IV	100/0	B/13/12/11	19,396	Jan-12	MAN	17900	1.08		92.4	102%	11.7	-7.2	22.3	
	SN602	2015-16	FCY-2 Bio+	II	75/25	201412012 LS	21400	Feb-15	MAN	21400	1.00		53.9	92%	6.6	-3.1	20.8	
	SN605	2015-16	MP III 2031	III-C	100/0	USHA035838	322	Mar-13	MAN	120	2.68		18.4	91%	20.6	-1.4	27.9	
	SN444	2014-15	EG106	IV	100/0	1J0201GKDR	3979	Jan-13	AIR	2230	1.78	H20%,C40%,T40%	77.8	105%	8.2	-22.2	33.5	103%
	SN477	2014-15	Polar Guard Advance	IV	75/25	13342	15,200 (for 100/0)	Jan-13	MAN	4400 (for 100/0)	3.45 (for 100/0)		224.0	97%	4.7	-5.3	10.3	
	SN506	2014-15	Polar Guard Advance	IV	100/0	13342	15200	Jan-13	MAN	4400	3.45		179.5	101%	3.7	-8.2	7.8	
	SNX1	2014-15	MP III 2031	III-C	100/0	USHA035996	554	Jan-14	MAN	120	4.62		37.6	70%	3.1	-2.9	22.0	
	SNX5	2014-15	EG106	IV	100/0	WT 11.12.EG106	37192	Jan-12	MAN	24850	1.50		84.1	101%	20.8	-0.2	38.3	
	SN532	2015-16	Polar Guard Advance	IV	100/0	13342	15200	Jan-13	MAN	4400	3.45		29.5	115%	32.3	-11.6	39.7	
	SN535	2015-16	ABC-Ice Clear II	II	75/25	X/1/2/15	5660	Mar-15	AIR/MAN	5660	1.00		14.7	129%	26.6	-10.6	40.6	
	SN560	2015-16	AeroClear MAX	III-C	100/0	CB1-PB8000A-2	7200	Feb-16	MAN	7300	0.99		90.3	102%	2.3	-4.4	19.8	
	SN548	2015-16	MaxFlight 04	IV	100/0	U49E001966	11658	Jan-13	MAN	5540	2.10		DNF - Rate Dropped Off After Pouring					

Table 3.3: Airfoil Testing Log (cont'd)

Test Surface	Test #	Year	Fluid Name	Fluid Type	Dilution	Fluid Batch	Measured Viscosity (cP)	Date of Viscosity Test	Viscosity Test Method	Listed LOWV	Ratio (Measured Visc. / LOWV)	Rotation Profile	Adjusted Airfoil Endurance Time (min)	Adjusted 10° Headwind Endurance Time Ratio (%)	Rate (g/dm²/h)	OAT (°C)	Wind Speed (km/h)	Average Adjusted 10° HW ET Ratio By Grouping (%)
Slatted Airfoil (Snow)	SN411	2014-15	EG106	IV	100/0	1J0201GK DR	3979	Jan-13	AIR	2230	1.78	H40%,C20%, T20%,C20%	89.9	71%	7.8	-9.6	17.0	76%
	SN425	2014-15	FCY 9311	IV	75/25	201311002 LS	23800	Jan-14	AIR/MAN	N/A	N/A		88.9	81%	1.8	-4.8	25.5	
	SN441	2014-15	Polar Guard Advance	IV	100/0	13342	15200	Jan-13	MAN	4400	3.45		DNF					
	SN457	2014-15	EG106	IV	100/0	1J0201GK DR	3979	Jan-13	AIR	2230	1.78	T40%, H20%, C40%	130.8	121%	7.5	-19.6	34.7	92%
	SN474	2014-15	Kilfrost P2586	II	75/25	P/1/4/14	5200	Apr-14	AIR/MAN	5200	1.00		61.7	94%	3.6	-4.5	16.0	
	SNX3	2014-15	MP III 2031	III-C	100/0	USHA035996	554	Jan-14	MAN	120	4.62		70.2	100%	2.8	-1.8	25.5	
	SN538	2015-16	ABC-S Plus	IV	100/0	B/13/12/11	19396	Jan-12	MAN	17900	1.08		82.2	103%	22.2	-8.3	29.5	
	SN551	2015-16	FCY-2 Bio+	II	50/50	201412012 LS	1900	Feb-15	MAN	1900	1.00		12.8	90%	10.3	-0.6	28.2	
	SN587	2015-16	LNT E450	IV	100/0	2014.04.11 LNT TIV	45300	Apr-14	MAN	45300	1.00		40.3	57%	32.3	-6.4	25.1	
	SN590	2015-16	AeroClear MAX	III-C	100/0	CB1-PB8000A	8000	Apr-15	MAN	7300	1.10		9.1	102%	57.9	-0.2	21.5	
	SN593	2015-16	Launch Plus	IV	50/50	TV523	12150	Feb-13	AIR	12150	1.00		5.3	86%	53.5	-0.2	21.5	
	SN599	2015-16	FCY-2 Bio+	II	75/25	201412012 LS	21400	Feb-15	MAN	21400	1.00		90.6	76%	2.4	-3.7	21.2	
	SN634	2015-16	Launch	IV	100/0	USHA039555	13997	Jan-13	AIR/MAN	7550	1.85		84.4	66%	18.9	-5.2	39.0	
	SN608	2015-16	MaxFlight 04	IV	100/0	U49E001966	11658	Jan-13	MAN	5540	2.10		DNF					
	SN596	2015-16	Launch	IV	100/0	WT.11.12.LAUNCH DEG4146145	13260	Apr-16	AIR/MAN	7550	1.76		DNF					
	SN554	2015-16	MaxFlight 04	IV	100/0	U49E001966	11658	Jan-13	MAN	5540	2.10		DNF - Freezing Drizzle Present					
	SN454	2014-15	MaxFlight 04	IV	100/0	U49E001966	11658	Jan-13	MAN	5540	2.10	HEAD ONLY	44.9	53%	8.8	-21.0	38.5	63%
	SN511	2014-15	Launch	IV	50/50	DEG4146164 (LOWV)	14777	Dec-12	AIR/MAN	17800	0.83		12.9	73%	14.6	-5.5	32.0	
	SN614	2015-16	EG106	IV	100/0	Aeromag Sample Mar 2 2016	38600	Mar-16	MAN	24850	1.55	TAIL ONLY	76.3	67%	17.4	-10.2	45.0	67%
	SN621	2015-16	EG106	IV	100/0	Aeromag Sample Mar 2 2016	38600	Mar-16	MAN	24850	1.55		61.1	67%	18.4	-9.8	45.6	

Table 3.3: Airfoil Testing Log (cont'd)

Test Surface	Test #	Year	Fluid Name	Fluid Type	Dilution	Fluid Batch	Measured Viscosity (cP)	Date of Viscosity Test	Viscosity Test Method	Listed LOWV	Ratio (Measured Visc. / LOWV)	Rotation Profile	Adjusted Airfoil Endurance Time (min)	Adjusted 10° Headwind Endurance Time Ratio (%)	Rate (g/dm²/h)	OAT (°C)	Wind Speed (km/h)	Average Adjusted 10° HW ET Ratio By Grouping (%)
Slatted Airfoil (Snow)	SN485	2014-15	Octaflo EF	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A	C40%,T40%,H20%	6.6	75%	7.1	-15.9	37.5	73%
	SN569	2015-16	AllClear E-188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		3.8	63%	11.5	-7.1	23.0	
	SN573	2015-16	AllClear E-188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		5.5	49%	8.7	-6.7	24.0	
	SN577	2015-16	AllClear E-188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		15.8	30%	1.3	-6.7	33.1	
	SN482	2014-15	Octaflo EF	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A	H40%,C40%,T20%	4.3	64%	9.3	-16.7	37.0	
	SN488	2014-15	Octaflo EF	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A	T40%, H20%, C40%	10.8	75%	5.5	-15.5	41.5	
	SN566	2015-16	Octaflo EF	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		14.4	75%	0.8	-8.1	23.6	
	SN628	2015-16	LNT E188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		3.9	41%	7.6	-5.4	33.0	
	SN542	2015-16	Polar Plus	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A	H20%,C40%,T40%	4.2	132%	15.7	-8.1	31.0	
	SN545	2015-16	Polar Plus	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		2.4	94%	27.5	-8.4	33.5	
	SN625	2015-16	LNT E188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		6.4	40%	5.1	-5.7	33.0	
	SN631	2015-16	LNT E188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		4.6	69%	13.9	-5.7	34.0	
Slatted Airfoil (ZP)	ZP139	2014-15	MP I 1938 ECO	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A	None (Freezing Precipitation)	4.8	73%	11.8	-10.0	n/a	
	ZP161	2015-16	LNT E188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		3.5	78%	12.8	-10.0	n/a	
	ZP170	2015-16	LNT E188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		12.4	138%	13.6	-3.0	n/a	
	ZP135	2014-15	EG106	IV	100/0	WT.11.12. EG106	37192	Jan-12	MAN	24850	1.50		64.3	79%	11.8	-10.0	n/a	94%
	ZP143	2014-15	AD-49	IV	100/0	L12-328	14397	Jan-13	MAN	12150	1.18		20.9	91%	24.5	-10.0	n/a	
	ZP147	2014-15	FCY 9311	IV	50/50	201311002	2180	Jan-14	AIR/MAN	N/A	N/A		19.0	93%	5.3	-3.0	n/a	
	ZP151	2014-15	ABC-S Plus	IV	75/25	B/13/12/11	19,396 (for 100/0)	Jan-12	MAN	17900 (for 100/0)	1.08 (for 100/0)		33.5	64%	14.7	-3.0	n/a	
	ZP155	2015-16	MaxFlight 04	IV	100/0	U49E001966	11658	Jan-13	MAN	5540	2.10		27.8	136%	26.6	-10.0	n/a	
	ZP158	2015-16	ABC-S Plus	IV	75/25	P/282/12/10	19,396 (for 100/0)	Jan-12	MAN	17900 (for 100/0)	1.08 (for 100/0)		21.3	79%	12.8	-10.0	n/a	
	ZP164	2015-16	ABAX AD-49	IV	50/50	Air France (May 2014)	N/A	N/A	N/A	N/A	N/A		26.0	121%	5.8	-3.0	n/a	
	ZP167	2015-16	ABC-Ice Clear II	II	100/0	X/1/2/15	7720	Mar-15	AIR/MAN	7720	1.00		36.3	91%	13.6	-3.0	n/a	

Table 3.3: Airfoil Testing Log (cont'd)

Test Surface	Test #	Year	Fluid Name	Fluid Type	Dilution	Fluid Batch	Measured Viscosity (cP)	Date of Viscosity Test	Viscosity Test Method	Listed LOWV	Ratio (Measured Visc. / LOWV)	Rotation Profile	Adjusted Airfoil Endurance Time (min)	Adjusted 10° Headwind Endurance Time Ratio (%)	Rate (g/dm^2/h)	OAT (°C)	Wind Speed (km/h)	Average Adjusted 10° HW ET Ratio By Grouping (%)
Simple Airfoil (ZP)	ZP140	2014-15	MP I 1938 ECO	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A	None (Freezing Precipitation)	11.1	168%	11.8	-10.0	n/a	
	ZP136	2014-15	EG106	IV	100/0	WT.11.12. EG106	37192	Jan-12	MAN	24850	1.50		52.9	65%	11.8	-10.0	n/a	139%
	ZP144	2014-15	AD-49	IV	100/0	L12-328	14397	Jan-13	MAN	12150	1.18		26.7	116%	24.5	-10.0	n/a	
	ZP148	2014-15	FCY 9311	IV	50/50	201311002	2180	Jan-14	AIR/MAN	N/A	N/A		55.0	268%	5.3	-3.0	n/a	
	ZP152	2014-15	ABC-S Plus	IV	75/25	B/13/12/11	19,396 (for 100/0)	Jan-12	MAN	17900 (for 100/0)	1.08 (for 100/0)		56.0	108%	14.7	-3.0	n/a	
Simple Airfoil (Snow)	SN410	2014-15	EG106	IV	100/0	1J0201GKDR	3979	Jan-13	AIR	2230	1.78	H40%,C20%, T20%,C20%	145.3	115%	7.2	-9.6	18.7	229%
	SN424	2014-15	FCY 9311	IV	75/25	201311002LS	23800	Jan-14	AIR/MAN	N/A	N/A		374.9	342%	3.5	-4.4	28.3	
	SN440	2014-15	Polar Guard Advance	IV	100/0	13342	15200	Jan-13	MAN	4400	3.45		DNF					
	SN539	2015-16	ABC-S Plus	IV	100/0	B/13/12/11	19396	Jan-12	MAN	17900	1.08	T40%, H20%, C40%	165.9	207%	22.7	-8.1	29.6	207%
	SN529	2015-16	Launch	IV	100/0	USHA039555	13997	Jan-13	AIR/MAN	7550	1.85	C40%,T40%,H20%	DNF					
	SN570	2015-16	AllClear E-188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		7.3	121%	11.2	-7.1	23.1	118%
	SN574	2015-16	AllClear E-188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		14.5	129%	6.3	-6.3	24.2	
	SN578	2015-16	AllClear E-188	I	n/a	N/A	N/A	N/A	N/A	N/A	N/A		52.8	104%	0.6	-6.7	31.2	

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4. FLAT PLATE TESTING RESULTS AND ANALYSIS

In this section, the flat plate testing data collected during the winters of 2010-11 to 2015-16 is analysed and discussed. This report contains all the data analysis to date, and therefore future reports should add to this data set.

4.1 Fluid Endurance Times on Simple and Nested Inclined Plates

The results from the natural snow testing and indoor freezing precipitation testing were analysed as a whole and are described in this section. A total of 386 comparative tests were conducted in both natural snow and simulated freezing precipitation; all tests were conducted with head wind orientation in accordance with standard endurance time testing procedures. Testing was primarily conducted with Type IV fluids in 100/0, 75/25, and 50/50 dilutions. Additional tests were conducted with different wind orientations as part of a separate, but related, testing objectives described in Section 6. Table 4.1 shows the breakdown of the tests conducted.

Table 4.1 Summary of Flat Plate Tests Conducted

# of Tests						
Fluid Type	**15° Simple**	**20º Nested**	**20º Simple**	**35° Nested**	**35° Simple**	**Grand Total**
I		**2**	**46**	**2**	**26**	**76**
NRC		2	14	2	11	29
PET			29		12	41
YMX			3		3	6
II			**18**		**2**	**20**
NRC			5		2	7
PET			13			13
III			**27**		**6**	**33**
NRC			13		6	19
PET			14			14
III-C	**1**	**1**	**18**	**1**	**1**	**22**
PET	1	1	18	1	1	22
IV	**15**	**29**	**84**	**37**	**70**	**235**
NRC		4	13	10	11	38
PET	15	19	62	20	49	165
YMX		4	7	5	8	24
YUL-Aéromag		2	2	2	2	8
Grand Total	**16**	**32**	**193**	**40**	**105**	**386**

4.2 Summary of Flat Plate Results

The endurance times recorded on the inclined flat plates were analysed. Separated by Type I, III, and II/IV, Table 4.2 and Table 4.3 summarize the 2010-11 to 2014-15 calculated average endurance times of the 15º, 20º and 35º simple and nested plates as a percentage of the baseline 10º plate; the standard deviation has also been included.

The results indicate a difference in the performance of the Type I fluid endurance times on inclined plates versus the Type III, II, and IV fluids. In general, the Type I fluid endurance times of the inclined plates were slightly less compared to the baseline 10º plate. In comparison, the thickened Type IV fluid endurance time results were slightly less in the nested configuration, and much less in the simple 20º and 35º configurations. The primary difference in the performance of the Type I versus Type IV fluid is the heat of the fluid. In the case of the Type IV fluid, it is applied at ambient temperature and the increased angle causes reduced fluid thickness which results in shorter fluid protection times. For the Type I fluids, the fluid is applied heated and in this case, the Type I heat is a primary source of the fluid protection time and therefore is not as strongly affected by the increase in surface angle. The results from the Type IV tests are assumed to be applicable to Type II fluids as well, whereas the limited Type III fluid testing indicates the reductions in endurance times may not be as significant as Type IV fluid, but not as good as Type I either.

Table 4.4 summarizes the 20º simple plate results as this was found to best correlate with the full-scale testing fluid failure results; details of this work are included in Section 5.

Table 4.2: Abbreviated Summary of Plate Test Results for All Winters

	Average Ratio (Compared to 10º Baseline Plate)					
Fluid Type	**15° Simple**	**20º Nested**	**20º Simple**	**35° Nested**	**35° Simple**	**Test Count**
I		104%	84%	112%	80%	76
II			59%		55%	20
III			72%		73%	33
III-C	99%	146%	65%	134%	89%	22
IV	70%	84%	54%	77%	35%	235
Grand Total	72%	87%	65%	80%	49%	386

Table 4.3: Detailed Summary of Plate Test Results for All Winters

	15° Simple			20º Nested			20º Simple			35° Nested			35° Simple		
Fluid Type and Location	**# of Tests**	**Average of RATIO**	**StdDev of RATIO**	**# of Tests**	**Average of RATIO**	**StdDev of RATIO**	**# of Tests**	**Average of RATIO**	**StdDev of RATIO**	**# of Tests**	**Average of RATIO**	**StdDev of RATIO**	**# of Tests**	**Average of RATIO**	**StdDev of RATIO**
I				**2**	**104%**	**8%**	**46**	**84%**	**17%**	**2**	**112%**	**1%**	**26**	**80%**	**21%**
NRC				2	104%	8%	14	98%	14%	2	112%	1%	11	94%	14%
PET							29	77%	12%				12	77%	12%
YMX							3	78%	33%				3	40%	20%
II							**18**	**59%**	**7%**				**2**	**55%**	**2%**
NRC							5	61%	9%				2	55%	2%
PET							13	58%	7%						
III							**27**	**72%**	**15%**				**6**	**73%**	**8%**
NRC							13	74%	7%				6	73%	8%
PET							14	71%	19%						
III-C	**1**	**99%**	**n/a**	**1**	**146%**	**n/a**	**18**	**65%**	**14%**	**1**	**134%**	**n/a**	**1**	**89%**	**n/a**
PET	1	99%	n/a	1	146%	n/a	18	65%	14%	1	134%	n/a	1	89%	n/a
IV	**15**	**70%**	**10%**	**29**	**84%**	**26%**	**84**	**54%**	**17%**	**37**	**77%**	**34%**	**70**	**35%**	**17%**
NRC				4	90%	15%	13	67%	23%	10	109%	29%	11	56%	26%
PET	15	70%	10%	19	82%	29%	62	53%	15%	20	63%	27%	49	32%	12%
YMX				4	84%	23%	7	43%	8%	5	71%	27%	8	24%	6%
YUL-Aéromag				2	n/a	n/a	2	39%	1%	2	52%	n/a	2	19%	0%
Grand Total	**16**	**72%**	**12%**	**32**	**87%**	**28%**	**193**	**65%**	**20%**	**40**	**80%**	**35%**	**105**	**49%**	**27%**

Table 4.4: Average 20° Simple Plate Endurance Time Ratio

Fluid Type	# of Tests	Average Ratio (Compared to 10° Baseline Plate)	StdDev of Ratio
I	46	**84%**	17%
III - Hot	27	**72%**	15%
III - Cold	18	**65%**	14%
II/IV	102	**55%**	16%
Total	193		

4.3 2010-11 Special Testing: Gap Distance Investigation on Nested Surfaces

Special indoor freezing precipitation testing conducted in 2010-11 consisted of ad-hoc tests which provided an initial indication of performance, the results of which would serve as a basis for planning of the winter 2011-12 testing. This testing primarily investigated the effect of the gap distance of nested surfaces on fluid endurance times. The limited results indicated that the effect of a gap between overlapping surfaces when simulating a nested flap is minor. The results from the indoor freezing precipitation testing are included in Appendix G.

4.4 2012-13 and 2013-14 Special Testing: Investigation of Flap/Slat Extension During Taxi

Special indoor freezing precipitation testing conducted in 2012-13 consisted of exploratory tests looking at the effects of extending flaps and slats midway during the expected fluid holdover time to better understand how the exposed areas (following extension) are effected by the precipitation, and if the fluid flow-off resulting from the steeper angle effects protection times. Two test runs were conducted, the first simulating a 20° slat and flap extension at -10°C in freezing drizzle conditions, and the second simulating a 35° slat and flap extension at -3°C in light freezing rain conditions. Photo 4.1 demonstrates the second test run plate setup in the "retracted" configuration, and Photo 4.2 demonstrates the test plate setup in "extended" configuration midway during the expected HOT.

The preliminary tests indicated that in a retracted configuration, covered areas that are not protected by fluid (i.e. the hard leading edge underneath a slat, or a flap leading edge) are susceptible to icing once they are extended as the surfaces are essentially bare.

The results also showed that the simulated retracted slat and flap, when extended was able to shed some of the ice formed on the top surface of the fluid; the increased angle allowed fluid to flow-off and consequently some contamination as well.

These tests were preliminary and served solely as a scoping study. Additional testing to better understand the dynamic situation occurring during slat and flap extension could be useful, especially to support potential mitigation tactics for aircraft operators operating with early deployed slats and flaps.

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Photo 4.1: Simulated Flap and Slat in Retracted Configuration

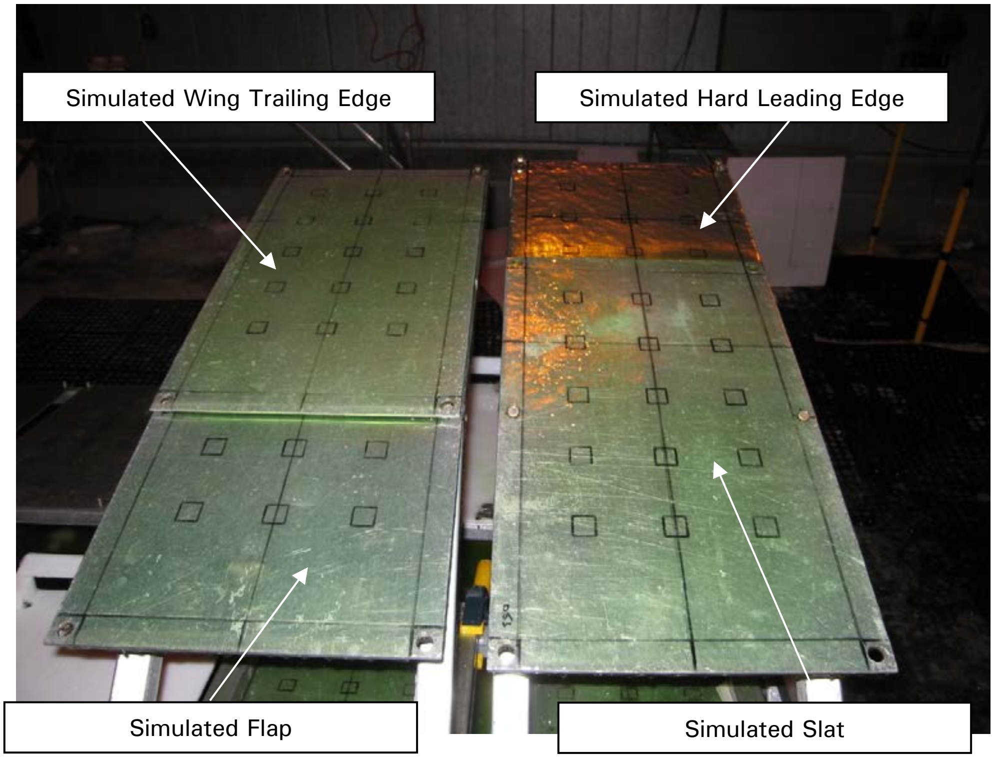
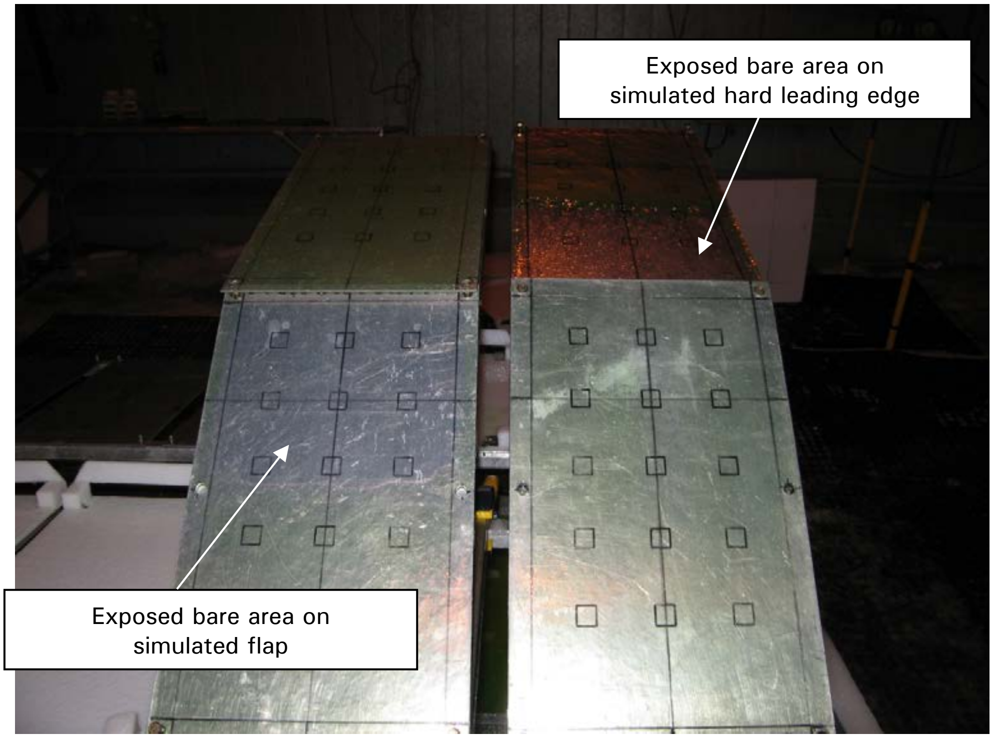


Photo 4.2: Simulated Flap and Slat in Extended Configuration (Extended Midway During Expected HOT)



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5. FULL-SCALE TESTING RESULTS AND ANALYSIS

In this section, the full-scale testing data collected during the winters of 2011-12, 2012-13, and 2015-16 is analysed and discussed; no full-scale tests were conducted during the winters of 2013-14 and 2014-15 due to lack of appropriate weather for testing. This testing was led by APS with the support of UPS and Air Canada.

Additional testing was conducted as part of a separate contract with Southwest Airlines, the details of which have been included in a separate report issued *"Test Report: Full-Scale Evaluation of Fluid Failure On Extended Flaps and Slats – August 2013".* For analysis purposes, some final values form this testing have been included as part of this report.

5.1 Testing Results

During the winter of 2011-12, 5 test runs were conducted with the support of UPS and their A-300 aircraft. The first served as a "wet run" where fluid was sprayed in non-active precipitation. Test runs 2, 3, and 4 were conducted with the two-step de/anti-icing process. Run 5 was conducted with Type I fluid only.

The testing was continued during the winter of 2012-13 when an additional four tests were completed in natural snow conditions with the support of UPS and their A-300 aircraft. Test runs 7 and 8 were conducted with the two-step de/anti-icing process, and test runs 6 and 9 were conducted with Type I fluid only.

Following a two-year delay due to lack of appropriate weather for testing, testing resumed in 2015-16, this time with the support of Air Canada and their A-319 aircraft. An additional 2 tests were completed in ice pellet conditions mixed with snow (forecasts indicated snow, however most of the precipitation came in the form of ice pellets). Test runs 10 and 11 were conducted with the two-step de/anti-icing process.

The data for these tests have been organized, plotted and included in Appendix H for reference. For each test (with the exception of Run #1), five documents were prepared:

1) A summary of the test parameters;
2) A chart demonstrating the rate of precipitation versus time;
3) A chart demonstrating the progression of fluid failure on the plates and wing as a function of time;

4) A timeline of the wing leading edge failure versus the standard plate failure; and
5) A timeline of the wing trailing edge failure versus the standard plate failure.

For demonstration purposes, the five documents prepared for Run #2 have been included in this section as Figure 5.1 to Figure 5.5, respectively. In addition, the wing fluid failure visual observation data were documented through drawings and notes. This documentation has been included in Appendix I for reference.

Figure 5.1 provides a summary of the test parameters including meteorological information, slat and flap angle information measured at the beginning of the test event, fluid information related to the quantities and type sprayed, and holdover time information related to the approximate start and end times of the multiple tests conducted.

Figure 5.2 demonstrates the rate of precipitation versus time during the test. The rate is generally measured using two staggered rate pans. The plot shows the average rate for each of the pan exposure periods plotted as individual 1 minute "X" or "O" points. The average pan rate is also plotted as a line.

Figure 5.3 provides a real-time summary of the progression of fluid failure on the plates and wing as a function of time. It should be noted that the data plotted is not normalized for precipitation rate fluctuations; the data plotted is as collected and un-altered. The individual plate test start and end times are plotted as horizontal bars related to the time on the x-axis; there is no relation to the y-axis. The 10° plate is demonstrated as an "average" as it is generally run as a simultaneous duplicate (and sometimes up to 4 instances of the same) in order to get a solid baseline value; the average start and end times of all the 10° plates run simultaneously is plotted. For the 20° and 35° plates, a label with a number in brackets represents a second or third instance of the test, run sequentially. In the same document, the failure patterns documented on the wing section are also plotted. The areas of the wing test section are separated into leading edge slats, flaps, and main wing and spoiler, each of which can equal 100 percent failure. The percentage failed as recorded in real-time is plotted against time on the x-axis and percentage failed on the y-axis. The full wing failure is calculated using the percentage failed of each of the test sections applied to the percentage of the full area of the wing it represents (described more in Table 5.3). The percentage failed as recorded in real-time is plotted against time on the x-axis and percentage failed on the y-axis.

Figure 5.4 and Figure 5.5 demonstrate a timeline of wing leading edge (slats) and trailing edge (flaps) failure milestones, respectively, versus the various related standard plate failures. It should be noted that this analysis was done in the early stages of the research project when the 20° and 35° plates were being used to simulate the slat alone and the 20º nested and 35° nested were being used to simulate the flap alone. Analysis has since adopted the method of correlating the full wing failure (based on the ratios of the test section areas failed versus the total area they represent) versus the 10º baseline and the 20º simple plate which has historically shown the best correlation to the full wing failure in extended configuration. Therefore, these figures should only be for information purposes only as they are not of significant value to the current day analysis.

Run # 2

Feb 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	- 1.2ºC
Aircraft Skin Temp: (at start of day)	- 0.4ºC
Aircraft/Stand Orientation:	Into wind/Into wind
Wind/Plate Direction:	60 - 80º/60 -80º
Aircraft Direction:	60º
Wind Speed:	15 - 20 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	15.2 g/dm^2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)	18.7º	21.0º
Mid Slat Angle (middle slat)	21.6º	24.0º
Mid Flap Angle (middle flap):	21.0º	32.0º

Fluid Information

Type I

Type I Fluid:	Type I UCAR ADF (40%) (Brix =25.25)
Application on Wing :	Sprayed from Nozzle
Temperature:	Not measured
Quantity of Type I used:	190 litres

Type IV

Type IV Fluid:	EG 106 (Brix = 33.00)
Application on Wing :	Sprayed from Nozzle
Application on Stand:	Extracted from truck tank and hand-poured onto plates.
Temperature:	Not measured
Quantity of Type IV used:	104 litres

Holdover Time Information

Start of Test:	14:33 PM
End of Test:	16:10 PM

Figure 5.1: Summary of Test Parameters

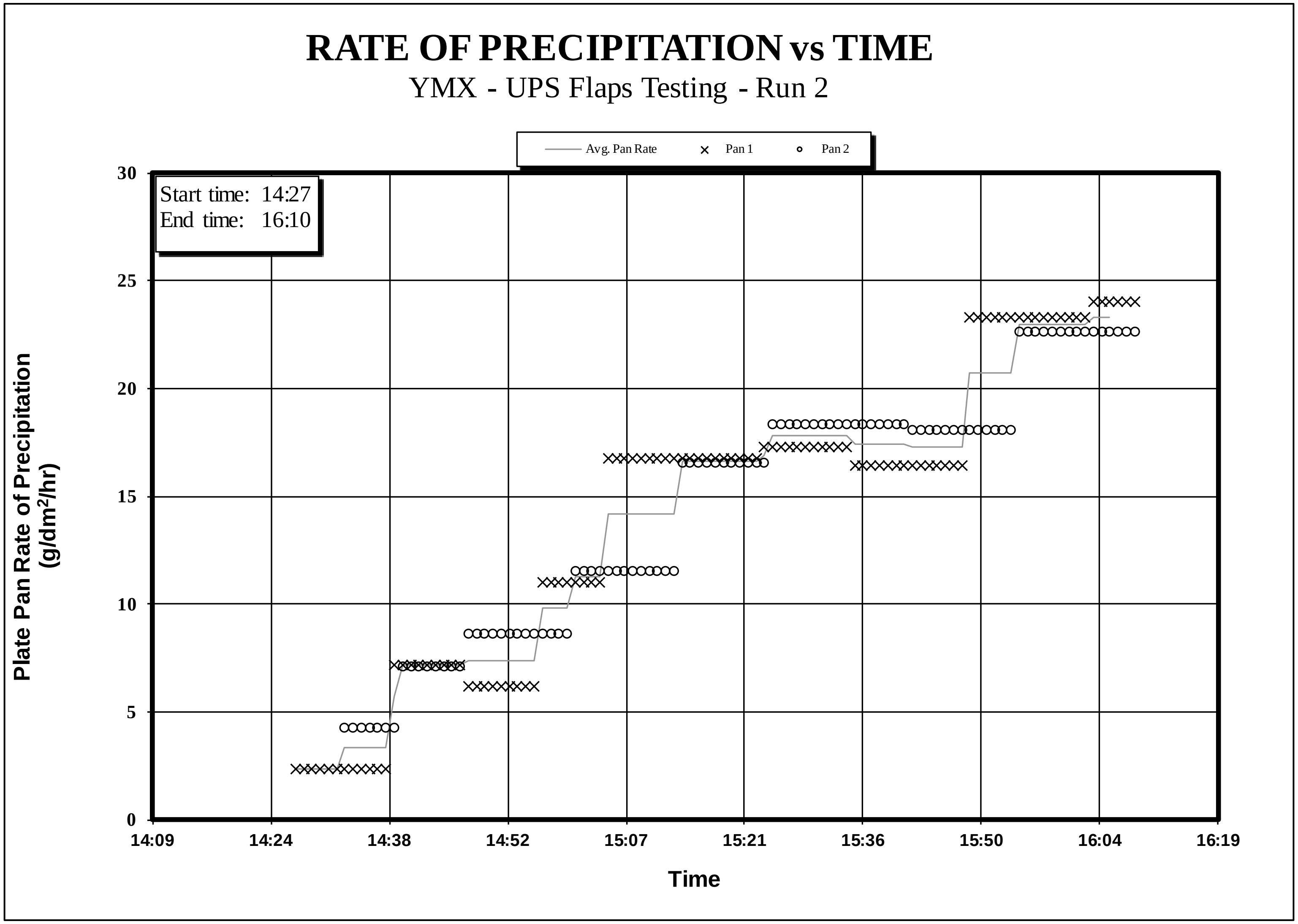


Figure 5.2: Rate of Precipitation vs. Time

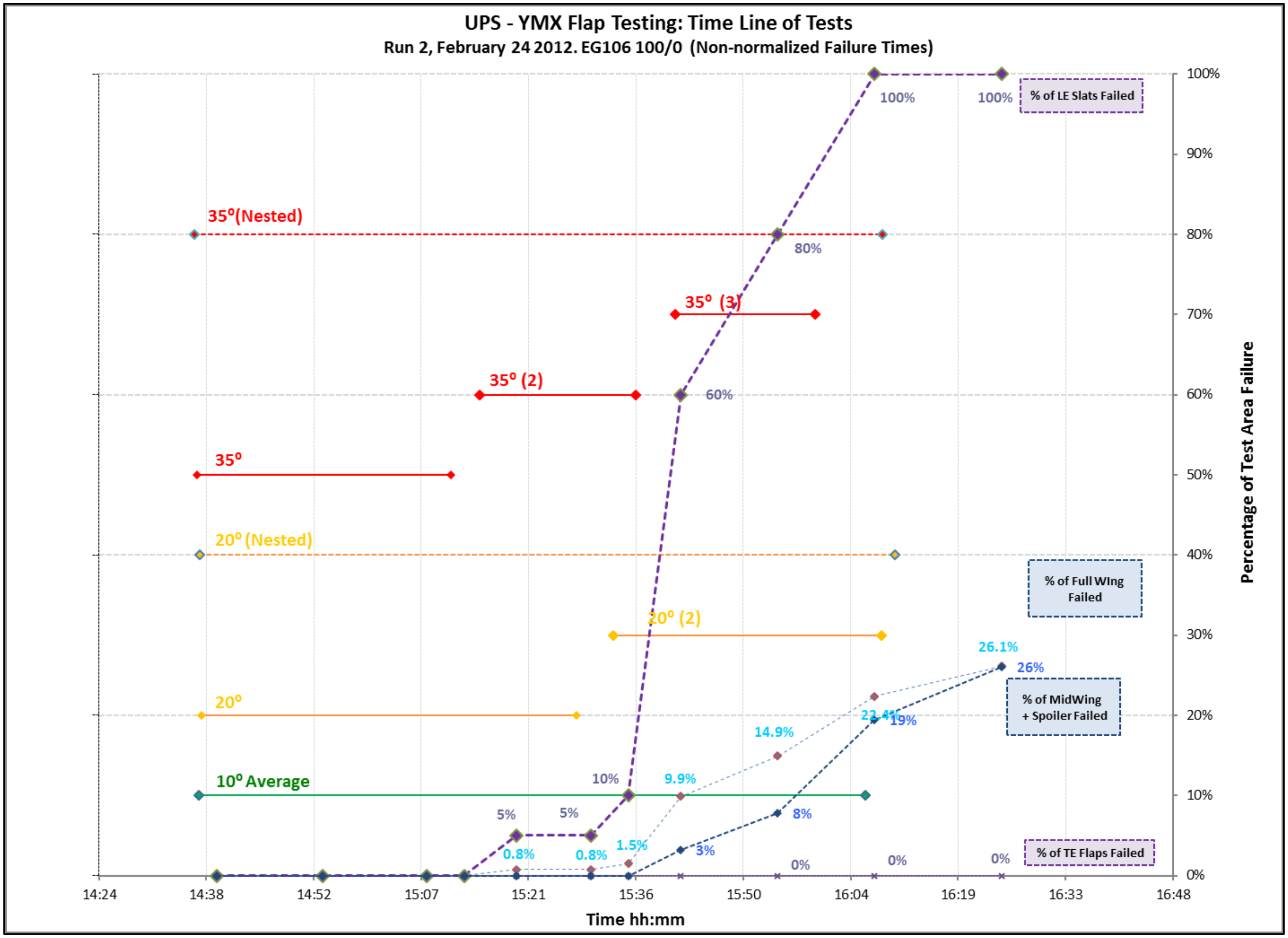


Figure 5.3: Progression of Fluid Failure on the Plates and Wing as a Function of Time

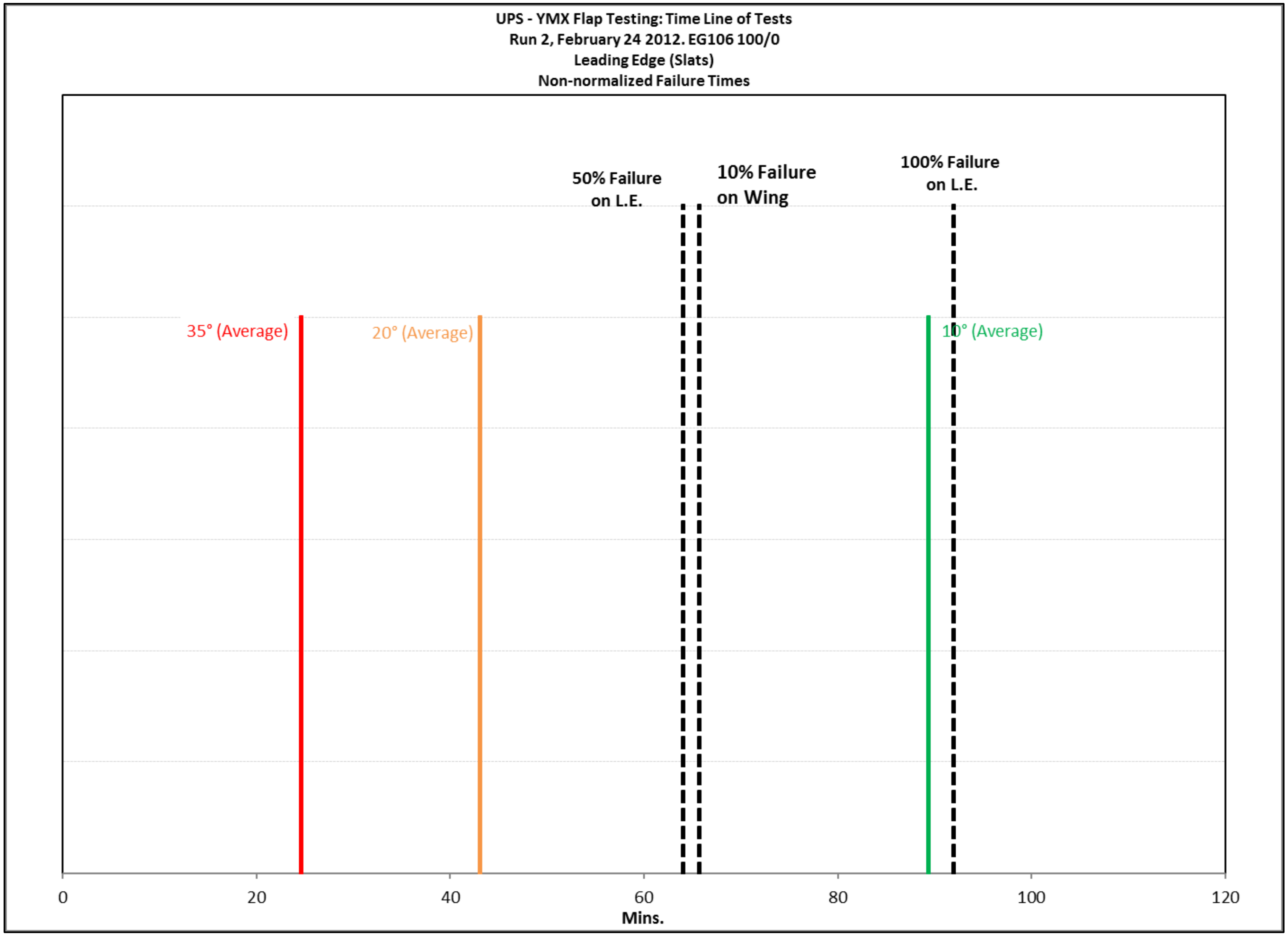


Figure 5.4: Timeline of the Wing Leading Edge (Slats) Failure vs. Standard Plate Failure

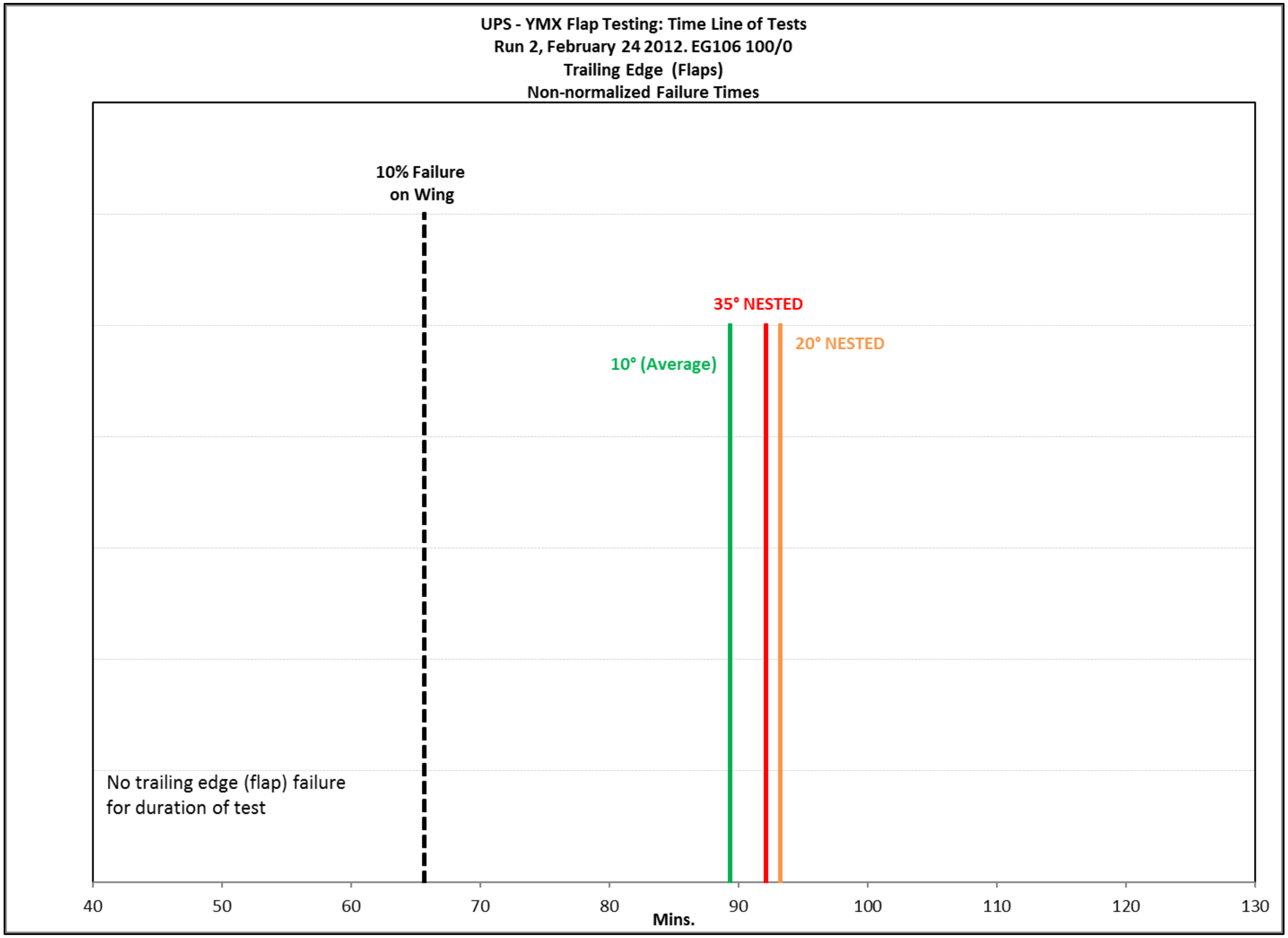


Figure 5.5: Timeline of the Wing Trailing Edge (Flaps) Failure vs. Standard Plate Failure

5.2 Wing Area Percentage Analysis

In order to be able to better analyse fluid failure patterns on the aircraft, the wings of the A-300 and A-319 were mapped out and the area of the individual wing sections were calculated. In the case of the A-300 where fluid was only applied to the middle third of the wing, span wise, areas were computed for both the section that was used for testing, as well as for the whole wing.

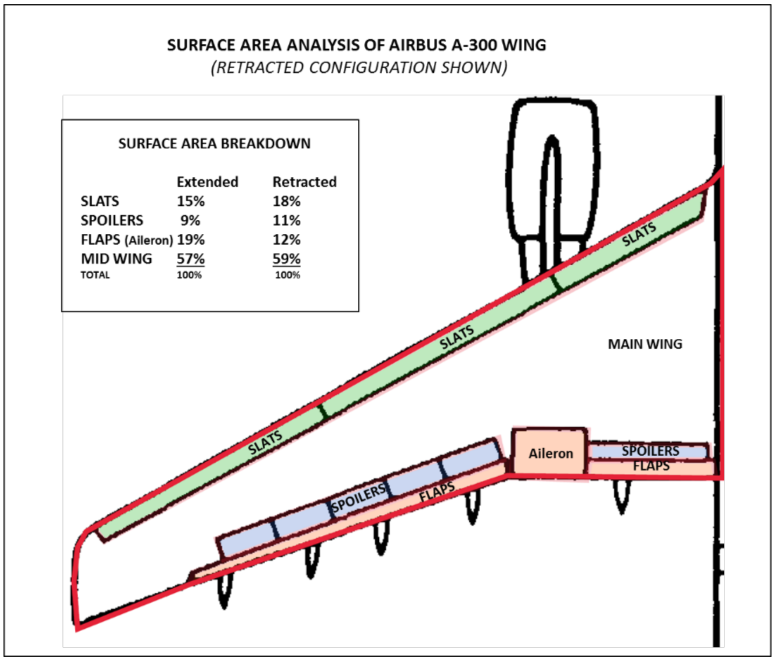
Table 5.1 and Table 5.2 contain the A-300 and A-319 estimated percentage area per wing section based on the extended and retracted configurations. Figure 5.6 and Figure 5.7 graphically demonstrate the retracted configuration of the wing with surface area analysis for the extended configuration. For the purpose of this report the aileron was analysed as part of the flaps. For the A-300, the "Extended Configuration - Whole Wing" values were used for analysis by using the percentage failed per area of the test section and proportionally scaling it to the respective percentage area of the full wing (see example in Table 5.3 based on values from Table 5.1).

Table 5.1: A-300 Wing Area Percentages

Wing Section	% of Entire Surface			
	Extended Configuration		Retracted Configuration	
	Test Section Only	Whole Wing	Test Section Only	Whole Wing
Slat	18%	15%	23%	18%
Spoilers	18%	9%	23%	11%
Flaps (and aileron)	26%	19%	15%	12%
Main Wing	38%	57%	39%	59%
Total	100%	100%	100%	100%

Table 5.2: A-319 Wing Area Percentages

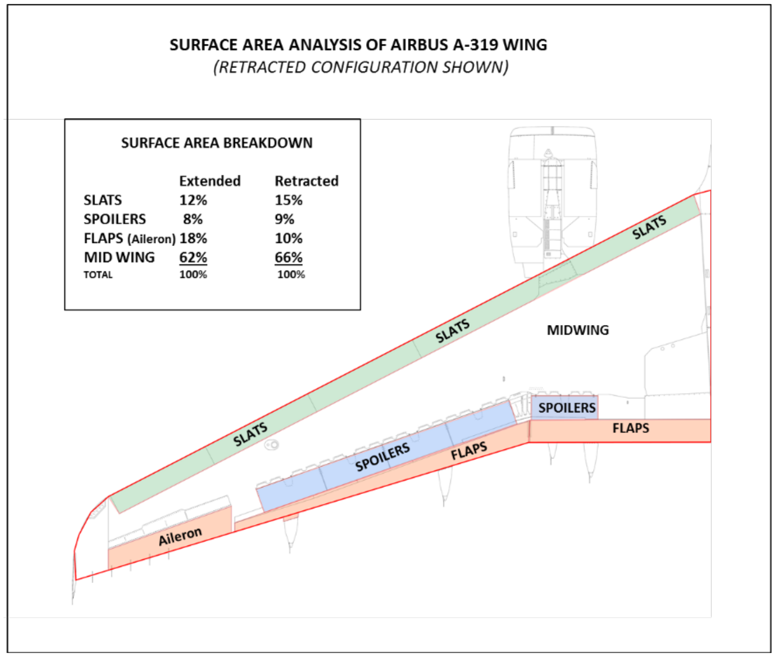
Wing Section	% of Entire Wing	
	Extended Configuration	Retracted Configuration
	Whole Wing	Whole Wing
Slat	12%	15%
Spoilers	8%	9%
Flaps (and Aileron)	18%	10%
Main Wing	62%	66%
Total	100%	100%



SURFACE AREA BREAKDOWN

	Extended	Retracted
SLATS	15%	18%
SPOILERS	9%	11%
FLAPS (Aileron)	19%	12%
MID WING	57%	59%
TOTAL	100%	100%

Figure 5.6: Diagram of A-300 Surface Area Analysis



SURFACE AREA ANALYSIS OF AIRBUS A-319 WING
(RETRACTED CONFIGURATION SHOWN)

SURFACE AREA BREAKDOWN

	Extended	Retracted
SLATS	12%	15%
SPOILERS	8%	9%
FLAPS (Aileron)	18%	10%
MID WING	62%	66%
TOTAL	100%	100%

Figure 5.7: Diagram of A-319 Surface Area Analysis

Table 5.3: Calculation of Full Wing Failure Percentage

Time	% of Test Section Leading Edge Slat Failed	% of Test Section Spoiler Failed	% of Test Section Main Wing Failed	% of Test Section Flap Failed	Calculated Combined % of Full Wing Failure	Combined % of Full Wing Failure
15:35:00	10%	0%	0%	0%	=10%x15% + 0%x9% + 0%x57% + 0%x19%	2%
15:42:00	60%	10%	0%	0%	=60%x15% + 10%x9% + 0%x57% + 0%x19%	10%
15:55:00	80%	20%	2%	0%	=80%x15% + 20%x9% + 2%x57% + 0%x19%	15%

5.3 Additional Full-Scale Testing with SWA

Additional full-scale testing was conducted during the winter of 2012-13 with a SWA B-737 aircraft at the Albany, New York) airport. SWA contracted directly with APS for these complementary tests. The testing objectives were similar to the UPS and Air Canada tests however rather than one, two aircraft were used and sprayed and tested simultaneously. During the SWA tests, Aircraft #1 had the flaps and slats extended to takeoff configuration for the entire duration of the test, whereas Aircraft #2 had the flaps and slats initially retracted, and deployed at initial sign of failure on wing. Originally the procedure called for a direct comparison of extended versus retracted configured aircraft, however at the time of testing, a decision was made by the testing team to have the retracted wing extended at the first sign of failure as this would be an operationally more representative situation than leaving the wing retracted until failure. Two tests were conducted on February 8-9, 2013; the OAT was approximately -5°C and the average snow rate was generally in the moderate range of 10 to 25 g/dm²/h. SWA agreed to share this data with TC and FAA and therefore the summary and conclusions of the SWA report are included in the following sections. Further details are available in the SWA test report: Full–Scale Evaluation of Fluid Failure on Extended Flaps and Slats.

5.4 Comparison of Wing to Baseline 10° Standard Plate Failure

An analysis of the wing failure patterns was conducted to correlate wing failure to the baseline 10° standard plate failure. Research in the 1990s (discussed in Subsection 5.4) used approximately 10 percent contamination as the criterion for wing failure and 33 percent contamination as the criterion for 10° standard plate failure, and using these criteria demonstrated a correlation. The purpose of this analysis was to determine how the full-scale tests conducted with deployed slats and flaps during the winter of 2011-12, 2012-13, and 2015-16 would compare to the historical bench marks. In addition, this analysis attempts to determine whether the plate models at 20° and 35° correlate with the wing failure patterns.

A criterion of approximately 10 percent contamination for wing failure was used for analysis; the actual time of failure was either documented or linearly interpolated based on most relevant failure progression observations, an example of which can be found in Figure 5.3, in which "full wing failure" was not documented at exactly 10 percent. The plot, however, shows a 9.9 percent failure time and a 14.9 percent failure time. The 10 percent failure time can be linearly interpolated between the 9.9 percent and 14.9 percent failure points (see example in Table 5.4). The failure times used for this analysis were then normalized and corrected for the rate of precipitation; tests were linearly normalized to the 10° plate average rate of precipitation (see example in Table 2.2).

Table 5.4: Calculation of 10% Wing Failure Time

Time	% of Full Wing Failure	Calculation for Approximate Time of 10% Full Wing Failure (if not documented)	Calculated Time of 10% Full Wing Failure
15:42:00	9.9%	= 15:45:00 + (10%-9.9%)/(14.9%-9.9%) x (15:55:00 – 15:42:00)	15:42:15
15:55:00	14.9%		

For the 2011-12 interim report, an additional analysis was conducted for the data collected during the winter of 2011-12 which compared the 50 percent, 67 percent, and 100 percent failure time of the leading edge only versus the baseline 10 º standard plate failures. The analysis is included in the 2011-12 interim report, however has been removed from this report as it applies specifically to head wind tests and not to tail wind tests. Also, the results from the 10 percent whole wing failure versus the 10º standard plate failure demonstrated a clearer and more relevant correlation between the wing and the plate as compared to focusing on either the leading edge of flap only. This actual data can still however be referenced in Figure 5.3 and related charts in Appendix H which plot the failure percentage of the individual wing surfaces versus time.

Note: When testing was performed with the aircraft oriented into the wind, the slats were generally the primary source of fluid failure on the wing. The opposite is true for the tail wind tests where generally the flaps were the primary source of the fluid failure on the wing.

5.4.1 10 Percent Wing Failure vs. Standard Plate Failure

To better understand the reduction in fluid endurance time experienced on a wing with the flaps and slats in extended configuration, the time when 10 percent of the whole wing demonstrated signs of fluid failure was correlated to the average endurance time of the baseline 10º plate. For this analysis, the data collected with the UPS A-300, Air Canada A-319, and in addition, the SWA B-737 was included. The results indicate that 10 percent contamination of the whole wing in extended configuration correlates on the average with 67 percent failure of the 10º plate. When eliminating Run #5, a likely outlier (see next paragraph), the average drops to 49 percent. The results are demonstrated in Table 5.5. This analysis includes all Type I and Type IV tests. Two separate tables were also developed to isolate the different fluid types; Table 5.6 and Table 5.7, respectively. These same results are also presented graphically in Figure 5.8, Figure 5.9, Figure 5.10, and Figure 5.11. An additional table showing the SWA side-by-side test result of the extended versus retracted flap slat configuration is shown in Figure 5.12.

The results indicate large variation in the Type I results. During Run #5 head wind test conducted in 2011-12 resulted in a much longer fluid protection time on the wing due to the rate of precipitation which was very low to start, and decreased during the test. The diminishing precipitation rate may have generated a longer protection time on the wing versus the box, and consequently, Run #5 could be considered as an outlier. During Run #6 and #9 conducted close to 0ºC, the rate of precipitation was higher and resulted in a much earlier 10 percent wing failure as compared to the 10º plate.

The Type IV results were more consistent and provided a clear indication of a reduction in fluid protection time. The results indicate that when the calculated 10 percent of the whole wing is contaminated, the 10º plate is on average 55 percent failed.

Table 5.5: 10 Percent Wing Failure vs. Standard Plate Failure

Run #	**Fluid/ Orientation**	**Normalized Time of 10% Wing Failure (min)**	*Non Corrected Time (min)*	**AVG. Endurance Time of 10º Plate (min)**	**Time of 10% Wing Failure as Percentage of 10º Standard Plate Failure (%)**
2	**TIV / Head Wind**	55.7	65.7	89.4	62%
3	**TIV / Head Wind**	33.7	37.0	58.7	57%
4	**TIV / Head Wind**	91.8	85.6	133.0	69%
5*	**TI / Head Wind**	35.9	49.0	13.9	258%
6	**TI / Tail Wind**	15.4	23.9	57.1	27%
7	**TIV / Tail Wind**	17.4	12.5	73.1	24%
8	**TIV / Tail Wind**	76.2	68.5	103.7	74%
9	**TI / Tail Wind**	3.4	3.0	16.3	21%
10	**TIV / Tail Wind**	48.7	38.5	114.3	43%
11	**TIV / Tail Wind**	64.0	64.0	91.0	70%
SWA 1 PORT (Retracted)	**TIV / Head Wind**	27.1	27.5	52.2	52%
SWA 1 STBD (Extended)	**TIV / Head Wind**	19.8	20.0	52.2	38%
SWA 2 PORT (Retracted)	**TIV / Head Wind**	111.0	132.0	80.4	138%
SWA 2 STBD (Extended)	**TIV / Head Wind**	44.8	31.5	80.4	56%
				Average (without SWA1 PORT and SWA2 PORT)	**67%**
				Average without potential outlier and without SWA1 PORT and SWA2 PORT	**49%**

*Potential outlier data point.

Table 5.6: 10 Percent Wing Failure vs. Standard Plate Failure – Type I Data Only

Run #	Fluid/ Orientation	Normalized Time of 10% Wing Failure (min)	*Non Corrected Time*	AVG. Endurance Time of 10º Plate (min)	Time of 10% Wing Failure as Percentage of 10º Standard Plate Failure (%)
5*	**TI / Head Wind**	35.9	49.0	13.9	258%
6	**TI / Tail Wind**	15.4	23.9	57.1	27%
9	**TI / Tail Wind**	3.4	3.0	16.3	21%
				Average	**102%**
				Average without potential outlier	**24%**

*Potential outlier data point.

Table 5.7: 10 Percent Wing Failure vs. Standard Plate Failure – Type IV Extended Configuration Data Only

Run #	Fluid/ Orientation	Normalized Time of 10% Wing Failure (min)	*Non Corrected Time*	AVG. Endurance Time of 10º Plate (min)	Time of 10% Wing Failure as Percentage of 10º Standard Plate Failure (%)
2	**TIV / Head Wind**	55.7	65.7	89.4	62%
3	**TIV / Head Wind**	33.7	37.0	58.7	57%
4	**TIV / Head Wind**	91.8	85.6	133.0	69%
7	**TIV / Tail Wind**	17.4	12.5	73.1	24%
8	**TIV / Tail Wind**	76.2	68.5	103.7	74%
10	**TIV / Tail Wind**	48.7	38.5	114.3	43%
11	**TIV / Tail Wind**	64.0	64.0	91.0	70%
SWA 1 STBD (Extended)	**TIV / Head Wind**	19.8	20.0	52.2	38%
SWA 2 STBD (Extended)	**TIV / Head Wind**	44.8	31.5	80.4	56%
				Average	**55%**

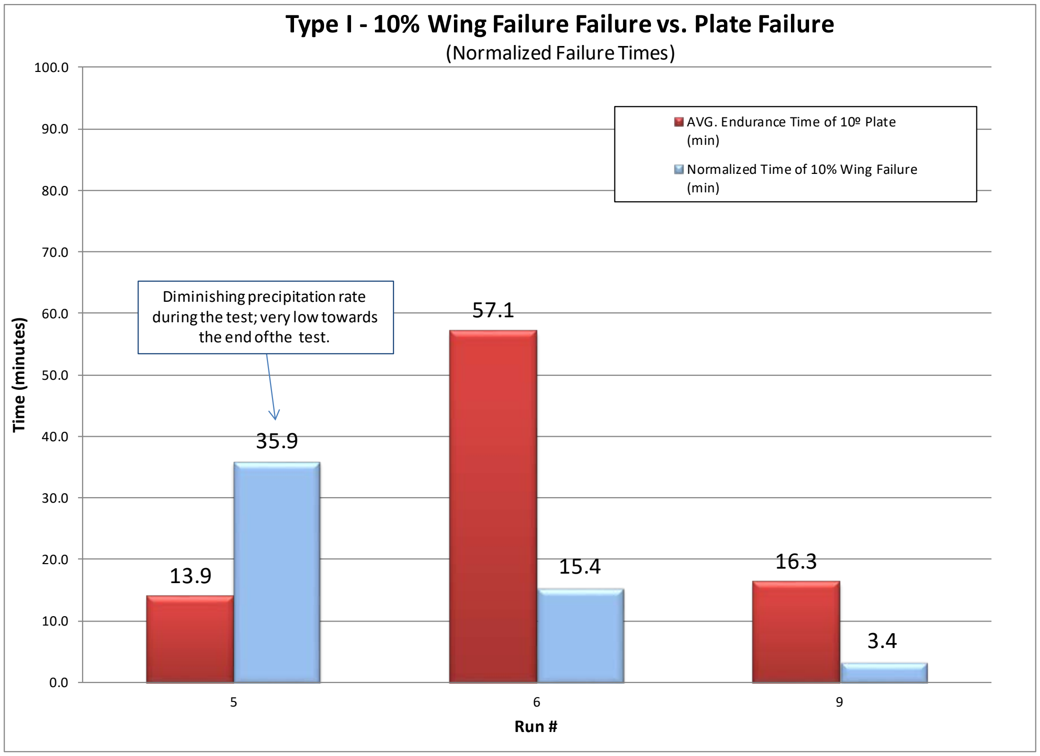


Figure 5.8: 10 Percent Wing Failure vs. Standard Plate Failure – Type I Data Only

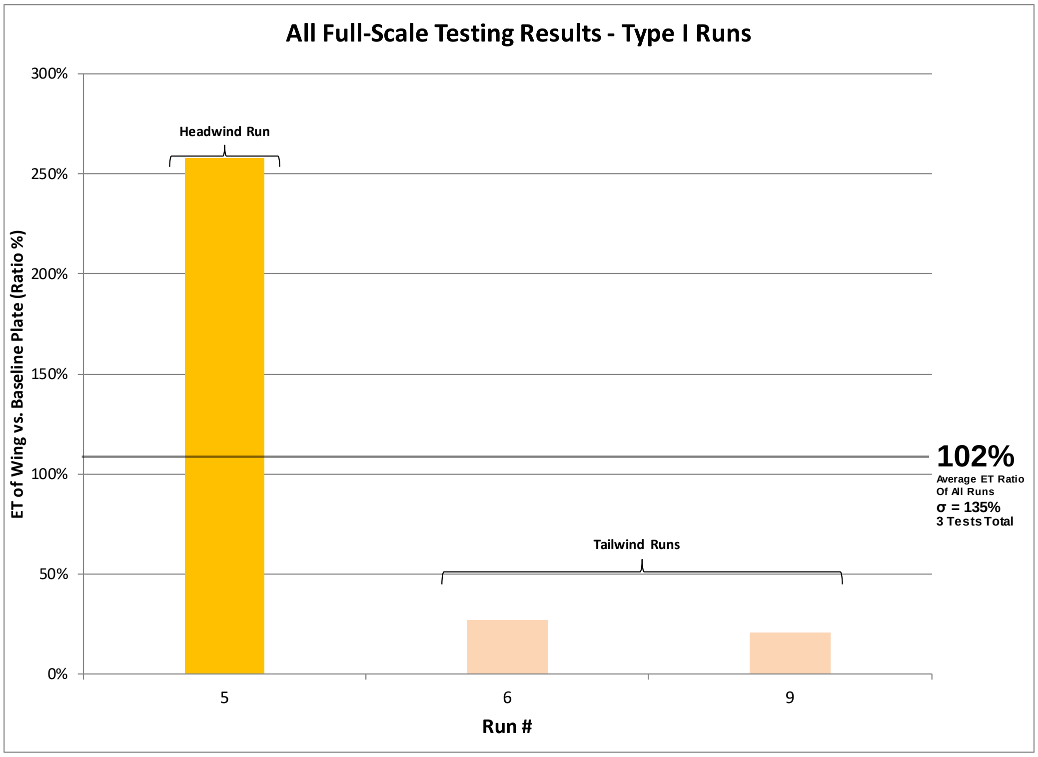


Figure 5.9: 10 Percent Wing Failure vs. Standard Plate Failure Ratio – Type I Data Only

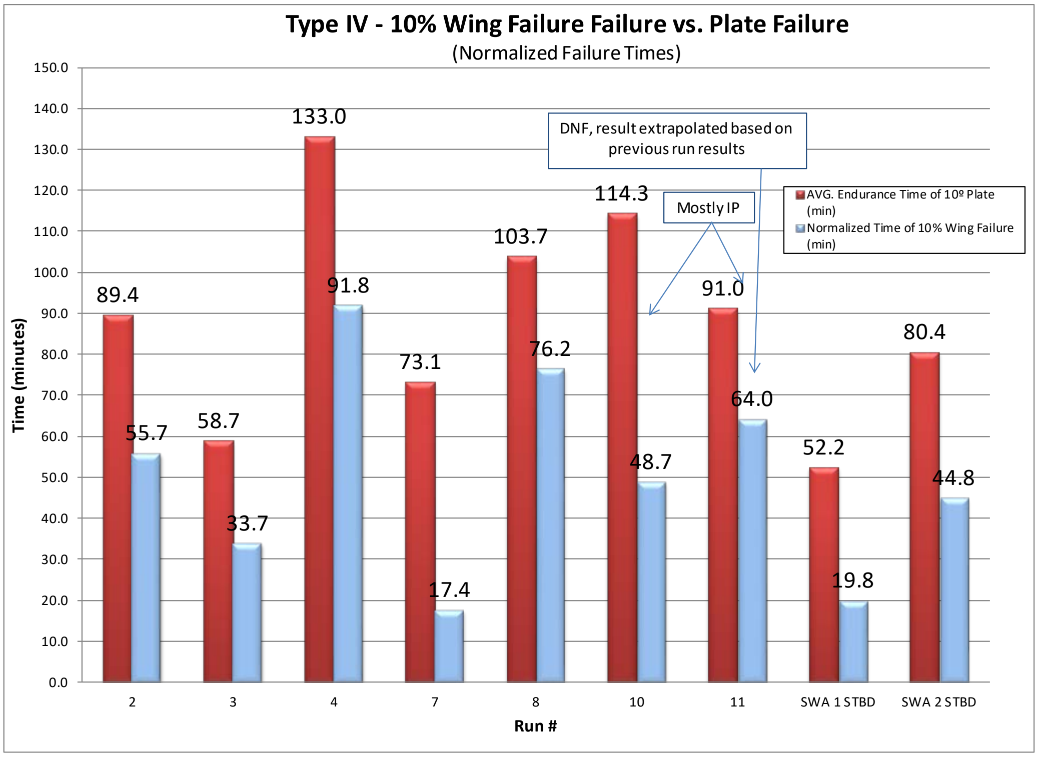


Figure 5.10: 10 Percent Wing Failure vs. Standard Plate Failure – Type IV Data Only

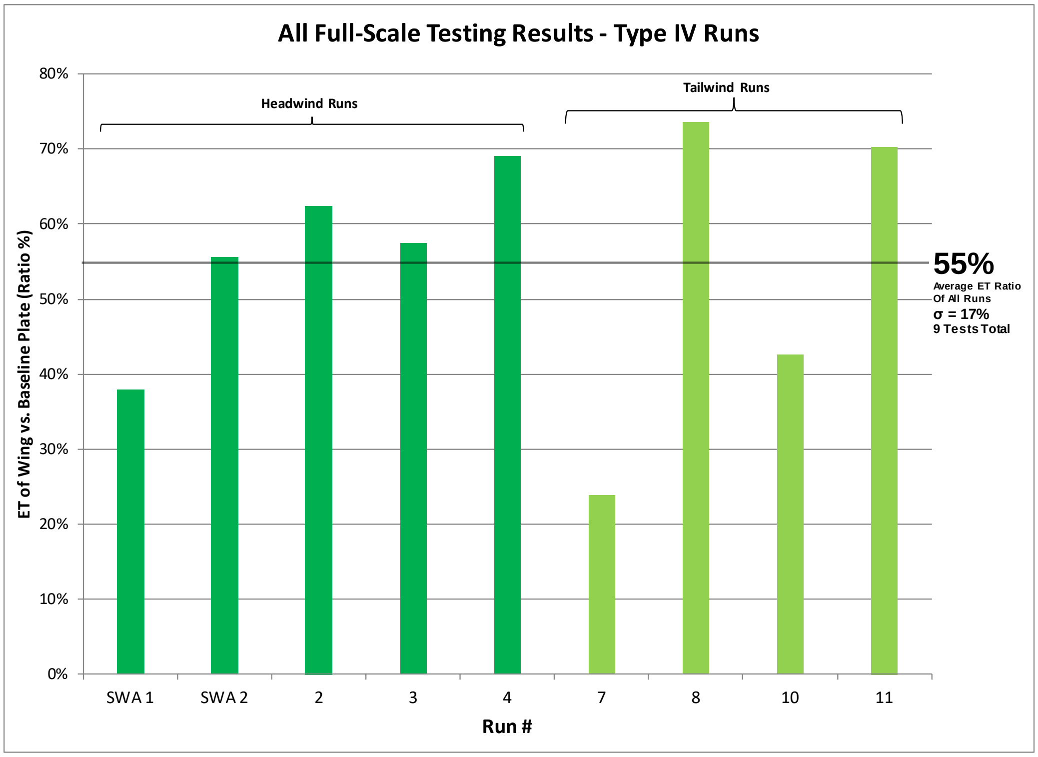


Figure 5.11: 10 Percent Wing Failure vs. Standard Plate Failure Ratio – Type IV Data Only

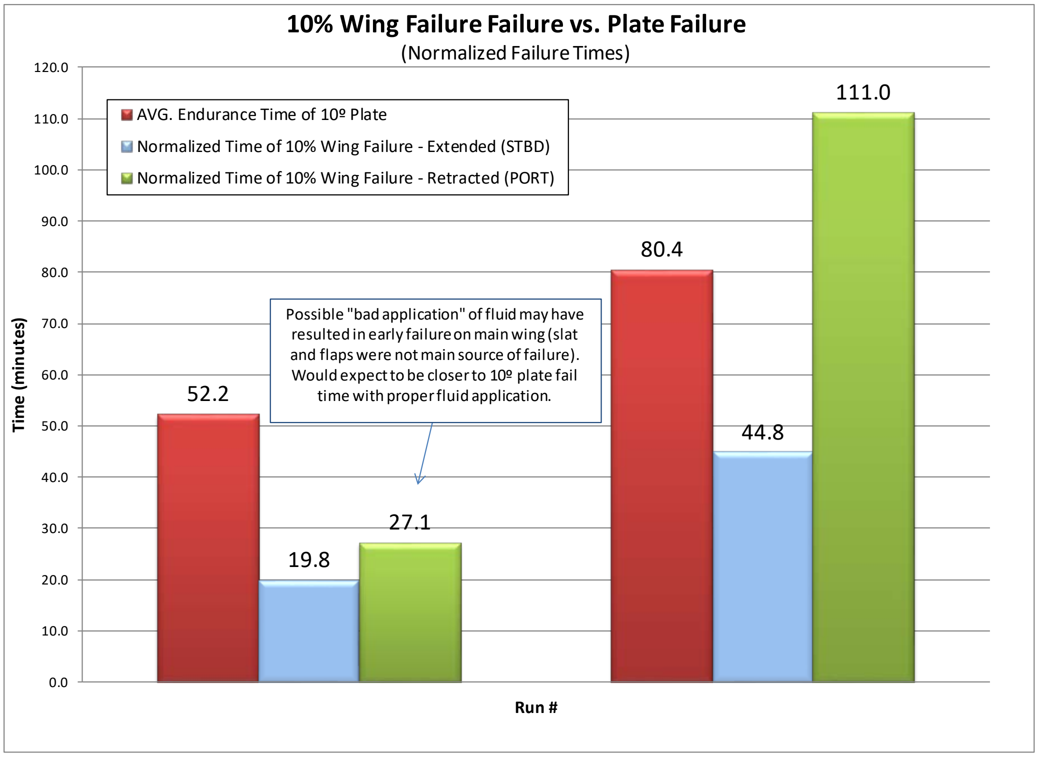


Figure 5.12: SWA Data – Extended vs. Retraced Wing Failure Times

5.5 Correlation of Results to Historical Full-Scale Tests

When the holdover time testing protocol was being developed (in the early 90's), a large series of full-scale tests were conducted comparing wing fluid failure to the failure on flat plates inclined to 10°. The historical data set indicates that a standard plate failure (1/3 of the plate covered in failed fluid) correlates to approximately 10 percent of the wing failed, with flaps and slats in the retracted position. The purpose of this analysis was to determine how the full-scale tests conducted with extended flaps and slats during the winter of 2011-12, 2012-13, and 2015-16 compare to the historical data set.

To analyse the results, the 2011-12, 2012-13, and 2015-16 normalized results were superimposed on historical Type I and Type IV fluid graphs (Figure 5.13 and Figure 5.14) sourced from TC's 1994-95 and 1996-97 aircraft full-scale test reports, TP12595E (3) and TP13130E (4). For analysis ease of reference, the 2011-12, 2012-13, and 2015-16 data were separated by fluid Type I and IV. With the exception of one likely outlier full-scale Type I test, both figures clearly indicate that the extended slats and flaps configuration reduces the fluid protection time.

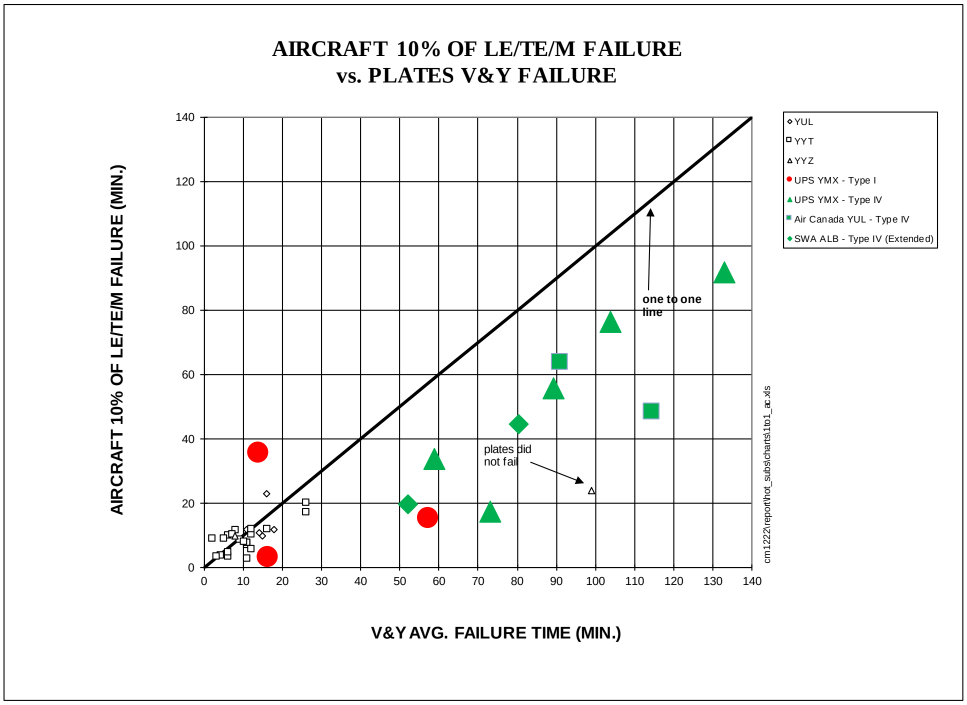


Figure 5.13: 1994-95 Full-Scale Data (Type I) with 2011-12, 2012-13, and 2015-16 Data Superimposed

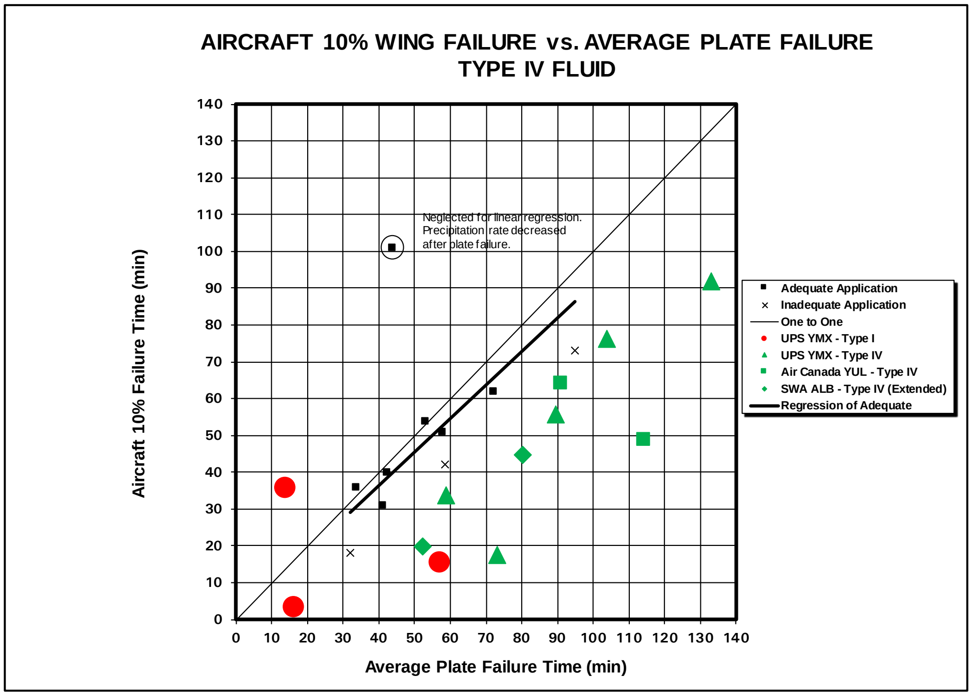


Figure 5.14: 1996-97 Full-Scale Data with 2011-12, 2012-13, and 2015-16 Data Superimposed

5.6 Evaluation of Flat Plate Models

Testing was conducted with the standard baseline 10º plate, as well as with 20º and 35º plates in simple and nested configurations. The 20º and 35º plates in simple and nested configuration were selected to represent a wide range of aircraft and takeoff configurations, however they generally will not exactly represent particular aircraft as they serve as generic models.

An analysis was conducted to determine what specific plate angle would allow for a best plate-to-wing correlation. The analysis aimed to linearly correlate the failure times on the 10º and 20º plates to the 10 percent wing failure time. The results are shown in Table 5.8. For example, the ideal plate angle for Run #2 was calculated based on the following equation: 17 = ((89-56)/(89-43)x10) + 10. The average result of the analysis indicates that a 19º simple plate would be best to represent the aircraft tested in extended configuration in head wind or tail wind conditions. Based on the current data available, the 20º simple plate results demonstrate the closest correlation to the full-scale results; use of this plate takes into account any variation in the results with aircraft type.

5.7 Fluid Failure of the Tail Horizontal Stabilizer

The following sections describe the results and analysis related to the fluid failure of the tail horizontal stabilizer.

5.7.1 UPS YMX Testing

As a secondary objective of the full-scale airfoil testing, a comparison of fluid failure on the main wing to the horizontal stabilizer was conducted for one test. The objective was to determine if fluid failure on the main wing precedes fluid failure on the horizontal stabilizer when the main wing is sprayed before the horizontal stabilizer. It should be noted that during these tests, the entire horizontal stabilizer was sprayed immediately after the main wing test section, as would typically occur in operations using the same fluid and dilution applied from the same deicing truck.

Table 5.8: Ideal Plate Angle Correlation to Wing Failure

Run #	Fluid/ Orientation	Normalized Time of 10% Wing Failure (min)	*Non Corrected Time*	AVG. Endurance Time of 10º Plate (min)	AVG. Endurance Time of 20º Plate (min)	AVG. Endurance Time of 20º Nested Plate (min)	AVG. Endurance Time of 35º Plate (min)	AVG. Endurance Time of 35º Nested Plate (min)	Ideal Plate Angle Based on 10% Wing Failure, 10º and 20º Plates (º)
2	**TIV / Head Wind**	56	66	89	43	95	23	93	17
3	**TIV / Head Wind**	34	37	59	24	36	13	35	17
4	**TIV / Head Wind**	92	86	133	51	136	35	126	15
5	**TI / Head Wind ***	36	49	14	11	-	8	-	n/a
6	**TI / Tail Wind**	15	24	57	26	-	10	-	23
7	**TIV / Tail Wind**	17	13	73	29	49	12	36	23
8	**TIV / Tail Wind**	76	68	104	52	-	24	47	15
9	**TI / Tail Wind**	3	3	16	18	-	7	-	n/a
10	**TIV / Tail Wind**	49	39	114	44	-	22	59	19
11	**TIV / Tail Wind**	64	64	91	36	-	18	-	15
SWA 1 PORT (Retracted)	**TIV / Head Wind**	27	28	52	28	38	21	24	20
SWA 1 STBD (Extended)	**TIV / Head Wind**	20	20	52	28	38	21	24	23
SWA 2 PORT (Retracted)	**TIV / Head Wind**	111	132	80	44	62	27	46	2
SWA 2 STBD (Extended)	**TIV / Head Wind**	45	32	80	44	62	27	46	20
								Average*	**19**

* Not including #5, #9, SWA1 PORT and SWA2 PORT.

Table 5.9 includes the completed assessment form from Run #8 on March 19, 2013. During this test, it was immediately apparent that the Type IV fluid was not adequately applied to the tail surface, in that a blotchy uneven spray was performed. As a result of this, the tail was subject to earlier fluid failure and this was apparent in the data collected. At the time that fluid failure progression was first observed on the main wing, the tail contamination was more advanced at about 50 percent failed. By the time the slat of the main wing was 50 percent failed (which is 7.5 percent of the whole wing), the tail was much more contaminated at about 70 percent failed.

The results of this test are likely not representative due to the inadequate application of fluid to the horizontal stabilizer during the test.

5.7.2 SWA ALB Testing

A similar test was conducted as part of the Southwest Airlines flaps and slats tests in Albany. The main difference was the availability of two aircraft during the test, the first of which had slats and flaps extended during the whole test, and the second of which had them retracted, then extended at first sign of fluid failure. During the second SWA test, the horizontal stabilizer of the aircraft with the wing in extended configuration (Aircraft #1) was also sprayed and the condition of the horizontal stabilizer was compared to both main wings in the extended and retracted configuration.

Table 5.10 includes the completed assessment data form from Run #SWA-2 on February 9, 2013. At the key events, the tail was compared to both main wing sections. At each of the key events, the condition of the tail was better, or much better, as compared to the condition of the extended wing, and was equal, or slightly better in terms of contamination as compared to the retracted wing. The results were as expected, since the condition of the tail should be equal to or better as compared to the wing considering the tail is sprayed after the wing.

Table 5.9: Horizontal Stabilizer Assessment Data from UPS YMX Testing Run#8

KEY EVENT ON MAIN WING	TIME OF OBSERVATIO N	ASSESSMENT OF TAIL (IN COMPARISON TO MAIN WING)					
		Much more contaminated	More contaminated	Equal	Less contaminated	Much less contaminated	Comments
Immediately after anti-icing	01:58:00			Tail was equal to wing			Type IV was sprayed unevenly on tail
First Failure on Wing	02:38:00		Tail was more contaminated than wing				H-stab was 50% failed
50% of the LE	02:47:00	Tail was much more contaminated than wing					H-stab was 70% failed

Table 5.10: Horizontal Stabilizer Assessment Data from SWA ALB Testing Run #SWA-2

KEY EVENT ON MAIN WING	**TIME OF OBSERVATION**	**ASSESSMENT OF TAIL (IN COMPARISON TO MAIN WING)** **(Check off one box only)**				
		Much more contaminated	**More contaminated**	**Equal**	**Less contaminated**	**Much less contaminated**
50% of the LE on Extended Wing	02:47:00			Tail was equal to retracted wing	Tail was less contaminated than the extended wing	
100% of the LE on Extended Wing	03:00:00			Tail was equal to retracted wing		Tail was much less contaminated than the extended wing
End of the Test	04:04:00				Tail was less contaminated than the retracted wing	Tail was much less contaminated than the extended wing

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6. TESTING TO SIMULATE AIRCRAFT ROTATION DURING TAXI WITH TEST PLATES AND AIRFOILS

As part of the flaps and slats research, testing was conducted to evaluate the potential effects on fluid endurance times of having an aircraft rotate and change orientation throughout the taxi from the deicing bay to the runway. In this section, the testing conducted to simulate aircraft rotation during taxi with test plates and airfoils during the winters of 2013-14, 2014-15, and 2015-16 is analysed and discussed.

6.1 Southwest Airlines Analysis of Wind Direction During Taxi

Southwest Airlines conducted an independent study of their aircraft operations over a four-month period starting in December 2013. The study monitored the wind direction relative to the airframe during the taxi to runway after deicing. A total of 2719 flights from eight different airports were included the data set. The results indicated a higher occurrence of tail winds during the taxi following deicing as compared to head winds. The detailed results from Southwest Airlines are included in Figure 6.1.

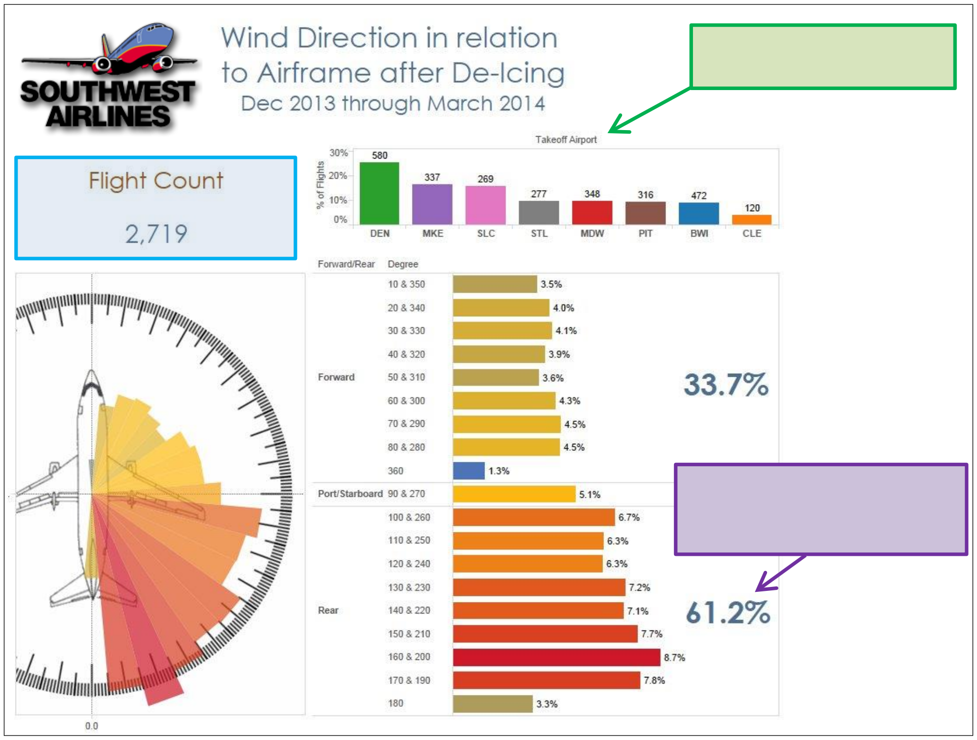
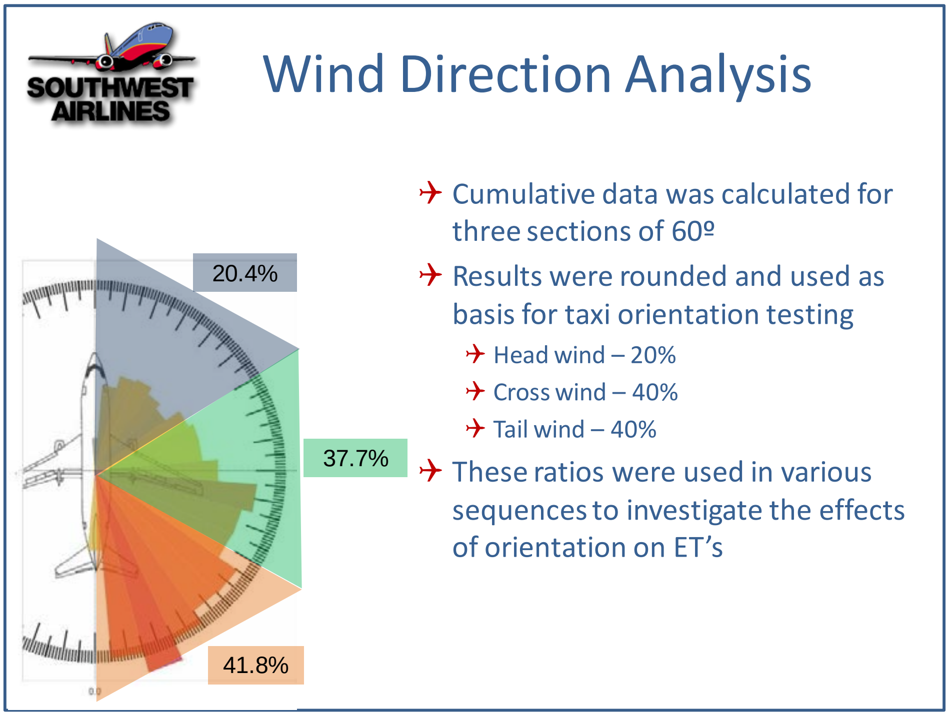


Figure 6.1: Southwest Airlines Wind Direction During Taxi Data

Additional analysis was conducted that looked at the weighted average of the static head wind, cross wind, and tail wind 20° flat plate endurance time ratios based on different taxi scenarios. The weighting was determined based on the expected orientation of the aircraft during a typical taxi. For example, some historical work (documented in report TP 14154E) indicated that at the P.E.T. airport, an aircraft would experience 40-45 percent head wind, 40-45 percent cross wind, and 10-20 percent tail wind; these ratios were used for some of the preliminary work done looking at effects of rotation n endurance times on flaps and slats. Some simple generalizations for the weighting also included 33.33 percent for head, cross, and tail wind, or 50 percent head wind, 50 percent cross wind, and 0 percent tail wind.

The Southwest Airlines data were referenced and simplified into three 60° sections with cumulative approximate weightings of 20 percent head wind, 40 percent cross wind, and 40 percent tail wind (see Figure 6.2).



SOUTHWEST AIRLINES

Wind Direction Analysis

- Cumulative data was calculated for three sections of 60º
- Results were rounded and used as basis for taxi orientation testing
  - Head wind – 20%
  - Cross wind – 40%
  - Tail wind – 40%
- These ratios were used in various sequences to investigate the effects of orientation on ET's

Figure 6.2: Simplified Analysis of Southwest Airlines Wind Direction During Taxi Data

6.2 Outdoor Flat Plate Testing Simulating Aircraft Rotation – Winters 2013-14 to 2014-15

The results from the outdoor rotating test plate setup were analysed as a whole and are described in this section. A total of 22 comparative test runs were conducted in natural snow. To investigate effect of wind direction, static cross wind and tail wind, 10º and 20º plates, with rate pans, were added to the head wind setup. The 20º simple plate provided the best representation of the aircraft with flaps/slats extended and the 10º plate provided a baseline reference to the HOT's. An additional set of dynamic 10º and 20º plates with a rate pan were included in the setup; these plates were rotated manually at pre-determined directions and intervals throughout the test. A typical sequence of stand rotations used during the winter of 2013-14 is described in Table 6.1; this sequence was developed based on data from the TC report, TP 14154E.

As a result of data collected by Southwest Airlines (more details included in Subsection 6.1), this sequence was changed slightly to put more emphasis on the cross and tail wind orientations. Table 6.2 demonstrates the typical sequence used during the winter of 2014-15. It should be noted that the sequences were guidelines and actual sequencing may have varied depending on rate variations and fluid viscosities which resulted in variation from the initial HOT estimates to either longer or shorter endurance times.

Table 6.3 summarizes the 20º simple plate results for the different wind orientation tests. The endurance ratio was calculated as a percentage of the 10º baseline head wind test. The 20º head wind results indicated that the 2013-15 tests were representative of the complete 2010-11 to 2015-16 data set as demonstrated by the 56 percent versus 55 percent calculated ratio. The results also showed that the 20º plate in tail wind orientation significantly increased the fluid endurance time; in fact, during some tests, the fail time needed to be estimated because either tests went on for several hours or the snow may have stopped prior to the fluid failure. The 20º plate in cross wind orientation demonstrated results in between the head and tail wind results. The dynamic rotation 20º plates also demonstrated results in between the head and tail wind results. Table 6.4 presents the wind orientation data collected with the 10º plate; this serves as a reference as the 10º plate is the standard for HOT testing.

Table 6.1: 2013-14 Typical Sequence and Timing for Rotating Flat Plates

Sequence	Stand Orientation	Duration
Start	Into Headwind	40% of expected Endurance Time
Rotation 1	Into Crosswind	20% of expected Endurance Time
Rotation 2	Into Tailwind	20% of expected Endurance Time
Rotation 3	Into Headwind	Until Failure.

Table 6.2: 2014-15 Typical Sequence and Timing for Rotating Flat Plates

Sequence	Stand Orientation	Duration
Position A	Into Headwind	20% of expected Endurance Time
Position B	Into Crosswind	40% of expected Endurance Time
Position C	Into Tailwind	40% of expected Endurance Time
Final Position	Into Crosswind	Until Failure.

Table 6.3: Endurance Time Ratio Analysis of 20° Simple Plate Tests

Type II/IV Plate Tests Only	10º Head Wind Endurance Time Ratio (%)
20º HEAD (10-16) all conditions	55%
20º HEAD (13-15) snow only	56%
20º TAIL (13-15) snow only	186%
20º CROSS (13-15) snow only	87%
20º ROTATING (13-15) snow only	86%

Table 6.4: Endurance Time Ratio Analysis of 10° Simple Plate Tests

Type II/IV Plate Tests Only	10º Head Wind Endurance Time Ratio (%)
10º HEAD (13-15) snow only	100%
10º TAIL (13-15) snow only	218%
10º CROSS (13-15) snow only	134%
10º ROTATING (13-15) snow only	134%

6.2.1 Weighted Average Analysis of Flat Plate Multi-Directional Data

The data collected in static head, cross, and tail wind configurations were used to calculate weighted average ratios to estimate the expected endurance time if simulating a taxi. The results of this analysis for the 20° plate data are included in Table 6.5. The results of the analysis indicated that the weighted average approach would extend the calculated endurance time; in some cases, the calculated weighted average endurance time would be equal to or longer than the 10° baseline test. These results were skewed by the tail wind plate results as these tests generally ran for very long, especially in high wind conditions where the catch factor was greatly reduced. Also to be considered is the full-scale data (Section 5) which indicates that the extended aircraft wing failed earlier whether tested in head wind or tail wind. For these reasons, the results were variable based on the orientation ratios used, and testing with a full-scale wing model was recommended in order to better validate the results.

Table 6.5: Weighted Average Ratio Analysis of 20° Simple Plate Tests

Type II/IV Plate Tests Only	10° Head Wind Endurance Time Ratio (%)
20° WEIGHTED 40%H/40%C/20%T	94%
20° WEIGHTED 45%H/45%C/10%T	83%
20° WEIGHTED 33%H/33%C/33%T	110%
20° WEIGHTED 50%H/50%C	72%
20° WEIGHTED 20%H/40%C/40%T	120%

6.3 Airfoil Testing Results

Testing was conducted using two airfoil models. The first was a simple airfoil without leading or trailing edge devices and based upon a F28 wing; will be referred to as "simple airfoil". The second was the same as the simple airfoil, however was modified by Southwest Airlines to have both a leading edge slat and trailing edge flap; will be referred to as "slatted airfoil".

The results from the airfoil testing were analysed as a whole and are described in this section. A total of 62 individual airfoil tests (54 tests with the slatted airfoil and 8 tests with the simple airfoil) were conducted outdoors in natural snow, and a total of 16 individual airfoil tests (11 tests with the slatted airfoil and 5 tests with the simple airfoil) were conducted indoors in simulated freezing precipitation. Similar to the set of dynamic 10° and 20° plates, the airfoils were rotated manually at pre-determined directions and intervals throughout the test in natural snow conditions; the airfoil was fixed in simulated freezing precipitation conditions. The typical rotation sequence was based on data collected by Southwest Airlines and is described in Table 6.2 (more details included in Subsection 6.2). It should be noted that the sequences were guidelines and actual sequencing may have varied depending on rate variations and fluid viscosities which made the initial HOT estimates longer or shorter.

The detailed data log can be found in Table 3.3. The airfoil with flaps and slats data were separated according to type and plotted in Figure 6.3, Figure 6.4, and Figure 6.5; tests that did not fail (DNF) were not included in the charts. Each bar represents and individual test and plots the endurance time ratio of the airfoil as compared to the 10° plate. The tests have been grouped according to similar rotation profile and abbreviated respectively. The averages of the data set, along with the comparative 20º flat plate data average have been plotted for each data set.

For the Type II/IV results, the graph indicates that the headwind orientation caused the greatest reduction to the airfoil endurance time. On average the airfoil results indicated 90 percent endurance time ratio compared to the 10º plate with a standard deviation of 21 percent. These results are greater than the 20º plate average data by a factor of about 2-sigma. It should be noted that the two static head wind and 2 static tail wind tests conducted in natural snow indicate a closer correlation to the flat plate results; no rotation was done during these tests for either the airfoil or the plates. Photo 6.1, Photo 6.2, and Photo 6.3 demonstrate some examples of the fluid failure progression observed on the airfoil with flaps and slats.

On average the Type I airfoil results indicated 73 percent endurance time ratio compared to the 10º plate with a standard deviation of 30 percent. These results are less than the 20º plate average data which indicates 84 percent endurance time ratio. These results may indicate that the flat plate models are not conservative enough; however further testing is required to substantiate this.

On average the Type III fluid (applied cold) airfoil results indicated 89 percent endurance time ratio compared to the 10º plate with a standard deviation of 13 percent. Similar to the Type II/IV data, these results are greater than the 20º plate average data by a factor of about 2-sigma.

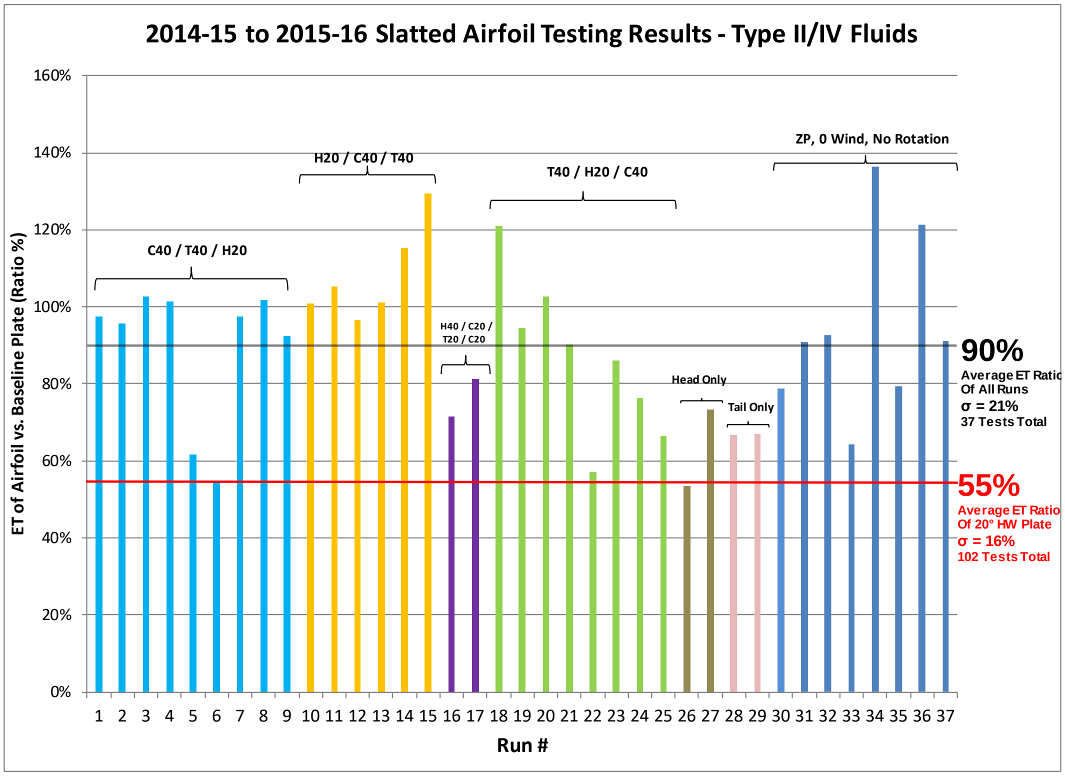


Figure 6.3: Type II and IV Airfoil with Flaps and Slats Testing Results

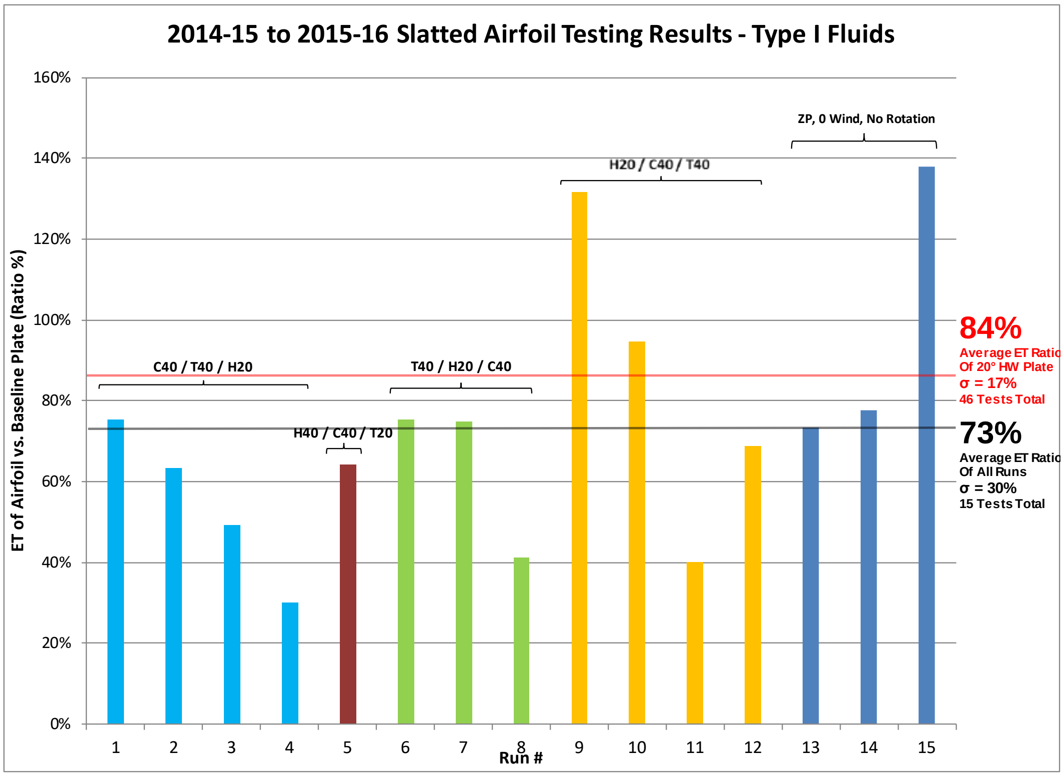


Figure 6.4: Type I Airfoil with Flaps and Slats Testing Results

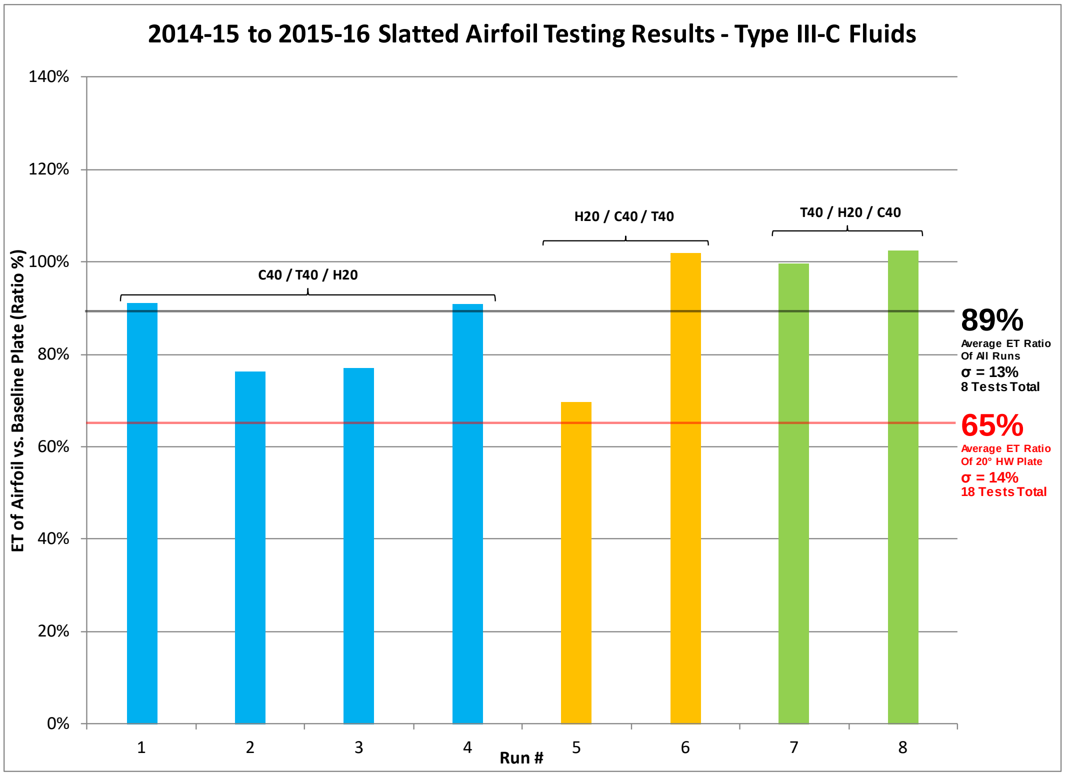


Figure 6.5: Type III-Cold Airfoil with Flaps and Slats Testing Results

In some cases, both the simple airfoil and the airfoil with flaps and slats were run simultaneously while simulating a rotation sequence. A comparison of the average results of these seven instances is provided in Table 6.6. The results indicated that the simple airfoil has a longer endurance time as compared to the airfoil with the flaps and slats, as expected; the simple airfoil results may be conservative as in many cases the test did not fail and the end time was estimated.

Table 6.6: Fluid Protection Time of Slated Airfoil and Simple Airfoil versus 10º Plate

<table>
<tr><th colspan="4">Performance of Slatted Airfoil and Simple Airfoil vs. 10º Plate
Type I and II/IV Fluid - All Conditions – Rotating Comparative Tests Only</th></tr>
<tr><th>Fluid Type</th><th>Slatted Airfoil
(Avg. % Ratio of 10º Plate)</th><th>Simple Airfoil
(Avg. % Ratio of 10º Plate)</th><th>Test Count</th></tr>
<tr><td>Type I</td><td>54%</td><td>131%</td><td>4</td></tr>
<tr><td>Type II/IV</td><td>83%</td><td>175%</td><td>7</td></tr>
</table>

6.4 General Observations

Similar results to the UPS, Air Canada, and SWA full-scale tests were obtained when testing with the airfoil in static headwind or tailwind configurations. The fluid protection time was extended when the airfoil was rotated to simulate a taxi. The reduction in protection time due to the extended flap and slat was likely related to the amount of time spent in headwind or tailwind orientation. The Type I data indicates that the 20° plate/box may not be conservative enough as a model if used as a surrogate for the airfoil with flaps and slats (similar results were seen with the full-scale aircraft correlation). The results also showed that the simple airfoil demonstrated longer fluid protection time as compared to airfoil with extended flaps and slats.

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Photo 6.1: Example of Type IV EG Fluid Failure – December 10, 2015

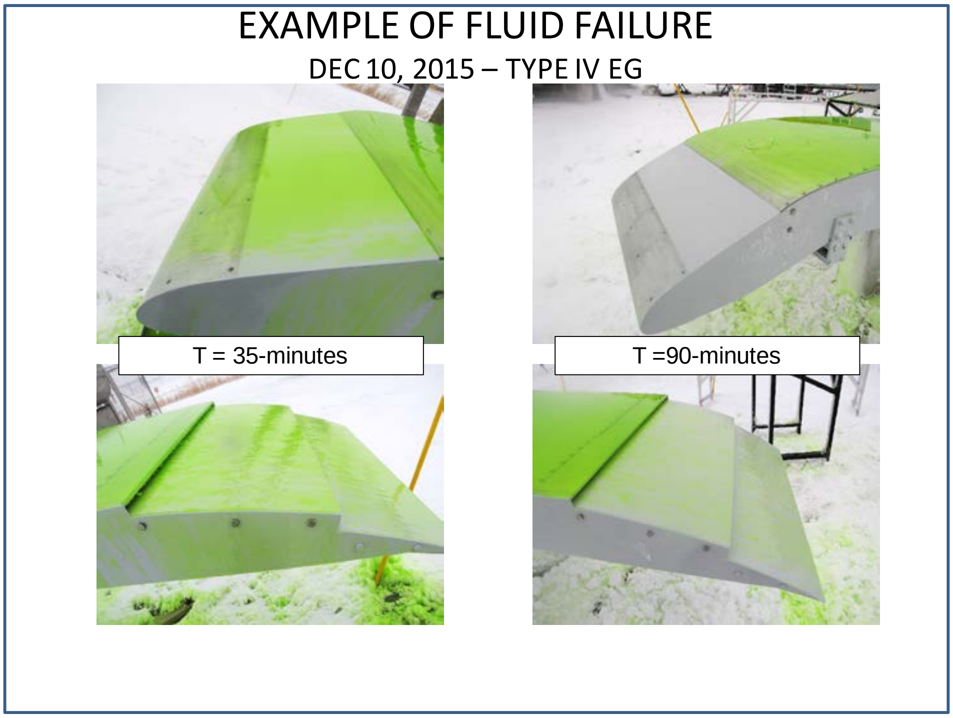


Photo 6.2: Example of Type IV EG Fluid Failure – February 2, 2015

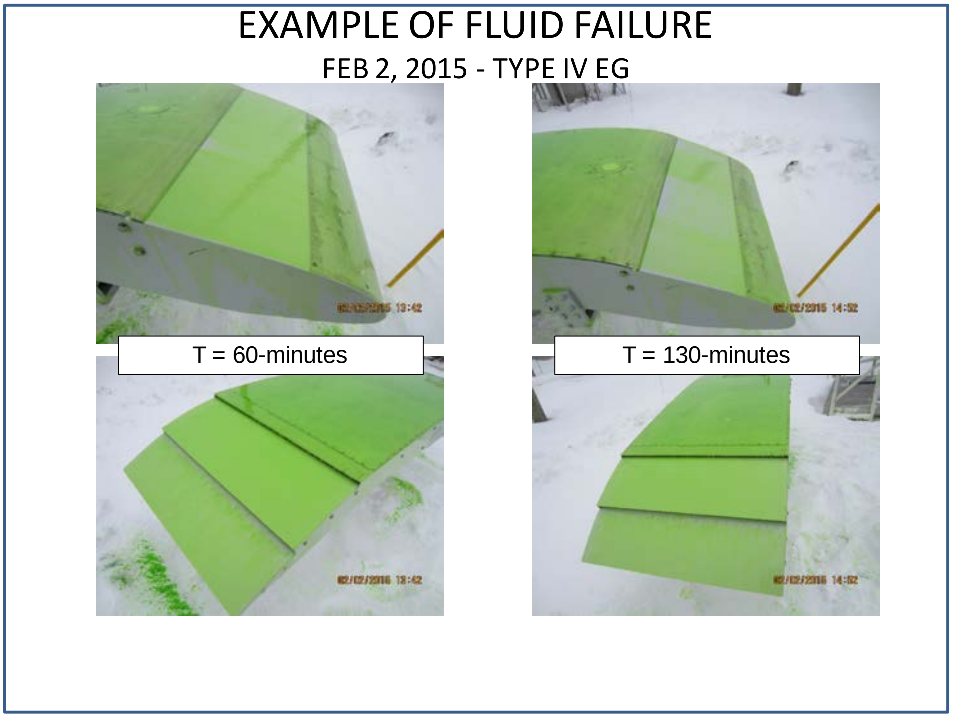
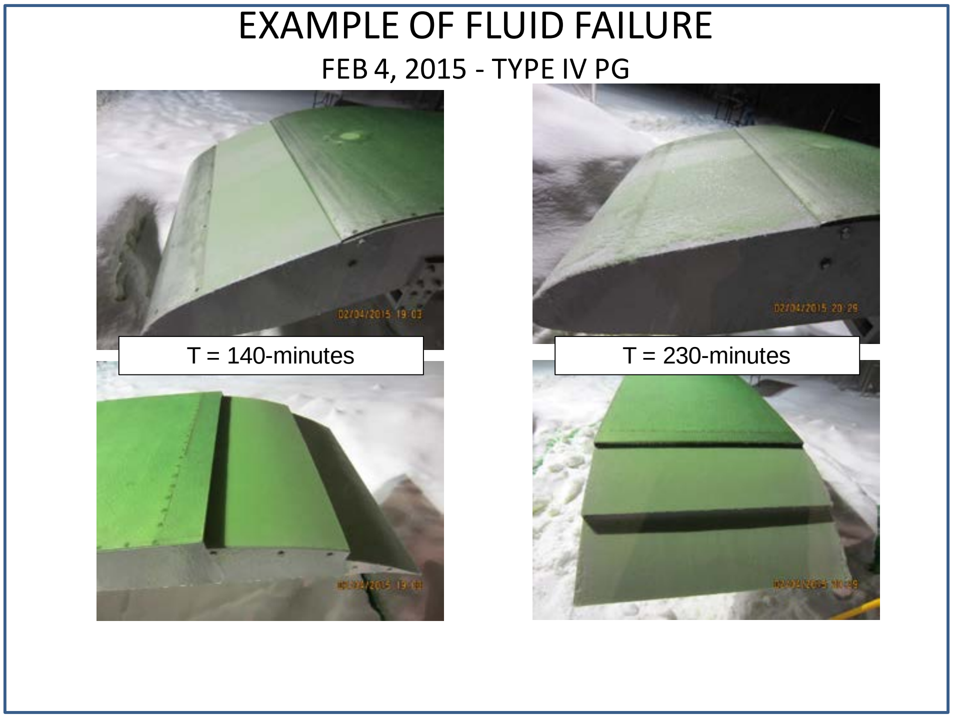


Photo 6.3: Example of Type IV PG Fluid Failure – February 4, 2015



EXAMPLE OF FLUID FAILURE

FEB 4, 2015 - TYPE IV PG

T = 140-minutes

T = 230-minutes

7. CONCLUSIONS

The conclusions drawn from the tests performed during the winter of 2011-12 to 2015-16 are described in this section.

7.1 Endurance Time Testing on Inclined Plates

Results have indicated that flat plate endurance times are shorter on higher angle surfaces; this reduction can be almost half for Type II/IV fluids. In general, the Type I fluid endurance times indicate that the protection is less affected by the increased angle of the plates; the Type I heat is a primary source of the fluid protection time and therefore the endurance time may not be as strongly affected by the increase in surface angle. Type IV fluid is applied at ambient temperature and the increased angle causes a higher snow catch rate and reduced fluid thickness which results in shorter fluid protection times. The results from the Type IV tests are assumed to be applicable to Type II fluids and Type III fluids (when applied unheated) as well. The Type III heated fluid testing indicates the reductions in endurance times may not be as significant as Type IV fluid, but not as small as for Type I either.

Results indicated that the impact of the test surface angle on endurance times may be dependent on the structural configuration as follows:

- A nested plate (simulating a nested flap configuration) will allow fluid to continually flow on the bottom plate (from the top plate) and may generate some reduction in holdover times; and
- A simple plate (simulating a slat or simple flap) will not have fluid feeding from an upper surface, resulting in significantly reduced endurance times.

The 20° simple plate has become the focus of flat plate testing as it has the closest relationship to the full-scale aircraft and airfoil 10 percent failure time. The summarized results of the 20° simple flat plate (or box for Type I and III heated) tests are described in Subsection 7.4.

7.2 Full-Scale Aircraft Testing

The following sections describe the full-scale aircraft testing results and conclusions.

7.2.1 Correlation of Results to Historical Full-Scale Tests

The historical data set (from the early testing conducted in the 1990's) indicates that a standard plate failure (1/3 of the plate covered in failed fluid) correlates to approximately 10 percent of the wing failed. The full-scale test results were superimposed on the data. The analysis indicated that with the exception of one likely outlier Type I test, the extended slats and flaps configuration reduces the fluid protection time.

7.2.2 Evaluation of Flat Plate Models

The 20º and 35º plates in simple and nested configurations were selected as generic models to represent a wide range of aircraft and takeoff configurations. Based on the comparison of the failure progression on the aircraft, the analysis indicated that a 19º simple plate would be best suited to represent the aircraft tested in extended configuration in head wind or tail wind conditions, which validates the selection of the 20º plate currently used.

7.2.3 Additional SWA Full-Scale B-737 Testing

The SWA results supported the UPS testing results indicating that a reduction in fluid protection time occurs when the slats and flaps are in extended configuration. This was demonstrated by comparing the fluid protection times of the two comparative aircraft tested simultaneously.

7.2.4 Tail Horizontal Stabilizer Failure

As a secondary objective, a comparison of fluid failure on the main wing versus the horizontal stabilizer was conducted with the UPS aircraft for one test. The results of this test are likely not representative due to the inadequate application of fluid to the horizontal stabilizer during the test which resulted in premature fluid failure.

A similar test was conducted as part of the Southwest Airlines flaps and slats tests in Albany. This result was as expected in light of the tail being sprayed after the wing, the condition of the tail was equal to or better as compared to the wing.

7.2.5 10 Percent Wing Failure vs. Standard Plate Failure

For the full-scale aircraft testing, the time when 10 percent of the whole wing demonstrated signs of fluid failure was correlated to the average baseline 10° plate endurance time. The deployed wing as a whole demonstrated earlier fluid failure as compared to the 10° plate.

The full-scale results are an important consideration for analysis as they provide a benchmark for correlation of to the 20° flat plate. The summarized results of the full-scale aircraft results are described in Subsection 7.4.

7.3 Testing Simulating Aircraft Orientation During Taxi

The following sections describe the simulating aircraft orientation during taxi results and conclusions.

7.3.1 Flat Plate Testing

This testing was done with static 10° and 20° plates oriented at 0°, 90°, and 180° with respect to the wind, and also following a methodology using dynamic rotating of test plates with respect to the wind. The results indicated that adjusting for taxi orientation extended the 20° plate protection time, but the results are variable with the orientation direction sequence and the ratios of allotted direction times. Additional testing with a wing model was undertaken in order to better assess the results.

7.3.2 Airfoil Testing

Similar results to the UPS, Air Canada, and SWA full-scale tests were obtained when testing with the airfoil in static headwind or tailwind configurations. The fluid protection time was extended when the airfoil was rotated to simulate a taxi. The reduction in protection time due to the extended flap and slat was likely related to the amount of time spent in headwind or tailwind orientation. The Type I data indicates that the 20° plate/box may not be conservative enough as a model if used as a surrogate for the airfoil with flaps and slats (similar results were seen with the full-scale aircraft correlation). The results also showed that the simple airfoil demonstrated longer fluid protection time as compared to airfoil with extended flaps and slats.

The airfoil testing results have become of greater importance as they provide an indication of how protection time is influenced as a result of rotating the test model (simulating an aircraft taxiing to the runway). The summarized results of the airfoil tests are described in Subsection 7.4.

7.4 Summary of Endurance Time Ratio Averages

To facilitate the referencing of results using the most relevant test models, a top-level summary has been provided in Figure 7.1 and Figure 7.2. For the purpose of this summary, the results were grouped by "Type II, III-Unheated, and IV fluids" and "Type I and Type III-Heated". The figures show the average percentage endurance time ratios of the test model as compared to the relative 10° plate baseline tests; this does not include tests that did not fail (DNF). Standard deviation and number of tests is also demonstrated in each figure.

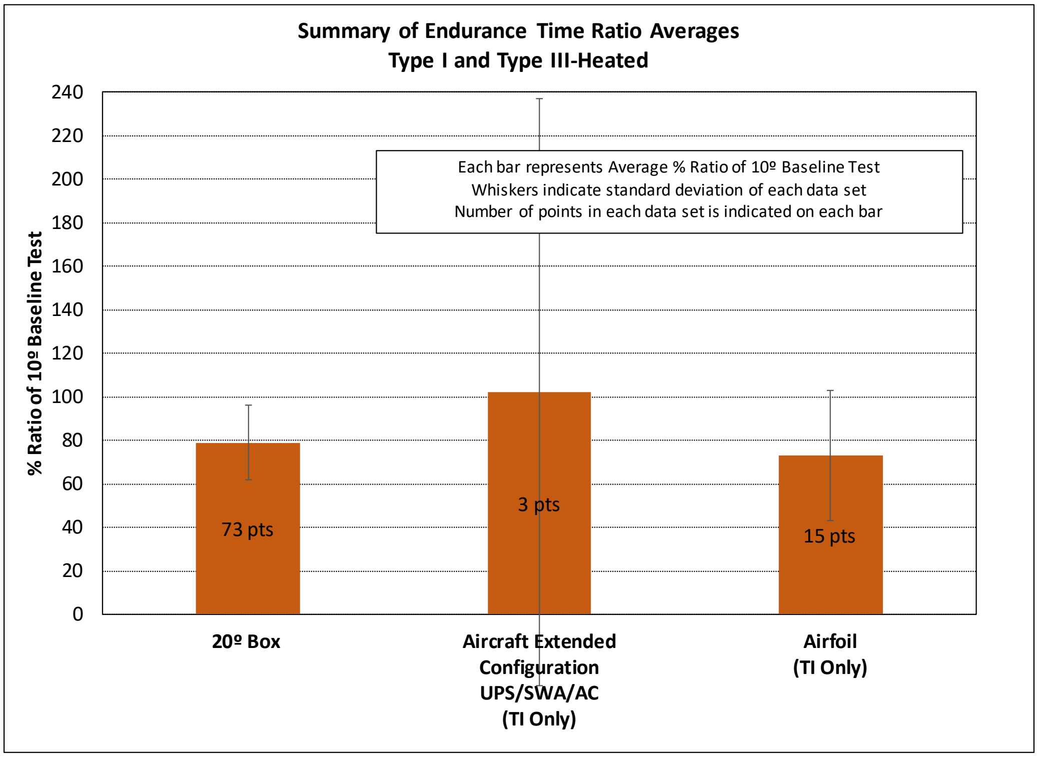


Figure 7.1: Top Level Summary of Type I and Type III-Heated Results

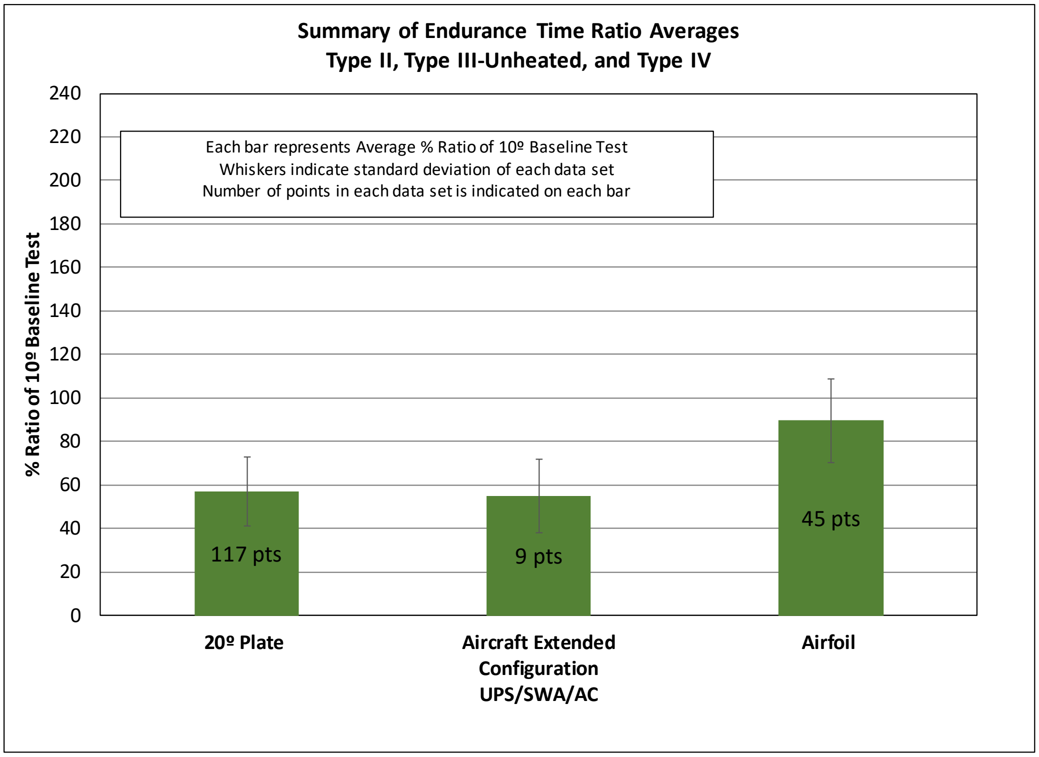


Figure 7.2: Top Level Summary of Type II, Type III-Unheated, and Type IV Results

7.5 Applicability of Wing and Plate Data to HOT Guidelines

The full-scale data has shown a reasonable correlation with Type IV fluid between the inclined plates and the wing surfaces. In the extended configuration, the wing as a whole demonstrated earlier fluid failure as compared to the 10° plate; the shorter endurance times of the 20° simple plate better represented the expected fluid protection on the wings with extended flaps and slats.

The flat plate data collected also showed a difference in the expected endurance time reductions on the extended flaps and slats when using Type I versus Type IV fluids. The Type I fluids were less susceptible to reductions in endurance times when tested on higher incline angles as compared to the Type IV, however this observation was not clearly demonstrated because of the limited Type I full-scale data collected.

In general, the limited full-scale data has indicated a reasonable correlation with Type IV between the aircraft surfaces and the flat plate models. If there is agreement in the use of the inclined flat plate models to represent the full-scale aircraft in extended configuration, then by default there is a more extensive data set from flat-plate-only testing done previously at the APS airport test facility and

NRC CEF. This data is also directly applicable to the flaps and slats questions, and provides a more thorough set of testing conditions, temperatures, and results.

Based on the full-scale data collected, and the assumption that the inclined flat plates are representative surrogate models, then the data supports the need to reduce holdover times when operating with extended flaps and slats, however this reduction may be less for Type I fluids (and Type III heated fluids) as compared to Type II, III, and IV fluids.

Testing simulating aircraft rotation during taxi to the runway has indicated that adjusting for taxi orientation extends the fluid protection time. These results have been demonstrated on flat plates as well as with airfoil models. These results have been highly variable based on the type of taxi simulated and how much time is spent in the head, cross, or tail-wind orientations; the longer time spent in headwind orientation, the greater the decrease in fluid protection time. Further work is required to better understand how to incorporate these results into proper guidance.

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1. D'Avirro, J., Chaput, M., Hanna, M., Peters, A., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1997/98 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 1998, TP 13318E, 204.

2. Ruggi, M., *Wind Tunnel Research to Support the Development of Ice Pellet Allowance Time Tables Winter 2009-10*, APS Aviation Inc., Transportation Development Centre, Montreal, August 2011.

3. Boutanios, Z., Dawson, P., D'Avirro, J., *Aircraft Full-Scale Test Program for the 1994-1995 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 1995, TP 12595E, 90.

4. D'Avirro, J., Chaput, M., Dawson, P., Hanna, M., Fleming, S., *Aircraft Full-Scale Test Program for the 1996/97 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 1997, TP 13130E, 180.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT:
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2015-16

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2015-16

3.6 Evaluation of Endurance Times on Deployed Flaps and Slats – Flat Plate, Model, and Full-Scale Aircraft Testing

a) Review previous results from outdoor and YMX testing conducted by APS;

b) Modify procedure and methodology as required based on testing already performed;

c) Conduct full-scale aircraft testing (two sessions shall be planned at YMX and YUL with either Air Canada or UPS) to evaluate the endurance time performance of wing surfaces with deployed flaps and slats as compared to flat plates;

d) Testing on airfoils (mostly slatted only) at YUL test site:

   i. Target 20-30 outdoor tests (and 10-15 indoor tests);

   ii. Continue outdoor testing simulating taxi to build on existing data set;

   iii. Include more Type I tests (30% of tests);

   iv. 10% testing should be done using both simple and slatted airfoil;

   v. Use the ratios 20% Headwind, 40% Crosswind, 40% Tailwind to determine how much time relative to the expected endurance time is spent in the respective orientation. Three scenarios will be simulated: starting with headwind, starting with crosswind, and starting with tailwind. The number of individual scenario tests should also follow the 20/40/40 ratio respectively; and

   vi. Conduct NRC testing, similar to previous winter.

e) Conduct limited flat plate tests (both inside and outside) to compliment data already collected on flat plate models (i.e.; different sloped surfaces and plate direction);

f) Analyze the data collected;

g) Evaluate current guidance material regarding flap configuration against results obtained and develop/modify guidance material, if necessary; and

h) Report the findings, and prepare presentation material for the SAE G-12 meetings.

3.12 Full-Scale Evaluation of Endurance Times on H-Stab vs. Wing

a) Review previous results from outdoor YMX testing conducted by APS;

b) Modify procedure and methodology as required based on testing already performed;

c) Conduct full-scale aircraft testing (at the same time that other flaps/slats tests are being conducted) to evaluate the endurance time performance of the H-stab wing surfaces with the main wing surfaces;

d) Analyze the data collected; and

e) Report the findings, and prepare presentation material for the SAE G-12 meetings.

APPENDIX B

PROCEDURE AND ADDENDUMS: EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS – NATURAL SNOW

CM2265.001

PROCEDURE:
EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS
NATURAL SNOW

Winter 2011-12

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef and John D'Avirro

D.

Reviewed by: John D'Avirro

APS
Aviation Inc.

January 25, 2012
Final Version 1.0

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS NATURAL SNOW

Winter 2011-2012

1. BACKGROUND

Currently both the FAA and Transport Canada provide guidance to operators for de/anti-icing with deployed flaps/slats.

Research has determined that fluid degradation may be accelerated by the steeper angles of the flaps/slats in the takeoff configuration. The degree of potential degradation is significantly affected by the specific aircraft design. Based on this work, further research was recommended to characterize the extent of the effect on the Holdover Times and Allowance times. The FAA advises all operators to review their policies and procedures in light of this information to assure appropriate consideration.

Application of anti-icing fluid to a wing with deployed flaps/slats, can quickly flow off, which would result in a reduced fluid thickness layer, and consequently shortened fluid endurance times. Due to a lack of data to quantify actual endurance times on wings with deployed flaps/slats, the industry has requested that testing be conducted to evaluate and potentially develop guidance material.

Preliminary work was conducted during the winter of 1997-1998, and is documented in the TC report, TP 13318E. The series of tests were conducted at NRC's CEF in Ottawa to determine the effect of plate slope variation on the holdover time of Type IV fluids. Standard holdover time tests with test surfaces set at a 10° slope were compared to test surfaces with increased slopes; mainly at 11° and 12°. It was noted that plate slope has a significant effect on the holdover time of a given fluid. When tests were performed on plates with a slight increase in plate inclination, it was noted that for every 1° increase in slope resulting holdover times were decreased over the standard tests by as much as 10 percent.

The current guidance provided by the regulators was based on limited testing in the NRC Wind Tunnel which indicated that a contaminated flap can cause a significant lift loss to aerodynamic performance (see interim report, *Wind Tunnel Research to Support the Development of Ice Pellet Allowance Time Tables, Winter 2009-10*). The results of this testing indicated that a contaminated flap section can have significant impacts on aerodynamic performance; to a 28% lift loss as compared to the dry wing with a heavily contaminated flap.

Further flat plate tests were conducted in the Winter of 2010-11 which indicated that reduced holdover times may result from highly sloped surfaces.

2. OBJECTIVE

The main objective for this research is to evaluate the endurance time performance of simulated wing surfaces with deployed flaps/slats and thereby evaluate the guidance material regarding flap configuration. The work described in this procedure is for the conduct of flat plat tests. Other related research is also planned on full-scale aircraft wing surfaces at Mirabel with the co-operation of UPS; this is described in a separate related procedure. The initial results from the Mirabel tests may lead to a refinement of the protocol described here-in.

3. PROCEDURE

The standard protocol for testing endurance time will be used in this testing. However, some differences will occur. These differences are explained in Section 3.1.

3.1 Test Surfaces

Standard aluminum test plates will be used for testing. The baseline plate will be positioned at 10°, two plates simulating deployed flaps/slats will be positioned at 20° and 35°. Two other plates that simulate nested flaps at 20° and 35° are also tested. The actual angles tested have been determined based on a detailed investigation; and agreed upon by the FAA and TC. Figure 3.1 depicts the setup for testing.

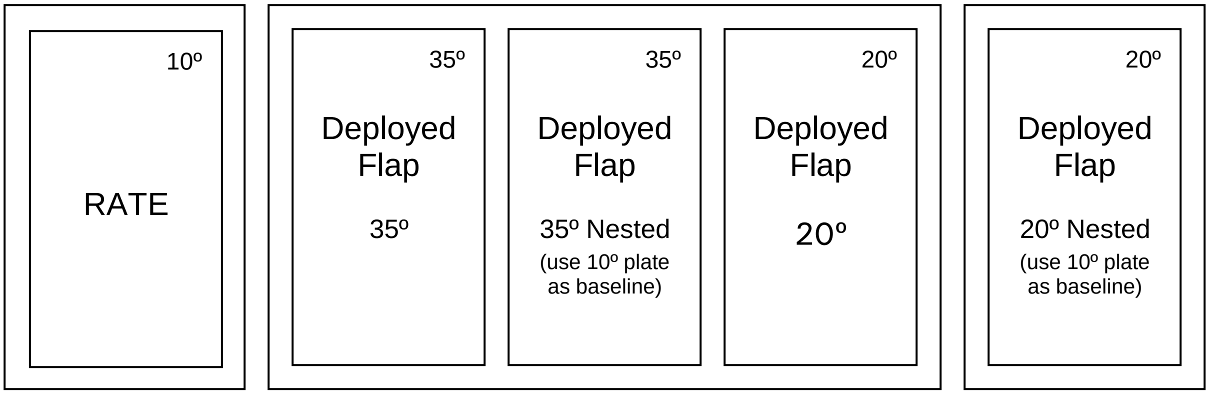


Figure 3.1: Testing Setup

3.2 Test Plan

Testing is to be conducted in natural conditions. The test runs are not specific to precipitation rate or outside temperature; however, a variety of different conditions are preferred.

3.3 General Notes

- Rate measurements should be conducted before fluid application, after each plate failure, and every 5-10 minutes during the test;
- 1L of fluid should be applied at OAT using a typical pour container;
- For Type I (only limited tests, say 10%, boxes should be used with 0.5 L of fluid heated to 60 º C;
- Measure Brix and thickness at 5-min after application and again at the time of failure. This should be done for a limited number of tests (approximately 3 runs);
- Endurance times shall be recorded for the fluid applied to each of the test surfaces; and
- Approximately 3 runs per snow event should be conducted. This equates to approximately 20 to 30 runs for this season.

4. SIMULATED PRECIPITATION TESTING

Additional testing in freezing precipitation conditions may be proposed based on the results of the initial outdoor testing.

5. FLUIDS

The following fluids will be used this research:

- DOW UCAR Type I EG (Limited tests);
- DOW UCAR Type IV EG 106; and
- Kilfrost ABC S+ Type IV (dilutions are being tested to have shorter endurance times).

6. EQUIPMENT

Standard equipment used for endurance tests outdoors will be used in this testing.

7. DATA FORMS

The following data form will be used to document fluid endurance time, Brix, and thickness data:

- Attachment I: End Condition Form for Endurance Time Testing
- Attachment II: Fluid/Brix Thickness Form

Rate measurements will be recorded using the electronic rate form typically used for endurance time testing.

8. PERSONNEL

Two persons will be required for the conduct of these tests.

ATTACHMENT I: END CONDITION FORM FOR ENDURANCE TIME TESTING

REMEMBER TO SYNCHRONIZE TIME WITH MSC - USE LOCAL TIME

LOCATION: **DATE:** **RUN NUMBER:** **STAND # :**

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 2°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

	Plate 7	Plate 8	Plate 9	Plate 10	Plate 11	Plate 12
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 2°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

AMBIENT TEMPERATURE: ________ °C

NOTE:

PLEASE ENSURE CORRECT FUNCTIONING OF PLATE TEMPERATURE LOGGING SYSTEM AT START OF TEST. AT THE END OF TEST SESSION, SAVE THE ELECTRONIC LOGGER FILE ON A FLOPPY DISK AND ALSO E-MAIL IT TO THE OFFICE. LABEL THE DISKETTE AND PLACE IT WITHIN THE DATA FORM ENVELOPE.

COMMENTS:

FAILURES CALLED BY: ____________________

LEADER / MANAGER: ____________________

ATTACHMENT II:

Fluid Brix/Thickness Data Form

DATE: _______________ **PERFORMED BY:** _______________

RUN #: _______________ **WRITTEN BY:** _______________

STAND: _______________ **LOCATION:** _______________

Plate / BOX: Fluid:			Plate / BOX: Fluid:			Plate / BOX: Fluid:			Plate / BOX: Fluid:		
TIME	**Brix at 15 cm Line**	**Thick. at 15 cm Line**	**TIME**	**Brix at 15 cm Line**	**Thick. at 15 cm Line**	**TIME**	**Brix at 15 cm Line**	**Thick. at 15 cm Line**	**TIME**	**Brix at 15 cm Line**	**Thick. at 15 cm Line**

CM2265.003

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS NATURAL SNOW

Addendum

Winter 2013-14

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

December 13, 2013
Final Version 1.0

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS NATURAL SNOW

Addendum

Winter 2013-2014

1. BACKGROUND

Preliminary testing with simulated deployed flaps has indicated a reduction in fluid protection time. However, recent industry discussions have indicated that the protection time could be increased during taxi. The changing aircraft direction relative to the wind direction could result in an increase to the protection time of deployed flaps, as they can be shielded from the wind during a segment of the taxi.

It was recommended that additional testing be conducted during the winter of 2013-14 to investigate the effects taxi has on the protection time of deployed flaps.

Endurance time tests have been conducted thus far using the procedures outlined in the program procedure: *Evaluation of Endurance Time Performance on Deployed Flaps/Slats, January 25th 2012. This document provides an Addendum to this earlier procedure and describes the test set-up to be used to examine the effects on protection time during taxi. In addition, based on industry discussions, it was recommended to add an additional simple plate, angled at 15 degrees, to the original basic set-up.*

2. METHODOLOGY

Past research conducted by APS on aircraft taxiing trajectories will be reviewed to best establish the protocol required to simulate aircraft exposure during taxi. Parameters such as taxi time and aircraft exposure to wind vectors will be analyzed. Using this research as a guide, initial tests will be run. Southwest Airlines has committed to collect trajectory data of their aircraft during winter operations. It is expected that they will provide that data to APS during the early part of this winter. Using the Southwest data as a guide, the test set-up may be revised.

2.1 Test Stand Setup

The test stand setup is an integral component to simulating aircraft testing.

The basic setup for testing of simulated flaps is a fixed stand providing only head wind tests. Figure 2.1 depicts this setup.

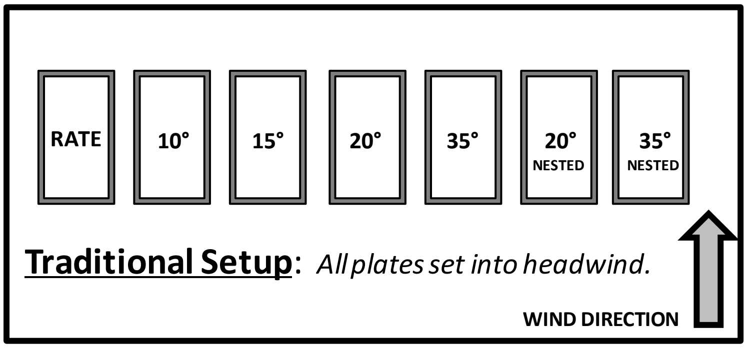


Figure 2.1 Basic Setup

This basic setup will not effectively simulate an aircraft during taxi because of its fixed state.

For this addendum, two additional test stand setup designs to simulate aircraft taxi were developed.

The first additional design is a rotating stand that will be manually turned. The stand will be rotated at pre-determined angles and intervals throughout the test. The timing of rotation will be established from the past research or Southwest data mentioned above. A rate measurement will be incorporated into this stand, and will also rotate. Figure 2.2 depicts this setup.

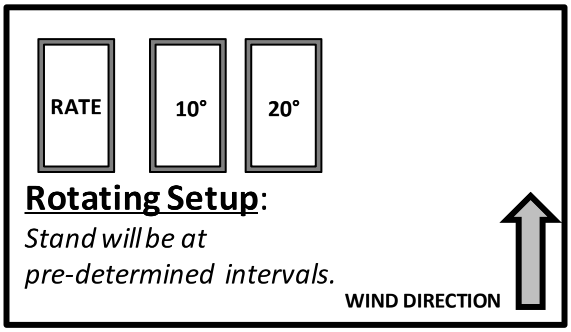


Figure 2.2 Rotational Setup

The second additional setup is a cross formation design that involves three stands. Test stands will be placed in a cross formation allowing simultaneous testing of headwind, crosswind and tailwind. Each stand will have an associated rate measurement. Figure 2.3 depicts this setup.

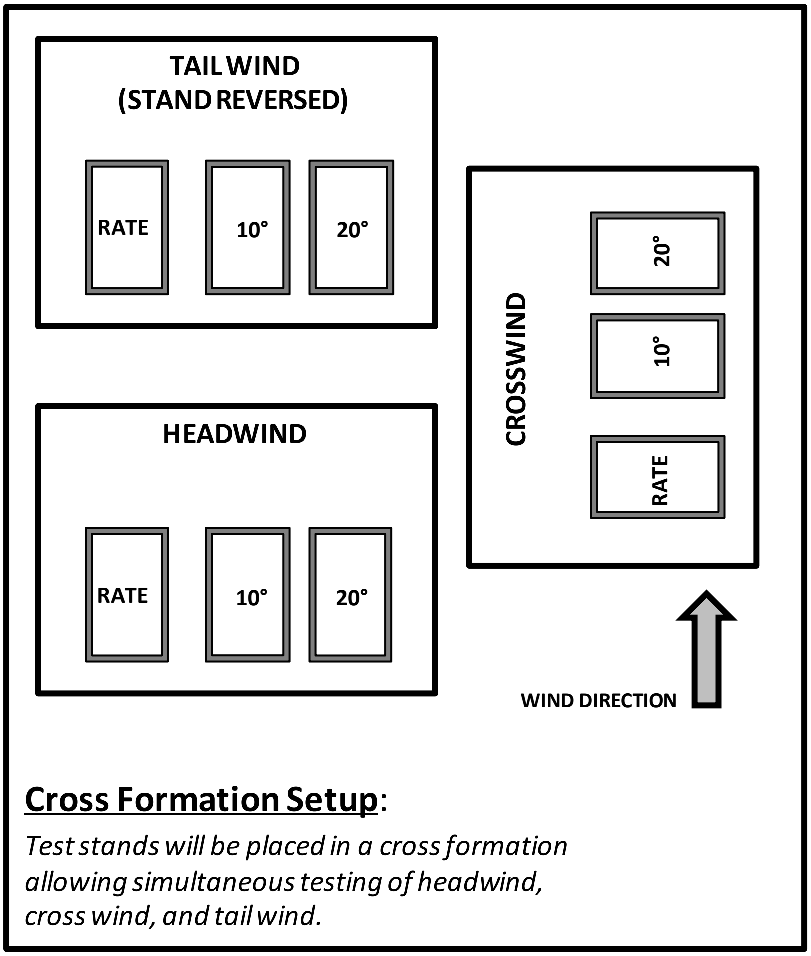


Figure 2.3: Cross Formation Setup

3. OBJECTIVE

There are two objectives for this research:

1. Develop and refine the procedural elements for this testing such as determination of flap angles, stand formation and setup and simulation of aircraft exposure to wind vectors.

2. Evaluate the endurance time performance of simulated wing surfaces with deployed flaps/slats during simulated taxi. The work described in this procedure is for the conduct of flat plat tests simulating aircraft taxi.

4. PROCEDURE

Endurance time tests will be conducted using the procedures outlined in the program procedure: *Evaluation of Endurance Time Performance on Deployed Flaps/Slats, January 25th 2012.* Standard fluid endurance time test procedures will apply. A new setup will be used for this testing as described in this addendum.

4.1 Test Methodology

Testing will simulate four different aircraft orientations/set-ups:

- Head Wind (stationary plates set into wind);
- Tail Wind (plates set away from wind);
- Crosswind (plates set perpendicular to wind); and
- Rotating (plates will be rotated between headwind, tailwind and crosswind).

4.2 Test Setup

The three stand designs mentioned above (traditional setup, rotating setup, and cross formation setup have been incorporated. Figure 4.1 depicts the setup for testing. Standard aluminum test plates will be used for testing. The baseline plate will be positioned at 10°, plates simulating deployed flaps/slats will be positioned at 15° (newly added), 20° and 35°. Two other plates that simulate nested flaps at 20° and 35° are also tested. Precipitation rates will be collected simultaneously for all setups.

4.3 Sequence and Timing for Rotating Stand.

Based on previous APS research that examined aircraft trajectories at a major airport in Canada, the sequence for the rotating stand was determined to be as follows. Depending on the data that is anticipated to be provided by Southwest, this sequence may be modified.

Sequence	STAND ORIENTATION	Duration
Start	Into Headwind	40% of expected Endurance Time
Rotation 1	Into Crosswind	20% of expected Endurance Time
Rotation 2	Into Tailwind	20% of expected Endurance Time
Rotation 3	Into Headwind	Until Failure.

To simplify the testing, it is desired to eliminate either the new rotational set-up testing or the cross formation set-up early in the winter.

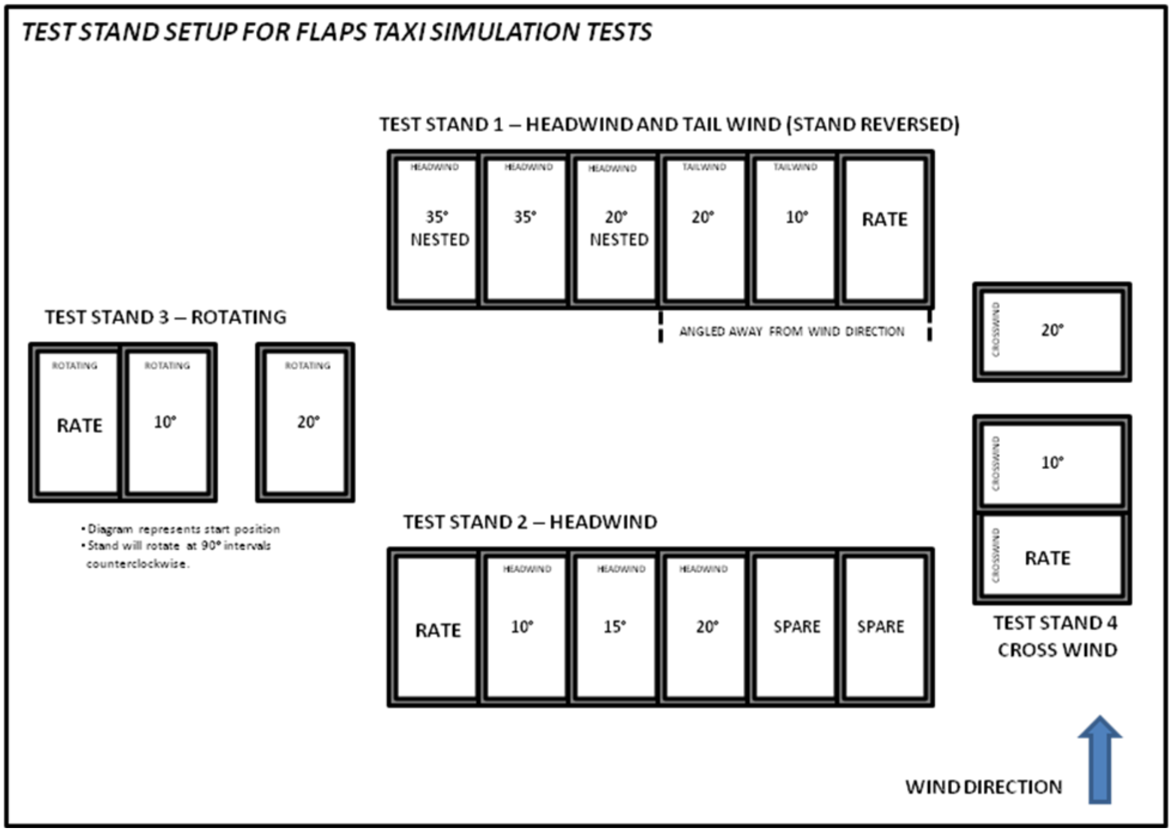


Figure 4.1: Testing Setup

4.4 Test Plan

Testing is to be conducted in natural conditions. The test runs are not specific to precipitation rate or outside temperature; however, a variety of different conditions are preferred.

5. FLUIDS

The following fluids will be used this research:

- DOW UCAR Type I EG;
- Clariant 2031Type III;
- DOW UCAR Type IV EG 106;
- Kilfrost ABC S+ Type IV;
- Cryotech Polar Guard Advance;
- Clariant Launch; and
- DOW UCAR AD-49.

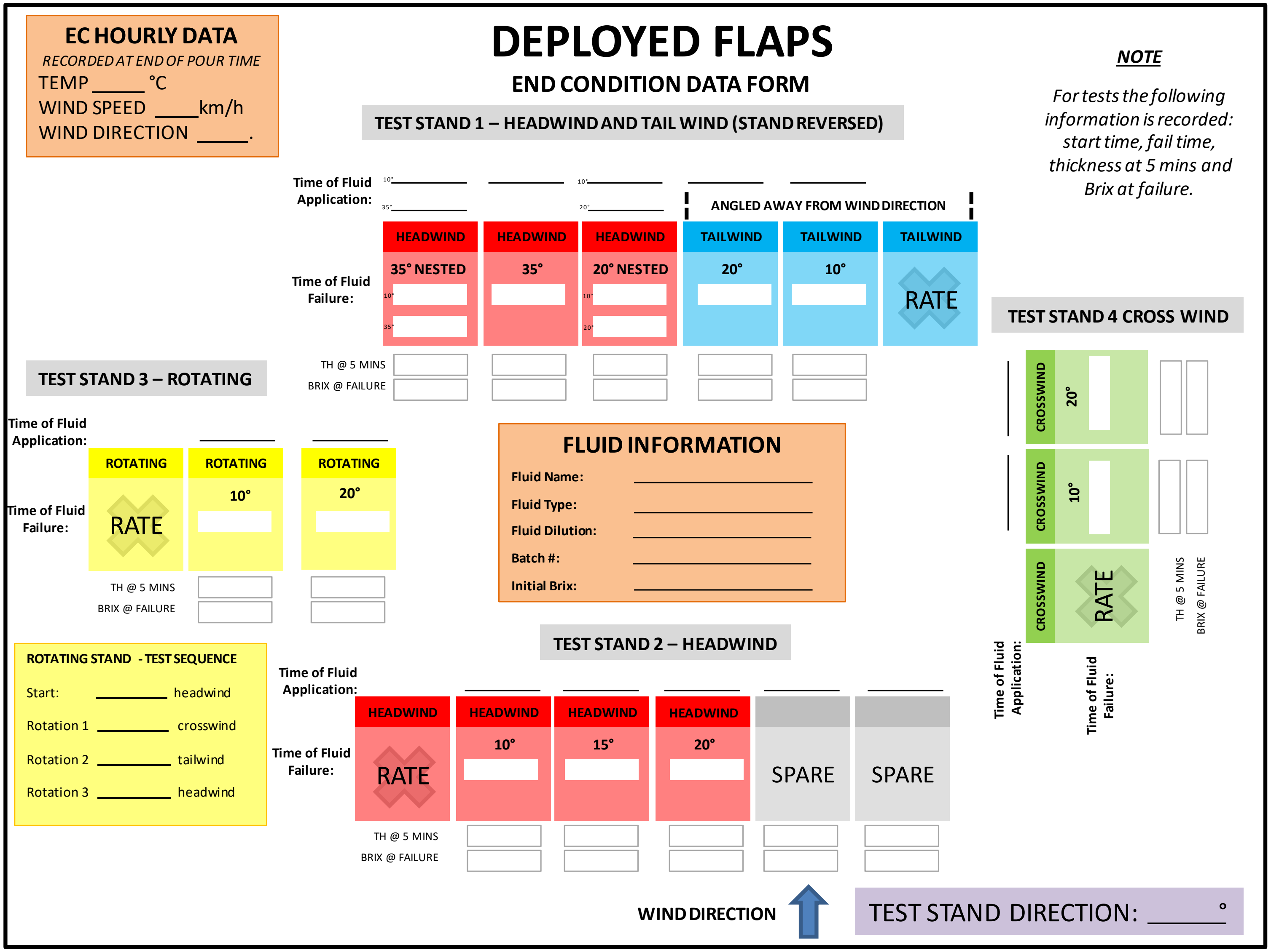
6. DATA FORMS

The following data form will be used to document fluid endurance time, Brix, and thickness data:

- Attachment I: End Condition Data form

Rate measurements will be recorded using the electronic rate form typically used for endurance time testing.

ATTACHMENT I: End Condition Data form



EC HOURLY DATA

RECORDED AT END OF POUR TIME

TEMP _____ °C

WIND SPEED ____km/h

WIND DIRECTION _____.

DEPLOYED FLAPS

END CONDITION DATA FORM

NOTE

For tests the following information is recorded: start time, fail time, thickness at 5 mins and Brix at failure.

TEST STAND 1 – HEADWIND AND TAIL WIND (STAND REVERSED)

ANGLED AWAY FROM WIND DIRECTION

Time of Fluid Application:	10° ____ 35° ____	____	10° ____ 20° ____	____	____	
	HEADWIND	HEADWIND	HEADWIND	TAILWIND	TAILWIND	TAILWIND
Time of Fluid Failure:	35° NESTED 10° ☐ 35° ☐	35° ☐	20° NESTED 10° ☐ 20° ☐	20° ☐	10° ☐	RATE
TH @ 5 MINS	☐	☐	☐	☐	☐	
BRIX @ FAILURE	☐	☐	☐	☐	☐	

TEST STAND 4 CROSS WIND

Time of Fluid Application:		**Time of Fluid Failure:**	TH @ 5 MINS	BRIX @ FAILURE
____	CROSSWIND	20° ☐	☐	☐
____	CROSSWIND	10° ☐	☐	☐
	CROSSWIND	RATE		

TEST STAND 3 – ROTATING

Time of Fluid Application:		____	____
	ROTATING	ROTATING	ROTATING
Time of Fluid Failure:	RATE	10° ☐	20° ☐
TH @ 5 MINS		☐	☐
BRIX @ FAILURE		☐	☐

FLUID INFORMATION

Fluid Name: ____________

Fluid Type: ____________

Fluid Dilution: ____________

Batch #: ____________

Initial Brix: ____________

ROTATING STAND - TEST SEQUENCE

Start: ________ headwind

Rotation 1 ________ crosswind

Rotation 2 ________ tailwind

Rotation 3 ________ headwind

TEST STAND 2 – HEADWIND

Time of Fluid Application:		____	____	____	____	____
	HEADWIND	HEADWIND	HEADWIND	HEADWIND		
Time of Fluid Failure:	RATE	10° ☐	15° ☐	20° ☐	SPARE	SPARE
TH @ 5 MINS		☐	☐	☐	☐	☐
BRIX @ FAILURE		☐	☐	☐	☐	☐

WIND DIRECTION ↑

TEST STAND DIRECTION: ______°

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CM2265.004

ADDENDUM TO PROCEDURE:

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS NATURAL SNOW

Winter 2014-15

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: John D'Avirro and Chloë Bernier

Reviewed by: John D'Avirro

APS
Aviation Inc.

November 19th, 2014
Final Version 1.0

ADDENDUM TO PROCEDURE:
EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS
NATURAL SNOW

1. OBJECTIVE

To compare the endurance of the 20° simple plate model to the standard 10° plate. These tests will be done to add more data to the current database and also to capture data for dilutions. Separate projects related to flaps/slats will also be run simultaneously and are described in another procedure document.

2. PROCEDURE

Endurance time tests will be conducted using the procedures outlined in the program procedure: *Evaluation of Endurance Times on Deployed Flaps/Slats, January 25th 2012.* In addition, the following criteria will be followed:

- Only test 20° simple vs. 10° standard plates, unless other flaps/slat testing is being conducted at the same time; and
- Expect to run approximately thirty tests over winter (three tests/storm) for approximately ten storms.

The test plan is as follows:

FLUID TYPE	DILUTION	# of Tests Completed in prev. Winters	Min # of Tests Required
I	-	28	3
II/IV	100/0	39	-
	75/25	6	2
	50/50	3	3
III Hot	100/0	10	2
	75/25	2	3
	50/50	1	3
III Cold	100/0	1	4
	75/25	-	5
	50/50	-	5
TOTAL		90	30

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CM2265.004

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS NATURAL SNOW

Revised Addendum (including Airfoil) for

Winter 2014-15

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

APS
Aviation Inc.

November 21, 2014
Final Version 1.0

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS NATURAL SNOW

Revised Addendum (including Airfoil) for

Winter 2014-2015

1. BACKGROUND

Preliminary testing with simulated deployed flaps has indicated a reduction in fluid protection time. However, recent industry discussions have indicated that the protection time could be increased during taxi. The changing aircraft direction relative to the wind direction could result in an increase to the protection time of deployed flaps, as they can be shielded from the wind during a segment of the taxi.

It was recommended that additional testing be conducted during the winter of 2013-14 to investigate the effects taxi has on the protection time of deployed flaps.

Initial research conducted in 2013-14 demonstrated that there can be increased protection times as a result of taxi. It was recommended that further research be conducted using a simulated airfoil model during the winter of 2014-15. This revised addendum includes the original methodology for testing plus a new methodology for airfoil testing.

Endurance time tests have been being conducted thus far using the procedures outlined in the program procedure: *Evaluation of Endurance Time Performance on Deployed Flaps/Slats, January 25th 2012. This document provides an Addendum to this earlier procedure and describes the test set-up to be used to examine the effects on protection time during taxi. In addition, based on industry discussions, it was recommended to add an additional simple plate, angled at 15 degrees, to the original basic set-up.*

2. METHODOLOGY

Past research conducted by APS on aircraft taxiing trajectories will be reviewed to best establish the protocol required to simulate aircraft exposure during taxi. Parameters such as taxi time and aircraft exposure to wind vectors will be analyzed. Using this research as a guide, initial tests will be run. Southwest Airlines has committed to collect trajectory data of their aircraft during winter operations. It is expected that they will provide that data to APS during the early part of this winter. Using the Southwest data as a guide, the test set-up may be revised.

2.1 Test Stand Setup

The test stand setup is an integral component to simulating aircraft testing. The basic setup for testing of simulated flaps is a fixed stand providing only head wind tests. Figure 2.1 depicts this setup.

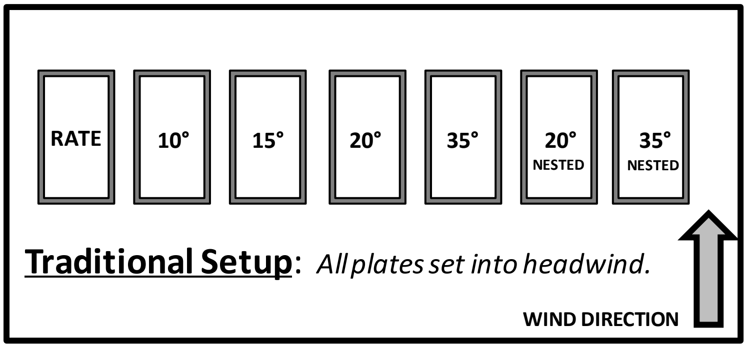


Figure 2.1 Basic Setup

This basic setup will not effectively simulate an aircraft during taxi because of its fixed state.

For this addendum, two additional test stand setup designs to simulate aircraft taxi were developed. In addition, the nested and 35^0 plates will not be used for this addendum.

The first additional design is a rotating stand and an airfoil that will be manually turned. There may be two airfoils used: one with slats/flaps and one without flaps and slats. The stand will be rotated at pre-determined angles and intervals throughout the test. The timing of rotation will be established from the past research or Southwest data mentioned above. A rate measurement will be incorporated into this stand, and will also rotate. Figure 2.2 depicts this setup.

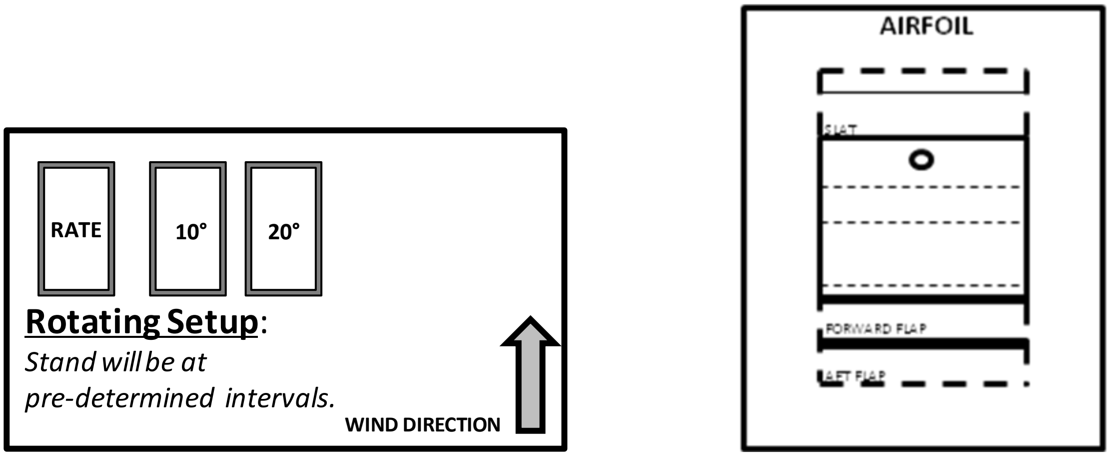
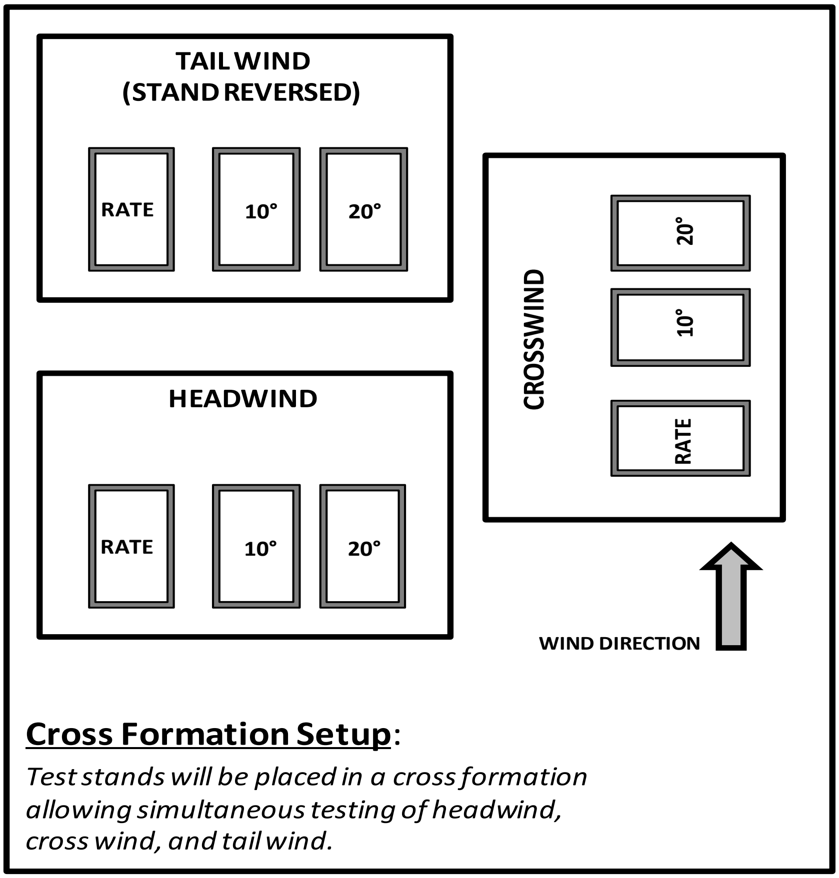


Figure 2.2 Rotational Setup

The second additional setup is a cross formation design that involves three stands. Test stands will be placed in a cross formation allowing simultaneous testing of headwind, crosswind and tailwind. Each stand will have an associated rate measurement. Figure 2.3 depicts this setup.



Cross Formation Setup:

Test stands will be placed in a cross formation allowing simultaneous testing of headwind, cross wind, and tail wind.

Figure 2.3: Cross Formation Setup

3. OBJECTIVE

There are two objectives for this research:

1. Develop and refine the procedural elements for this testing such as determination of flap angles, stand formation and setup and simulation of aircraft exposure to wind vectors.
2. Evaluate the endurance time performance of simulated wing surfaces with deployed flaps/slats during simulated taxi. The work described in this procedure is for the conduct of both flat plat tests and an airfoil simulating aircraft taxi.

4. PROCEDURE

Endurance time tests will be conducted using the procedures outlined in the program procedure: *Evaluation of Endurance Time Performance on Deployed Flaps/Slats, January 25th 2012.* Standard fluid endurance time test procedures will apply. A new setup will be used for this testing as described in this addendum.

4.1 Test Methodology

Testing will simulate four different aircraft orientations/set-ups:

- Head Wind (stationary plates set into wind);
- Tail Wind (plates set away from wind);
- Crosswind (plates set perpendicular to wind);
- Rotating (plates will be rotated between headwind, tailwind and crosswind); and
- Rotating airfoil (will be rotated between headwind, tailwind and crosswind).

4.2 Test Setup

The three stand designs mentioned above (traditional setup, rotating setup, and cross formation setup) have been incorporated. Figure 4.1 depicts the setup for testing. Standard aluminum test plates will be used for testing. The baseline plate will be positioned at 10°, plates simulating deployed flaps/slats will be positioned at 15° (newly added), 20° and 35°. Two other plates that simulate nested flaps at 20° and 35° are also tested. Precipitation rates will be collected simultaneously for all setups.

In addition, the rotating airfoil will be included as part of the 2014-15 winter season setup.

4.3 Sequence and Timing for Rotating Stand.

Based on previous APS research that examined aircraft taxi trajectories at a major airport in Canada, the sequence for the rotating stand was determined to be as follows. This was used in Winter 2013-14 and will be used in the 1st three tests in the test plan for Winer 2014-15.

Sequence	STAND ORIENTATION	Duration
Start	Into Headwind	40% of expected Endurance Time
Rotation 1	Into Crosswind	20% of expected Endurance Time
Rotation 2	Into Tailwind	20% of expected Endurance Time
Rotation 3	Crosswind or Into Headwind	Until Failure.

For the 2014-15 seasons, a dataset was provided by Southwest Airlines to further examine aircraft taxi trajectories. In addition, three different sequences were identified for use with the airfoil by TC/FAA/APS/SouthWest/UPS, and are outlined as follows:

	Sequence 1	% of Expected HOT	***Sequence 2**	% of Expected HOT	**Sequence 3**	% of Expected HOT
Start	Into Headwind	20%	Into Crosswind	40%	Into Tailwind	40%
Rotation 1	Into Crosswind	40%	Into Tailwind	40%	Into Headwind	20%
Rotation 2	Into Tailwind	40%	Into Headwind	20%	Into Crosswind	40%

**Sequence 2 should be reserved for events in low wind conditions.*

To simplify the testing, it is desired to eliminate either the original rotational set-up testing or the cross formation set-up early in the winter (see test plan).

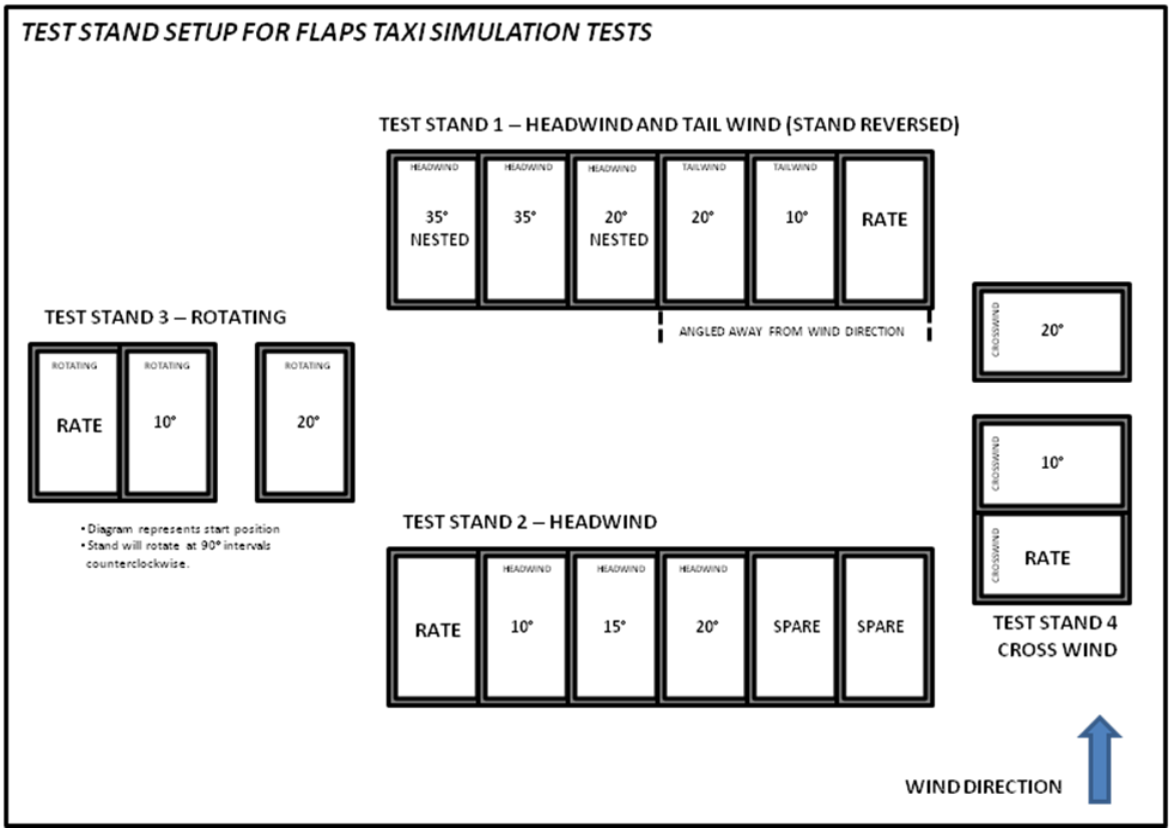


Figure 4.1: Testing Setup

4.4 Test Plan

Testing is to be conducted in natural conditions. The test runs are not specific to precipitation rate or outside temperature; however, a variety of different conditions are preferred.

Failure on the airfoil is determined and should be noted on the data form when initial (more than 315 cm^2) and when 10 percent of the airfoil is failed.

2014-15 Test Plan

Test #	CROSS FORMATION SETUP	SLATTED AIRFOIL	UNSLATTED AIRFOIL	STANDARD 10° AND 20° PLATES HEADWIND	FLUID	SEQUENCING	COMMENTS
1	yes	yes	yes	yes	IV	LE40%, X20%, TE20%, X20%	SAME AS 2013-14
2	yes	yes	yes	yes	IV	LE40%, X20%, TE20%, X20%	SAME AS 2013-14
3	yes	yes	yes	yes	I	LE40%, X20%, TE20%, X20%	SAME AS 2013-14
4		yes		yes	IV	LE20%, X40%, TE40%	Sequence 1
5		yes		yes	IV	LE20%, X40%, TE40%	Sequence 1
6		yes		yes	IV	X40%, TE40%, LE20%	Sequence 2
7		yes		yes	IV	X40%, TE40%, LE20%	Sequence 2
8		yes		yes	IV	TE40%, LE20%, X40%	Sequence 3
9		yes		yes	IV	TE40%, LE20%, X40%	Sequence 3
10		yes		yes	I	LE20%, X40%, TE40%	Sequence 1
11		yes		yes	I	LE20%, X40%, TE40%	Sequence 1
12		yes		yes	I	X40%, TE40%, LE20%	Sequence 2
13		yes		yes	I	TE40%, LE20%, X40%	Sequence 3
14		yes		yes	III	LE20%, X40%, TE40%	Sequence 1
15		yes		yes	III	X40%, TE40%, LE20%	Sequence 2

5. FLUIDS

Some of the following fluids will be used this research:

- DOW UCAR Type I EG;
- Clariant 2031Type III;
- DOW UCAR Type IV EG 106;
- Kilfrost ABC S+ Type IV;

- Cryotech Polar Guard Advance;
- Clariant Launch; and
- DOW UCAR AD-49.

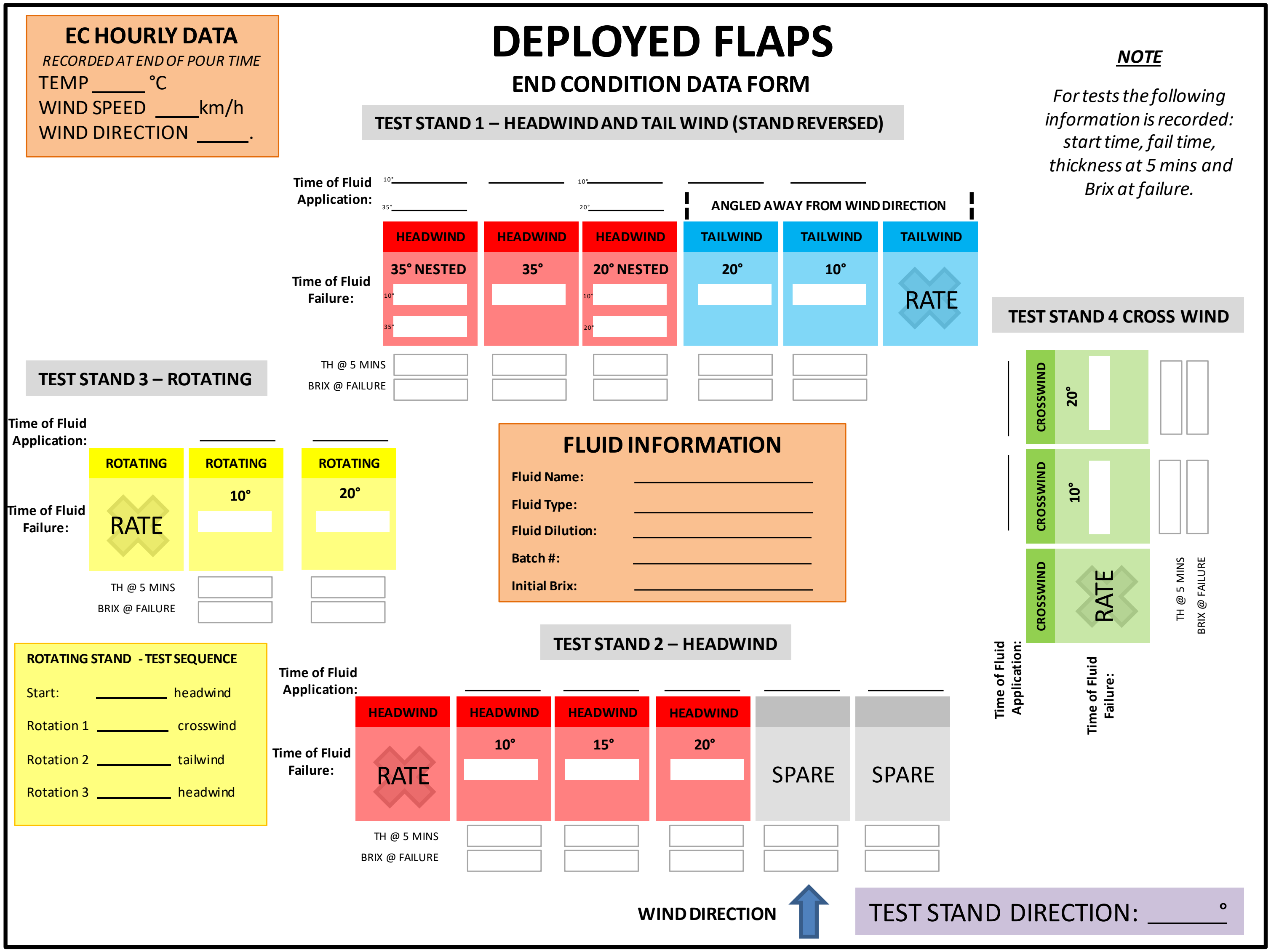
6. DATA FORMS

The following data form will be used to document fluid endurance time, Brix, and thickness data:

- Attachment I: End Condition Data form - Plates
- Attachment II: End Condition Data form - Airfoil

Rate measurements will be recorded using the electronic rate form typically used for endurance time testing.

ATTACHMENT I: End Condition Data form - Plates



EC HOURLY DATA

RECORDED AT END OF POUR TIME

TEMP _____ °C

WIND SPEED ____km/h

WIND DIRECTION _____.

DEPLOYED FLAPS

END CONDITION DATA FORM

NOTE

For tests the following information is recorded: start time, fail time, thickness at 5 mins and Brix at failure.

TEST STAND 1 – HEADWIND AND TAIL WIND (STAND REVERSED)

ANGLED AWAY FROM WIND DIRECTION (over the three TAILWIND columns)

Time of Fluid Application:	10° ____ 35° ____	____	10° ____ 20° ____	____	____	
	HEADWIND	**HEADWIND**	**HEADWIND**	**TAILWIND**	**TAILWIND**	**TAILWIND**
Time of Fluid Failure:	**35° NESTED** 10° ☐ 35° ☐	**35°** ☐	**20° NESTED** 10° ☐ 20° ☐	**20°** ☐	**10°** ☐	RATE
TH @ 5 MINS	☐	☐	☐	☐	☐	
BRIX @ FAILURE	☐	☐	☐	☐	☐	

TEST STAND 3 – ROTATING

Time of Fluid Application:		____	____
	ROTATING	**ROTATING**	**ROTATING**
Time of Fluid Failure:	RATE	**10°** ☐	**20°** ☐
TH @ 5 MINS		☐	☐
BRIX @ FAILURE		☐	☐

FLUID INFORMATION

Fluid Name: ____________

Fluid Type: ____________

Fluid Dilution: ____________

Batch #: ____________

Initial Brix: ____________

TEST STAND 4 CROSS WIND

Time of Fluid Application:		**Time of Fluid Failure:**		TH @ 5 MINS	BRIX @ FAILURE
____	**CROSSWIND**	**20°**	☐	☐	☐
____	**CROSSWIND**	**10°**	☐	☐	☐
	CROSSWIND	RATE			

ROTATING STAND - TEST SEQUENCE

Start:	________	headwind
Rotation 1	________	crosswind
Rotation 2	________	tailwind
Rotation 3	________	headwind

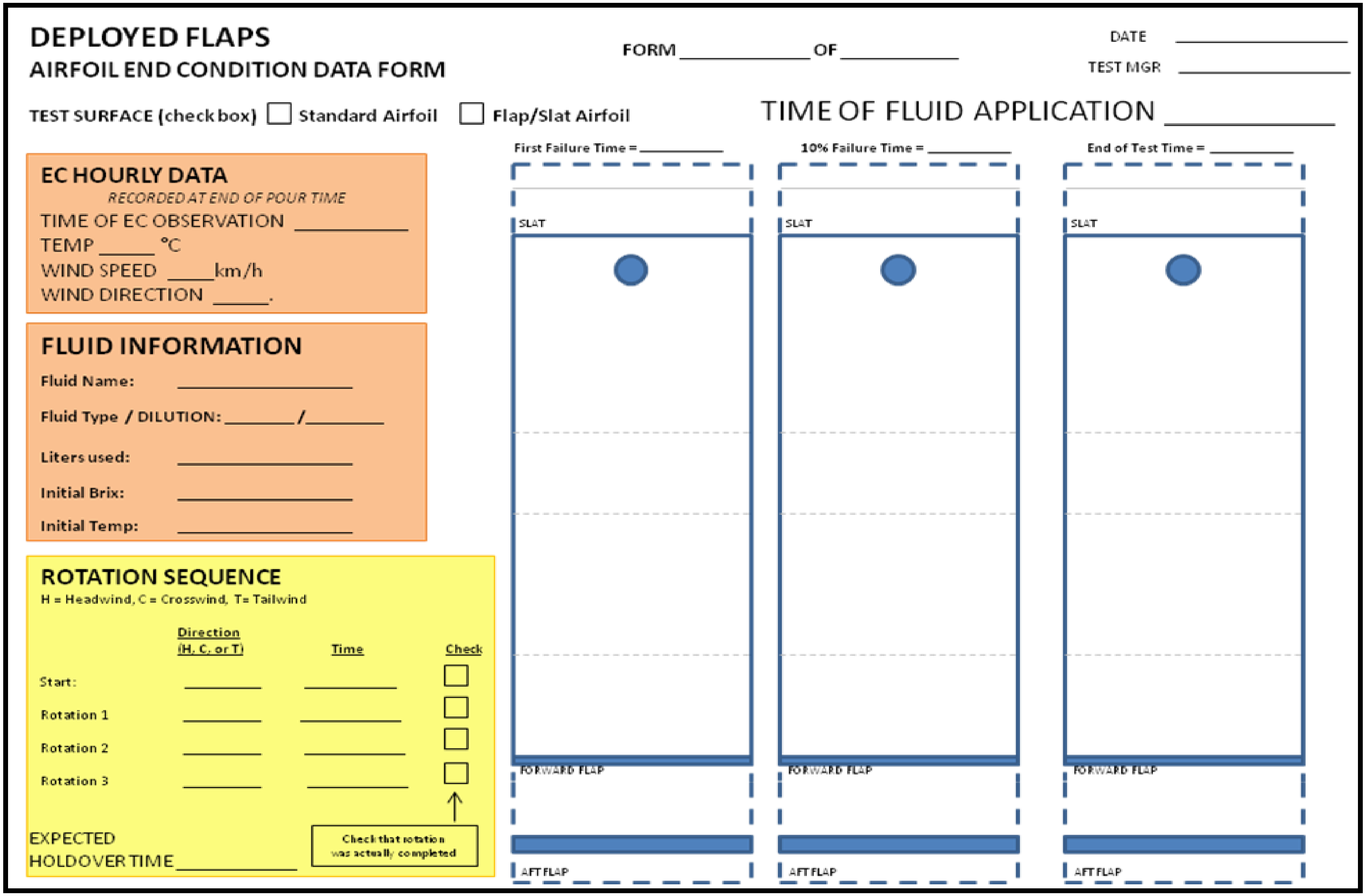
TEST STAND 2 – HEADWIND

Time of Fluid Application:		____	____	____	____	____
	HEADWIND	**HEADWIND**	**HEADWIND**	**HEADWIND**		
Time of Fluid Failure:	RATE	**10°** ☐	**15°** ☐	**20°** ☐	SPARE	SPARE
TH @ 5 MINS		☐	☐	☐	☐	☐
BRIX @ FAILURE		☐	☐	☐	☐	☐

WIND DIRECTION ↑

TEST STAND DIRECTION: ______°

ATTACHMENT II: End Condition Data form - Airfoil



DEPLOYED FLAPS
AIRFOIL END CONDITION DATA FORM

FORM ____________ OF ____________

DATE ________________

TEST MGR ________________

TEST SURFACE (check box) ☐ Standard Airfoil ☐ Flap/Slat Airfoil

TIME OF FLUID APPLICATION ____________

EC HOURLY DATA

RECORDED AT END OF POUR TIME

TIME OF EC OBSERVATION __________

TEMP _____ °C

WIND SPEED _____km/h

WIND DIRECTION _____.

FLUID INFORMATION

Fluid Name: ________________

Fluid Type / DILUTION: _______/_______

Liters used: ________________

Initial Brix: ________________

Initial Temp: ________________

ROTATION SEQUENCE

H = Headwind, C = Crosswind, T= Tailwind

	Direction (H, C, or T)	Time	Check
Start:	________	__________	☐
Rotation 1	________	__________	☐
Rotation 2	________	__________	☐
Rotation 3	________	__________	☐

↑ Check that rotation was actually completed

EXPECTED HOLDOVER TIME ____________

First Failure Time = ________

10% Failure Time = ________

End of Test Time = ________

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CM2480.002

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS - NATURAL SNOW

Addendum for Additional Airfoil Testing

Winter 2015-16

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

November, 2015
Final Version1.0

EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS/SLATS - NATURAL SNOW

Addendum for Additional Airfoil Testing

Winter 2015-16

1. BACKGROUND

Preliminary testing with simulated deployed flaps has indicated a reduction in fluid protection time. However, recent industry discussions have indicated that the protection time could be increased during taxi. The changing aircraft direction relative to the wind direction could result in an increase to the protection time of deployed flaps, as they can be shielded from the wind during a segment of the taxi.

Research conducted in 2013-14 and 2014-15 has demonstrated that there can be increased protection times as a result of taxi; this was seen on flat plates and using an airfoil model. It was recommended that research continue to collect additional data using a simulated airfoil model during the winter of 2015-16. This revised addendum includes a new elaborated test plan for continued airfoil testing during the winter of 2015-16.

2. METHODOLOGY AND PROCEDURES

The effect of deployed flaps and slats on fluid protection time has been investigated since the winter of 2009-10. Since then several different procedures and methodologies have been employed to investigate particular aspects of this effect. The procedures relevant to the testing planned for the winter of 2015-16 are listed in Table 2.1. It should be noted that this document is a direct addendum to the procedure *"Evaluation of Endurance Times on Deployed Flaps/Slats – Natural Snow – Revised Addendum (including Airfoil)", November 21, 2014*.

2.1 2015-16 Test Plan

Testing is to be conducted in natural conditions; it is expected that a plan will also be developed for NRC cold chamber testing. It should be noted that the test runs are not specific to precipitation rate or outside temperature, however a variety of different conditions are preferred. The test plan for the winter of 2015-16 is included in Table 4.1.

Table 2.1: List of Relevant Procedures

TITLE	PUBLICATION DATE	OBJECTIVE
Evaluation of Endurance Times on Deployed Flaps/Slats – Natural Snow	25-Jan-12	Flat Plate Testing Using Higher Inclined Surfaces
Evaluation of Endurance Times on Deployed Flaps/Slats – Natural Snow – Addendum	13-Dec-13	Addendum to Jan 25, 2012 to investigate effects of wind direction
Addendum to Procedure: Evaluation of Endurance Times on Deployed Flaps/Slats – Natural Snow	19-Nov-14	Addendum to Jan 25, 2012 procedure to collect more data
Evaluation of Endurance Times on Deployed Flaps/Slats – Natural Snow – Revised Addendum (including Airfoil)	21-Nov-14	Addendum to Dec 13, 2013 procedure include testing with airfoil models
Evaluation of Endurance Times on Deployed Flaps/Slats – Natural Snow – Addendum for Additional Airfoil Testing	New 2015-16	Addendum to Nov 21, 2014 procedure to include additional testing

3. DATA FORMS

The data forms from November 21st, 2014 procedure have been included again in this procedure (un-modified) for ease of access and will be used to document fluid endurance time, Brix, and thickness data (see Attachment 1 and Attachment 2). Rate measurements will be recorded using the electronic rate form typically used for endurance time testing.

4. FLUIDS

Testing will primarily be performed with commercial fluids of mid-production viscosity (for comparative testing). If in surplus and available, LOWV or suitable prototype fluids can also be used.

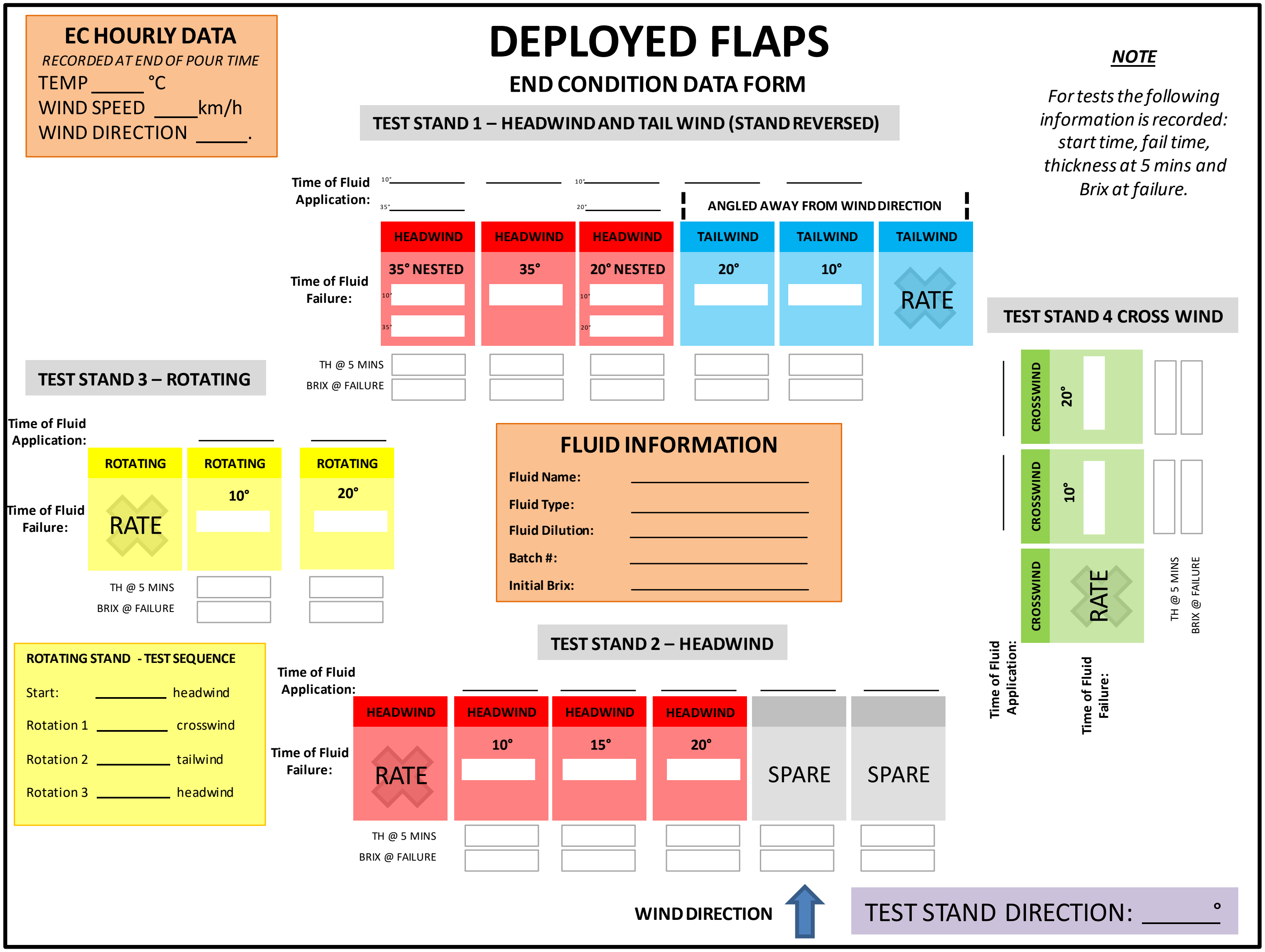
Table 4.1: Test Plan for Winter 2015-16

Test #	SLATTED AIRFOIL	UNSLATTED AIRFOIL	STANDARD 10° AND 20° PLATES HEADWIND	FLUID	SEQUENCING	COMMENTS
1	yes		yes	IV	LE20%, X40%, TE40%	Sequence 1
2	yes		yes	IV	LE20%, X40%, TE40%	Sequence 1
3	yes		yes	IV*	LE20%, X40%, TE40%	Sequence 1
4	yes	yes	yes	IV	X40%, TE40%, LE20%	Sequence 2
5	yes		yes	IV	X40%, TE40%, LE20%	Sequence 2
6	yes		yes	IV	X40%, TE40%, LE20%	Sequence 2
7	yes		yes	IV	X40%, TE40%, LE20%	Sequence 2
8	yes		yes	IV	X40%, TE40%, LE20%	Sequence 2
9	yes		yes	IV*	X40%, TE40%, LE20%	Sequence 2
10	yes	yes	yes	IV	TE40%, LE20%, X40%	Sequence 3
11	yes		yes	IV	TE40%, LE20%, X40%	Sequence 3
12	yes		yes	IV	TE40%, LE20%, X40%	Sequence 3
13	yes		yes	IV	TE40%, LE20%, X40%	Sequence 3
14	yes		yes	IV	TE40%, LE20%, X40%	Sequence 3
15	yes		yes	IV*	TE40%, LE20%, X40%	Sequence 3
16	yes		yes	I	LE20%, X40%, TE40%	Sequence 1
17	yes		yes	I	LE20%, X40%, TE40%	Sequence 1
18	yes	yes	yes	I	X40%, TE40%, LE20%	Sequence 2
19	yes		yes	I	X40%, TE40%, LE20%	Sequence 2
20	yes		yes	I	X40%, TE40%, LE20%	Sequence 2
21	yes		yes	I	X40%, TE40%, LE20%	Sequence 2
22	yes		yes	I	TE40%, LE20%, X40%	Sequence 3
23	yes		yes	I	TE40%, LE20%, X40%	Sequence 3
24	yes		yes	I	TE40%, LE20%, X40%	Sequence 3
25	yes		yes	I	TE40%, LE20%, X40%	Sequence 3
26	yes		yes	III	LE20%, X40%, TE40%	Sequence 1
27	yes		yes	III	X40%, TE40%, LE20%	Sequence 2
28	yes		yes	III	X40%, TE40%, LE20%	Sequence 2
29	yes		yes	III	TE40%, LE20%, X40%	Sequence 3
30	yes		yes	III	TE40%, LE20%, X40%	Sequence 3

*Could consider using a Type II fluid if available

Note: Cross-formation testing is not planned, however if resources are available, a maximum of 3 tests with Type IV fluid can be attempted in conjunction with both airfoils and the standard 10 and 20º plates. .

Attachment 1: End Condition Data form - Plates



EC HOURLY DATA

RECORDED AT END OF POUR TIME

TEMP _____ °C

WIND SPEED ____km/h

WIND DIRECTION _____.

DEPLOYED FLAPS

END CONDITION DATA FORM

NOTE

For tests the following information is recorded: start time, fail time, thickness at 5 mins and Brix at failure.

TEST STAND 1 – HEADWIND AND TAIL WIND (STAND REVERSED)

ANGLED AWAY FROM WIND DIRECTION

Time of Fluid Application:	10° ______ 35° ______	______	10° ______ 20° ______	______	______	
	HEADWIND	HEADWIND	HEADWIND	TAILWIND	TAILWIND	TAILWIND
Time of Fluid Failure:	35° NESTED 10° 35°	35°	20° NESTED 10° 20°	20°	10°	RATE
TH @ 5 MINS						
BRIX @ FAILURE						

TEST STAND 4 CROSS WIND

Time of Fluid Application:	Time of Fluid Failure:	TH @ 5 MINS	BRIX @ FAILURE
CROSSWIND 20°			
CROSSWIND 10°			
CROSSWIND RATE			

TEST STAND 3 – ROTATING

Time of Fluid Application:		______	______
	ROTATING	ROTATING	ROTATING
Time of Fluid Failure:	RATE	10°	20°
TH @ 5 MINS			
BRIX @ FAILURE			

FLUID INFORMATION

Fluid Name: ____________________

Fluid Type: ____________________

Fluid Dilution: ____________________

Batch #: ____________________

Initial Brix: ____________________

ROTATING STAND - TEST SEQUENCE

Start: ________ headwind

Rotation 1 ________ crosswind

Rotation 2 ________ tailwind

Rotation 3 ________ headwind

TEST STAND 2 – HEADWIND

Time of Fluid Application:		______	______	______	______	______
	HEADWIND	HEADWIND	HEADWIND	HEADWIND		
Time of Fluid Failure:	RATE	10°	15°	20°	SPARE	SPARE
TH @ 5 MINS						
BRIX @ FAILURE						

WIND DIRECTION

TEST STAND DIRECTION: _____°

Attachment 2: End Condition Data form - Airfoil

DEPLOYED FLAPS

AIRFOIL END CONDITION DATA FORM

FORM ____________ OF ___________

DATE ________________

TEST MGR ________________

TEST SURFACE (check box) ☐ Standard Airfoil ☐ Flap/Slat Airfoil

TIME OF FLUID APPLICATION __________

EC HOURLY DATA

RECORDED AT END OF POUR TIME

TIME OF EC OBSERVATION __________

TEMP _____ °C

WIND SPEED ____km/h

WIND DIRECTION _____.

FLUID INFORMATION

Fluid Name: ________________

Fluid Type / DILUTION: ______ /_______

Liters used: ________________

Initial Brix: ________________

Initial Temp: ________________

ROTATION SEQUENCE

H = Headwind, C = Crosswind, T= Tailwind

	Direction (H, C, or T)	Time	Check
Start:	_______	_________	☐
Rotation 1	_______	_________	☐
Rotation 2	_______	_________	☐
Rotation 3	_______	_________	☐

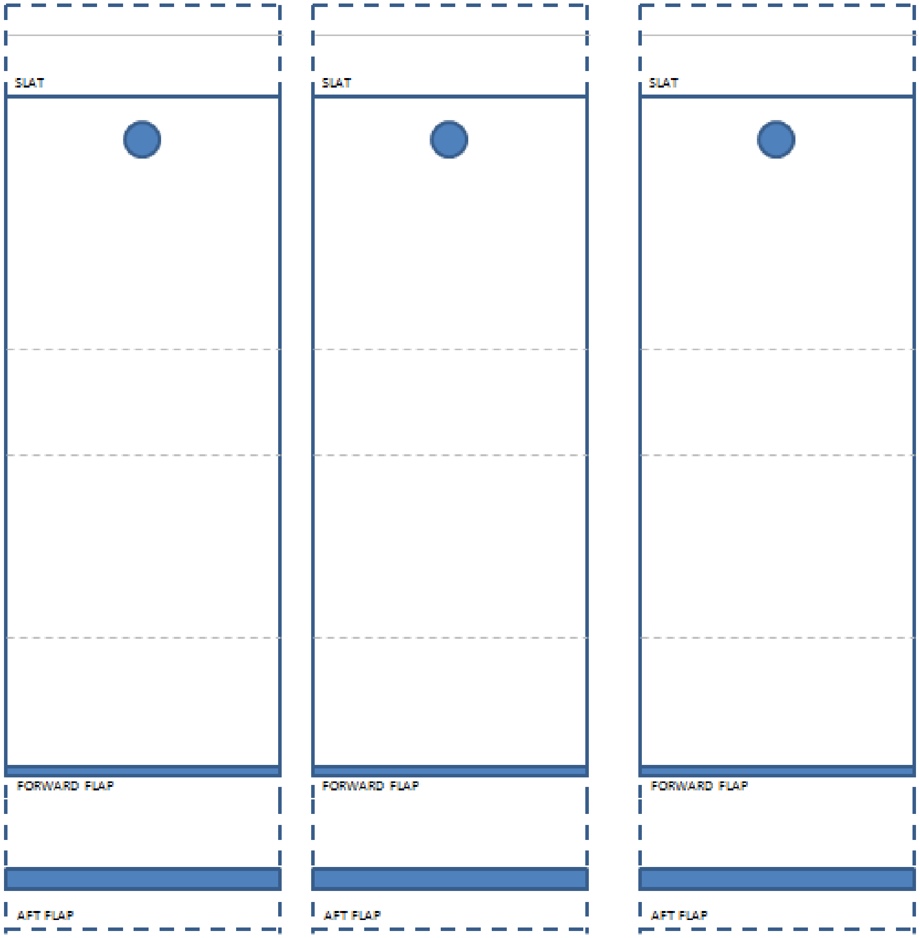
↑ Check that rotation was actually completed

EXPECTED HOLDOVER TIME __________

First Failure Time = ________

10% Failure Time = ________

End of Test Time = ________



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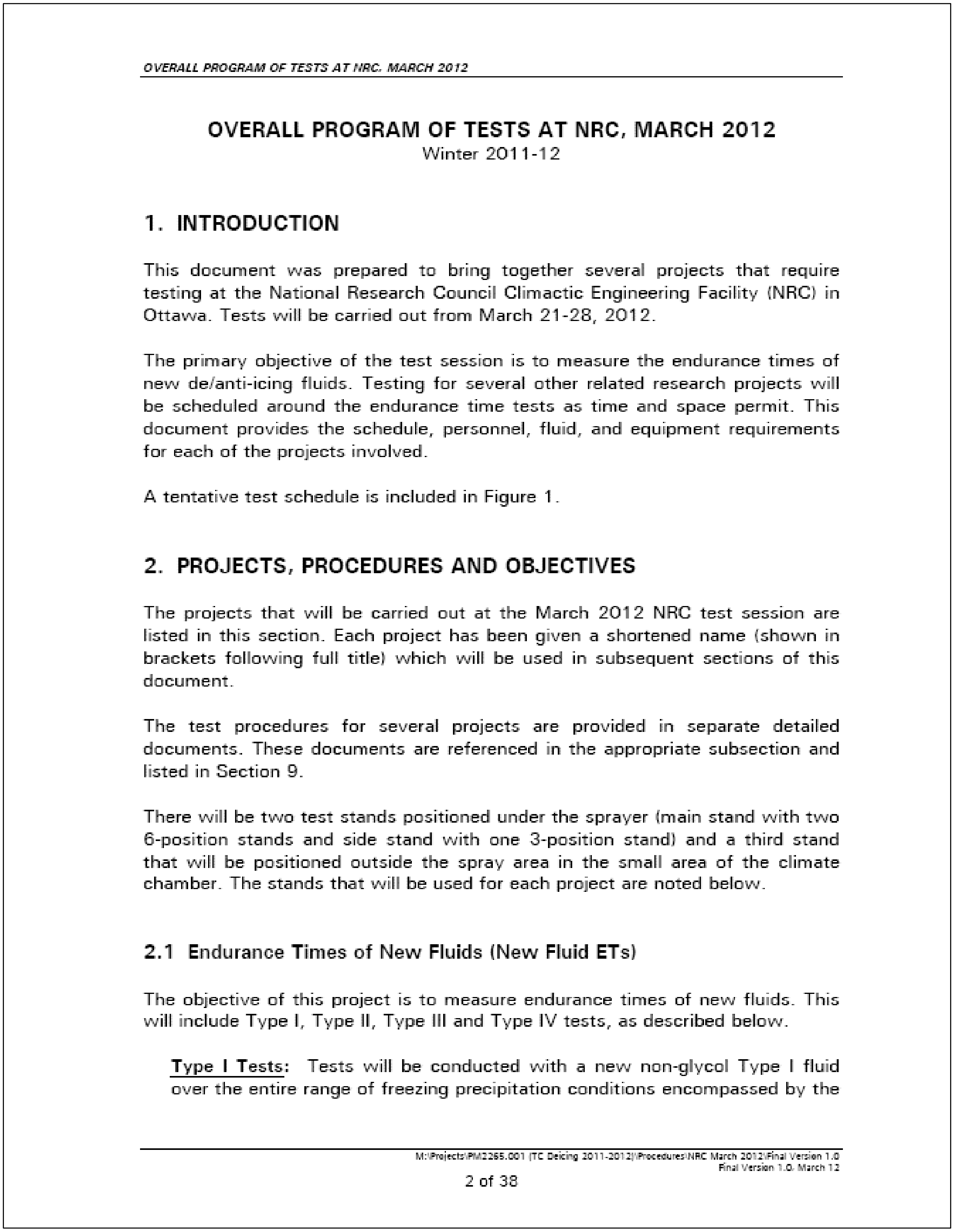
APPENDIX C

EXCERPTS FROM INDOOR NRC CLIMATIC ENGINEERING FACILITY TESTING PROCEDURES

EXCERPT FROM: OVERALL PROGRAM OF TESTS AT NRC, MARCH 2012
WINTER 2011-12

(MARCH 20, 2012 - FINAL VERSION 1.0)



OVERALL PROGRAM OF TESTS AT NRC, MARCH 2012

Winter 2011-12

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from March 21-28, 2012.

The primary objective of the test session is to measure the endurance times of new de/anti-icing fluids. Testing for several other related research projects will be scheduled around the endurance time tests as time and space permit. This document provides the schedule, personnel, fluid, and equipment requirements for each of the projects involved.

A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The projects that will be carried out at the March 2012 NRC test session are listed in this section. Each project has been given a shortened name (shown in brackets following full title) which will be used in subsequent sections of this document.

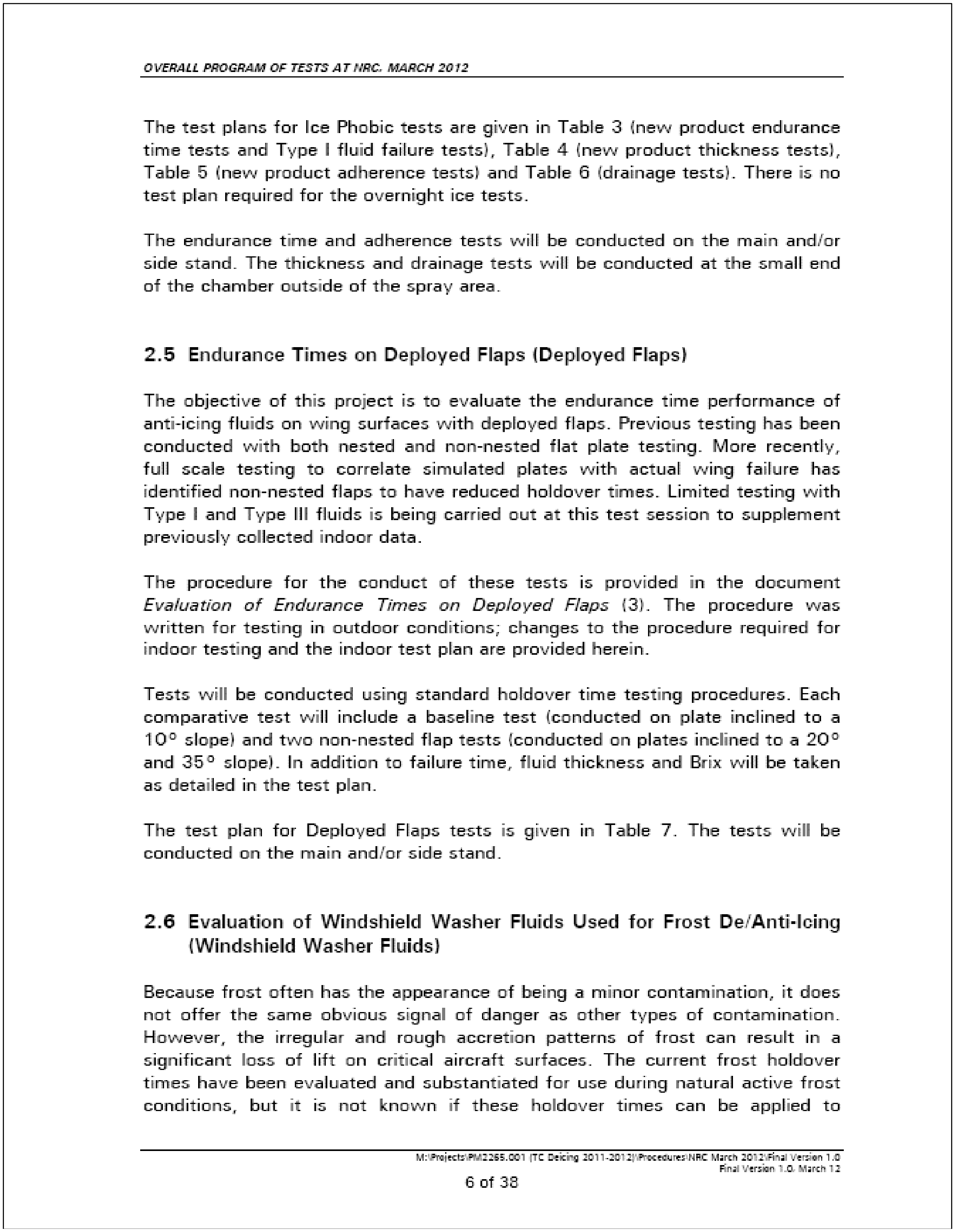
The test procedures for several projects are provided in separate detailed documents. These documents are referenced in the appropriate subsection and listed in Section 9.

There will be two test stands positioned under the sprayer (main stand with two 6-position stands and side stand with one 3-position stand) and a third stand that will be positioned outside the spray area in the small area of the climate chamber. The stands that will be used for each project are noted below.

2.1 Endurance Times of New Fluids (New Fluid ETs)

The objective of this project is to measure endurance times of new fluids. This will include Type I, Type II, Type III and Type IV tests, as described below.

Type I Tests: Tests will be conducted with a new non-glycol Type I fluid over the entire range of freezing precipitation conditions encompassed by the



OVERALL PROGRAM OF TESTS AT NRC. MARCH 2012

The test plans for Ice Phobic tests are given in Table 3 (new product endurance time tests and Type I fluid failure tests), Table 4 (new product thickness tests), Table 5 (new product adherence tests) and Table 6 (drainage tests). There is no test plan required for the overnight ice tests.

The endurance time and adherence tests will be conducted on the main and/or side stand. The thickness and drainage tests will be conducted at the small end of the chamber outside of the spray area.

2.5 Endurance Times on Deployed Flaps (Deployed Flaps)

The objective of this project is to evaluate the endurance time performance of anti-icing fluids on wing surfaces with deployed flaps. Previous testing has been conducted with both nested and non-nested flat plate testing. More recently, full scale testing to correlate simulated plates with actual wing failure has identified non-nested flaps to have reduced holdover times. Limited testing with Type I and Type III fluids is being carried out at this test session to supplement previously collected indoor data.

The procedure for the conduct of these tests is provided in the document *Evaluation of Endurance Times on Deployed Flaps* (3). The procedure was written for testing in outdoor conditions; changes to the procedure required for indoor testing and the indoor test plan are provided herein.

Tests will be conducted using standard holdover time testing procedures. Each comparative test will include a baseline test (conducted on plate inclined to a 10° slope) and two non-nested flap tests (conducted on plates inclined to a 20° and 35° slope). In addition to failure time, fluid thickness and Brix will be taken as detailed in the test plan.

The test plan for Deployed Flaps tests is given in Table 7. The tests will be conducted on the main and/or side stand.

2.6 Evaluation of Windshield Washer Fluids Used for Frost De/Anti-Icing (Windshield Washer Fluids)

Because frost often has the appearance of being a minor contamination, it does not offer the same obvious signal of danger as other types of contamination. However, the irregular and rough accretion patterns of frost can result in a significant loss of lift on critical aircraft surfaces. The current frost holdover times have been evaluated and substantiated for use during natural active frost conditions, but it is not known if these holdover times can be applied to

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Final Version 1.0. March 12

6 of 38

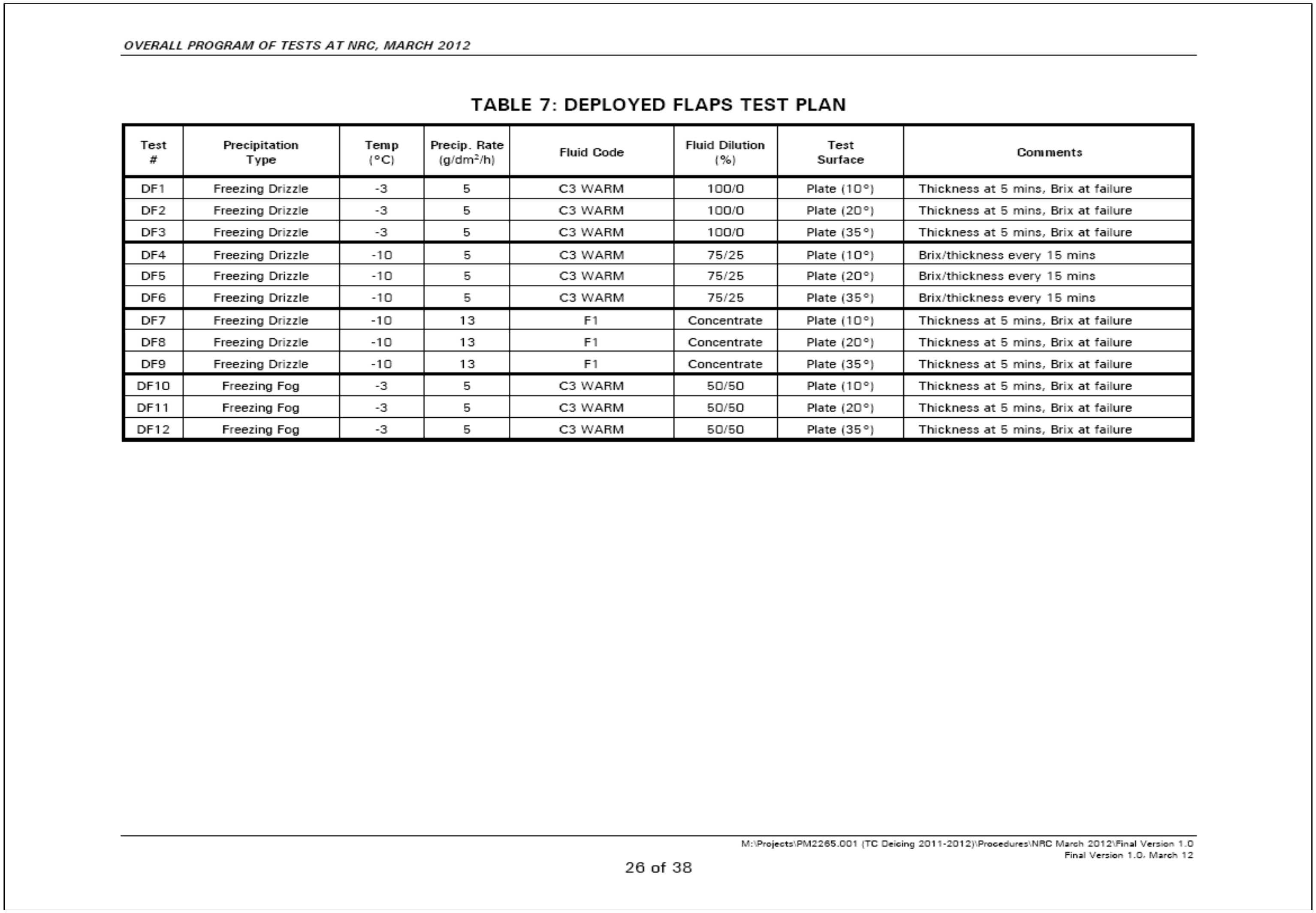

TABLE 7: DEPLOYED FLAPS TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Code	Fluid Dilution (%)	Test Surface	Comments
DF1	Freezing Drizzle	-3	5	C3 WARM	100/0	Plate (10°)	Thickness at 5 mins, Brix at failure
DF2	Freezing Drizzle	-3	5	C3 WARM	100/0	Plate (20°)	Thickness at 5 mins, Brix at failure
DF3	Freezing Drizzle	-3	5	C3 WARM	100/0	Plate (35°)	Thickness at 5 mins, Brix at failure
DF4	Freezing Drizzle	-10	5	C3 WARM	75/25	Plate (10°)	Brix/thickness every 15 mins
DF5	Freezing Drizzle	-10	5	C3 WARM	75/25	Plate (20°)	Brix/thickness every 15 mins
DF6	Freezing Drizzle	-10	5	C3 WARM	75/25	Plate (35°)	Brix/thickness every 15 mins
DF7	Freezing Drizzle	-10	13	F1	Concentrate	Plate (10°)	Thickness at 5 mins, Brix at failure
DF8	Freezing Drizzle	-10	13	F1	Concentrate	Plate (20°)	Thickness at 5 mins, Brix at failure
DF9	Freezing Drizzle	-10	13	F1	Concentrate	Plate (35°)	Thickness at 5 mins, Brix at failure
DF10	Freezing Fog	-3	5	C3 WARM	50/50	Plate (10°)	Thickness at 5 mins, Brix at failure
DF11	Freezing Fog	-3	5	C3 WARM	50/50	Plate (20°)	Thickness at 5 mins, Brix at failure
DF12	Freezing Fog	-3	5	C3 WARM	50/50	Plate (35°)	Thickness at 5 mins, Brix at failure

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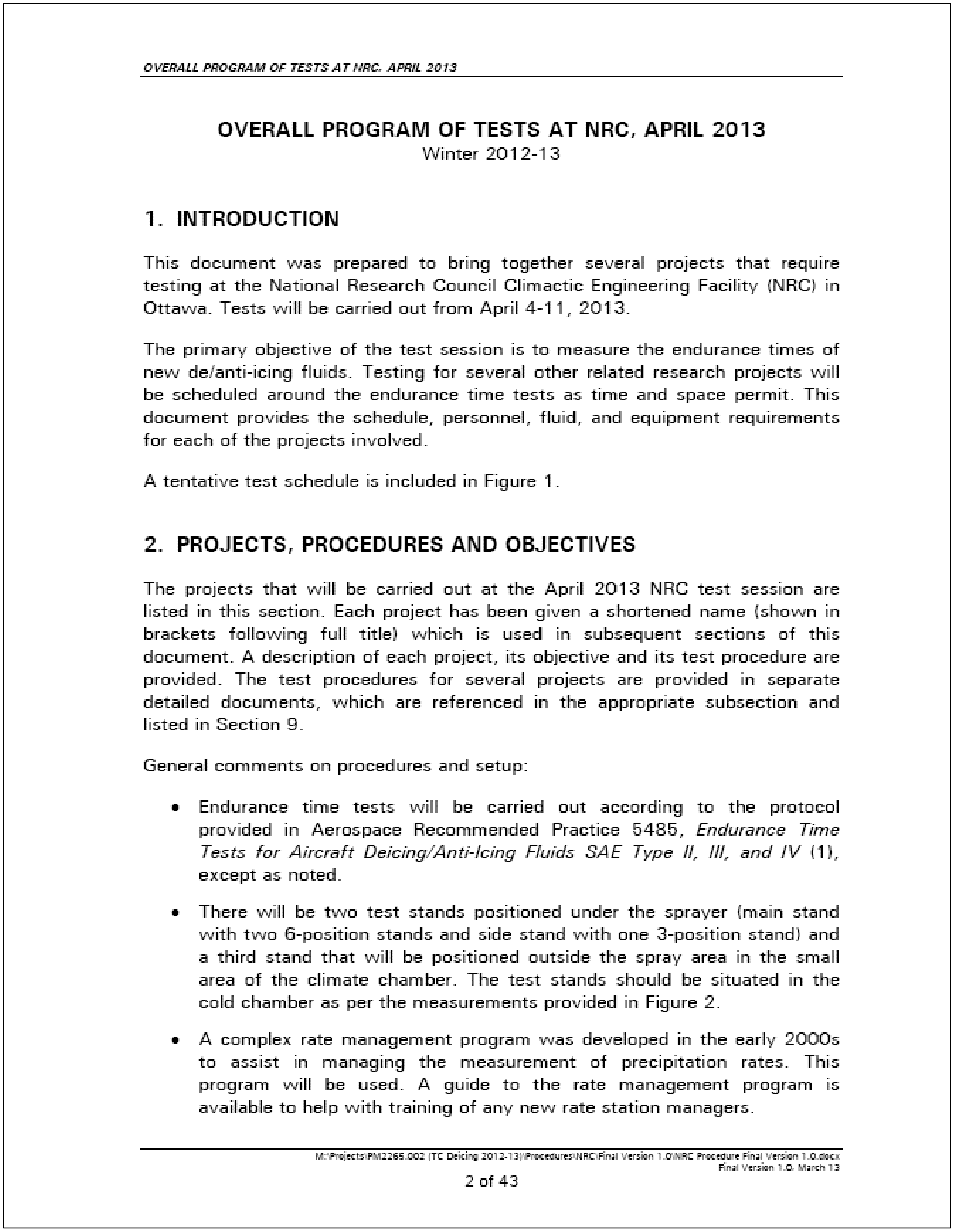
EXCERPT FROM: OVERALL PROGRAM OF TESTS AT NRC, APRIL 2013
WINTER 2012-13

(APRIL 2, 2013 – FINAL VERSION 1.0)



OVERALL PROGRAM OF TESTS AT NRC, APRIL 2013

Winter 2012-13

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from April 4-11, 2013.

The primary objective of the test session is to measure the endurance times of new de/anti-icing fluids. Testing for several other related research projects will be scheduled around the endurance time tests as time and space permit. This document provides the schedule, personnel, fluid, and equipment requirements for each of the projects involved.

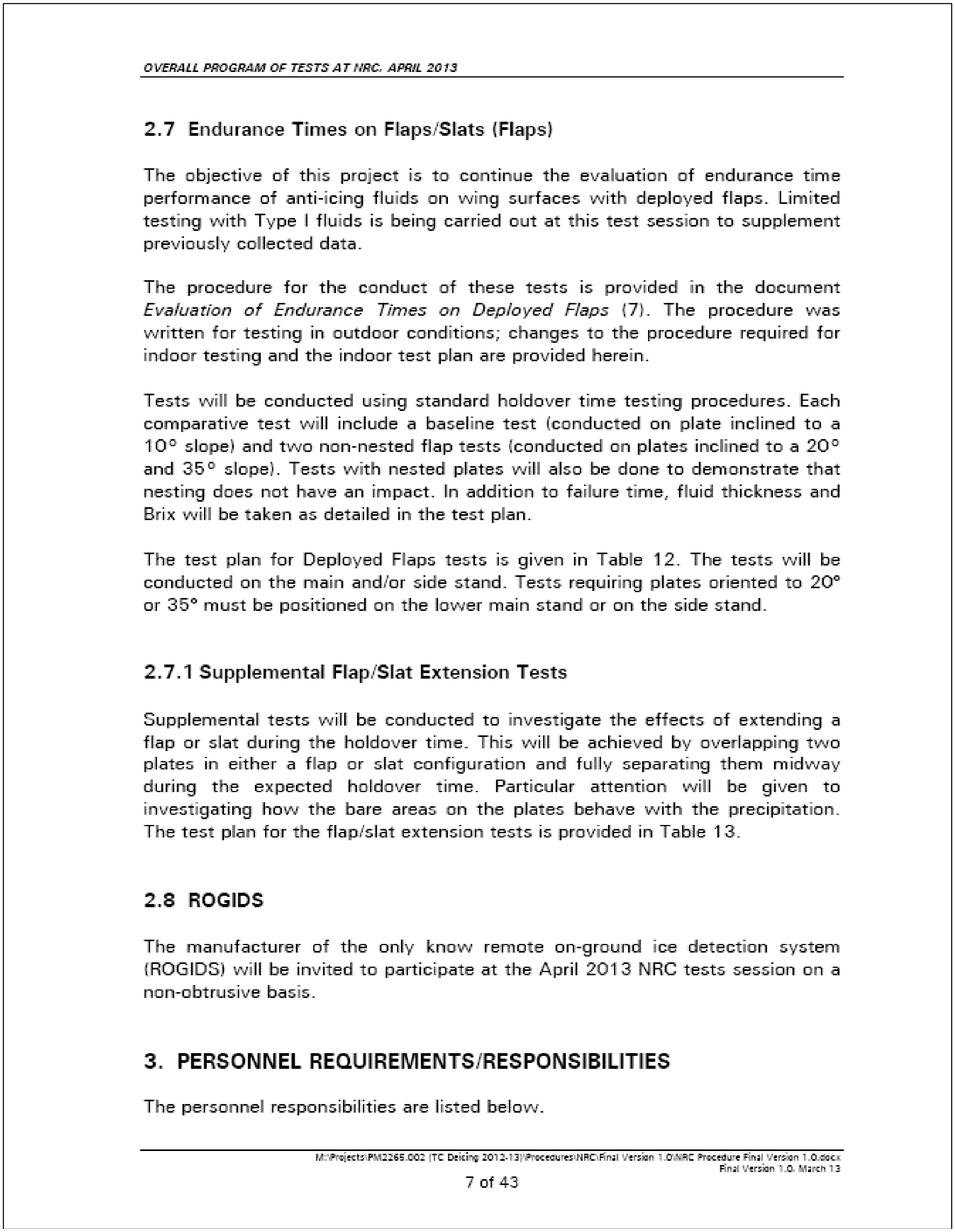
A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The projects that will be carried out at the April 2013 NRC test session are listed in this section. Each project has been given a shortened name (shown in brackets following full title) which is used in subsequent sections of this document. A description of each project, its objective and its test procedure are provided. The test procedures for several projects are provided in separate detailed documents, which are referenced in the appropriate subsection and listed in Section 9.

General comments on procedures and setup:

- Endurance time tests will be carried out according to the protocol provided in Aerospace Recommended Practice 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type II, III, and IV* (1), except as noted.
- There will be two test stands positioned under the sprayer (main stand with two 6-position stands and side stand with one 3-position stand) and a third stand that will be positioned outside the spray area in the small area of the climate chamber. The test stands should be situated in the cold chamber as per the measurements provided in Figure 2.
- A complex rate management program was developed in the early 2000s to assist in managing the measurement of precipitation rates. This program will be used. A guide to the rate management program is available to help with training of any new rate station managers.



2.7 Endurance Times on Flaps/Slats (Flaps)

The objective of this project is to continue the evaluation of endurance time performance of anti-icing fluids on wing surfaces with deployed flaps. Limited testing with Type I fluids is being carried out at this test session to supplement previously collected data.

The procedure for the conduct of these tests is provided in the document *Evaluation of Endurance Times on Deployed Flaps* (7). The procedure was written for testing in outdoor conditions; changes to the procedure required for indoor testing and the indoor test plan are provided herein.

Tests will be conducted using standard holdover time testing procedures. Each comparative test will include a baseline test (conducted on plate inclined to a 10° slope) and two non-nested flap tests (conducted on plates inclined to a 20° and 35° slope). Tests with nested plates will also be done to demonstrate that nesting does not have an impact. In addition to failure time, fluid thickness and Brix will be taken as detailed in the test plan.

The test plan for Deployed Flaps tests is given in Table 12. The tests will be conducted on the main and/or side stand. Tests requiring plates oriented to 20° or 35° must be positioned on the lower main stand or on the side stand.

2.7.1 Supplemental Flap/Slat Extension Tests

Supplemental tests will be conducted to investigate the effects of extending a flap or slat during the holdover time. This will be achieved by overlapping two plates in either a flap or slat configuration and fully separating them midway during the expected holdover time. Particular attention will be given to investigating how the bare areas on the plates behave with the precipitation. The test plan for the flap/slat extension tests is provided in Table 13.

2.8 ROGIDS

The manufacturer of the only know remote on-ground ice detection system (ROGIDS) will be invited to participate at the April 2013 NRC tests session on a non-obtrusive basis.

3. PERSONNEL REQUIREMENTS/RESPONSIBILITIES

The personnel responsibilities are listed below.

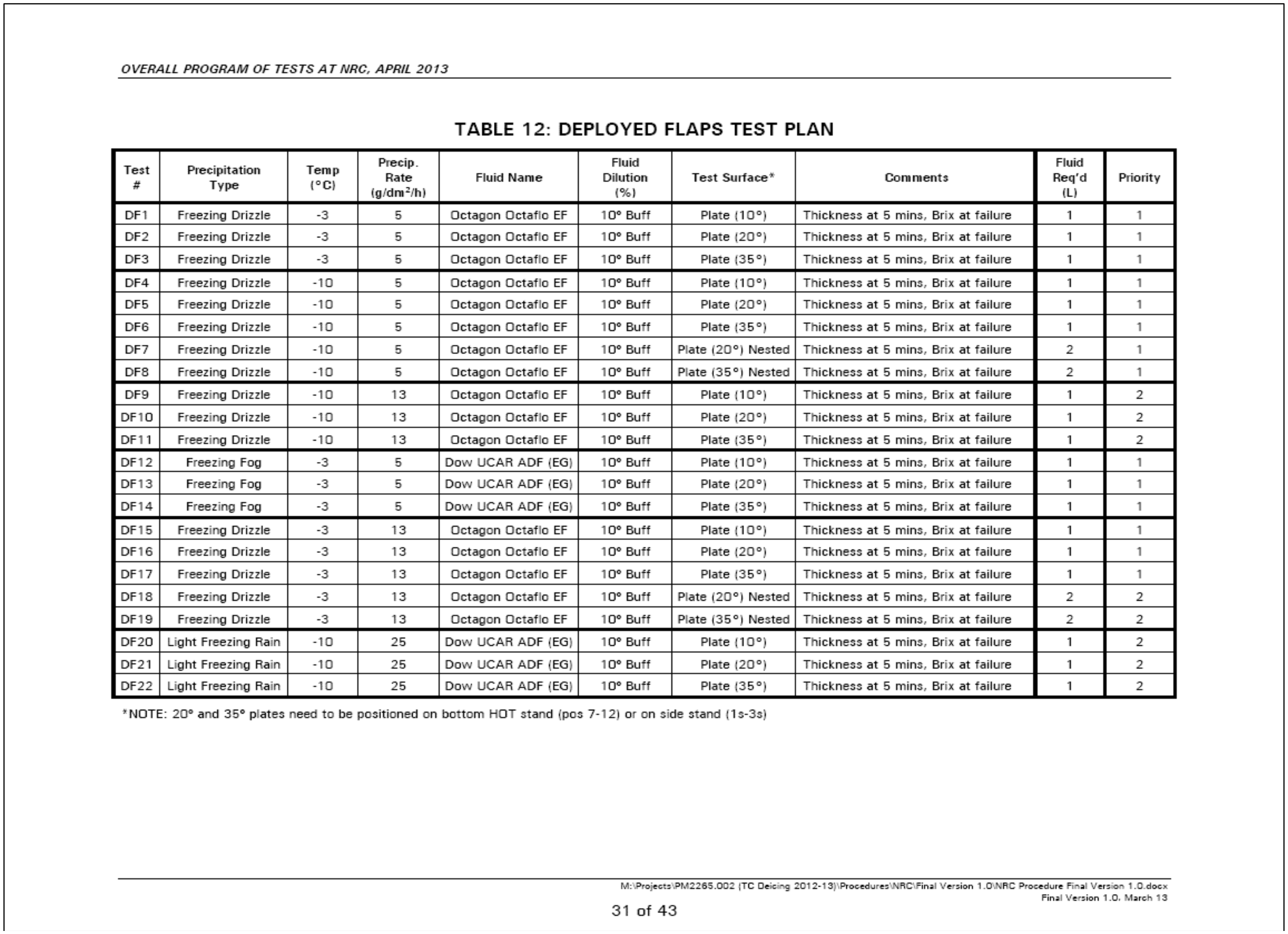


TABLE 12: DEPLOYED FLAPS TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Name	Fluid Dilution (%)	Test Surface*	Comments	Fluid Req'd (L)	Priority
DF1	Freezing Drizzle	-3	5	Octagon Octaflo EF	10° Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF2	Freezing Drizzle	-3	5	Octagon Octaflo EF	10° Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF3	Freezing Drizzle	-3	5	Octagon Octaflo EF	10° Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF4	Freezing Drizzle	-10	5	Octagon Octaflo EF	10° Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF5	Freezing Drizzle	-10	5	Octagon Octaflo EF	10° Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF6	Freezing Drizzle	-10	5	Octagon Octaflo EF	10° Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF7	Freezing Drizzle	-10	5	Octagon Octaflo EF	10° Buff	Plate (20°) Nested	Thickness at 5 mins, Brix at failure	2	1
DF8	Freezing Drizzle	-10	5	Octagon Octaflo EF	10° Buff	Plate (35°) Nested	Thickness at 5 mins, Brix at failure	2	1
DF9	Freezing Drizzle	-10	13	Octagon Octaflo EF	10° Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	2
DF10	Freezing Drizzle	-10	13	Octagon Octaflo EF	10° Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	2
DF11	Freezing Drizzle	-10	13	Octagon Octaflo EF	10° Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	2
DF12	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10° Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF13	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10° Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF14	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10° Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF15	Freezing Drizzle	-3	13	Octagon Octaflo EF	10° Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF16	Freezing Drizzle	-3	13	Octagon Octaflo EF	10° Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF17	Freezing Drizzle	-3	13	Octagon Octaflo EF	10° Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF18	Freezing Drizzle	-3	13	Octagon Octaflo EF	10° Buff	Plate (20°) Nested	Thickness at 5 mins, Brix at failure	2	2
DF19	Freezing Drizzle	-3	13	Octagon Octaflo EF	10° Buff	Plate (35°) Nested	Thickness at 5 mins, Brix at failure	2	2
DF20	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10° Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	2
DF21	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10° Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	2
DF22	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10° Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	2

*NOTE: 20° and 35° plates need to be positioned on bottom HOT stand (pos 7-12) or on side stand (1s-3s)

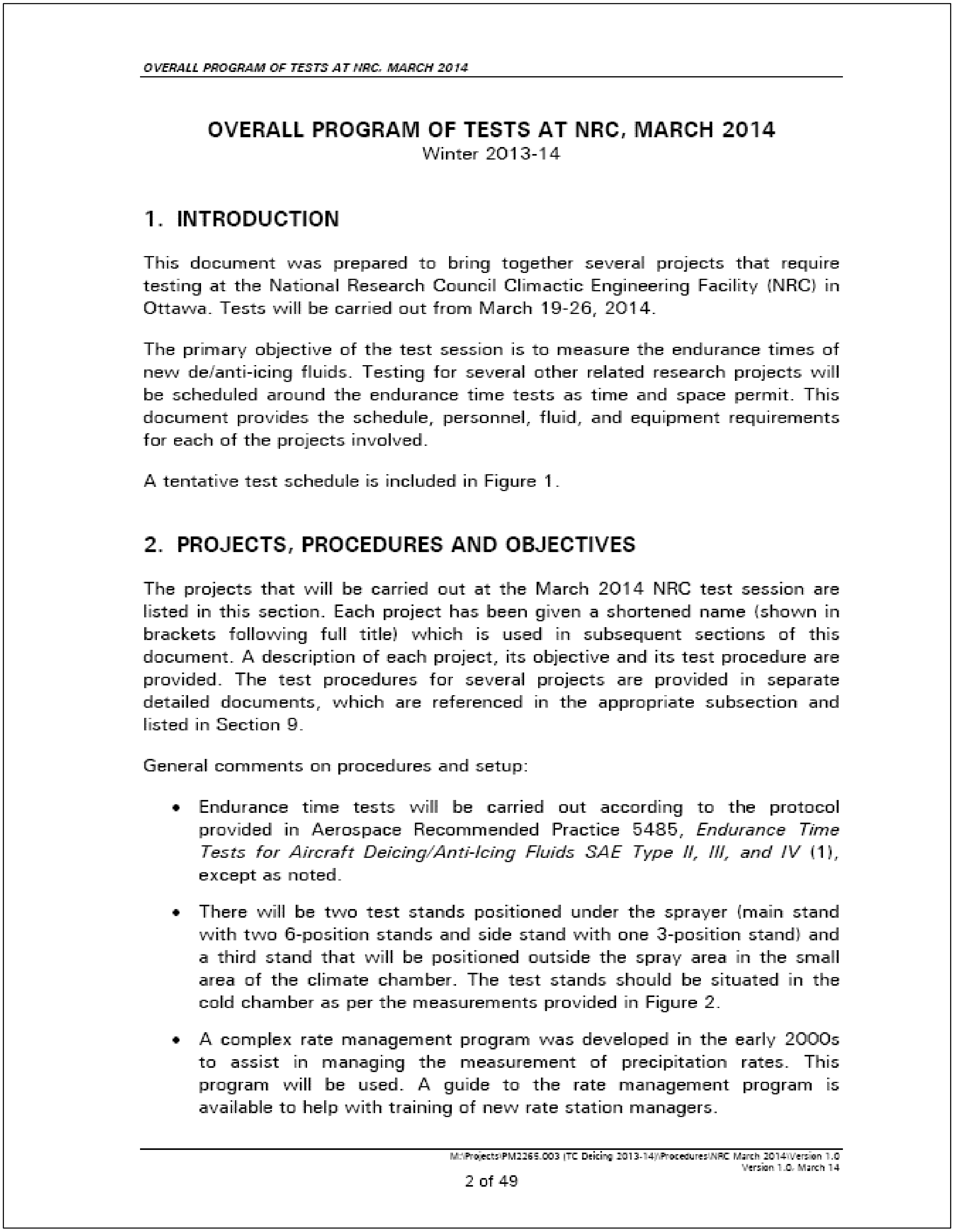
TABLE 13: FLAPS SLATS EXTENSION TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm^2/h)	Fluid	Fluid Dil. (%)	Test Surface	Comments	Fluid Required (L)	Priority
FSE1	Freezing Drizzle	-10	13	Clariant Launch Plus	100/0	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
FSE2	Freezing Drizzle	-10	13	Clariant Launch Plus	100/0	2 Plates (20°) Slat	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	1
FSE3	Freezing Drizzle	-10	13	Clariant Launch Plus	100/0	2 Plates (20°) Flap	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	1
FSE4	Light Freezing Rain	-3	25	Clariant Launch Plus	75/25	Plate (10°)	Thickness at 5 mins, Brix at failure	1	2
FSE5	Light Freezing Rain	-3	25	Clariant Launch Plus	75/25	2 Plates (35°) Slat	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	2
FSE6	Light Freezing Rain	-3	25	Clariant Launch Plus	75/25	2 Plates (35°) Flap	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	2

NOTE: 2 plates used. 1 on top of other at 10° to start (with overlap), then split into 10° and 20/35°

EXCERPT FROM: OVERALL PROGRAM OF TESTS AT NRC, MARCH 2014
WINTER 2013-14

(MARCH 17, 2014 – VERSION 1.0)



OVERALL PROGRAM OF TESTS AT NRC, MARCH 2014

Winter 2013-14

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from March 19-26, 2014.

The primary objective of the test session is to measure the endurance times of new de/anti-icing fluids. Testing for several other related research projects will be scheduled around the endurance time tests as time and space permit. This document provides the schedule, personnel, fluid, and equipment requirements for each of the projects involved.

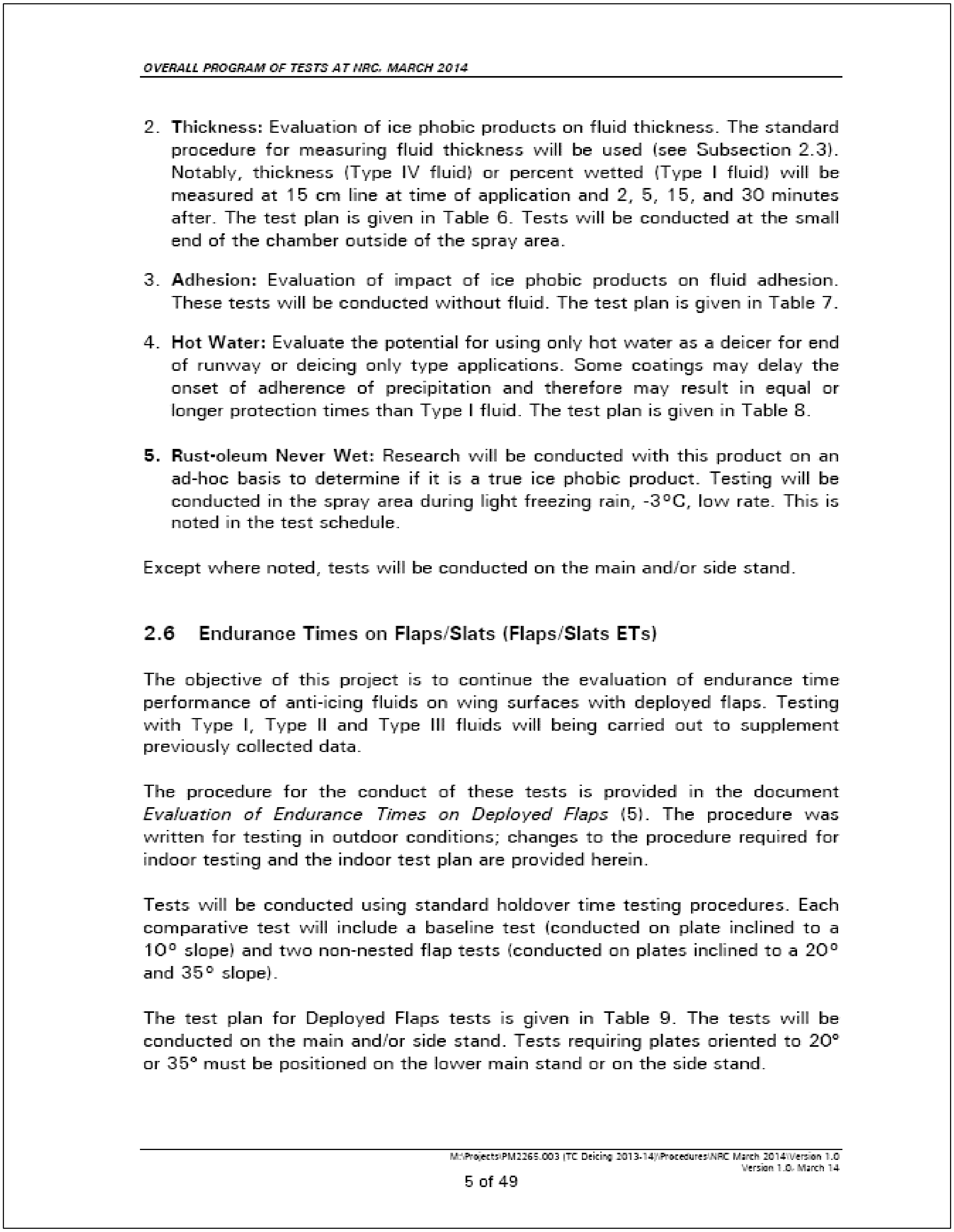
A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The projects that will be carried out at the March 2014 NRC test session are listed in this section. Each project has been given a shortened name (shown in brackets following full title) which is used in subsequent sections of this document. A description of each project, its objective and its test procedure are provided. The test procedures for several projects are provided in separate detailed documents, which are referenced in the appropriate subsection and listed in Section 9.

General comments on procedures and setup:

- Endurance time tests will be carried out according to the protocol provided in Aerospace Recommended Practice 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type II, III, and IV* (1), except as noted.
- There will be two test stands positioned under the sprayer (main stand with two 6-position stands and side stand with one 3-position stand) and a third stand that will be positioned outside the spray area in the small area of the climate chamber. The test stands should be situated in the cold chamber as per the measurements provided in Figure 2.
- A complex rate management program was developed in the early 2000s to assist in managing the measurement of precipitation rates. This program will be used. A guide to the rate management program is available to help with training of new rate station managers.



2. **Thickness:** Evaluation of ice phobic products on fluid thickness. The standard procedure for measuring fluid thickness will be used (see Subsection 2.3). Notably, thickness (Type IV fluid) or percent wetted (Type I fluid) will be measured at 15 cm line at time of application and 2, 5, 15, and 30 minutes after. The test plan is given in Table 6. Tests will be conducted at the small end of the chamber outside of the spray area.

3. **Adhesion:** Evaluation of impact of ice phobic products on fluid adhesion. These tests will be conducted without fluid. The test plan is given in Table 7.

4. **Hot Water:** Evaluate the potential for using only hot water as a deicer for end of runway or deicing only type applications. Some coatings may delay the onset of adherence of precipitation and therefore may result in equal or longer protection times than Type I fluid. The test plan is given in Table 8.

5. **Rust-oleum Never Wet:** Research will be conducted with this product on an ad-hoc basis to determine if it is a true ice phobic product. Testing will be conducted in the spray area during light freezing rain, -3°C, low rate. This is noted in the test schedule.

Except where noted, tests will be conducted on the main and/or side stand.

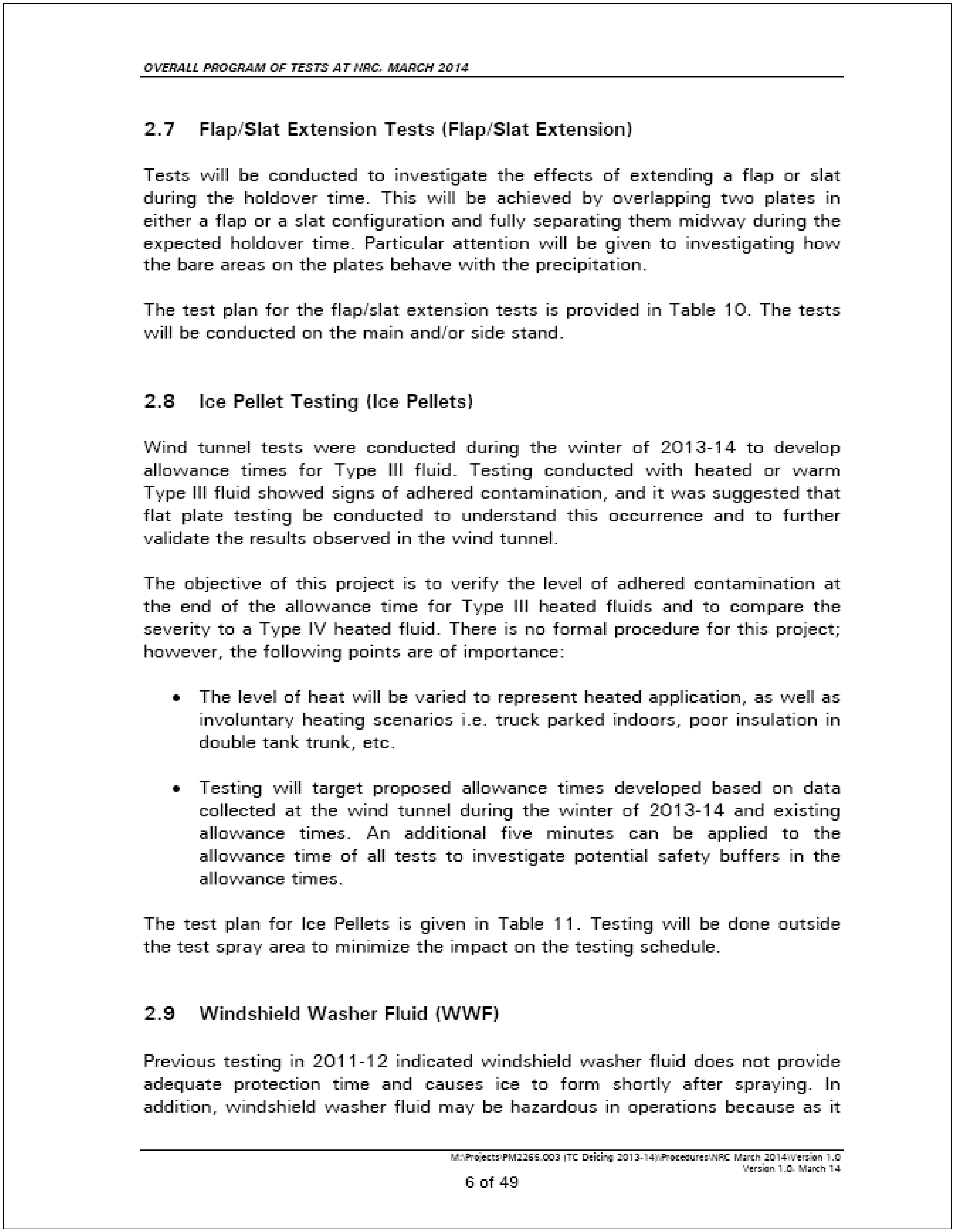
2.6 Endurance Times on Flaps/Slats (Flaps/Slats ETs)

The objective of this project is to continue the evaluation of endurance time performance of anti-icing fluids on wing surfaces with deployed flaps. Testing with Type I, Type II and Type III fluids will being carried out to supplement previously collected data.

The procedure for the conduct of these tests is provided in the document *Evaluation of Endurance Times on Deployed Flaps* (5). The procedure was written for testing in outdoor conditions; changes to the procedure required for indoor testing and the indoor test plan are provided herein.

Tests will be conducted using standard holdover time testing procedures. Each comparative test will include a baseline test (conducted on plate inclined to a 10° slope) and two non-nested flap tests (conducted on plates inclined to a 20° and 35° slope).

The test plan for Deployed Flaps tests is given in Table 9. The tests will be conducted on the main and/or side stand. Tests requiring plates oriented to 20° or 35° must be positioned on the lower main stand or on the side stand.



2.7 Flap/Slat Extension Tests (Flap/Slat Extension)

Tests will be conducted to investigate the effects of extending a flap or slat during the holdover time. This will be achieved by overlapping two plates in either a flap or a slat configuration and fully separating them midway during the expected holdover time. Particular attention will be given to investigating how the bare areas on the plates behave with the precipitation.

The test plan for the flap/slat extension tests is provided in Table 10. The tests will be conducted on the main and/or side stand.

2.8 Ice Pellet Testing (Ice Pellets)

Wind tunnel tests were conducted during the winter of 2013-14 to develop allowance times for Type III fluid. Testing conducted with heated or warm Type III fluid showed signs of adhered contamination, and it was suggested that flat plate testing be conducted to understand this occurrence and to further validate the results observed in the wind tunnel.

The objective of this project is to verify the level of adhered contamination at the end of the allowance time for Type III heated fluids and to compare the severity to a Type IV heated fluid. There is no formal procedure for this project; however, the following points are of importance:

- The level of heat will be varied to represent heated application, as well as involuntary heating scenarios i.e. truck parked indoors, poor insulation in double tank trunk, etc.

- Testing will target proposed allowance times developed based on data collected at the wind tunnel during the winter of 2013-14 and existing allowance times. An additional five minutes can be applied to the allowance time of all tests to investigate potential safety buffers in the allowance times.

The test plan for Ice Pellets is given in Table 11. Testing will be done outside the test spray area to minimize the impact on the testing schedule.

2.9 Windshield Washer Fluid (WWF)

Previous testing in 2011-12 indicated windshield washer fluid does not provide adequate protection time and causes ice to form shortly after spraying. In addition, windshield washer fluid may be hazardous in operations because as it

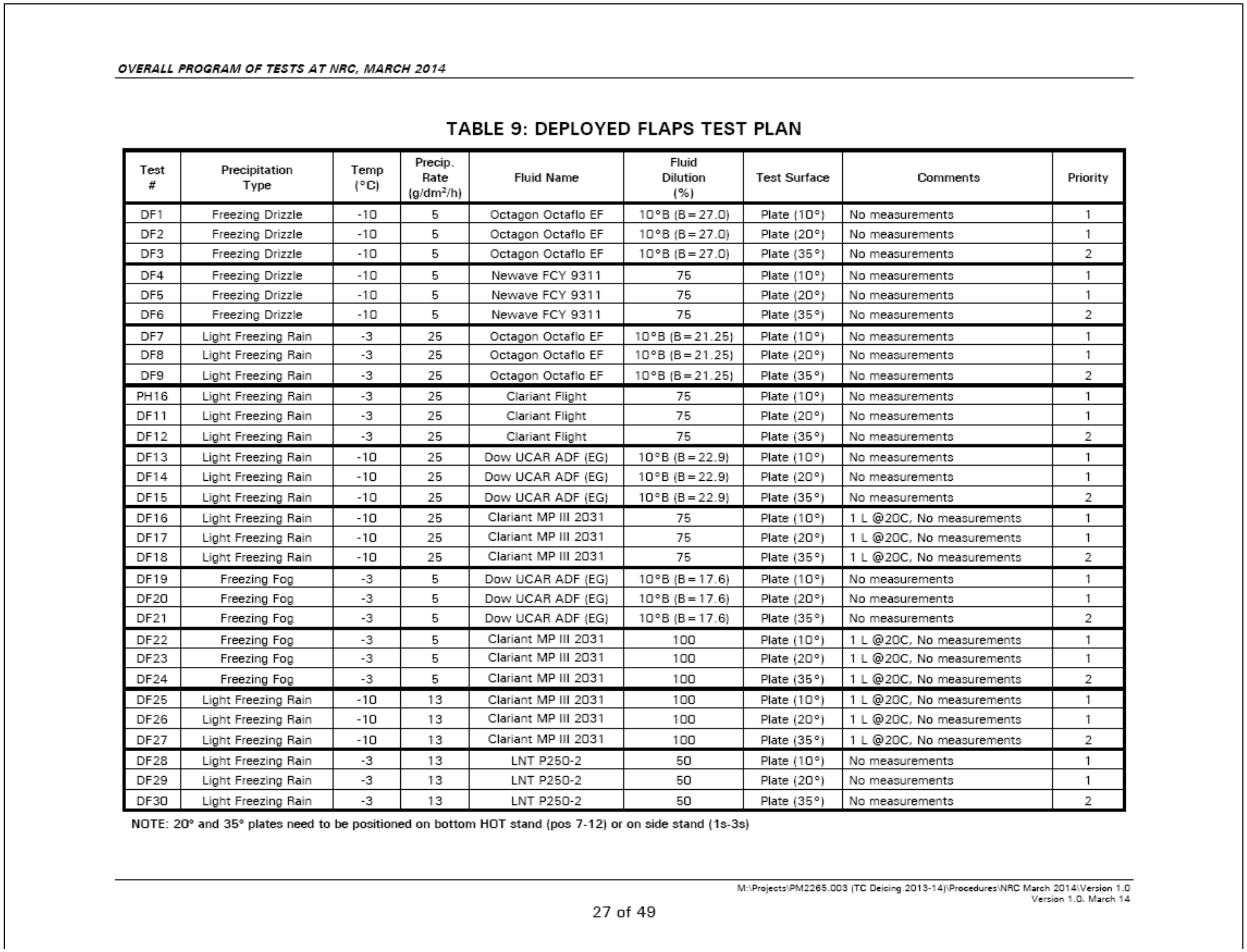
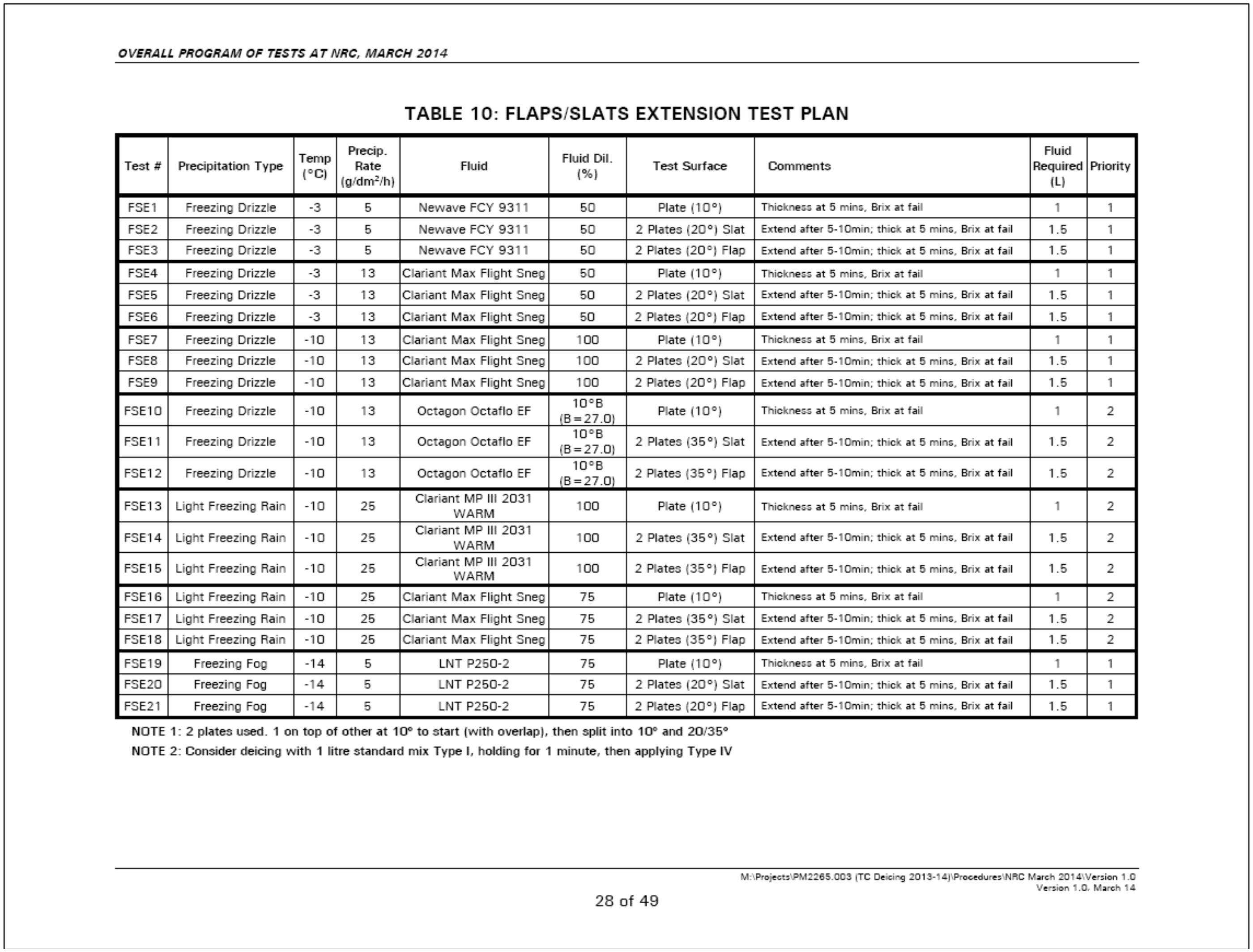


TABLE 9: DEPLOYED FLAPS TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Name	Fluid Dilution (%)	Test Surface	Comments	Priority
DF1	Freezing Drizzle	-10	5	Octagon Octaflo EF	10°B (B=27.0)	Plate (10°)	No measurements	1
DF2	Freezing Drizzle	-10	5	Octagon Octaflo EF	10°B (B=27.0)	Plate (20°)	No measurements	1
DF3	Freezing Drizzle	-10	5	Octagon Octaflo EF	10°B (B=27.0)	Plate (35°)	No measurements	2
DF4	Freezing Drizzle	-10	5	Newave FCY 9311	75	Plate (10°)	No measurements	1
DF5	Freezing Drizzle	-10	5	Newave FCY 9311	75	Plate (20°)	No measurements	1
DF6	Freezing Drizzle	-10	5	Newave FCY 9311	75	Plate (35°)	No measurements	2
DF7	Light Freezing Rain	-3	25	Octagon Octaflo EF	10°B (B=21.25)	Plate (10°)	No measurements	1
DF8	Light Freezing Rain	-3	25	Octagon Octaflo EF	10°B (B=21.25)	Plate (20°)	No measurements	1
DF9	Light Freezing Rain	-3	25	Octagon Octaflo EF	10°B (B=21.25)	Plate (35°)	No measurements	2
PH16	Light Freezing Rain	-3	25	Clariant Flight	75	Plate (10°)	No measurements	1
DF11	Light Freezing Rain	-3	25	Clariant Flight	75	Plate (20°)	No measurements	1
DF12	Light Freezing Rain	-3	25	Clariant Flight	75	Plate (35°)	No measurements	2
DF13	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10°B (B=22.9)	Plate (10°)	No measurements	1
DF14	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10°B (B=22.9)	Plate (20°)	No measurements	1
DF15	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10°B (B=22.9)	Plate (35°)	No measurements	2
DF16	Light Freezing Rain	-10	25	Clariant MP III 2031	75	Plate (10°)	1 L @20C, No measurements	1
DF17	Light Freezing Rain	-10	25	Clariant MP III 2031	75	Plate (20°)	1 L @20C, No measurements	1
DF18	Light Freezing Rain	-10	25	Clariant MP III 2031	75	Plate (35°)	1 L @20C, No measurements	2
DF19	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10°B (B=17.6)	Plate (10°)	No measurements	1
DF20	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10°B (B=17.6)	Plate (20°)	No measurements	1
DF21	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10°B (B=17.6)	Plate (35°)	No measurements	2
DF22	Freezing Fog	-3	5	Clariant MP III 2031	100	Plate (10°)	1 L @20C, No measurements	1
DF23	Freezing Fog	-3	5	Clariant MP III 2031	100	Plate (20°)	1 L @20C, No measurements	1
DF24	Freezing Fog	-3	5	Clariant MP III 2031	100	Plate (35°)	1 L @20C, No measurements	2
DF25	Light Freezing Rain	-10	13	Clariant MP III 2031	100	Plate (10°)	1 L @20C, No measurements	1
DF26	Light Freezing Rain	-10	13	Clariant MP III 2031	100	Plate (20°)	1 L @20C, No measurements	1
DF27	Light Freezing Rain	-10	13	Clariant MP III 2031	100	Plate (35°)	1 L @20C, No measurements	2
DF28	Light Freezing Rain	-3	13	LNT P250-2	50	Plate (10°)	No measurements	1
DF29	Light Freezing Rain	-3	13	LNT P250-2	50	Plate (20°)	No measurements	1
DF30	Light Freezing Rain	-3	13	LNT P250-2	50	Plate (35°)	No measurements	2

NOTE: 20° and 35° plates need to be positioned on bottom HOT stand (pos 7-12) or on side stand (1s-3s)



OVERALL PROGRAM OF TESTS AT NRC, MARCH 2014

TABLE 10: FLAPS/SLATS EXTENSION TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dil. (%)	Test Surface	Comments	Fluid Required (L)	Priority
FSE1	Freezing Drizzle	-3	5	Newave FCY 9311	50	Plate (10°)	Thickness at 5 mins, Brix at fail	1	1
FSE2	Freezing Drizzle	-3	5	Newave FCY 9311	50	2 Plates (20°) Slat	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1
FSE3	Freezing Drizzle	-3	5	Newave FCY 9311	50	2 Plates (20°) Flap	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1
FSE4	Freezing Drizzle	-3	13	Clariant Max Flight Sneg	50	Plate (10°)	Thickness at 5 mins, Brix at fail	1	1
FSE5	Freezing Drizzle	-3	13	Clariant Max Flight Sneg	50	2 Plates (20°) Slat	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1
FSE6	Freezing Drizzle	-3	13	Clariant Max Flight Sneg	50	2 Plates (20°) Flap	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1
FSE7	Freezing Drizzle	-10	13	Clariant Max Flight Sneg	100	Plate (10°)	Thickness at 5 mins, Brix at fail	1	1
FSE8	Freezing Drizzle	-10	13	Clariant Max Flight Sneg	100	2 Plates (20°) Slat	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1
FSE9	Freezing Drizzle	-10	13	Clariant Max Flight Sneg	100	2 Plates (20°) Flap	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1
FSE10	Freezing Drizzle	-10	13	Octagon Octaflo EF	10°B (B=27.0)	Plate (10°)	Thickness at 5 mins, Brix at fail	1	2
FSE11	Freezing Drizzle	-10	13	Octagon Octaflo EF	10°B (B=27.0)	2 Plates (35°) Slat	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	2
FSE12	Freezing Drizzle	-10	13	Octagon Octaflo EF	10°B (B=27.0)	2 Plates (35°) Flap	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	2
FSE13	Light Freezing Rain	-10	25	Clariant MP III 2031 WARM	100	Plate (10°)	Thickness at 5 mins, Brix at fail	1	2
FSE14	Light Freezing Rain	-10	25	Clariant MP III 2031 WARM	100	2 Plates (35°) Slat	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	2
FSE15	Light Freezing Rain	-10	25	Clariant MP III 2031 WARM	100	2 Plates (35°) Flap	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	2
FSE16	Light Freezing Rain	-10	25	Clariant Max Flight Sneg	75	Plate (10°)	Thickness at 5 mins, Brix at fail	1	2
FSE17	Light Freezing Rain	-10	25	Clariant Max Flight Sneg	75	2 Plates (35°) Slat	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	2
FSE18	Light Freezing Rain	-10	25	Clariant Max Flight Sneg	75	2 Plates (35°) Flap	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	2
FSE19	Freezing Fog	-14	5	LNT P250-2	75	Plate (10°)	Thickness at 5 mins, Brix at fail	1	1
FSE20	Freezing Fog	-14	5	LNT P250-2	75	2 Plates (20°) Slat	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1
FSE21	Freezing Fog	-14	5	LNT P250-2	75	2 Plates (20°) Flap	Extend after 5-10min; thick at 5 mins, Brix at fail	1.5	1

NOTE 1: 2 plates used. 1 on top of other at 10° to start (with overlap), then split into 10° and 20/35°

NOTE 2: Consider deicing with 1 litre standard mix Type I, holding for 1 minute, then applying Type IV

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Version 1.0, March 14

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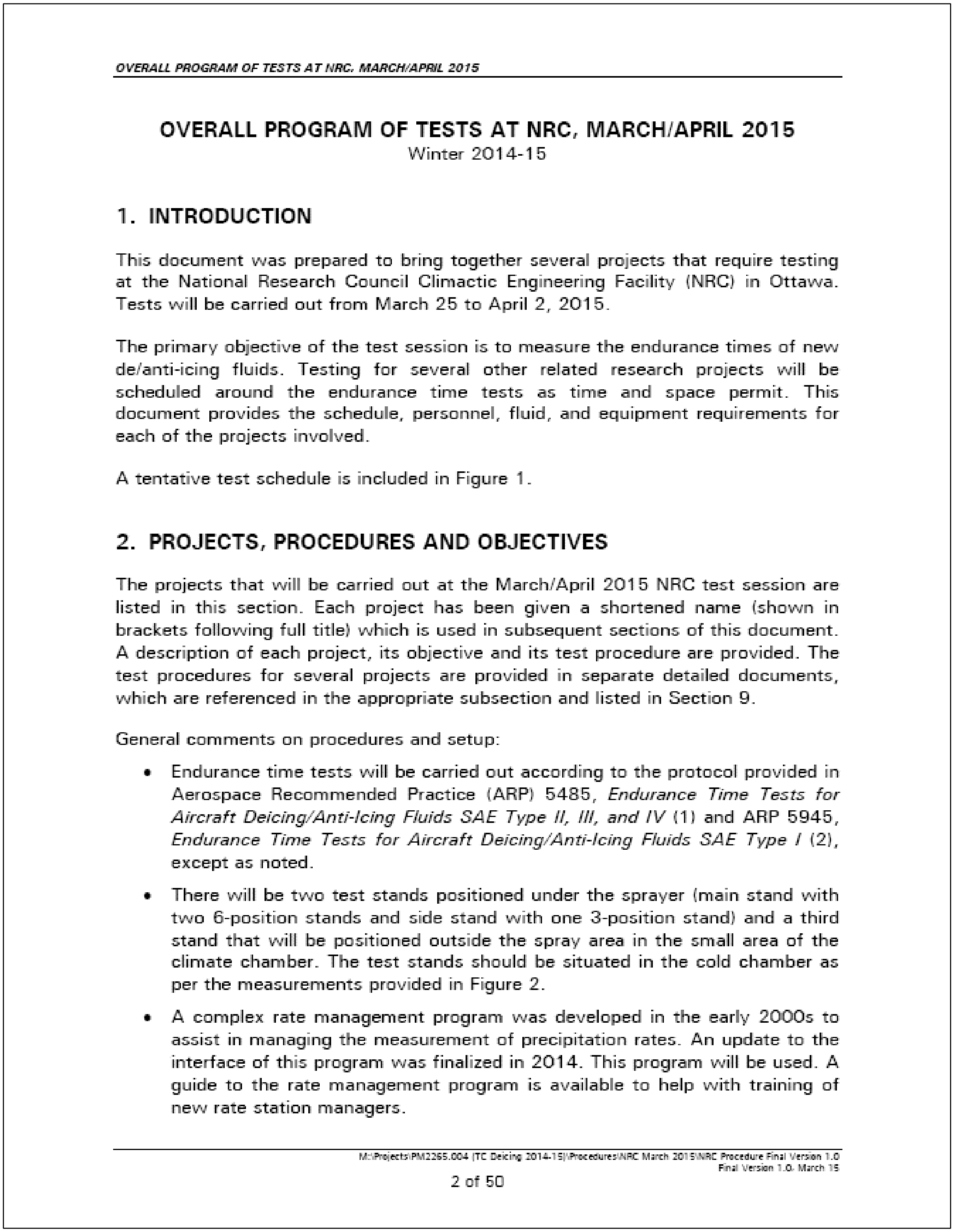
EXCERPT FROM: OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015
WINTER 2014-15

(MARCH 20, 2015 – FINAL VERSION 1.0)



OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015

Winter 2014-15

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from March 25 to April 2, 2015.

The primary objective of the test session is to measure the endurance times of new de/anti-icing fluids. Testing for several other related research projects will be scheduled around the endurance time tests as time and space permit. This document provides the schedule, personnel, fluid, and equipment requirements for each of the projects involved.

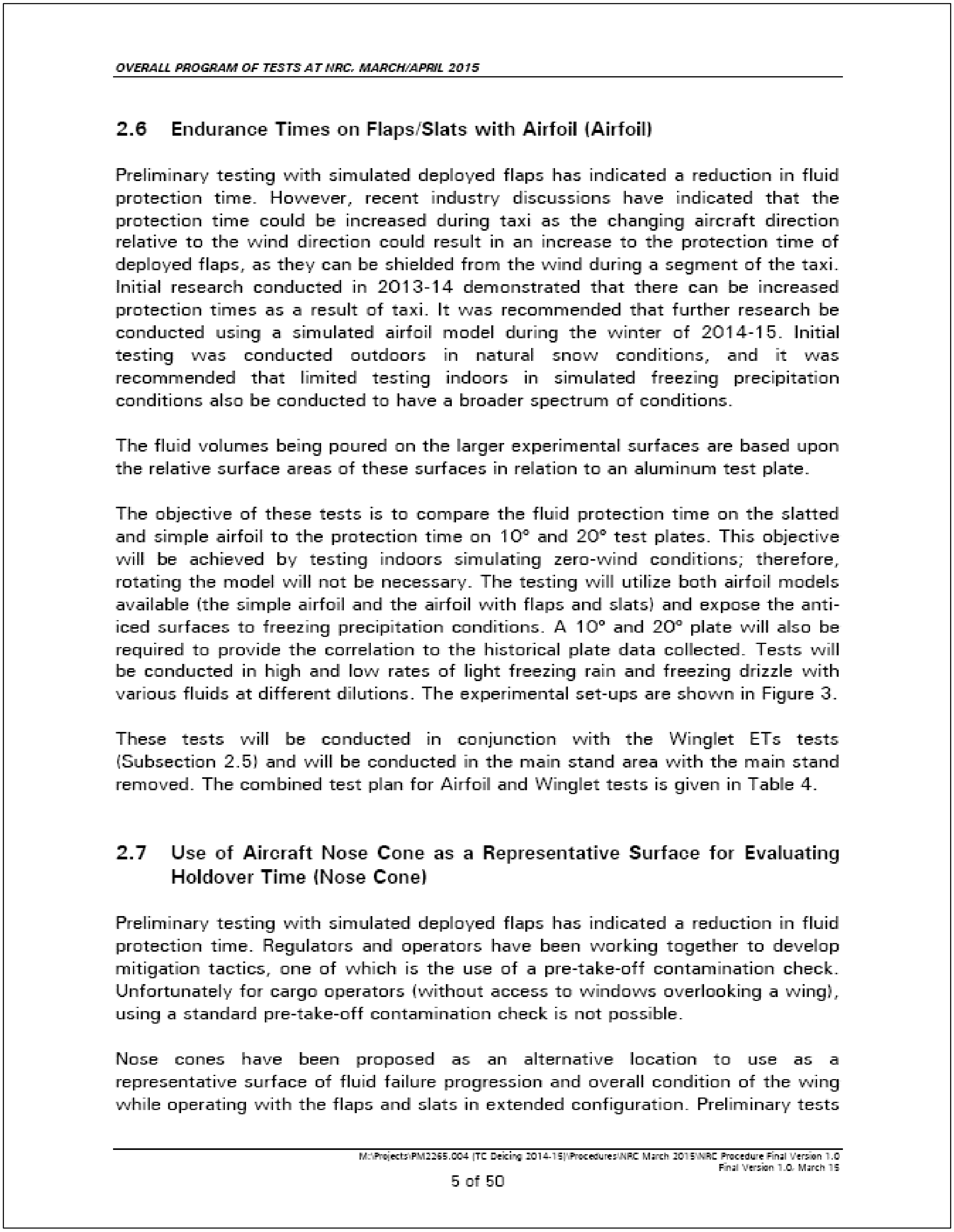
A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The projects that will be carried out at the March/April 2015 NRC test session are listed in this section. Each project has been given a shortened name (shown in brackets following full title) which is used in subsequent sections of this document. A description of each project, its objective and its test procedure are provided. The test procedures for several projects are provided in separate detailed documents, which are referenced in the appropriate subsection and listed in Section 9.

General comments on procedures and setup:

- Endurance time tests will be carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type II, III, and IV* (1) and ARP 5945, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type I* (2), except as noted.
- There will be two test stands positioned under the sprayer (main stand with two 6-position stands and side stand with one 3-position stand) and a third stand that will be positioned outside the spray area in the small area of the climate chamber. The test stands should be situated in the cold chamber as per the measurements provided in Figure 2.
- A complex rate management program was developed in the early 2000s to assist in managing the measurement of precipitation rates. An update to the interface of this program was finalized in 2014. This program will be used. A guide to the rate management program is available to help with training of new rate station managers.



2.6 Endurance Times on Flaps/Slats with Airfoil (Airfoil)

Preliminary testing with simulated deployed flaps has indicated a reduction in fluid protection time. However, recent industry discussions have indicated that the protection time could be increased during taxi as the changing aircraft direction relative to the wind direction could result in an increase to the protection time of deployed flaps, as they can be shielded from the wind during a segment of the taxi. Initial research conducted in 2013-14 demonstrated that there can be increased protection times as a result of taxi. It was recommended that further research be conducted using a simulated airfoil model during the winter of 2014-15. Initial testing was conducted outdoors in natural snow conditions, and it was recommended that limited testing indoors in simulated freezing precipitation conditions also be conducted to have a broader spectrum of conditions.

The fluid volumes being poured on the larger experimental surfaces are based upon the relative surface areas of these surfaces in relation to an aluminum test plate.

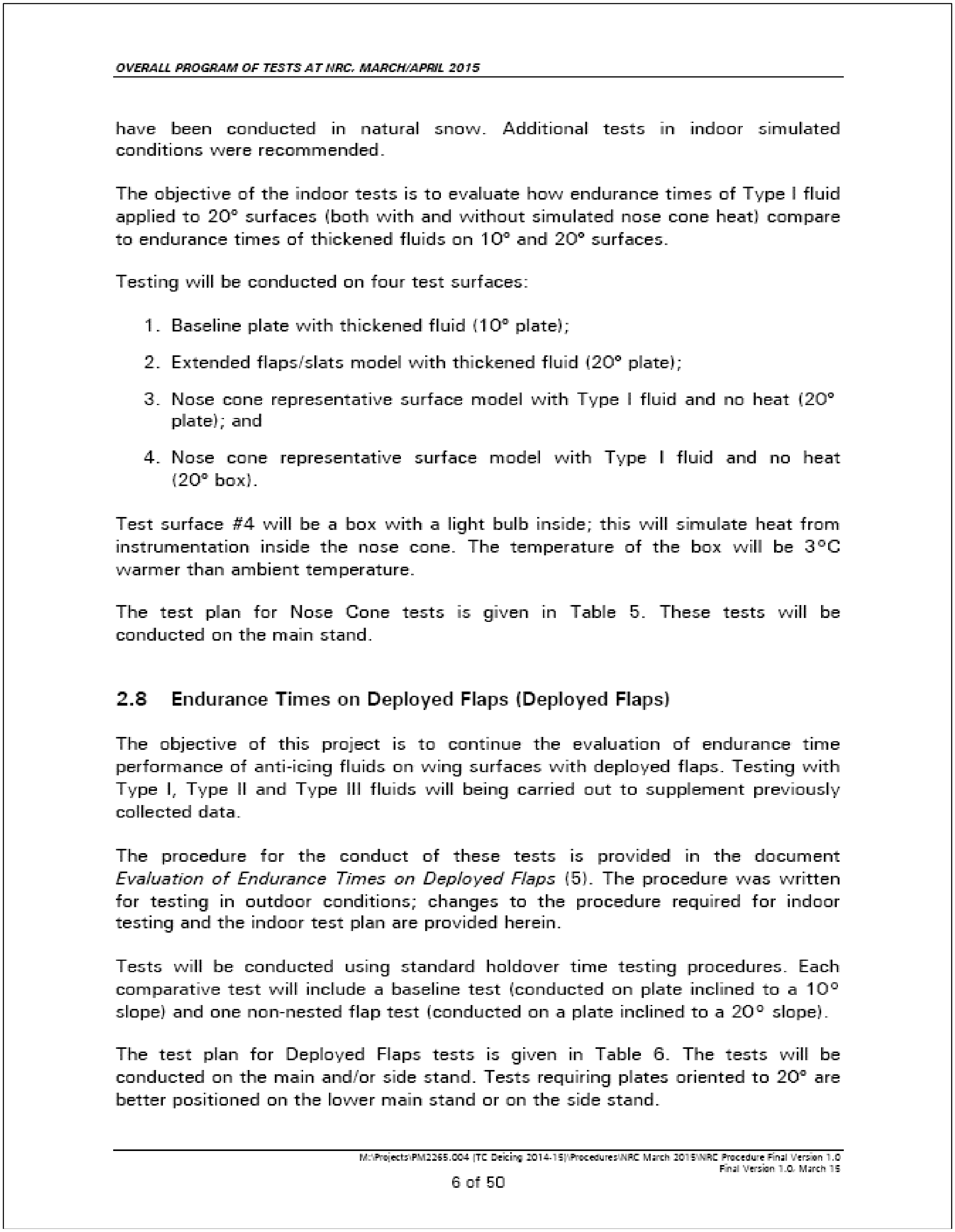
The objective of these tests is to compare the fluid protection time on the slatted and simple airfoil to the protection time on 10° and 20° test plates. This objective will be achieved by testing indoors simulating zero-wind conditions; therefore, rotating the model will not be necessary. The testing will utilize both airfoil models available (the simple airfoil and the airfoil with flaps and slats) and expose the anti-iced surfaces to freezing precipitation conditions. A 10° and 20° plate will also be required to provide the correlation to the historical plate data collected. Tests will be conducted in high and low rates of light freezing rain and freezing drizzle with various fluids at different dilutions. The experimental set-ups are shown in Figure 3.

These tests will be conducted in conjunction with the Winglet ETs tests (Subsection 2.5) and will be conducted in the main stand area with the main stand removed. The combined test plan for Airfoil and Winglet tests is given in Table 4.

2.7 Use of Aircraft Nose Cone as a Representative Surface for Evaluating Holdover Time (Nose Cone)

Preliminary testing with simulated deployed flaps has indicated a reduction in fluid protection time. Regulators and operators have been working together to develop mitigation tactics, one of which is the use of a pre-take-off contamination check. Unfortunately for cargo operators (without access to windows overlooking a wing), using a standard pre-take-off contamination check is not possible.

Nose cones have been proposed as an alternative location to use as a representative surface of fluid failure progression and overall condition of the wing while operating with the flaps and slats in extended configuration. Preliminary tests



have been conducted in natural snow. Additional tests in indoor simulated conditions were recommended.

The objective of the indoor tests is to evaluate how endurance times of Type I fluid applied to 20° surfaces (both with and without simulated nose cone heat) compare to endurance times of thickened fluids on 10° and 20° surfaces.

Testing will be conducted on four test surfaces:

1. Baseline plate with thickened fluid (10° plate);
2. Extended flaps/slats model with thickened fluid (20° plate);
3. Nose cone representative surface model with Type I fluid and no heat (20° plate); and
4. Nose cone representative surface model with Type I fluid and no heat (20° box).

Test surface #4 will be a box with a light bulb inside; this will simulate heat from instrumentation inside the nose cone. The temperature of the box will be 3°C warmer than ambient temperature.

The test plan for Nose Cone tests is given in Table 5. These tests will be conducted on the main stand.

2.8 Endurance Times on Deployed Flaps (Deployed Flaps)

The objective of this project is to continue the evaluation of endurance time performance of anti-icing fluids on wing surfaces with deployed flaps. Testing with Type I, Type II and Type III fluids will being carried out to supplement previously collected data.

The procedure for the conduct of these tests is provided in the document *Evaluation of Endurance Times on Deployed Flaps* (5). The procedure was written for testing in outdoor conditions; changes to the procedure required for indoor testing and the indoor test plan are provided herein.

Tests will be conducted using standard holdover time testing procedures. Each comparative test will include a baseline test (conducted on plate inclined to a 10° slope) and one non-nested flap test (conducted on a plate inclined to a 20° slope).

The test plan for Deployed Flaps tests is given in Table 6. The tests will be conducted on the main and/or side stand. Tests requiring plates oriented to 20° are better positioned on the lower main stand or on the side stand.

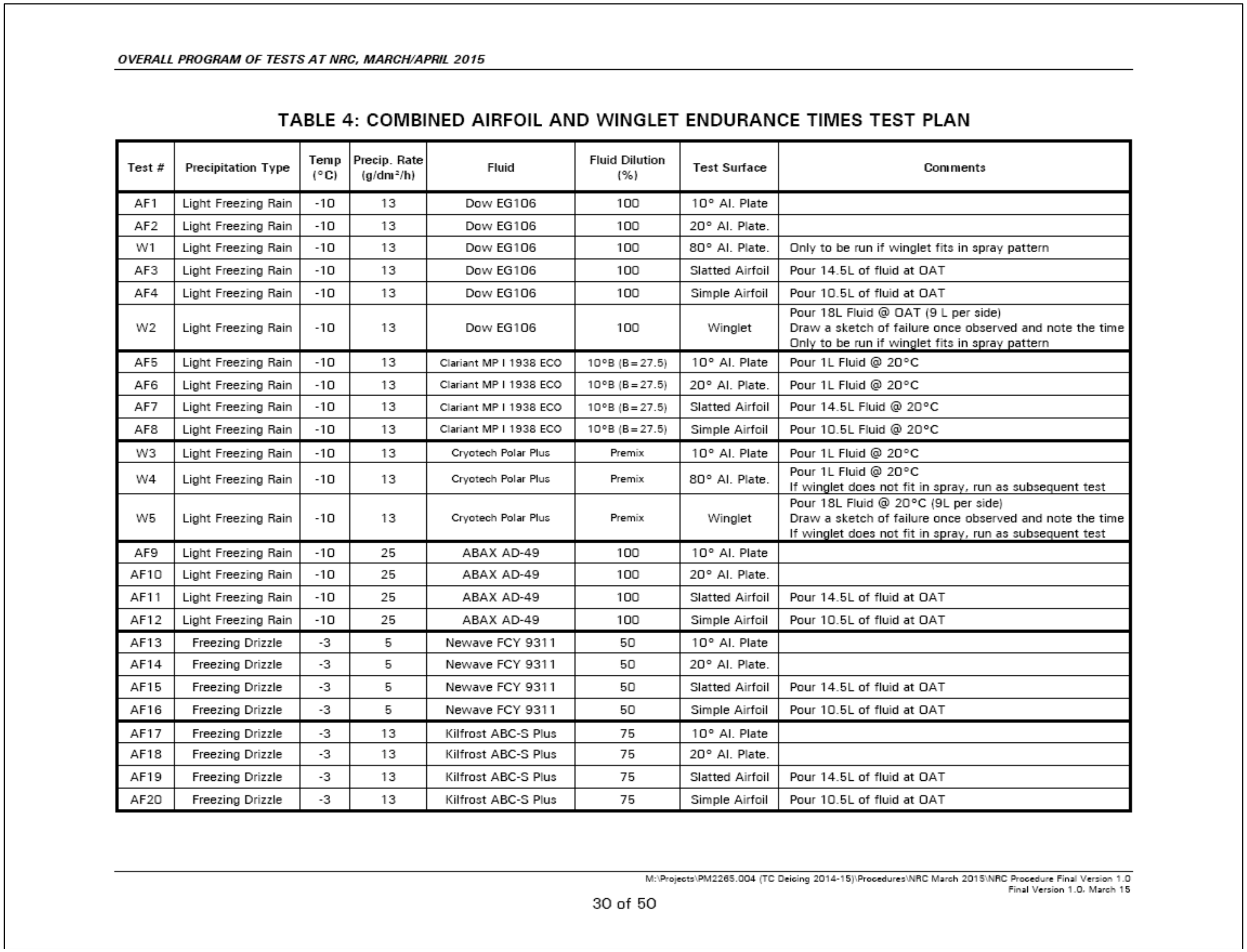


TABLE 4: COMBINED AIRFOIL AND WINGLET ENDURANCE TIMES TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm^2/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
AF1	Light Freezing Rain	-10	13	Dow EG106	100	10° Al. Plate	
AF2	Light Freezing Rain	-10	13	Dow EG106	100	20° Al. Plate.	
W1	Light Freezing Rain	-10	13	Dow EG106	100	80° Al. Plate.	Only to be run if winglet fits in spray pattern
AF3	Light Freezing Rain	-10	13	Dow EG106	100	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF4	Light Freezing Rain	-10	13	Dow EG106	100	Simple Airfoil	Pour 10.5L of fluid at OAT
W2	Light Freezing Rain	-10	13	Dow EG106	100	Winglet	Pour 18L Fluid @ OAT (9 L per side) Draw a sketch of failure once observed and note the time Only to be run if winglet fits in spray pattern
AF5	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	10° Al. Plate	Pour 1L Fluid @ 20°C
AF6	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	20° Al. Plate.	Pour 1L Fluid @ 20°C
AF7	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	Slatted Airfoil	Pour 14.5L Fluid @ 20°C
AF8	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	Simple Airfoil	Pour 10.5L Fluid @ 20°C
W3	Light Freezing Rain	-10	13	Cryotech Polar Plus	Premix	10° Al. Plate	Pour 1L Fluid @ 20°C
W4	Light Freezing Rain	-10	13	Cryotech Polar Plus	Premix	80° Al. Plate.	Pour 1L Fluid @ 20°C If winglet does not fit in spray, run as subsequent test
W5	Light Freezing Rain	-10	13	Cryotech Polar Plus	Premix	Winglet	Pour 18L Fluid @ 20°C (9L per side) Draw a sketch of failure once observed and note the time If winglet does not fit in spray, run as subsequent test
AF9	Light Freezing Rain	-10	25	ABAX AD-49	100	10° Al. Plate	
AF10	Light Freezing Rain	-10	25	ABAX AD-49	100	20° Al. Plate.	
AF11	Light Freezing Rain	-10	25	ABAX AD-49	100	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF12	Light Freezing Rain	-10	25	ABAX AD-49	100	Simple Airfoil	Pour 10.5L of fluid at OAT
AF13	Freezing Drizzle	-3	5	Newave FCY 9311	50	10° Al. Plate	
AF14	Freezing Drizzle	-3	5	Newave FCY 9311	50	20° Al. Plate.	
AF15	Freezing Drizzle	-3	5	Newave FCY 9311	50	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF16	Freezing Drizzle	-3	5	Newave FCY 9311	50	Simple Airfoil	Pour 10.5L of fluid at OAT
AF17	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	10° Al. Plate	
AF18	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	20° Al. Plate.	
AF19	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF20	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	Simple Airfoil	Pour 10.5L of fluid at OAT

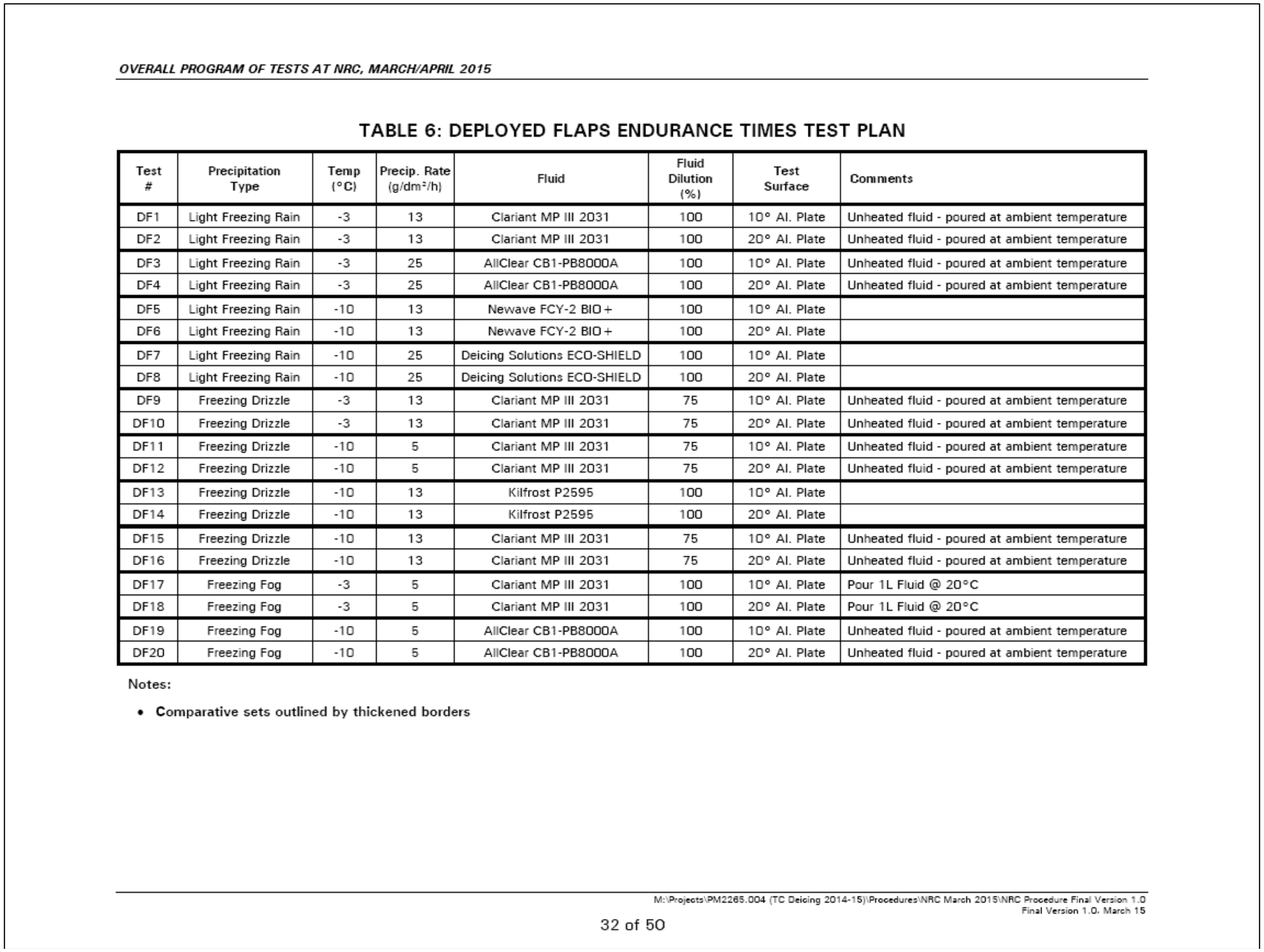


TABLE 6: DEPLOYED FLAPS ENDURANCE TIMES TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
DF1	Light Freezing Rain	-3	13	Clariant MP III 2031	100	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF2	Light Freezing Rain	-3	13	Clariant MP III 2031	100	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF3	Light Freezing Rain	-3	25	AllClear CB1-PB8000A	100	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF4	Light Freezing Rain	-3	25	AllClear CB1-PB8000A	100	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF5	Light Freezing Rain	-10	13	Newave FCY-2 BIO+	100	10° Al. Plate	
DF6	Light Freezing Rain	-10	13	Newave FCY-2 BIO+	100	20° Al. Plate	
DF7	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	10° Al. Plate	
DF8	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	20° Al. Plate	
DF9	Freezing Drizzle	-3	13	Clariant MP III 2031	75	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF10	Freezing Drizzle	-3	13	Clariant MP III 2031	75	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF11	Freezing Drizzle	-10	5	Clariant MP III 2031	75	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF12	Freezing Drizzle	-10	5	Clariant MP III 2031	75	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF13	Freezing Drizzle	-10	13	Kilfrost P2595	100	10° Al. Plate	
DF14	Freezing Drizzle	-10	13	Kilfrost P2595	100	20° Al. Plate	
DF15	Freezing Drizzle	-10	13	Clariant MP III 2031	75	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF16	Freezing Drizzle	-10	13	Clariant MP III 2031	75	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF17	Freezing Fog	-3	5	Clariant MP III 2031	100	10° Al. Plate	Pour 1L Fluid @ 20°C
DF18	Freezing Fog	-3	5	Clariant MP III 2031	100	20° Al. Plate	Pour 1L Fluid @ 20°C
DF19	Freezing Fog	-10	5	AllClear CB1-PB8000A	100	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF20	Freezing Fog	-10	5	AllClear CB1-PB8000A	100	20° Al. Plate	Unheated fluid - poured at ambient temperature

Notes:

- **Comparative sets outlined by thickened borders**

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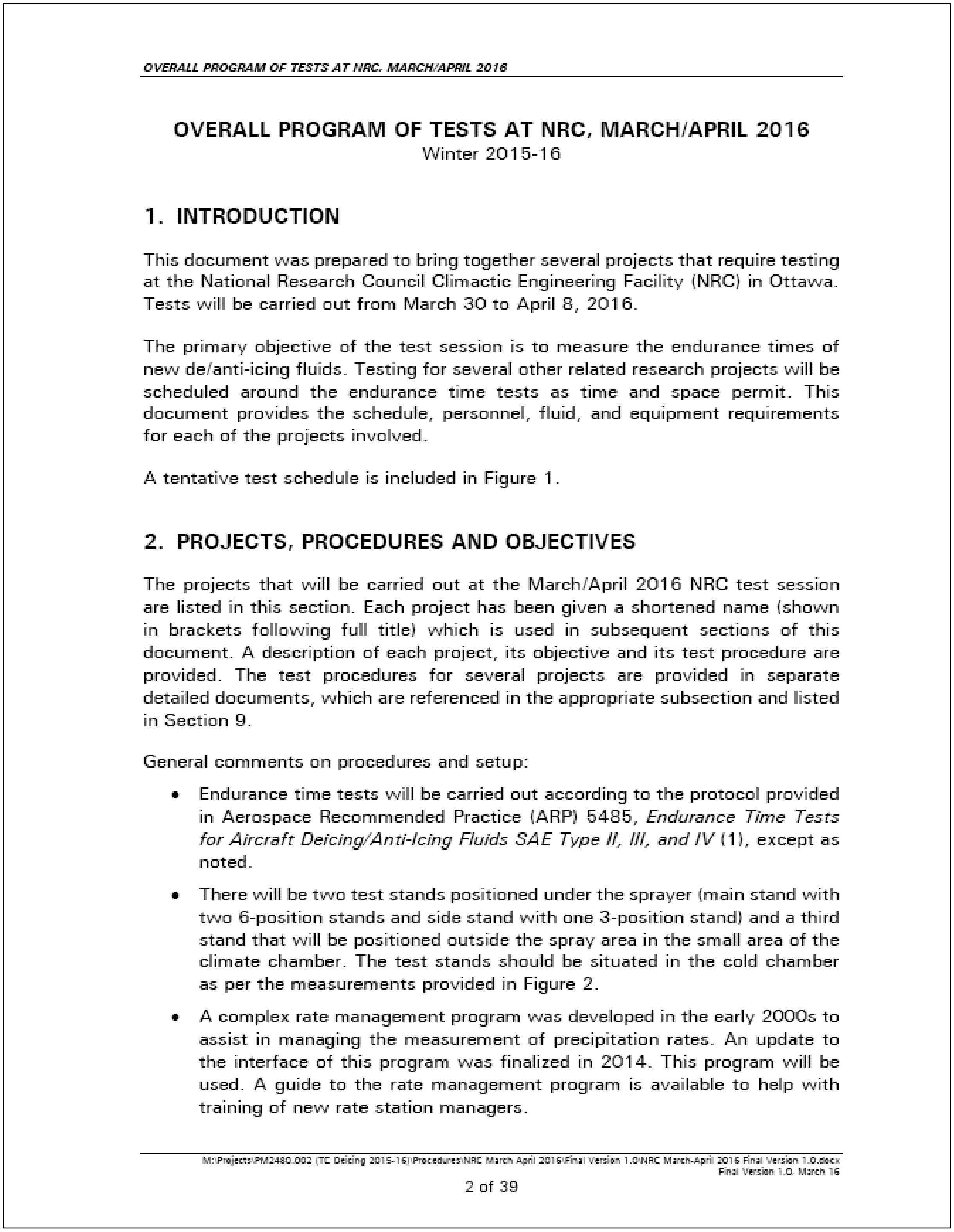
EXCERPT FROM: OVERALL PROGRAM OF TESTS AT NRC,
MARCH/APRIL 2016
WINTER 2015-16

(MARCH 29, 2016 – FINAL VERSION 1.0)



OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2016

Winter 2015-16

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from March 30 to April 8, 2016.

The primary objective of the test session is to measure the endurance times of new de/anti-icing fluids. Testing for several other related research projects will be scheduled around the endurance time tests as time and space permit. This document provides the schedule, personnel, fluid, and equipment requirements for each of the projects involved.

A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The projects that will be carried out at the March/April 2016 NRC test session are listed in this section. Each project has been given a shortened name (shown in brackets following full title) which is used in subsequent sections of this document. A description of each project, its objective and its test procedure are provided. The test procedures for several projects are provided in separate detailed documents, which are referenced in the appropriate subsection and listed in Section 9.

General comments on procedures and setup:

- Endurance time tests will be carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type II, III, and IV* (1), except as noted.
- There will be two test stands positioned under the sprayer (main stand with two 6-position stands and side stand with one 3-position stand) and a third stand that will be positioned outside the spray area in the small area of the climate chamber. The test stands should be situated in the cold chamber as per the measurements provided in Figure 2.
- A complex rate management program was developed in the early 2000s to assist in managing the measurement of precipitation rates. An update to the interface of this program was finalized in 2014. This program will be used. A guide to the rate management program is available to help with training of new rate station managers.

The procedure for conducting endurance time tests is given in the document *Test Requirements for Simulated Freezing Precipitation Flat Plate Testing* (2).

The Type III tests are included in the New Fluid ETs test plan in Table 1. All tests will be conducted on the main test stand.

2.3 Thickness of New Fluids (ET Thickness)

The objective of these tests is to measure the thickness of new fluids on flat plates. The procedure for these tests is entitled *Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates* (3) and can be found in Transport Canada Report TP 13991E, Appendix I. All tests will be conducted with fluid at -3°C.

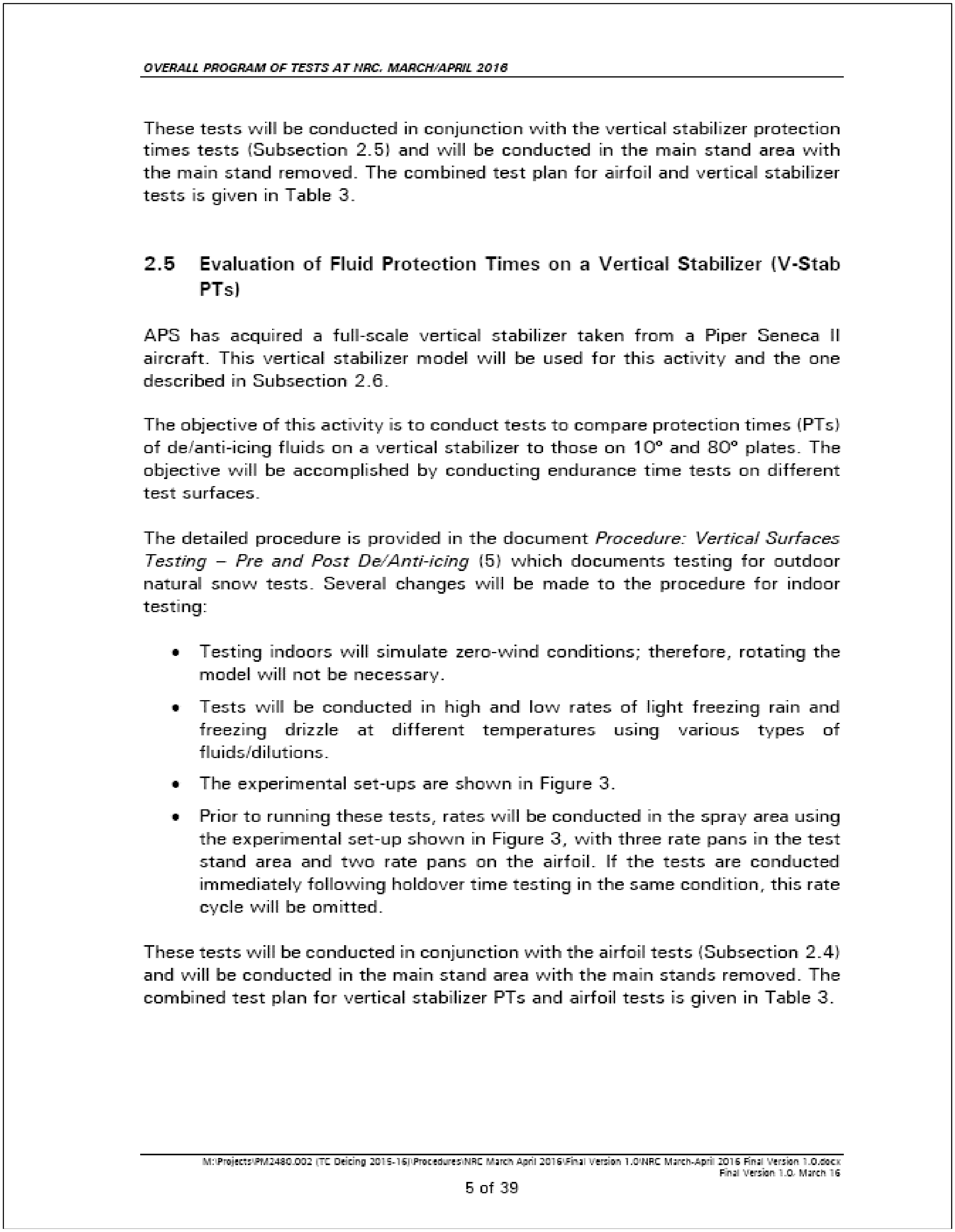
The test plan for Fluid Thickness tests is given in Table 2. The tests will be conducted at the small end of the chamber outside of the spray area.

2.4 Endurance Times on Airfoil with Flaps/Slats (Airfoil)

The objective of these tests is to compare endurance times on an airfoil with flaps/slats to endurance times on 10° and 20° test plates.

The procedure for these tests is provided in the document *Evaluation of Endurance Times on Deployed Flaps/Slats – Natural Snow, Addendum for Additional Airfoil Testing* (4), which documents testing for outdoor natural snow tests. Several changes will be made to the procedure for indoor testing:

- Testing indoors will simulate zero-wind conditions; therefore, rotating the model will not be necessary.
- Tests will be conducted in high and low rates of light freezing rain and freezing drizzle at different temperatures using various types of fluids/dilutions.
- The experimental set-ups are shown in Figure 3.
- Prior to running these tests, rates will be conducted in the spray area using the experimental set-up shown in Figure 3, with three rate pans in the test stand area and two rate pans on the airfoil. If the tests are conducted immediately following holdover time testing in the same condition, this rate cycle will be omitted.



These tests will be conducted in conjunction with the vertical stabilizer protection times tests (Subsection 2.5) and will be conducted in the main stand area with the main stand removed. The combined test plan for airfoil and vertical stabilizer tests is given in Table 3.

2.5 Evaluation of Fluid Protection Times on a Vertical Stabilizer (V-Stab PTs)

APS has acquired a full-scale vertical stabilizer taken from a Piper Seneca II aircraft. This vertical stabilizer model will be used for this activity and the one described in Subsection 2.6.

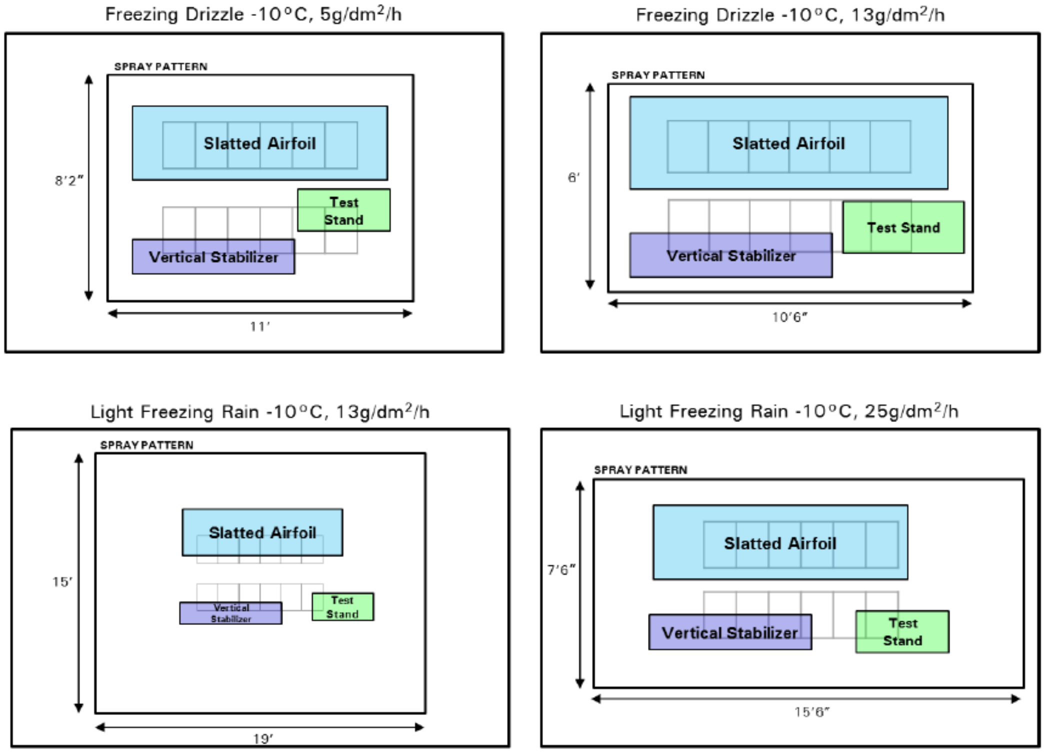
The objective of this activity is to conduct tests to compare protection times (PTs) of de/anti-icing fluids on a vertical stabilizer to those on 10° and 80° plates. The objective will be accomplished by conducting endurance time tests on different test surfaces.

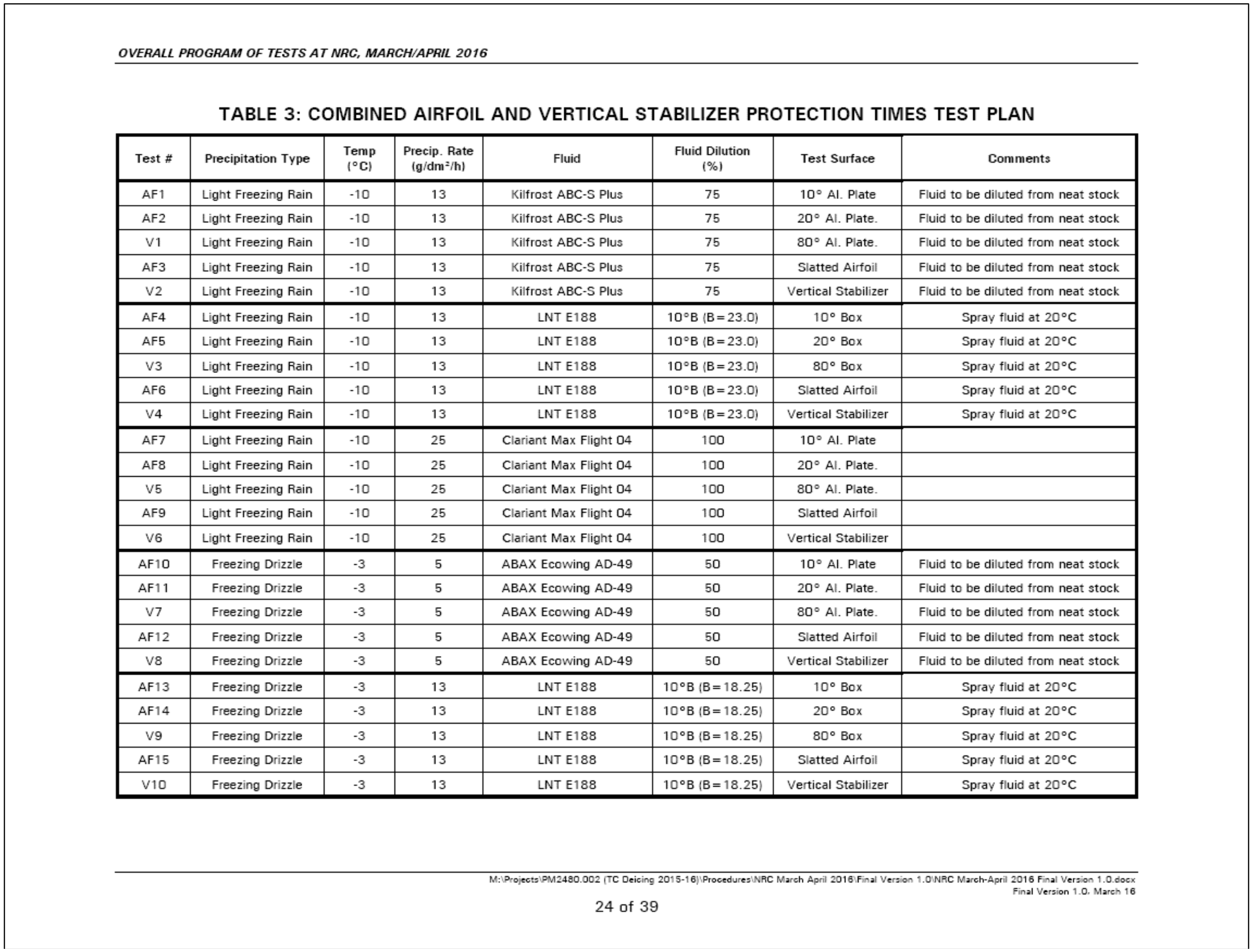
The detailed procedure is provided in the document *Procedure: Vertical Surfaces Testing – Pre and Post De/Anti-icing* (5) which documents testing for outdoor natural snow tests. Several changes will be made to the procedure for indoor testing:

- Testing indoors will simulate zero-wind conditions; therefore, rotating the model will not be necessary.
- Tests will be conducted in high and low rates of light freezing rain and freezing drizzle at different temperatures using various types of fluids/dilutions.
- The experimental set-ups are shown in Figure 3.
- Prior to running these tests, rates will be conducted in the spray area using the experimental set-up shown in Figure 3, with three rate pans in the test stand area and two rate pans on the airfoil. If the tests are conducted immediately following holdover time testing in the same condition, this rate cycle will be omitted.

These tests will be conducted in conjunction with the airfoil tests (Subsection 2.4) and will be conducted in the main stand area with the main stands removed. The combined test plan for vertical stabilizer PTs and airfoil tests is given in Table 3.

FIGURE 3: COMBINED AIRFOIL AND WINGLET EXPERIMENTAL SET-UPS





OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2016

TABLE 3: COMBINED AIRFOIL AND VERTICAL STABILIZER PROTECTION TIMES TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid	Fluid Dilution (%)	Test Surface	Comments
AF1	Light Freezing Rain	-10	13	Kilfrost ABC-S Plus	75	10° Al. Plate	Fluid to be diluted from neat stock
AF2	Light Freezing Rain	-10	13	Kilfrost ABC-S Plus	75	20° Al. Plate.	Fluid to be diluted from neat stock
V1	Light Freezing Rain	-10	13	Kilfrost ABC-S Plus	75	80° Al. Plate.	Fluid to be diluted from neat stock
AF3	Light Freezing Rain	-10	13	Kilfrost ABC-S Plus	75	Slatted Airfoil	Fluid to be diluted from neat stock
V2	Light Freezing Rain	-10	13	Kilfrost ABC-S Plus	75	Vertical Stabilizer	Fluid to be diluted from neat stock
AF4	Light Freezing Rain	-10	13	LNT E188	10°B (B=23.0)	10° Box	Spray fluid at 20°C
AF5	Light Freezing Rain	-10	13	LNT E188	10°B (B=23.0)	20° Box	Spray fluid at 20°C
V3	Light Freezing Rain	-10	13	LNT E188	10°B (B=23.0)	80° Box	Spray fluid at 20°C
AF6	Light Freezing Rain	-10	13	LNT E188	10°B (B=23.0)	Slatted Airfoil	Spray fluid at 20°C
V4	Light Freezing Rain	-10	13	LNT E188	10°B (B=23.0)	Vertical Stabilizer	Spray fluid at 20°C
AF7	Light Freezing Rain	-10	25	Clariant Max Flight 04	100	10° Al. Plate	
AF8	Light Freezing Rain	-10	25	Clariant Max Flight 04	100	20° Al. Plate.	
V5	Light Freezing Rain	-10	25	Clariant Max Flight 04	100	80° Al. Plate.	
AF9	Light Freezing Rain	-10	25	Clariant Max Flight 04	100	Slatted Airfoil	
V6	Light Freezing Rain	-10	25	Clariant Max Flight 04	100	Vertical Stabilizer	
AF10	Freezing Drizzle	-3	5	ABAX Ecowing AD-49	50	10° Al. Plate	Fluid to be diluted from neat stock
AF11	Freezing Drizzle	-3	5	ABAX Ecowing AD-49	50	20° Al. Plate.	Fluid to be diluted from neat stock
V7	Freezing Drizzle	-3	5	ABAX Ecowing AD-49	50	80° Al. Plate.	Fluid to be diluted from neat stock
AF12	Freezing Drizzle	-3	5	ABAX Ecowing AD-49	50	Slatted Airfoil	Fluid to be diluted from neat stock
V8	Freezing Drizzle	-3	5	ABAX Ecowing AD-49	50	Vertical Stabilizer	Fluid to be diluted from neat stock
AF13	Freezing Drizzle	-3	13	LNT E188	10°B (B=18.25)	10° Box	Spray fluid at 20°C
AF14	Freezing Drizzle	-3	13	LNT E188	10°B (B=18.25)	20° Box	Spray fluid at 20°C
V9	Freezing Drizzle	-3	13	LNT E188	10°B (B=18.25)	80° Box	Spray fluid at 20°C
AF15	Freezing Drizzle	-3	13	LNT E188	10°B (B=18.25)	Slatted Airfoil	Spray fluid at 20°C
V10	Freezing Drizzle	-3	13	LNT E188	10°B (B=18.25)	Vertical Stabilizer	Spray fluid at 20°C

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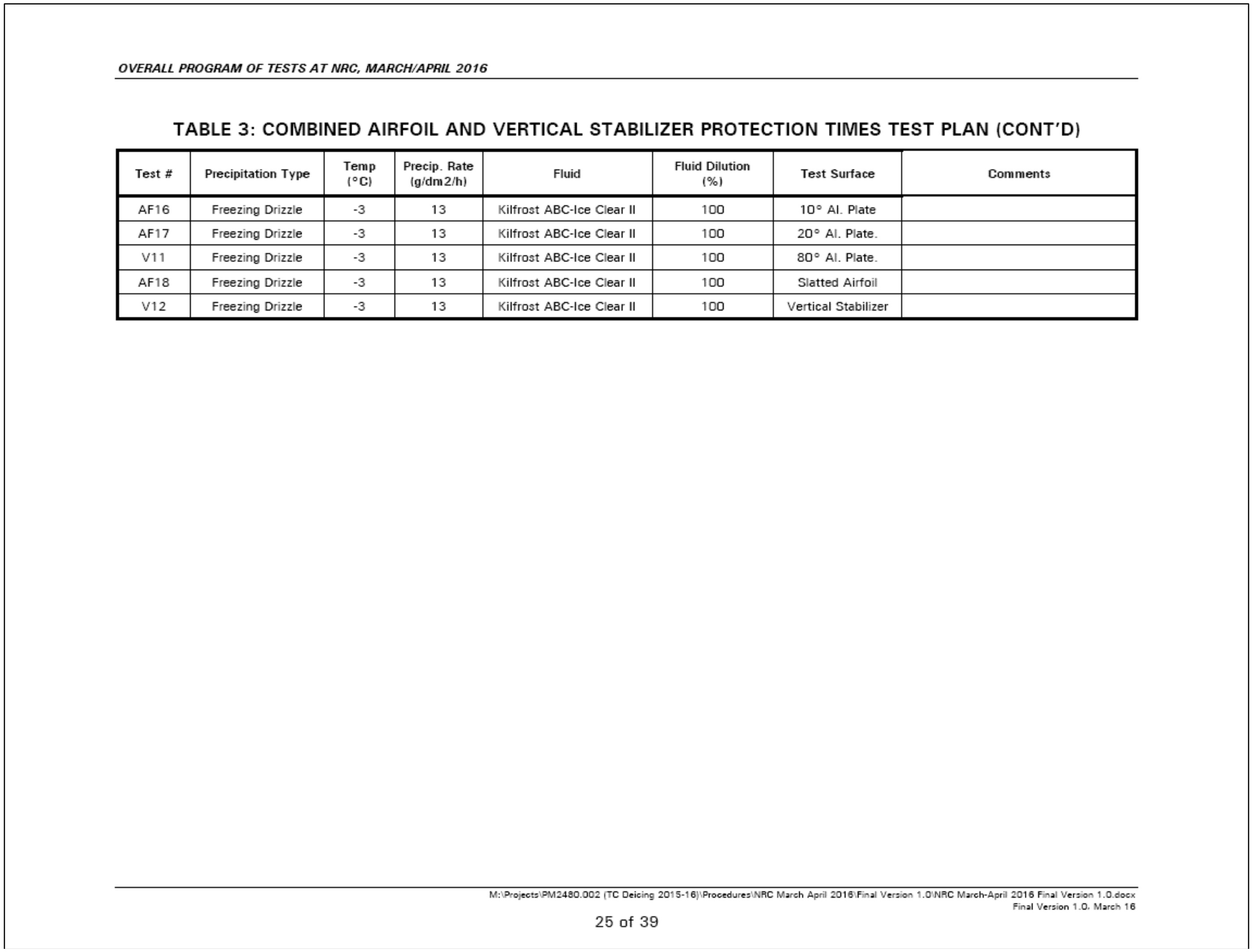

OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2016

TABLE 3: COMBINED AIRFOIL AND VERTICAL STABILIZER PROTECTION TIMES TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm2/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
AF16	Freezing Drizzle	-3	13	Kilfrost ABC-Ice Clear II	100	10° Al. Plate	
AF17	Freezing Drizzle	-3	13	Kilfrost ABC-Ice Clear II	100	20° Al. Plate.	
V11	Freezing Drizzle	-3	13	Kilfrost ABC-Ice Clear II	100	80° Al. Plate.	
AF18	Freezing Drizzle	-3	13	Kilfrost ABC-Ice Clear II	100	Slatted Airfoil	
V12	Freezing Drizzle	-3	13	Kilfrost ABC-Ice Clear II	100	Vertical Stabilizer	

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APPENDIX D

EXPERIMENTAL PROGRAM
FOR FULL-SCALE AIRCRAFT TESTING –
FLUID FAILURE ON DEPLOYED FLAPS AND SLATS

CM2480.002

EXPERIMENTAL PROGRAM
FOR FULL-SCALE AIRCRAFT TESTING –
FLUID FAILURE ON DEPLOYED FLAPS AND SLATS

Winter 2015-16

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

And

John D'Avirro

Reviewed by: John D'Avirro

APS Aviation Inc.

October, 2015
Final Version 4.0

EXPERIMENTAL PROGRAM
FOR FULL-SCALE AIRCRAFT TESTING –
FLUID FAILURE ON DEPLOYED FLAPS AND SLATS

Winter 2015-16

Initial testing was conducted at Mirabel Airport on four occasions during the winter of 2011-12 and 2012-13. An additional test occasion was completed with an associated project in Albany N.Y. where comparative wing data was collected with two aircraft simultaneously.

Based on the current data, the 20º plate (compared to the 10º baseline plate) has a closer correlation to the wing configured with the flaps and slats extended. Data also appears to indicate a potential fluid endurance time reduction on the higher inclined plates, and on extended flaps and slats; this reduction may be less for Type I fluids as compared to Type II, III, and IV fluids.

Some additional work with different aircraft orientations with respect to wind and different configurations is required to complement the findings to date. Due to lack of appropriate testing conditions during the operational windows, testing was not possible during the winters of 2013-14 and 2014-15. For winter 2015-16, it is anticipated that an additional two to four sessions will be conducted at Mirabel. In addition, for 2015-16 testing plans has also been coordinated with Air Canada at YUL in order to increase the chances of collecting the necessary data to complete this research.

This document provides an update to the previously published procedure for Winter 2013-14 (Version 3.0).

Anti-icing fluid applied to a wing with deployed flaps and slats can quickly flow off, resulting in a reduced fluid thickness layer, and consequently may shorten fluid holdover times (see Figure 1.1). During the winter of 2010-11 both the Federal Aviation Administration (FAA) and Transport Canada (TC) provided guidance to operators for de/anti-icing with deployed flaps. The industry expressed concern with the applicability of the issue to different wing configurations and requested a full-scale validation with operational aircraft. Also there was concern that a change in operating procedures (deploying flaps just prior to take-off as a mitigation tactic) could impact the safety of operations.

Since 2011-12, work has been conducted with industry support, primarily from UPS, SWA (through a separate project) and more recently from Air Canada, to correlate the flat plate results to full-scale aircraft wings. UPS and Air Canada has volunteered to participate in the trials and provide support through the availability of aircraft, ground equipment, and facilities to demonstrate the fluid failure trends on the flap and slat surfaces of their A-300 and E190 fleet respectively. For UPS, the YMX gateway will be used as the test location for the research to be conducted to reduce costs, facilitate logistics due to the equipment required to document the test, and to minimize safety concerns for personnel required to document the tests. For Air Canada, the YUL CDF operated by Aéromag 2000 will used as the test location.

This document provides the detailed procedures and equipment required for the conduct of full-scale fluid failure testing for the 2015-16 winter season.

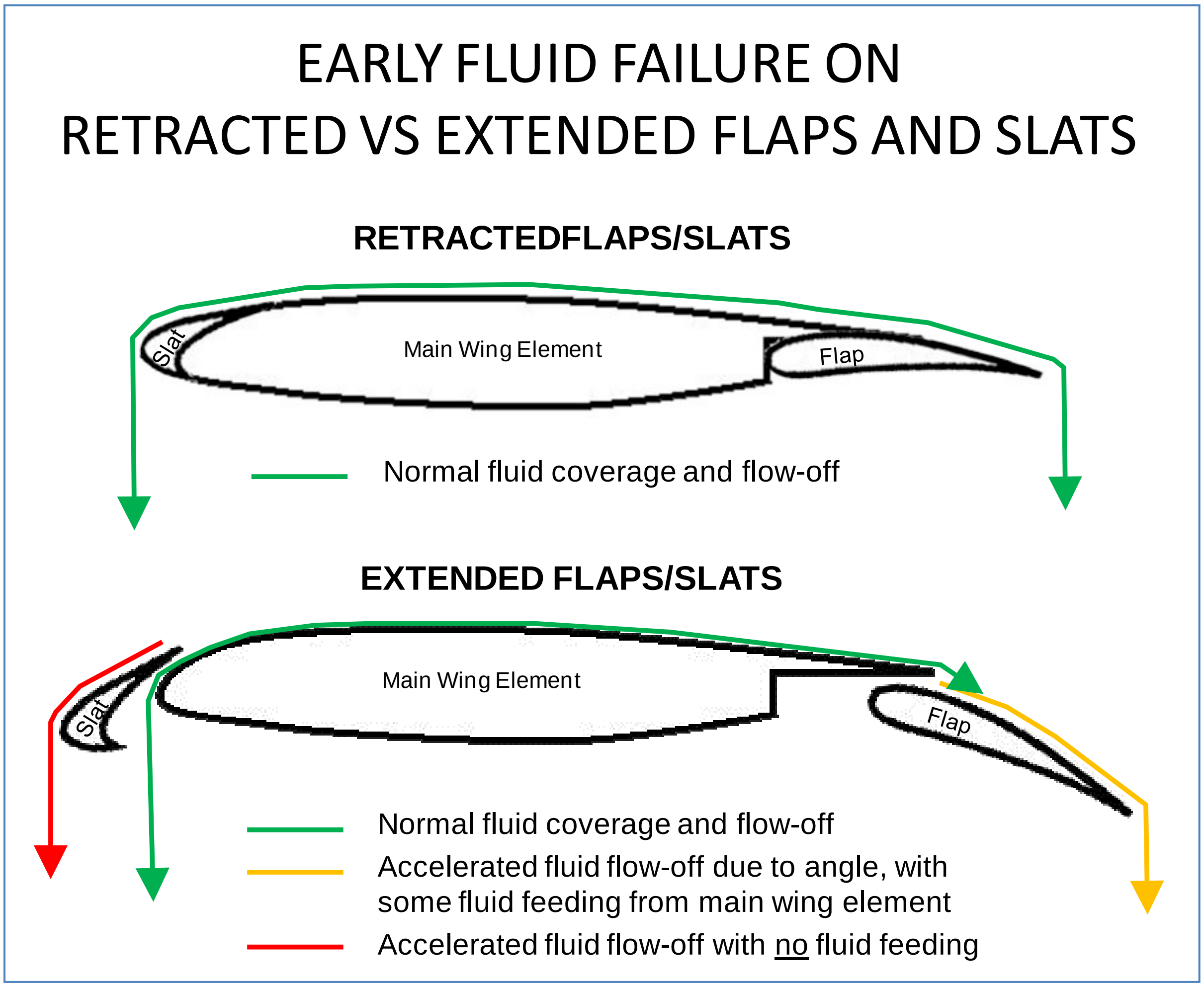


Figure 1.1: Fluid Failure Progression on Flaps and Slats

1. PURPOSE OF TESTS

1.1 Objectives

- To observe anti-icing fluid failure characteristics on aircraft flaps and slats under conditions of winter precipitation and simultaneously observe fluid failure behaviour on aircraft wings; and
- To compare the performance of de/anti-icing fluids on aircraft surfaces (flaps, slats, and main wing) with the performance of de/anti-icing fluids on flat plates mounted at 10°, 15°, 20°, and 35° to the horizontal and possibly with a smaller-scale airfoil equipped with a flap and/or slat. The determination of 20° and 35° the flat plates was based upon an analysis of various flaps in commercial service and provide a reasonable representation.

1.2 Applications

- To determine the fluid failure times on the aircraft flaps and slats when set in take-off (extended) position in various natural precipitation conditions as compared to the main wing section; and
- To observe the failure propagation on the flat plates inclined at different angles and to correlate the results to the failure observed on the aircraft surfaces and, if available, to the small-scale airfoil.

2. AIRCRAFT, TEST LOCALE, AND TEST SET-UP

2.1 UPS Supported Testing

Aircraft:	Airbus A-300, and other aircraft, if available.
Location:	Mirabel (YMX) International Airport, Montreal
	Access to UPS: 11955 Rue Henry Giffard, Mirabel Airport (YMX), Mirabel, QC J7N 1G3 GPS: 45.675861,-74.04651 Entrance is to the right of main entrance. Look for UPS sign above door.
Site Amenities:	Internet not available; small office to keep warm; no food or restaurants close by but possibly order in food.
Test Set-up:	

- Aircraft out-of-service, typically daytime tests based on predicted precipitation;

- Aircraft parked at pre-determined orientation based on wind direction prior to start of test. Re-orientation may be required during each test session; and
- De/anti-icing to be performed by AéroMag 2000 Inc.

2.2 Air Canada Supported Testing

Aircraft:	Embraer E190, Airbus A 319, or other Airbus aircraft if available.
Location:	P.E.T (YUL) International Airport, Montreal Central Deicing Facility Operated by Aéromag 2000 Access to Aéromag 2000: 8191 Rue Hervé Saint Martin, Saint-Laurent, QC H4S 2A5 Entrance is through Aéromag 2000. Look for Aéromag 2000 sign above door.
Site Amenities:	Internet not available; small office to keep warm; small vending machine, food or restaurants within short drive, can possibly order in food.

Test Set-up:

- Aircraft out-of-service, typically overnight tests based on predicted precipitation;
- Preference is to have Air Canada tow aircraft to the Aéromag 2000 deicing pad before test time and be ready to go as of 12:00 AM;
- The aircraft will be parked at pre-determined orientation based on wind direction prior to start of test. Re-orientation may be required during each test session;
- A GPU provided by Air Canada will be required to position the aircraft flaps/slats; and
- De/anti-icing to be performed by AéroMag 2000 Inc.

3. TEST PROGRAM

As testing has been ongoing over several years, the plan has changed to reflect the data collected. The first version of the test plan is included as Attachment I. Session 1 and Session 2 of Winter 2011-12 were essentially completed. A revised test plan was issued for Winter 2012-13, a portion of which was completed (see Attachment II). A second revised test plan was issued for the 2013-14 winter season based on the outstanding tests, and revised testing objectives (see Attachment III). Due to lack of testing in 2013-14, the same procedure was used for the winter of 2014-15 as the objectives (see Attachment III) had not changed. A new test plan has now been issued for the winter of 2015-16 to reflect the current testing objectives (see Attachment IV). It is anticipated that testing will be conducted on a minimum of 2 occasions with 2-3 tests per session. There may be an additional session required based on quality of data collected.

A matrix of tests is anticipated based on:

- Headwind and tailwind orientation tests and limited retracted wing configuration will be planned for Winter 2015-16;
- Application of Deicing, and De/Anti-icing fluids; and
- Snow, freezing drizzle or light freezing rain precipitation.

Test Period (nominal):

- UPS Supported Testing
  - November 9, 2015 to April 29, 2016;
  - Blackout periods: November 26-27, 2015 and December 8, 2015 to January 4, 2016;
  - No tests on Saturdays, Sundays, or Mondays unless by prior agreement; and
  - Test period is Tuesdays-Fridays 9:00 AM to 4:00 PM.

- Air Canada Supported Testing
  - November 9, 2015 to April 29, 2016;
  - Blackout period from December 10, 2015 to January 10, 2016;
  - Testing on Saturdays is not recommended due to high traffic and associated potential for delayed start of testing; and
  - Test period is Sundays-Fridays- 12:00 AM* to 5:00 AM - *potential to start earlier to be determined.

Test Parameters:

- Tests are prescribed using the highest take-off flap/slat setting;
- Tests been prescribed to examine failure of Type I and Type IV fluid;
- Additional optional tests has been prescribed to examine fluid failure times on the tail (horizontal stabilizer) in comparison to the wing sections;
- Tests have been prescribed to examine failure patterns in head wind and tail wind conditions;
- Testing with retracted wing configuration or different flap settings may be considered;
- Airfoil models will also be included the testing setups; and
- The test plan may be modified following the first testing event.

4. TEST REQUIREMENTS

APS will co-ordinate the planned test activities and prepare a final report as well as present results at industry deicing meetings.

APS will provide support to these tests for instrumentation, fluid application, and fluid failure monitoring on the aircraft, flat plate models, and airfoils. A high-quality digital video and/or still pictures of the fluid on the various surfaces during the precipitation will be documented.

Desired weather conditions are snow, with subfreezing outside air temperature. Testing should be planned for events when greater than 10 cm of constant snow are expected. Ideal conditions are light to moderate snow conditions with 10-20cm accumulation expected over an 8-hour period.

5. EQUIPMENT

Test equipment required for the tests is provided in Attachment V. Details and specifications for some of the equipment is not provided in this procedure because it is the same as the equipment used for Endurance Time testing and is further described in SAE ARP 5485.

6. PERSONNEL

Several personnel are required to conduct tests for each occasion. A description of the responsibilities and duties of each of the personnel is provided in Attachment VI. Attachment VII shows a schematic of the positioning of the test personnel. Ground support personnel and equipment from AéroMag 2000 and from the airlines will be available to apply fluids, position the aircraft, and facilitate the inspection of the critical aircraft surfaces.

7. SUMMARY OF PROCEDURE AND MEASUREMENTS

The test procedure is included in Attachment VIII. The following observations are anticipated:

- Trained observer assessment of wing condition from outside the aircraft;
- Comparisons of fluid performance on the aircraft with fluid performance on standard test plates; and
- Video and photo record coverage of the tests.

8. DATA FORMS

The data forms are listed below:

• Attachment IX	General Data Form (every test)
• Attachment X	General Data Form (once per session)
• Attachment XI	De/Anti-Icing Form for A300-600 Aircraft Port Wing
• Attachment XII	De/Anti-Icing Form for A300-600 Aircraft STBD Wing
• Attachment XIII	De/Anti-Icing Form for E190 Aircraft Port Wing
• Attachment XIV	De/Anti-Icing Form for E190 Aircraft STBD Wing
• Attachment XV	End od Condition Data Form

9. ROLES OF PARTICIPATING AGENCIES

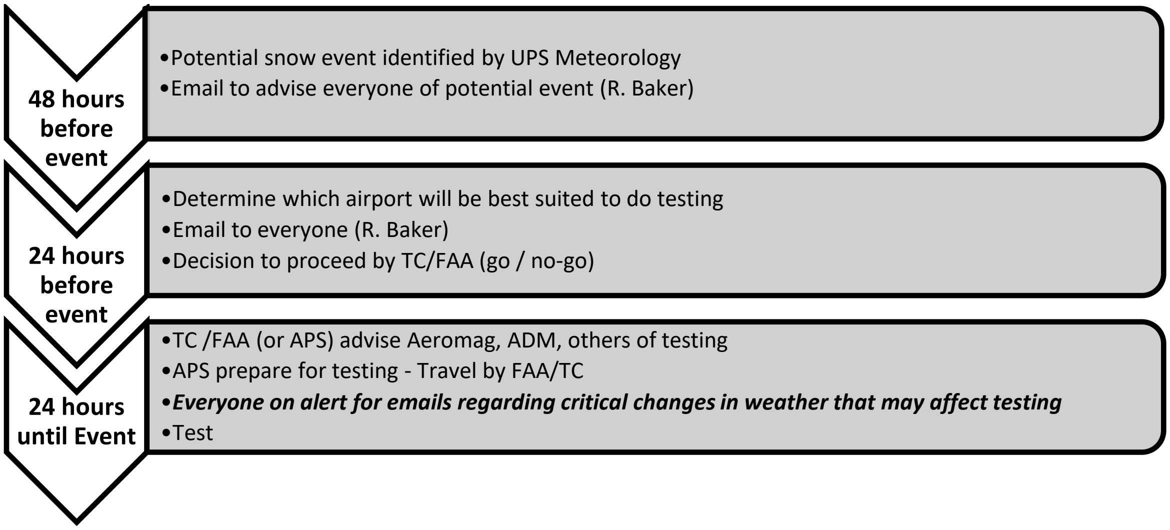
APS:	To coordinate and conduct tests on behalf of TDC.
TDC/FAA:	FAA and Transport Canada or its contractor/representative will organize the tests. Transport Canada will assume the cost of trained observers, conduct of tests and provision of instrumentation, and power supplies. TDC has made arrangements with Aéroports de Montréal and has obtained approval for conducting tests at the UPS YMX apron (See Mitigation Plan Attachment XVI), and at the YUL CDF operated by Aéromag 2000. Findings and reports will be made available to the aviation community.
UPS:	Provide and tow aircraft as required. Provide access to LE and TE for test observation. Responsible for costs associated with fluid supply, fluid application and fluid recovery. A written agreement between the FAA and UPS that describes the commitments and liabilities has been implemented. During the course of one event, it may be necessary to change the orientation of the aircraft due to wind shifts. A mechanic should be available to change the flap/slat settings during the testing session.
Air Canada:	Provide and tow aircraft as required. Provide access to LE and TE for test observation. Responsible for costs associated with fluid supply, fluid application and fluid recovery. During the course of one event, it may be necessary to change the orientation of the aircraft due to wind shifts. A mechanic should be available to change the flap/slat settings during the testing session.

Aéromag: AéroMag 2000 (under separate arrangement with UPS and Air Canada) will provide a deicing vehicle, personnel and a vacuum vehicle to recover spent glycol at the YMX UPS gateway and at the YUL CDF. APS will arrange for a security escort for its staff and other visitors (10 total). UPS, Air Canada, or Aéromag 2000 will arrange for security access for the balance.

DOW: Dow Chemical will provide a credit for quantities of UCAR ENDURANCE EG106 ADF/AAF Type IV fluid that is used at YMX or YUL for the purpose of this testing.

LNT: LNT Solutions will provide a credit for both quantities of LNT E188Type I fluid and LNT E450 Type IV fluid that is used at YMX or YUL for the purpose of this testing.

10. PROPOSED NOTICE PROCEDURE



48 hours before event

- Potential snow event identified by UPS Meteorology
- Email to advise everyone of potential event (R. Baker)

24 hours before event

- Determine which airport will be best suited to do testing
- Email to everyone (R. Baker)
- Decision to proceed by TC/FAA (go / no-go)

24 hours until Event

- TC /FAA (or APS) advise Aeromag, ADM, others of testing
- APS prepare for testing - Travel by FAA/TC
- ***Everyone on alert for emails regarding critical changes in weather that may affect testing***
- Test

11. EQUIPMENT AND SERVICES REQUESTED FROM AIRLINES

Airlines are requested to make aircraft available for Transport Canada to implement the above test program.

Aircraft to be initially positioned, re-positioned following individual tests, and towed away at end of each test session.

AéroMag 2000 Inc. is requested to provide a de/anti-icing truck with crew for fluid application in accordance with the above program.

12. ADDITIONAL FORMS AND IMPORTANT DOCUMENTS

The following is a list of additional forms and important documents that will be reference during the full-scale testing:

• Attachment XVII	Safety Awareness Issues
• Attachment XVIII	Fluid Application – Test Stand Position
• Attachment XIX	General Aircraft Positioning
• Attachment XX	Special Considerations for Tail Wind, Cross Wind, Tail Tests and Type I Tests
• Attachment XXI	Data Form for Condition of Tail

Attachment I: Test Plan Winter 2011-12

SESSION 1 OF 3

Test #	Comments
Briefing of Observers	• Prepare handout of day's plan; • Provide procedure • Safety
Briefing of Key Test Team	• Prepare handout; describe to personnel • Provide procedure • Safety
Baseline Run	• Spray wing & Collect data • Review procedure & modify if necessary
1	Type IV spray (head wind) (highest flat/slat)
2	Type IV spray (head wind) (highest flat/slat)

SESSION 2 OF 3

Test #	Comments
3	Type IV spray (head wind) (typical flap/slat)
4	Type IV spray (head wind) Spray Tail Also (typical flap/slat)
5	Type IV spray (head wind) (highest flap/slat)
6	Type I spray (head wind) Full Wing (highest flap/slat)

SESSION 3 OF 3

Test #	Comments
7	Type IV spray (tail wind) (typical flap/slat)
8	Type IV spray (tail wind) (typical flap/slat)
9	Type IV spray (tail wind) (highest flap/slat)
10	Type IV spray (cross wind) Spray Both Wings (highest flap/slat)

GENERALLY COMPLETED
WINTER 2011-12

NOT COMPLETED
REVISED PLAN
SEE ATTACHMENT IA

Attachment II: Anticipated Test Plan Winter 2012-13

SESSION 3 OF 4(1)

TEST #	COMMENTS/PARAMETERS
6	Type IV spray (head wind) (retracted flap/slat)
7	Type IV spray (head wind) (highest flap/slat)
8(2) ***COMPLETED*** ***2X***	Type IV spray (tail wind) (highest flap/slat) *(2nd time with tail spray)*
9 ***COMPLETED*** ***2X***	~~TBD~~ Type I spray (tail wind) (highest flap/slat)

(1) An additional session(s) may be needed depending on the results of Sessions 3 and 4.

(2) Consider changing with test # 10 to minimize aircraft rotation.

SESSION 4 OF 4

TEST #	COMMENTS/PARAMETERS
10	Type IV spray (head wind) Spray tail also (highest flap/slat)
11	Type I spray (head wind) (highest flap/slat)
12	Type IV spray (cross wind) spray tail also (highest flap/slat)
13	Type I spray (cross wind) spray tail also (highest flap/slat)

OBSOLETE

NOT COMPLETED
REVISED PLAN
SEE ATTACHMENT Ib

Attachment III: Anticipated Test Plan Winter 2013-14

SESSION 5 of 7 (1) (1st of 3 for 2013-14)

TEST #	COMMENTS/PARAMETERS
A	Type IV spray (tail wind) (highest flap/slat)
B	Type IV spray (tail wind) Spray tail also (highest flap/slat)
C	Type IV spray (tail wind) Spray tail also (retracted wing configuration)
D	Type IV spray (tail wind) (highest flap/slat)
E(2)	Type I spray (tail wind) (highest flap/slat)

(1) An additional session(s) may be needed depending on the results of Sessions 5 to 7.

(2) This test is in addition to tests that were discussed at the working group.

Anticipated Test Plan Winter 2013-14 (cont'd)

SESSION 6 OF 7

TEST #	COMMENTS/PARAMETERS
F	Type I spray (head wind) (highest flap/slat)
G	Type I spray (head wind) Spray tail also (highest flap/slat)
H	Type IV spray (head wind) Spray tail also (retracted wing configuration)
I	Type I spray (head wind) (highest flap/slat)

Anticipated Test Plan Winter 2013-14 (cont'd)

SESSION 7 OF 7

TEST #	COMMENTS/PARAMETERS
J	Type IV spray (cross wind) (highest flap/slat)
K	Type IV spray (cross wind) spray tail also (highest flap/slat)
L(1)	Type I spray (cross wind) (highest flap/slat)
M	TBD
N	TBD

(1) This test is in addition to tests that were discussed at the working group.

Attachment IV: Anticipated Test Plan Winter 2015-16

SESSION 5 of 6 (1st of 2 for 2015-16)

First Choice Aircraft: UPS A300
Second Choice Aircraft: Air Canada E190

TEST #	COMMENTS/PARAMETERS
O	Type IV spray (tail wind) Spray tail also (highest flap/slat) *Include Airfoil with flaps/slats (simple airfoil optional)*
P	Type I spray (tail wind) Spray tail also (highest flap/slat) *Include Airfoil with flaps/slats (simple airfoil optional)*
Q	TBD (Consider retracted configuration, or different flap setting) *Include Airfoil with flaps/slats (simple airfoil optional)*

Anticipated Test Plan Winter 2015-16 (cont'd)

SESSION 6 OF 6 (2nd of 2 for 2015-16)

First Choice Aircraft: Air Canada E190
Second Choice Aircraft: UPS A300

TEST #	COMMENTS/PARAMETERS
R	Type IV spray (head wind) (highest flap/slat) Spray tail also *Include Airfoil with flaps/slats (simple airfoil optional)*
S	Type I spray (head wind) (highest flap/slat) Spray tail also *Include Airfoil with flaps/slats (simple airfoil optional)*
T	TBD (Consider retracted configuration, or different flap setting) *Include Airfoil with flaps/slats (simple airfoil optional)*

Attachment V: Test Equipment Checklist

	TRUCK	DAVE	CHLOË	MARCO	JOHN	BEN G	BEN B
Logistics for Every Test							
Security Escorts for staff and visitors		DY					
Rent Truck for equipment		DY					
Rent SUV (or JD SUV) for transport and airside shelter				MR	JD		
Pick up lens						BG	
Call Personnel				MR			
Pack		DY					
Advise Airlines (Personnel, A/C Orientation, Equip)				MR	JD		
Ensure all personnel have proper ID (drivers license or passport)		DY		MR			
Monitor Forecast		DY	CB	MR	JD		
Call potential participants (Aéromag)				MR			
UPS/Air Canada / Other Equipment							
Pylons							
K Loaders							
Spray Vehicle							
Rolling Stairs							
First Aid Kit							
Orange Safety Vests							
Mobile lighting							
Test Equipment							
15 Procedures, envelopes	TRUCK						
All data forms required (wing, plates, general)			CB				
2 X 1 position test stand		DY					
2 x 6 position test stand with required marked plates and flap simulation apparatuses (see test stand position table)		DY					
4 Extension chords stored in bin.	TRUCK						
1 tool kit including tie-wraps, duct tape, speed tape, safety goggles, spare Batteries (D)	TRUCK						
3 Standard plate pans		DY					
2 Wide plastic shovels	TRUCK						
2 large and 2 small squeegees		DY					
2 small plate scrapers		DY					
Pens and pencils			CB				
Paper Towels and rags	TRUCK						
4 ordinary Octagon thickness gauges. 4 Rectangular Gauges, 1 pole (optional) for thickness gauge extension		DY		MR	JD		BB
1 Rates station with 2 weight scale from test site, (Cable and PC)	TRUCK						
6 Stop watches and sync with clock		DY	CB	MR	JD		BB
3 Tape measures (1 long, 2 standard). (Automatic retracting measuring tapes)	TRUCK				JD		
Large Table for Rate Station. 2-3 chairs.	TRUCK						
1 Flashlights	TRUCK			MR			
5 Clipboards		DY	CB	MR			
2 temperature readers with 2 immersion probes and 2 surface temp probes.		DY		MR			
Garbage bags	TRUCK						
Invertor for Truck power x 2	TRUCK						
Small white electrical chord	TRUCK						
Power Bar	TRUCK						
Bungee Chords to secure CSW boxes		DY					
20 litre Pails with Lids x 3		DY					
Sample Bottles	TRUCK						
Compass			CB				
Inclinometer		DY					
Long Squeegee		DY					
Felt Board			CB				
Rubber Mats (Quantity to determine)	TRUCK						
Collection Pans for Stands							
Thermos x 4		DY					
CSW Boxes x 3		DY					
Vacuum		DY					
Spreaders x 1		DY					
Measuring Cups x6		DY					
Walkie talkies and spare batteries and all chargers		DY	CB	MR	JD	BG	BB
2 Brixometers		DY		MR	JD		BB
Laptop x 1 (for rate station)						BG	
Isopropyl	TRUCK						
Gloves (plastic) for pouring	TRUCK						
Gloves (cotton)	TRUCK						
Safety vests (all)	TRUCK						
Masks	TRUCK						
Poker chips for leveling stand (no white chips, only coloured)	TRUCK						
Drain cover	TRUCK						
Stepladder	TRUCK						
Camera Equipment							
Digital still cameras x3						BG	
All required lenses, flashes, spare batteries, chargers, extra storage cards, storage card reader.							

Attachment VI: Full-Scale Fluid Failure

RESPONSIBILITIES/DUTIES OF TEST PERSONNEL

Refer to Attachment VII for position of equipment and personnel relative to the aircraft. Also refer to the test procedure (Attachment VIII) for more detailed test requirements.

Video/Photographer

- One video/photographer operator;
- Located on ground for setup shots and possible in deicing vehicle or on lift for active test recording;
- Ensure proper plate identification – zoom in and out;
- Know test procedures and end conditions;
- Videotape application of all fluids;
- Videotape wing (slats and flaps) before and after fluid application, concentrating on fluid contamination and failure;
- Ensure proper identification of wing;
- Would be best have to individual videographer, however could be same person as photographer;
- Photograph aircraft test site (Photography is far more important than video);
- Photograph wing (slats and flaps) during and after fluid application, concentrating on fluid contamination and failure;
- Overall photography of wing condition is extremely important;
- Ensure proper storage and documentation of test runs (run #'s);
- Ensure that there are no objects on the ground that may cause foreign object damage at end of session;
- Photograph fluid roughness on wing;
- Ensure picture is steady and well lit;
- Photography of wing, to include upper surfaces and deployed flaps and slats; and
- Photograph general setup (area, office, equipment, etc).

Meteo/Equipment Tester

- Co-ordinate all equipment (inventory and operation);
- Record meteorological conditions;
- Rotate pans and measure plate pan weights;
- Complete and sign general data form (Attachment IX and Attachment X) for each test;
- Manage and direct equipment deployment and return;

- Ensure power cables and lighting (if needed) are in place;
- Prepare plate pans;
- Ensure electronic data are being collected for all tests;
- Ensure all materials are available (pens, paper, batteries, etc.);
- Complete general data form (Attachment IX) at beginning of night;
- Ensure all clocks are synchronized (including cameras);
- Ensure that there are no objects on the ground that may cause foreign object damage at end of session;
- Ensure collection of data forms and electronic files;
- Record rates (if possible) for both aircraft wings during crosswind tests;
- Located by test stand;
- Apply fluids to test plates, and flap/slat models on test stand. Fluid will be taken directly from the truck tank to avoid foaming;
- Make observations and call end conditions on test stand;
- Ensure detail of contamination on slats and flaps is recorded; and
- Know procedures for test stands and models.

Wing Observer

- Located on ground (rolling stairs or lifts) or in cherry picker;
- Communicate with plate observer when wing failures occur;
- Ensure that there are no objects on the ground that may cause foreign object damage at end of session;
- Make observations of failures on starboard or port wing;
- For tests that include the tail, observations will be required on the tail; and
- Know procedures and calling end conditions.

Plate Tester

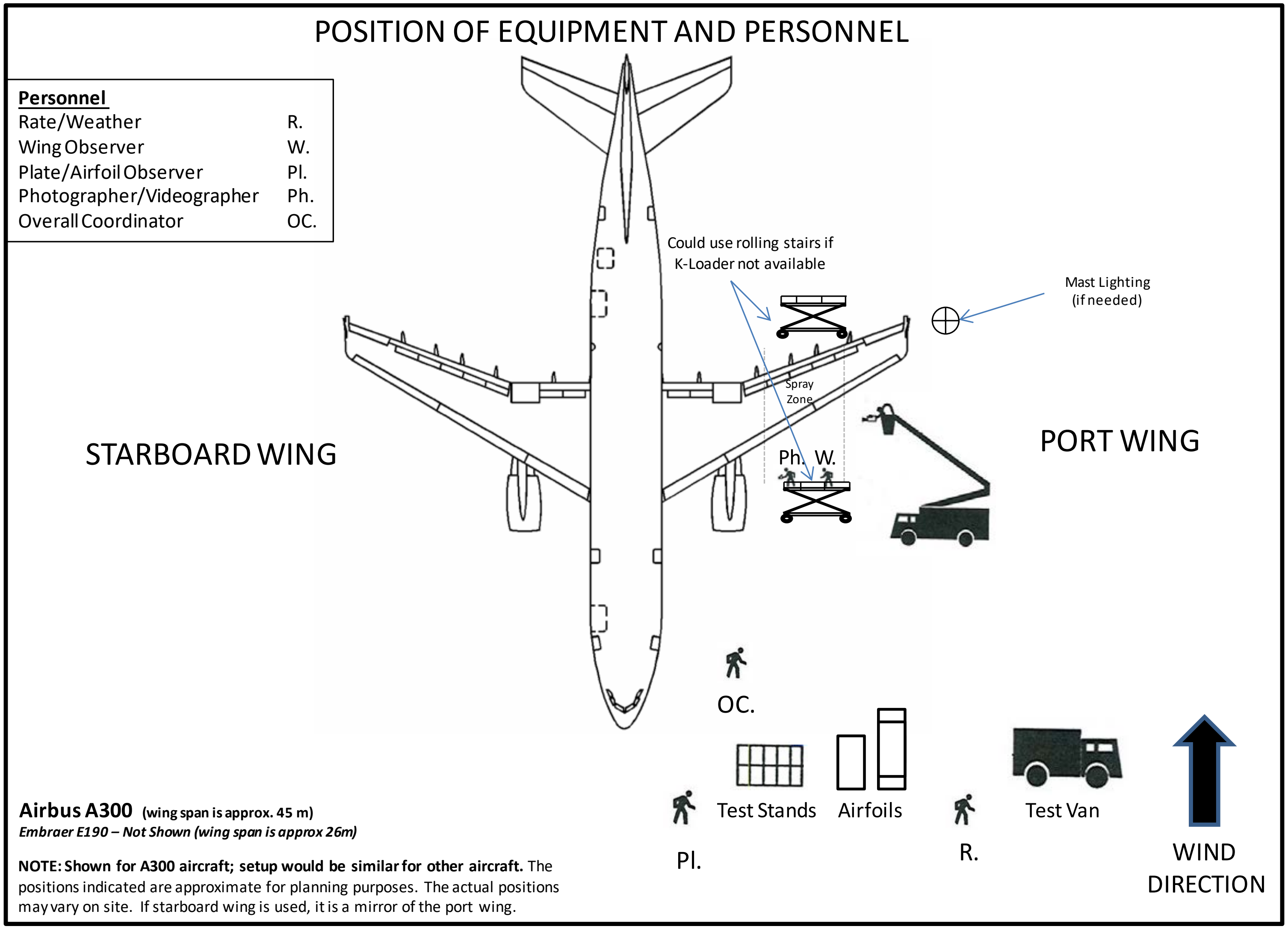
- Located by test stand;
- Apply fluids to test plates on stand. Fluid will be taken directly from the truck tank to avoid foaming;
- Ensure that there are no objects on the ground that may cause foreign object damage at end of session;
- Make observations and call end conditions on test stand; and
- Know procedures for test stands.

Overall Co-ordinator

- Act as team Co-ordinator;
- Know test procedures and calling end conditions;
- Be responsible for area and people;
- Aid any personnel;

- Co-ordinate actions of APS team and, as required, airline personnel;
- Be responsible for weather condition observations and forecast, advise tester team;
- Ensure that there are no objects on the ground that may cause foreign object damage at end of session;
- Ensure test site is safe, functional and operational at all times;
- Supervise site personnel during the conduct of tests;
- Ensure aircraft positioned appropriately;
- Monitor weather forecasts during test period;
- Ensure fluids are available and verify that correct fluids are being used for test;
- Ensure electronic data are being collected for all tests;
- Verify test set-up and procedure are correct (e.g. stand into wind);
- Ensure all materials are available (pens, paper, batteries, etc.);
- Ensure failure calls on plates and wings are consistent;
- Communicate initial failure to all involved;
- Assist wing and plate observers as required;
- Coordinate with PV Labs;
- Ensure that Aéromag 2000 does the fluid recovery; and
- Review data forms upon completion of test for completeness and correctness (sign).

Attachment VII: Position of Equipment and Personnel



Personnel

Rate/Weather	R.
Wing Observer	W.
Plate/Airfoil Observer	Pl.
Photographer/Videographer	Ph.
Overall Coordinator	OC.

Airbus A300 **(wing span is approx. 45 m)**

Embraer E190 – Not Shown (wing span is approx 26m)

NOTE: Shown for A300 aircraft; setup would be similar for other aircraft. The positions indicated are approximate for planning purposes. The actual positions may vary on site. If starboard wing is used, it is a mirror of the port wing.

Attachment VIII: Test Procedure

1. TRAINING AND SAFETY

Training for this experiment will consist of a *dry run or baseline run* (on Day 1) in which team members are assembled and duties are assigned to each member. This will allow the team to conduct an experiment in which team members will co-ordinate their activities to prepare for a systematic and comprehensive execution of a given experimental run and try to determine the logistics of an actual experiment. The dry run will familiarize all test members with the equipment and provide the participating airline with an understanding of the procedure. This procedure will inevitably be streamlined during field testing. Most team members should be familiar with salient aspects of flat plate testing. They should possess the ability to identify fluid failures and call end conditions.

Attachment XVII refers to Safety Awareness Issues for these tests. Ensure that these are observed and understood.

NOTE: The dry run test was done the first year of testing. As the testing team has remained consistent over the years, a refresher briefing should be conducted on the first test event in 2015-16 rather than a full dry run.

2. PRE-TEST SET-UP

Attachment VII should be consulted in reference to the responsibilities.

1. Arrange favourable aircraft orientation (leading edge into the wind unless otherwise specified) and place pylons below wings to delineate sections (1/3 of wing) to be sprayed. Flaps and slats shall be setup to the highest take-off configuration (except on session 2 and 3 as per the test plan.
2. When positioning aircraft, ensure roadways are clear by a minimum of 7.5m (see Attachment XIX).
3. Set up power cords and generator, if necessary. Position stairs and lights, if any.
4. Ensure temperature probes and weigh scales are functional.
5. Position flat plate test stand into the wind as per the flat plate test procedure (Ensure the plates simulating the slat and flap are at the proper angles of 20 and 35°). Note that for the head wind tests, the orientation of the plates may be slightly different than that of the aircraft.
6. Position test fluid containers, squeegees, and scrapers accordingly. (Type I fluids for applied to wing shall be at 60°C (or at the temperature of the fluid provided from the truck by Aéromag, but shall be heated); Type IV fluids are applied at ambient temperature.)

7. Check cameras, sensors and recording devices for proper function.
8. Ensure proper illumination of test areas.
9. Establish communication between team members and co-ordinator.
10. Ensure laptop used to record weather conditions and precipitation rates is functional and synchronized.
11. Synchronize all timepieces (Atomic clock) including cameras and ROGIDS.
12. Ensure airline personnel are aware and knowledgeable of test procedures.
13. Prepare data forms (water repellent) in advance of all tests.

3. INITIALIZATION OF FLUID TEST

1. Ensure all aircraft de/anti-icing systems are off.
2. Obtain from airline designee a record of fuel load in the wing to be tested.
3. Obtain slat/flap positioning from airline designee and measure slat and flap angles. Measure and record slat and flap geometry.
4. Measure wing skin temperature at predetermined locations before fluid application (see Attachment X).
5. Record all necessary data from fluid delivery vehicle (cherry picker): temperature, nozzle-type, fluid type, dilution of fluid, etc.
6. Record all general measurements and general information on the data forms.
7. Ensure all fluids are prepared to the appropriate concentrations.
8. Collect sample (Type I and Type IV) of fluid from deicing truck.

4. EXECUTION OF FLUID TEST

1. Type IV Fluid Test (Attachment XVIII)
   - i. Apply Type I and then Type IV to aircraft wing (1/3 section of wing) with deicing vehicle.
   - ii. Apply Type IV from pour containers to plates when application of Type IV to the aircraft wing begins.

2. Type I Fluid Test (Attachment XII)
   - i. Apply heated Type I fluid with deicing vehicle to aircraft wing (full wing).
   - ii. Simultaneously with aircraft wing deicing, apply Type I from thermos containers to boxes.

3. Put two rate pans on test stand prior to deicing vehicle fluid application. Measure rates as per the standard endurance time test procedure.

5. HOLDOVER TIME (END CONDITION) TESTING

Holdover time testing will consist of: a) video/photo recording of all procedures and fluid failures; and b) visual monitoring and manual recording of failure data.

A) Video/Photo Recording

Camera recordings are to be systematic so that subsequent viewing of documented tests allow for the visual identification of failing sections of the wing surface with respect to the aircraft itself.

1. Record the complete fluid application on plates, and the aircraft wing from a distance.
2. Record the conditions of the flat plate set-up, and the aircraft wing slats/flaps at time = 0.
3. For Type IV fluids, record conditions of aircraft wing, aircraft flaps and slats, flap and slat models, and flat plates every five minutes.
4. Once the first failure on the wing, the aircraft flaps, the aircraft slats, the flap model, the slat model, or on the 2.5cm line on the plate is called, monitor (record) continuously until the end of the test.

B) Visual Recording

1. For the plates, refer to the standard endurance time test procedure for determination of the end condition.
2. For the aircraft wing and flaps/slats, manually record the failure contours on pre-printed data form (Attachment XIII).

Procedures and training must emphasize the requirement to identify the precise location of first failure. Additional observers are to be assigned from the test team to assist in failure identification when rapid progress of failure is expected. A further discipline can be added by requiring observer to comment on wing conditions at defined intervals while awaiting the occurrence of first failure;

The pattern of failures should be drawn on the data form **every 15 minutes for Type IV after first failure on the wing or the flap/slat**.

When the first flat plate failure is reported at the 5th crosshair (1/3 of plate), the visual data recorder must acquire contours every 2 to 5 minutes, thereafter. Time increment is dependent upon weather. Process is continued until all flat plates have failed.

Additional important documentation on the plate data form shall include:

1. Angle of test plate.
2. Nested or simple plate indication.
3. Thickness at 5min.
4. Brix at failure.
5. First failure.
6. Progressive failures on all crosshairs.
7. Orientation in degrees of test stand.

If the wing or the flap/slat fails before the first flat plate fails, continue data collection of wing on the data form.

Co-ordinator must confirm initial end condition calls on flat plate tests. Once the first flat plate fails at the 15 cm line (1/3 of plate), the co-ordinator is notified and makes inspection of the wing and slat/flap contour drawing to confirm the accuracy of the data and instructs camera operator to make a record of the area. If the wing or the slat/flap starts to fail first, the coordinator must confirm this and simultaneously note areas of failure on the flat plates.

6. END CONDITION

Refer to the standard flat plate endurance time test procedure for this definition.

7. END OF TEST

This occurs when all plates have reached the end condition (under heavy snow conditions, continue testing until nine crosshairs have failed) and when a substantial part of the aircraft wings leading/trailing edge has reached the end condition. Ensure all data collection is completed including plate pan measurements. The current moderate snow HOT's for EG106 are 40 to 80 min for -3°C; and 30 to 65 min for -14°C. The current moderate snow HOT's for E450 are 60 to 95 min for -3°C; and 45 to 70 min for -14°C.

8. TEST PROCEDURES FOR SPECIAL TESTS

More refined and detailed procedures and considerations for the tailwind, crosswind, tail, and Type I tests are described in Attachment XX.

Attachment IX

GENERAL FORM (ONCE PER TEST)

(TO BE FILLED IN BY METEO/EQUIPMENT TESTER)

GENERAL INFORMATION

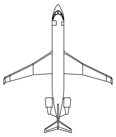
Date: ____________________

Aircraft Type: A-300 E-190 Other___

Test #: ____________

Wing: PORT (A) STARBOARD (B)

Draw Direction of Wind WRT Wing:



Direction of the aircraft: ________________

Flap/Slat Setting: ________________

1ST FLUID APPLICATION

Actual Start Time ____________ am / pm

Amount of Fluid Sprayed ____________ L / gal

Fluid Temperature ____________ °C

Actual End Time ____________ am / pm

Brand/Concentration on Aircraft: ____________

Brand/Concentration on Plates: ____________

2nd FLUID APPLICATION

Actual Start Time ____________ am / pm

Amount of Fluid Sprayed ____________ L / gal

Fluid Temperature ____________ °C

Actual End Time ____________ am / pm

Brand/Concentration on Aircraft: ____________

Brand/Concentration on Plates: ____________

End of Test Time: ____________ am / pm

Expected HOT: ____________

Initial Thickness (time)* ________ (____________)

Brix at Failure* ________________

* measurements should be taken half way of the slat

COMMENTS

____

____

____

____

____

Measurements by: ______________

Written by: ________________

Attachment X

GENERAL FORM (ONCE PER SESSION)

(TO BE FILLED IN BY OVERALL COORDINATOR)

GENERAL INFORMATION

Date ____________

Aircraft Type: A-300 E-190 Other___

Airport: ____________

Airline: ____________

Exact Pad Location of Test: ____________

Fin #: ____________

Approx. Air Temp ____________ °C

Fuel Load: ____________ LB/KG

Skin Temp. Measurements at Beginning of the event(Top of the Wing): ________ °C

TYPE I FLUID APPLICATION

Type I Truck #: ____________

Type I Fluid Nozzle Type ____________

Sample Collected: Y / N

Fluid Brix: ________

TYPE IV FLUID APPLICATION

Type IV Truck #: ____________

Type IV Fluid Nozzle Type: ____________

Sample Collected Spray: Y / N

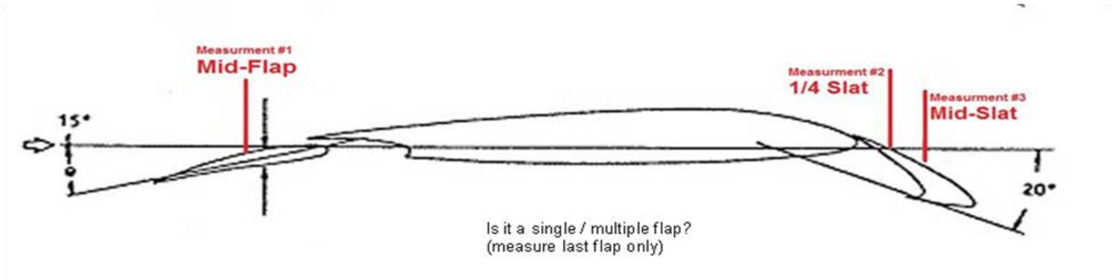
Sample Collected from Truck: Y / N

Fluid Brix:

COMMENTS

MEASURE THE ANGLE OF THE MID-FLAP, ¼ SLAT, AND MID-SLAT AT TWO LOCATIONS:

1. ***The edge of test section close to fuselage (≈19°,22°,21°)*; and***
2. ***The edge of test section close to wing tip.***



(*Note: Values above are from Winter 2011-12 measured on A300-600)

Measurements by: ____________

Written by: ____________

Attachment XI

De/Anti-Icing Form for A300-600 Aircraft Port Wing

Date ______________________ Run # ______________________

Failures Called by: ______________________ Comments: ______________________

Handwritten by: ______________________ ______________________

Assisted by: ______________________ ______________________

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)

Time: __________

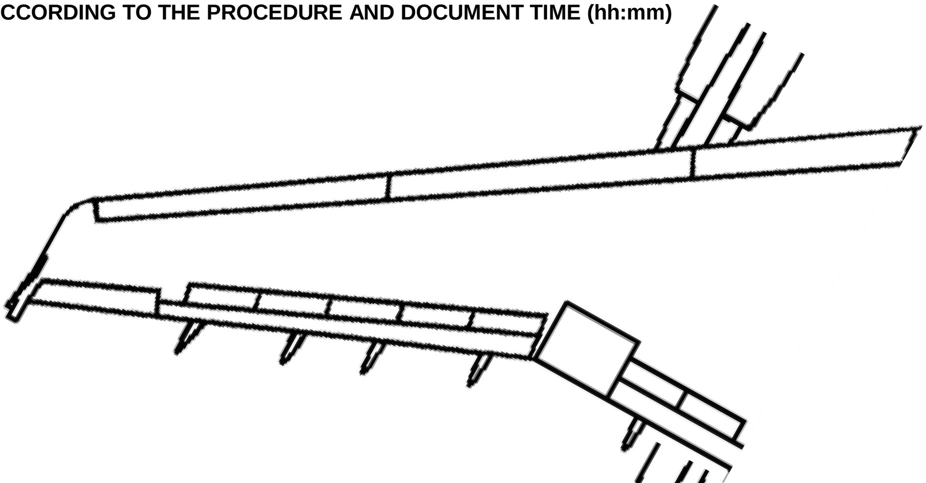
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

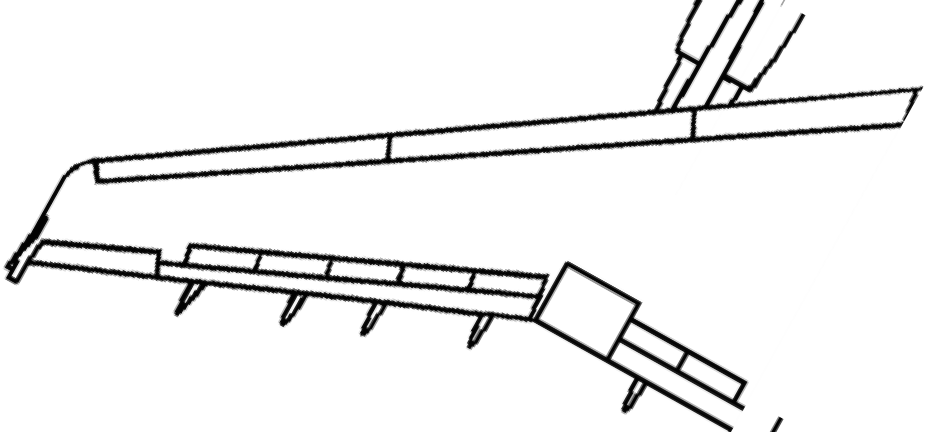
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

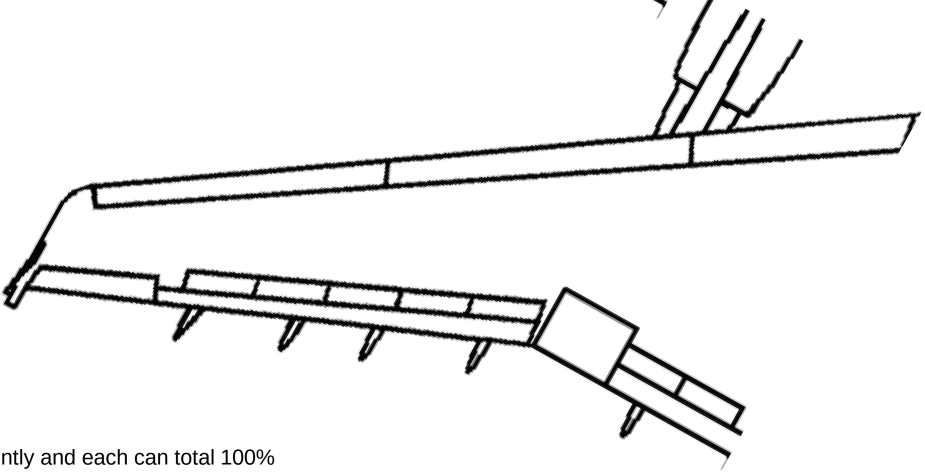
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Note: % above is for each section independently and each can total 100%

Attachment XII

De/Anti-Icing Form for A300-600 Aircraft STBD Wing

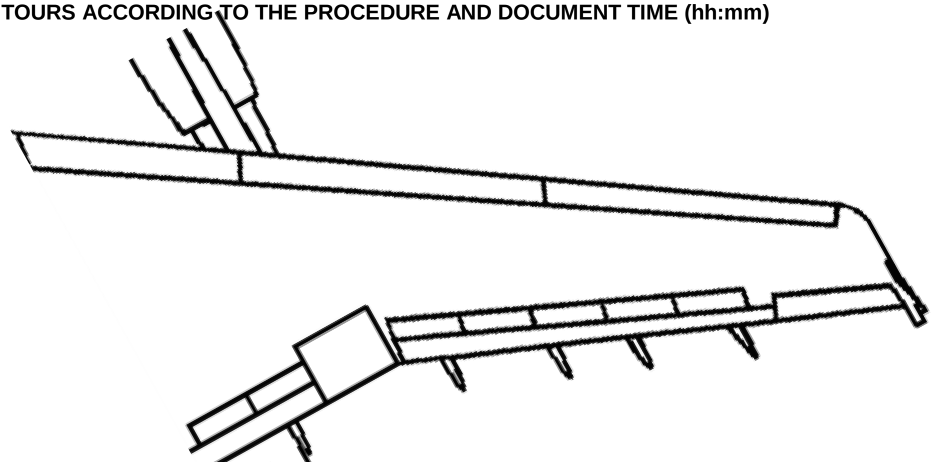
Date ______________________________ Run # ______________________________

Failures Called by: ______________________________ Comments: ______________________________

Handwritten by: ______________________________ ______________________________

Assisted by: ______________________________ ______________________________

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)



Time: __________

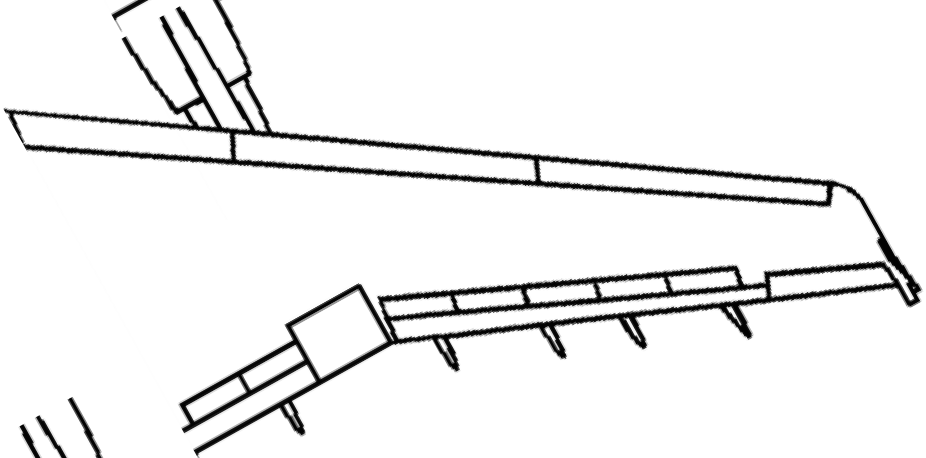
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

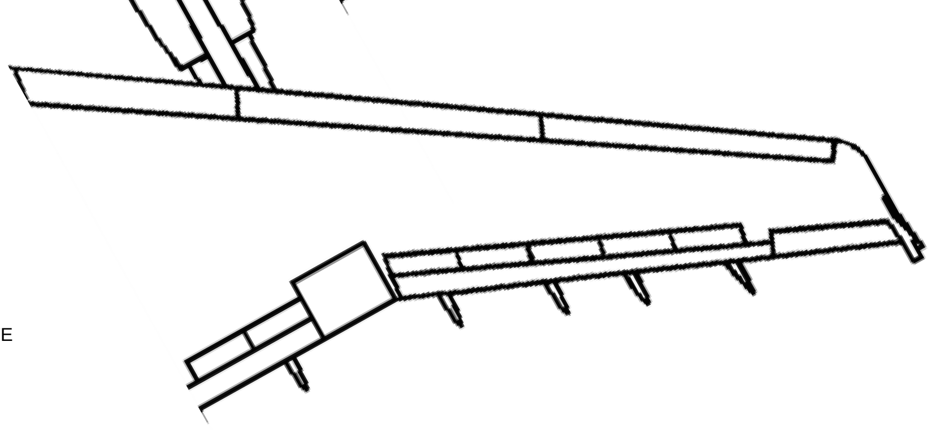
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE

Note: % above is for each section independently and each can total 100%

Attachment XIII

De/Anti-Icing Form for E190 Aircraft Port Wing

Date ______________________ Run # ______________________

Failures Called by: ______________________ Comments: ______________________

Handwritten by: ______________________ ______________________

Assisted by: ______________________ ______________________

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)

Time: __________

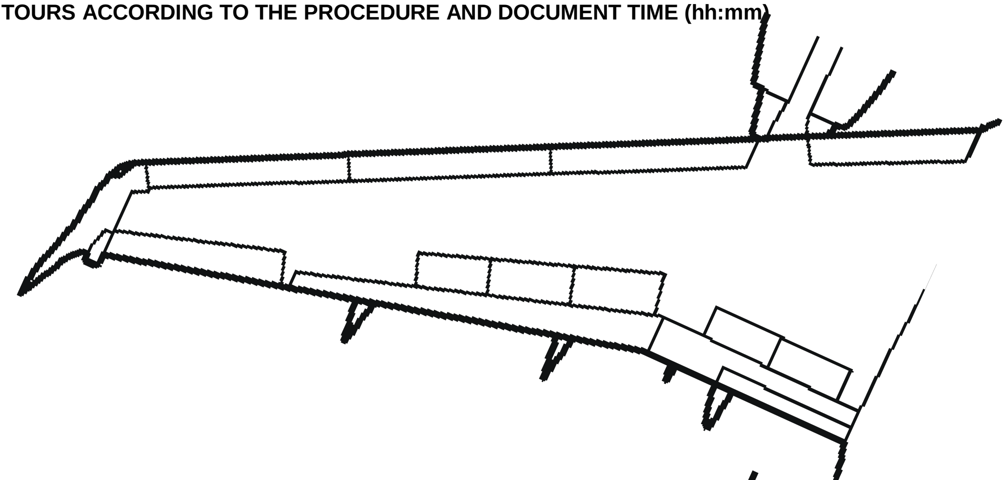
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

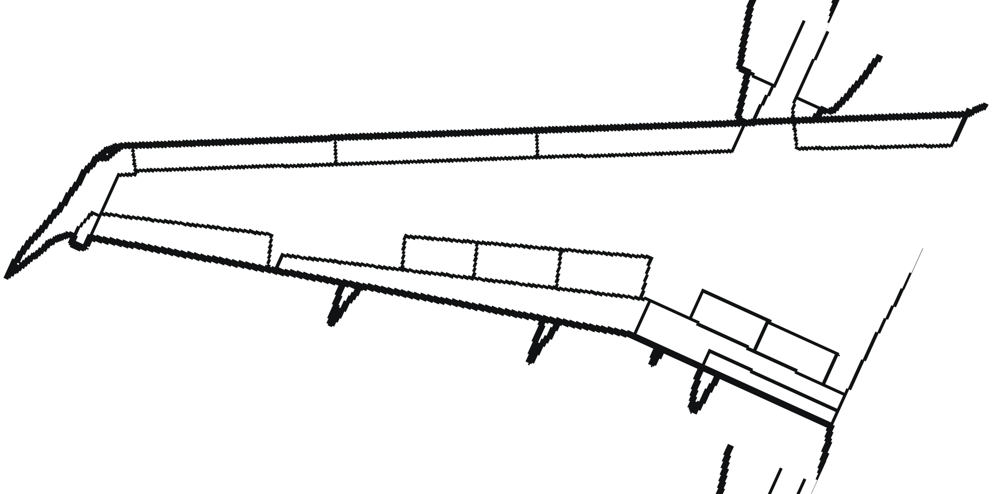
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

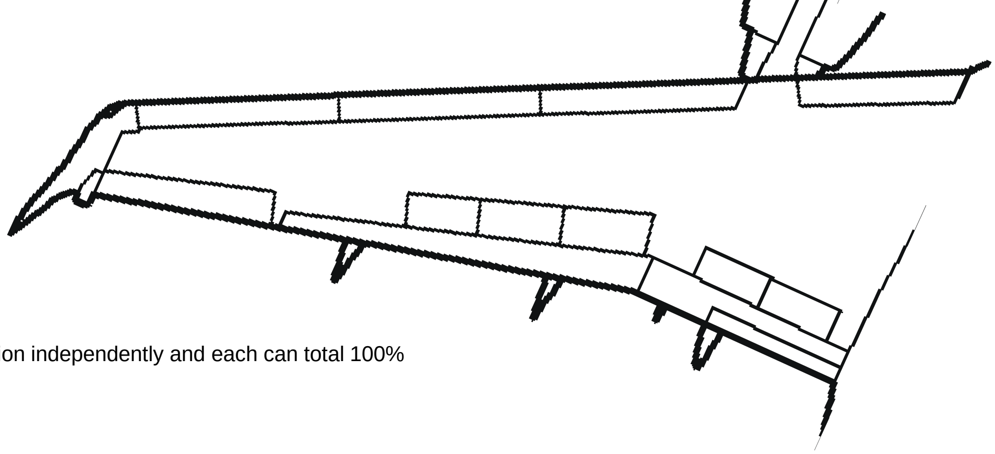
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Note: % above is for each section independently and each can total 100%

Attachment XIV

De/Anti-Icing Form for E190 Aircraft STBD Wing

Date ____________________

Run # ____________________

Failures Called by: ____________________

Comments: ____________________

Handwritten by: ____________________

Assisted by: ____________________

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)

Time: __________

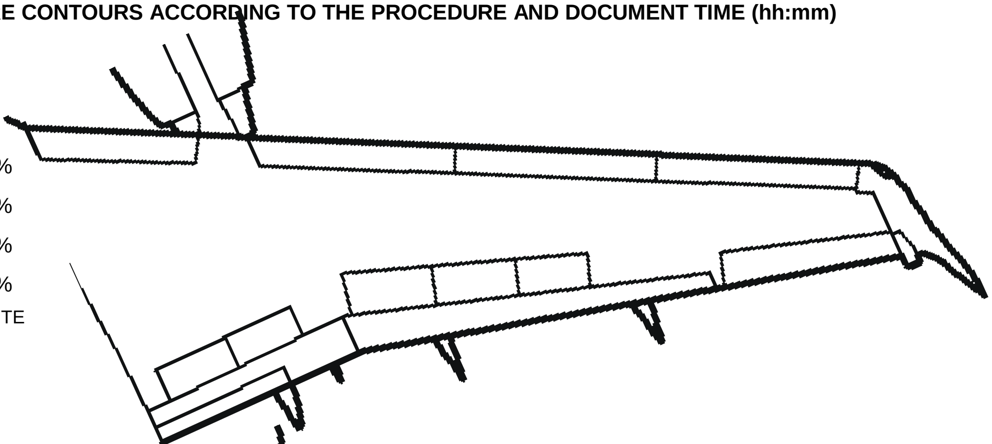
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

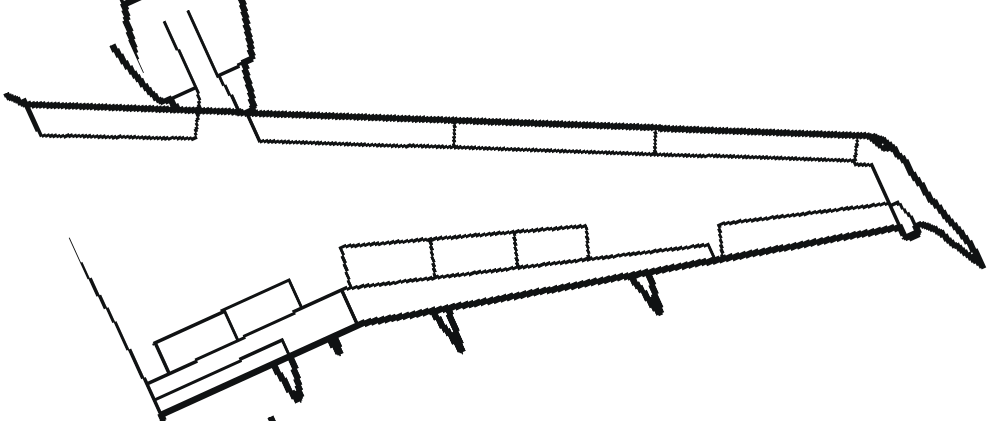
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Time: __________

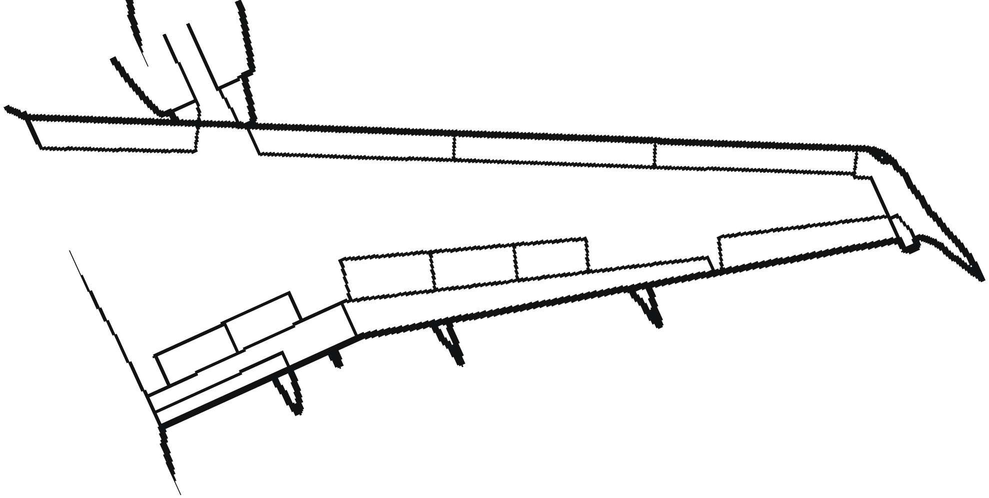
LE __________ %

Main __________ %

Spoiler __________ %

Flaps __________ %

Observation Loc. (circle) LE / TE



Note: % above is for each section independently and each can total 100%

Attachment XV: End of Condition Data Form

(FOR TYPE IV FLUID APPLICATION)

REMEMBER TO SYNCHRONIZE TIME WITH MSC - USE LOCAL TIME

LOCATION: YMX **DATE:** **RUN NUMBER:** **STAND # :** FLAPS

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application:	______		______		______	______
	35° PLATE		TOP (10° BASELINE)	15° PLATE	TOP (10° BASELINE)	20° PLATE
	Plate 1	Plate 2	Plate 3A	Plate 11 or 1S	Plate 5A	Plate 6
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3		EMPTY				
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

Time of Fluid Application:		______	______	______	______	
		10° BASELINE	BOTTOM (35° NESTED)	10° BASELINE	BOTTOM (20° NESTED)	
	Plate 7	Plate 8	Plate 3B	Plate 10	Plate 5B	Plate 12
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3	RATE 1					RATE 2
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

AMBIENT TEMPERATURE: ________ °C

COMMENTS:	Thickness @ 5 mins	Brix @ Failure
Plate 1:		
Plate 3A/3B:	/	/
Plate 5A/5B:	/	/
Plate 6:		
Plate 8:		
Plate 10:		

TEST STAND DIRECTION: _____ °

FAILURES CALLED BY: ________________________

LEADER / MANAGER: ________________________

End of Condition Data Form (cont'd)

(FOR TYPE I FLUID APPLICATION)

REMEMBER TO SYNCHRONIZE TIME WITH MSC - USE LOCAL TIME

LOCATION: YMX **DATE:** **RUN NUMBER:** **STAND # :** FLAPS

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application: ________ ________ ________ ________ ________ ________

Initial Box Temperature (°C) ________ ________ ________ ________ ________ ________
(NEEDS TO BE WITHIN 2°C OF AIR TEMP)

	35° BOX			15° BOX		20° BOX
	Box 1	Box 2	Box 3	Box 4	Box 5	Box 6
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

Time of Fluid Application: ________ ________ ________ ________

Initial Box Temperature (°C) ________ ________ ________ ________
(NEEDS TO BE WITHIN 2°C OF AIR TEMP)

			10° BOX			
	Box 7	Box 8	Box 9	Box 10	Box 11	Box 12
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3	RATE 1					RATE 2
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

AMBIENT TEMPERATURE: ________ °C

TEST STAND DIRECTION: _____ °

COMMENTS: Thickness @ 5 mins	Brix @ Failure
Box1:	
Box 6:	
Box 9:	
Initial Fluid Temperature: _____ °C	

FAILURES CALLED BY: ____________________

LEADER / MANAGER: ____________________

Attachment XVI

Glycol Mitigation Plan

for
Aéroports de Montréal
prepared by
APS AVIATION INC.

UPS TRIALS TO EXAMINE DE/ANTI-ICING FLUID FAILURE ON DEPLOYED FLAPS AND SLATS

MIRABEL, QUEBEC (YMX)
ORIGINAL ISSUE JANUARY – APRIL, 2012
REVISION #1 NOVEMBER 2013
REVISION #2 OCTOBER 2015

Initial testing was conducted at Mirabel Airport on four occasions; two in the winter of 2011-12, and two in the winter of 2012-13. Data appears to indicate a potential fluid endurance time reduction on the higher inclined plates, and on extended flaps and slats.

Some additional work with different aircraft orientations and configurations is required to compliment the findings to date. Due to lack of appropriate testing conditions during the operational windows, testing was not possible during the winters of 2013-14 and 2014-15. For winter 2015-16, it is anticipated that an additional two to four sessions will be conducted at Mirabel. This document provides an update to the glycol mitigation plan document submitted to Aéroports de Montréal.

NOTE: For 2015-16, testing plans has also been coordinated with Air Canada at YUL in order to increase the chances of collecting the necessary data to complete this research. As the testing with Air Canada is planned to occur at the YUL central deicing facility operated by Aéromag 2000, a separate glycol mitigation plan is not necessary as this will be handled by Aéromag 2000.

1. CORPORATE PROFILE

APS Aviation Inc. (APS), member of the ADGA Group of companies, is a worldwide leader in aircraft deicing research and development. Since 1990, APS has been contracted by the Transport Canada to further advance aircraft pre-flight de/anti-icing technology.

2. BACKGROUND

At the request of the Transport Canada, APS has undertaken a research program to obtain aircraft specific data that will be used to evaluate the current guidance material regarding operations with de/anti-iced flap and slat surfaces with respect to the A-300 and B-757 aircraft.

Anti-icing fluid applied to a wing with deployed flaps and slats can quickly flow off, resulting in a reduced fluid thickness layer, and consequently may shorten fluid holdover times. During the winter of 2010-11 both the Federal Aviation Administration (FAA) and Transport Canada (TC) provided guidance to operators for de/anti-icing with deployed flaps. The industry expressed concern with the applicability of the issue to different wing configurations. Also there was concern that a change in operating procedures (deploying flaps just prior to take-off as a mitigation tactic) could impact the safety of operations.

UPS has volunteered to participate in the trials and provide support through the availability of aircraft, ground equipment, and facilities to demonstrate the fluid failure trends on the flap and slat surfaces of their A-300 and B-757 fleet. The UPS YMX gateway will be used as the test location for the research to be conducted to reduce costs, facilitate logistics due to the equipment required to document the test, and to minimize safety concerns for personnel required to document the tests.

This document describes the glycol mitigation plan for the planned tests as follows:

- The fluid application procedures;
- The locations designated for fluid application;
- The anticipated fluid quantities to be sprayed; and
- The fluid recovery plan.

3. FLUID APPLICATION PROCEDURES

Aéromag 2000 personnel will apply the LNT E188 and Dow EG106 Type IV fluid to the wings of the A-300 or B-757 at the UPS gateway. The equipment used by Aéromag 2000 will be the same equipment used during their standard winter deicing operations; deicing truck model may vary based on availability. It is anticipated that one, potentially two, de/anti-icing spray trucks will be required for each test event. The deicing trucks used will be either open bucket or closed cabin FMC or Vestergaard model deicing trucks.

The fluid application will be performed by Aéromag 2000 with supervision by

APS Aviation Inc. APS personnel are highly experienced in aircraft deicing matters, and attempts will be made to limit the quantities of fluid applied to the aircraft. For each Type IV test, it is anticipated that the fluids will be applied to a 1/3 section of the wing, thus limiting the amount of fluid spent. One or two tests will be conducted with Type I Fluid which will require that the entire wing is sprayed due to the heat transfer characteristics.

4. LOCATIONS DESIGNATED FOR FLUID APPLICATION

The fluid application will be performed by Aéromag 2000 personnel at the UPS gateway. An area will be designated for testing in order to minimize the spread of de/anti-icing fluid. The aircraft will be stationary with engines off throughout the test, thus limiting the tracking and blowing of fluid on the ramp.

5. ANTICIPATED FLUID QUANTITIES TO BE SPRAYED

It is anticipated that testing will be conducted on a minimum of 2 occasions with 3-4 tests per session. There may be up to two additional sessions required based on quality of data collected.

During each Type IV fluid test, approximately 100L of both Type I and Type IV fluid would be required to de/anti-ice a 1/3 section of the wing. For the Type I fluid tests, approximately 400L would be required for head or tail wind tests and 800L for the crosswind test. The total fluid quantities sprayed for all tests during a test event will be minimal.

6. FLUID RECOVERY PLAN

Aéromag 2000 services will be used for the recovery of the glycol used during the test events. At the end of each test event, Aéromag 2000 will recover the spent fluid using the vacuum trucks typically used in operations. Efforts to isolate the fluid spray area and eliminate fluid tracking and blowing away will help facilitate the clean-up efforts required at the end of each test event. ADM will be contacted to ensure all drains near the spray location are properly closed and sealed prior to testing; the use of drain covers or plugs may also be considered. The waste solutions recovered will be processed in accordance with standard procedures currently used by Aéromag 2000.

9. CONDITIONAL ACCEPTANCE OF MITIGATION PLAN

A presentation of the mitigation plan to conduct the test at the UPS apron was provided to Aéroport de Montréal (ADM) in December 2011. Subsequently, ADM conditionally accepted to conduct these experiments at the UPS apron on the 1st session. Based on the results from a sampling of the storm water runoff by ADM after the 1st session, a go-ahead was provided for the subsequent two additional sessions as the sampling did not reveal any quantities of glycol.

Attachment XVII

Safety Awareness Issues

1. Protective clothing appropriate for cold wet and icy conditions is required.
2. Care should be taken when climbing rolling stairs due to slipperiness.
3. When moving rolling stairs, ensure they do not touch aircraft.
4. Review MSDS sheets for fluids.
5. To take fluid samples or measure film thickness on the aircraft, ensure minimum pressure is applied to the wing.
6. Entry into the aircraft cabin is not authorized.
7. When aircraft is being sprayed with fluid, testers and observers should be positioned away from the aircraft.
8. First aid kit, water and fire extinguisher is available at UPS hangar.
9. No smoking permitted.
10. Care to be taken when moving generators and fuel for the generators.
11. Do not walk by yourself in any area away from the pad – if required to do so, ask the coordinator who will advise the security escort service.
12. Gasoline containers maybe needed to power the generators – ensure you know where these are. Do not carry the gasoline containers near the aircraft.
13. Do not store or carry the gasoline containers anywhere near the aircraft; replenish the fuel in the generator and take the can away as soon as refuelling is completed.
14. Keep an adequately sized fire extinguisher appropriate for fuel fires ready at each generator.
15. Ensure rolling stairs are stabilized so as not to damage the wing.
16. Ensure all objects and equipment are removed from test area at end of night.
17. Personnel with escort required passes must always be accompanied by a person with a permanent pass.
18. Rolling stairs should always be positioned such that the stairs are into the wind. Small ladders should be laid down under windy conditions.
19. Tests involving personnel not trained and experienced in ramp operations must take particular care to ensure safety of personnel.

Attachment XVIII

FLUID APPLICATION – TEST STAND POSITION

Type IV Fluid Application

35° PLATE	EMPTY	**35° NESTED PLATE**	EMPTY	**20° NESTED PLATE**	**20° PLATE**

↑ **WIND**

RATE Measure every 10 minutes (stagger with other rate pan)	**10° PLATE**	EMPTY	**10° PLATE**	**15° PLATE**	**RATE** Measure every 10 minutes (stagger with other rate pan)

<u>NOTE:</u> Pour 20 L (Type IV) from truck tank into a 20 L pail prior to wing application. Apply 1 L per plate (as soon as Type IV is first sprayed on wing) as per the standard endurance time test procedure. In Winter 2011-12, the Type IV was supposed to be sprayed from the nozzle, however due to excessive foaming it was decided to extract fluid directly from the truck tank.

All plates are to be placed facing into the wind.

Type I Fluid Application (cont’d)

35° BOX	EMPTY	EMPTY	**15° BOX**	EMPTY	**20° BOX**

↑

WIND

RATE Measure every 10 minutes (stagger with other rate pan)	EMPTY	**10° BOX**	EMPTY	EMPTY	**RATE** Measure every 10 minutes (stagger with other rate pan)

<u>NOTE:</u> Spray more than 5 L from truck into a 20 L pail prior to wing application. Apply 0.5 L at 60°C (or at the temperature of the fluid provided from the truck by Aéromag) per box (as soon as Type I starts to be sprayed on wing) as per the standard endurance time test procedure (using spreader).

Attachment XIX

General Aircraft Positioning

YMX UPS Gateway

Typical Parking

NE Direction Parking

YUL Aéromag 2000 CDF

Typical Parking in CDF

NE Parking in CDF

Attachment XX

Special Considerations for Tail Wind, Cross Wind, Tail Tests and Type I Tests

TAIL WIND TESTS

1) Plates are still oriented into wind.
2) Aircraft need to be rotated following a head or cross wind test.
3) Rate pans are still oriented into the wind.
4) The positioning of the test stand would be best positioned on the trailing edge side of the aircraft.

CROSS WIND TESTS

1) Plates are still oriented into wind.
2) Aircraft needs to be rotated following a head or cross wind test.
3) Rate pans are still oriented into the wind.
4) Additional single position stand shall be positioned near each wing on the leading edge side near each test section. The stands shall be oriented into the wind direction (perpendicular to the fuselage). Rate pans shall be used to collect additional rate and these rate pans shall be labelled “up wind” and “down wind”. If stand is positioned close to the wing section, consider using only one rate pan (“down wind”).The frequency of measurement of these rate pans can be double the time of the regular rate pans.
5) Fluid shall be applied to both wings and the sections shall be larger than the 1/3 section for the head wind or tail wind tests.

TAIL TESTS

1) One or more tests will be conducted by applying the same fluid that is applied to the wing to the tail section.
2) A simple data form is developed (Attachment XXI) to capture information that indicates whether there is a difference between the wing failures and the tail failures.

Special Considerations for Tail Wind, Cross Wind, Tail Tests and Type I Tests (cont'd)

TYPE I FLUID TESTS

1) Boxes are used rather than plates.
2) Fluid temperature is as per the deicing vehicle rather than 60°C. Fluid shall be heated as per the standard procedures for Type I fluids.
3) More tests should be considered as many operations are conducted with Type I fluids only.
4) May require airport authority approval for more tests.
5) Limited flat plate tests with models (20° and 35°) show that the degradation of HOT may not be as severe as with Type IV fluids.
6) Rate pan measurements shall be more frequent.

Attachment XXI: Data Form for Condition of Tail

(Use two forms for crosswind tail tests)

Run # ____________ **Date** ______________________ **Port or Starboard** ______________ **Observer** _________________

KEY EVENT ON MAIN WING	TIME OF OBSERVATION	PHOTO/ VIDEO (Y/N)	ASSESSMENT OF TAIL (IN COMPARISON TO MAIN WING) (Check off one box only)					COMMENTS
			Much more contaminated	More contaminated	Equal	Less contaminated	Much less contaminated	
1. Immediately after anti-icing								
2. First Failure on Wing (> 315 cm^2)								
3. 50% of the LE								
4. 50% of the TE								
5. 50% of the TE								
6. 50% of the MidChord								

APPENDIX E

FULL-SCALE TESTING PHOTOS: GENERAL, PROCEDURES, AND METHODOLOGIES

BIRD'S EYE VIEW OF TEST LOCATION

TYPICAL PARKING

BIRD'S EYE VIEW OF TEST LOCATION

NE DIRECTION PARKING

SSW DIRECTION PARKING

K-LOADERS TO ACCESS WING

K-LOADER FROM LEADING EDGE

VIEW FROM K-LOADER

CREW STAIRS FOR TRAILING EDGE

VIEW OF CREW STAIRS

OPEN BUCKET DE/ANTI-ICING TRUCK

CLOSED BUCKET DE/ANTI-ICING TRUCK

OPEN BUCKET DE/ANTI-ICING TRUCK

FLUID SAMPLE FROM TANK

FLUID SPRAY SAMPLE

SPRAY AREA

WING SECTION DEICING

WING SECTION ANTI-ICING

WING SECTION ANTI-ICING

WING SECTION DE/ANTI-ICING

TAIL DEICING (ADDITIONAL TEST)

TAIL DEICING (ADDITIONAL TEST)

FLUID APPLICATION ON TEST PLATES

GLYCOL RECOVERY VEHICLE

CONTAINING SPENT FLUID

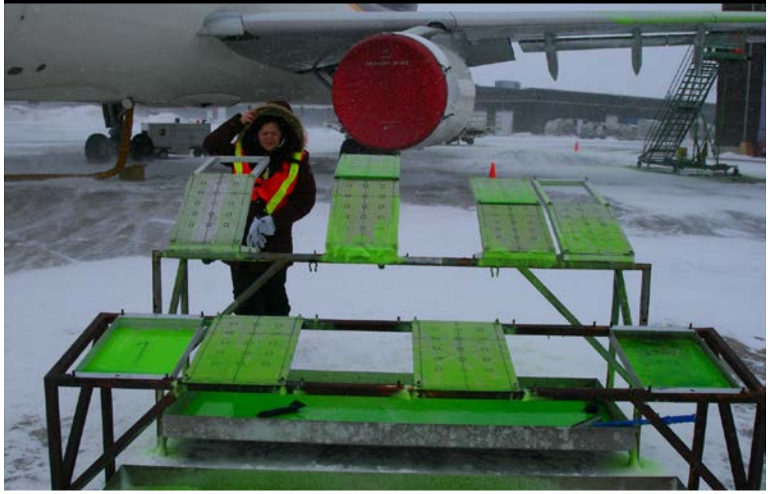
GENERAL VIEW OF SETUP

GENERAL VIEW OF SETUP

AERIAL VIEW OF SETUP

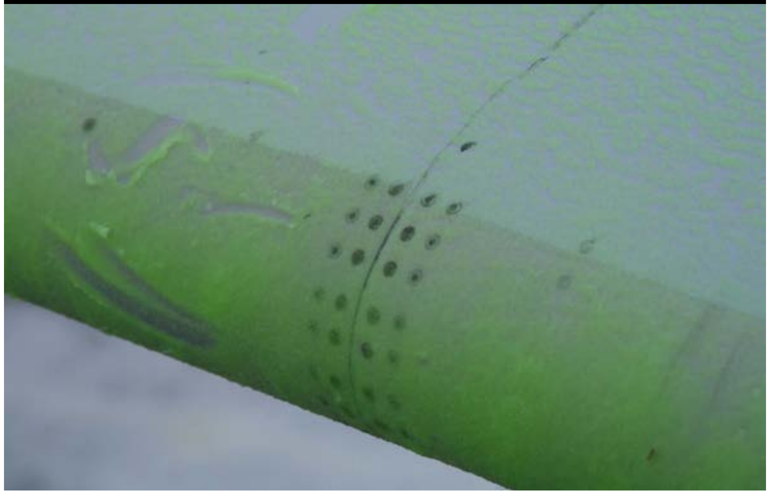
AERIAL VIEW OF SETUP

FLUID FAILURE ON PLATES



FLUID FAILURE ON PLATES

FLUID FAILURE ON WING LEADING EDGE



MEASURING PRECIPIATION RATE

PARTICIPANTS AND OBSERVERS

TEST TEAM

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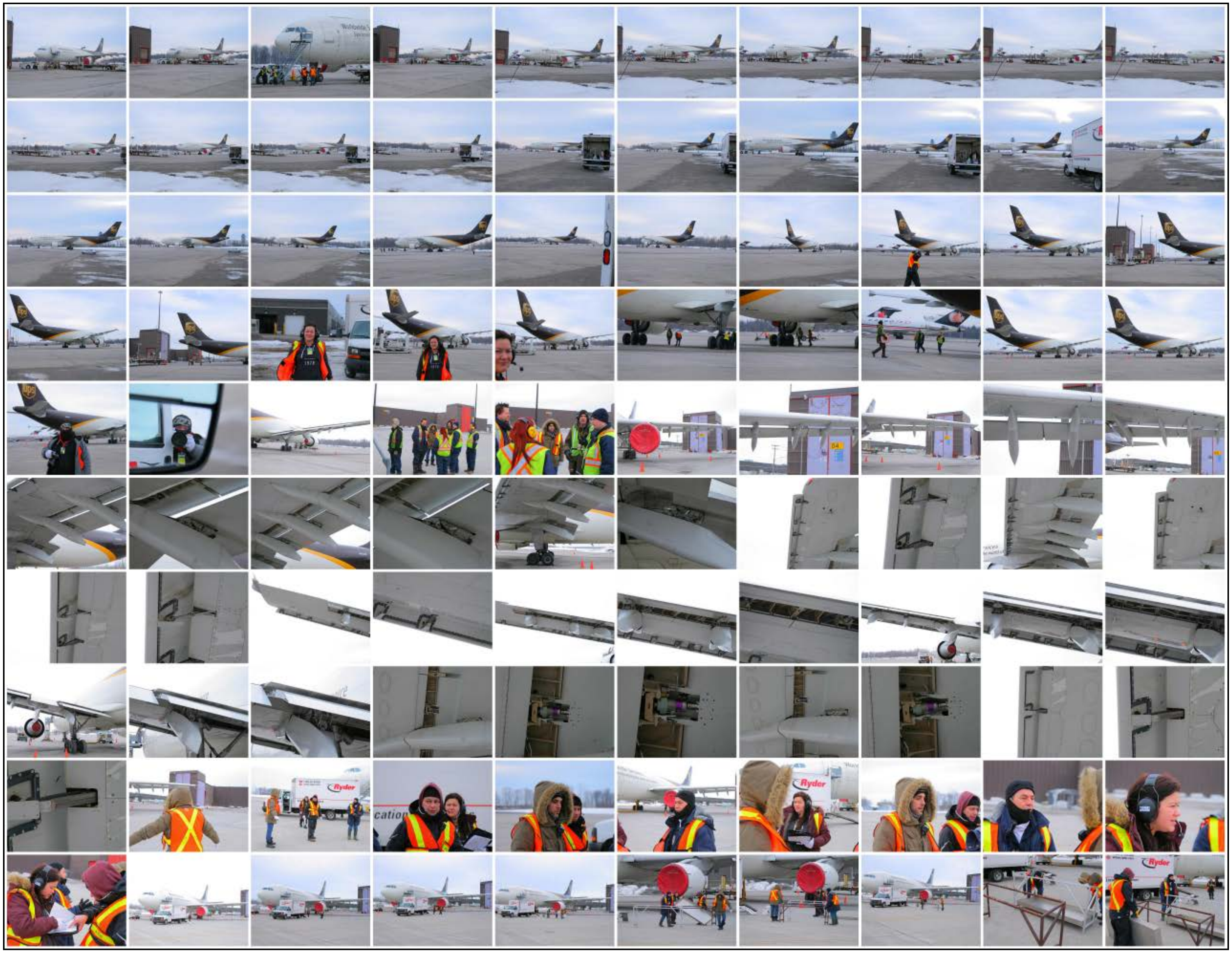
APPENDIX F

TILE MOSAIC OF PHOTOS FOR EACH FULL-SCALE TESTING RUN

UPS TESTING

FEBRUARY 24, 2012 - RUN 1

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AERO MAG 2000 YMX
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UPS TESTING

FEBRUARY 24, 2012 - RUN 2


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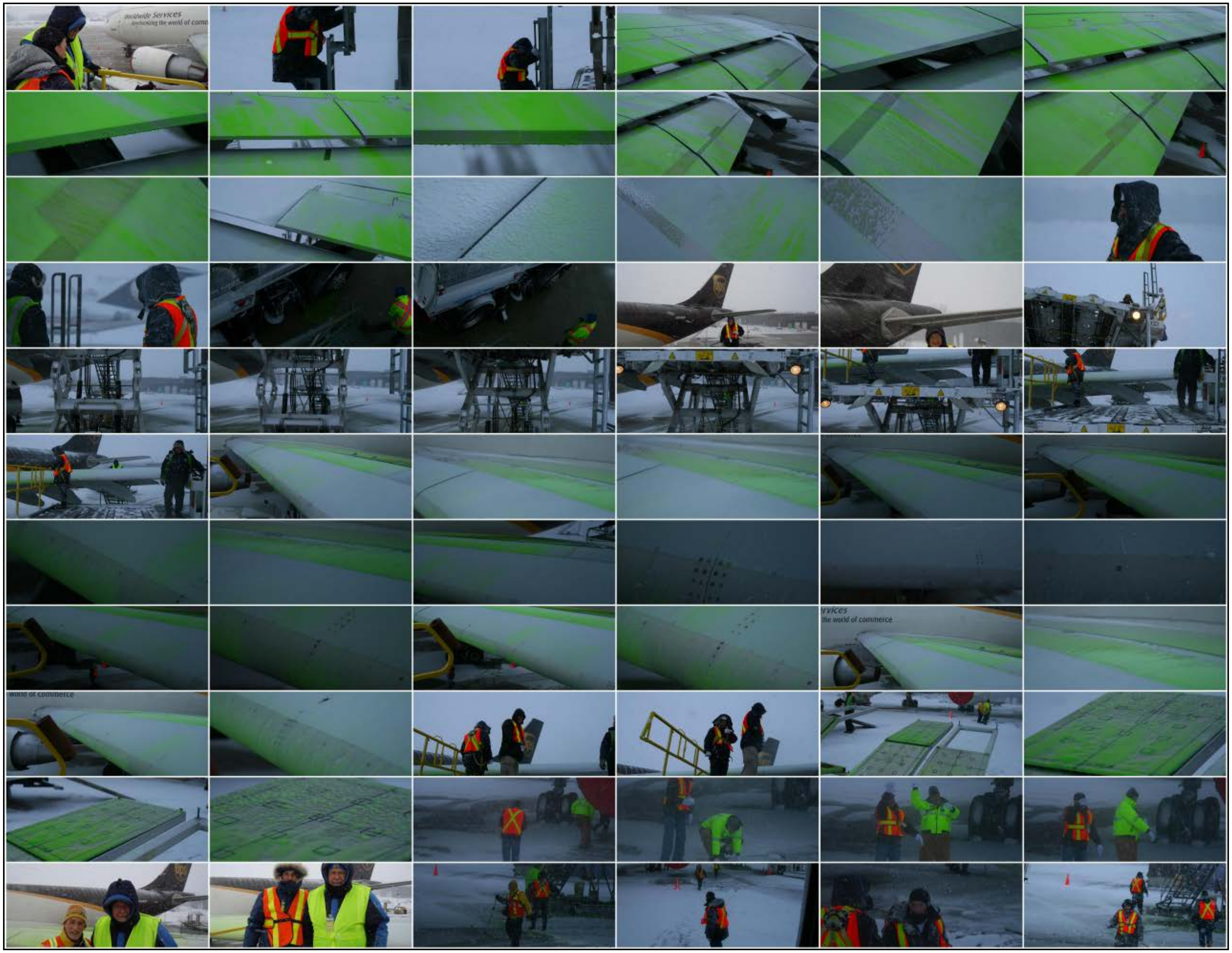
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Synchronizing the world of commerce
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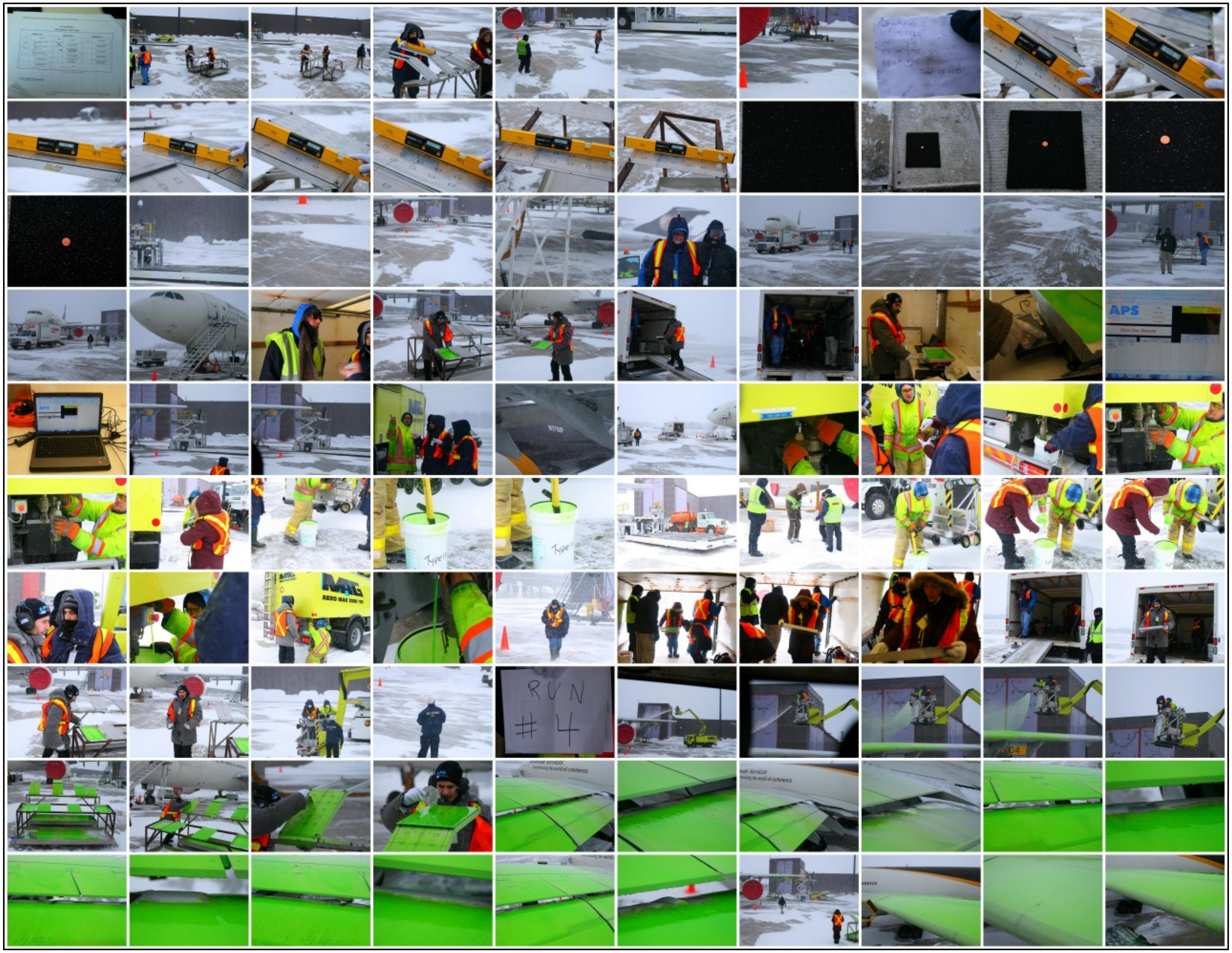
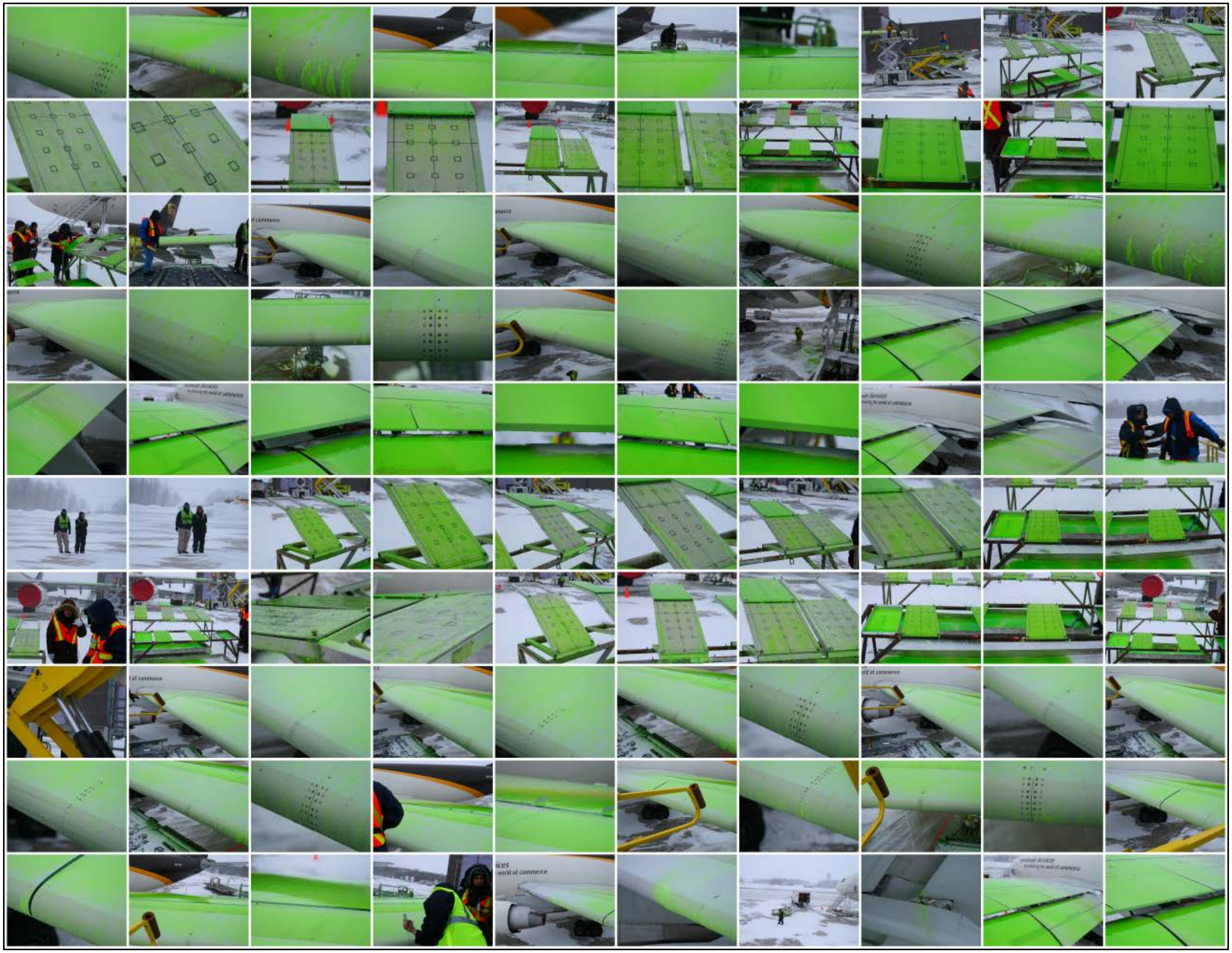
UPS TESTING

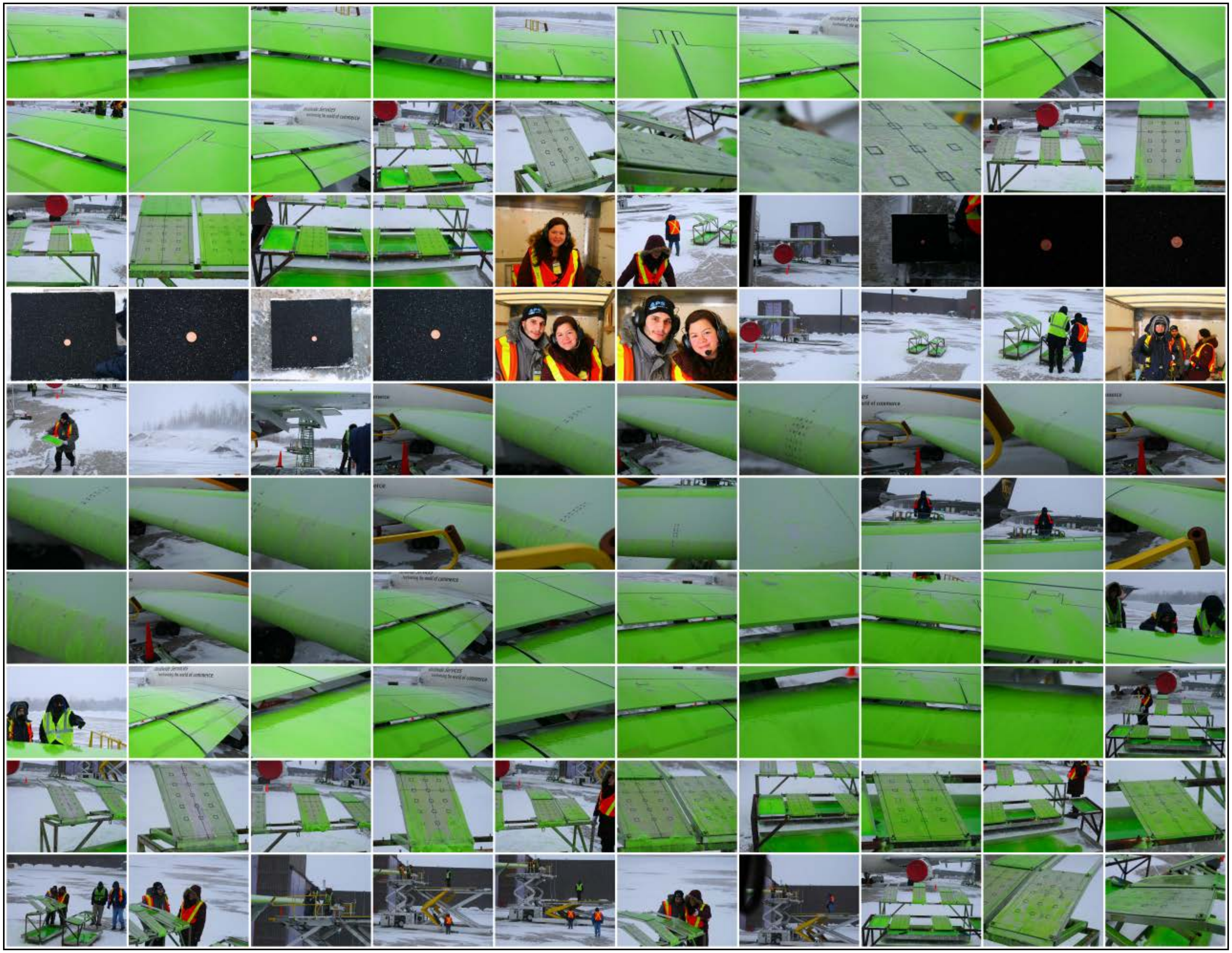
FEBRUARY 24, 2012 - RUN 3

UPS TESTING

MARCH 1, 2012 - RUN 4


RUN
#4
APS





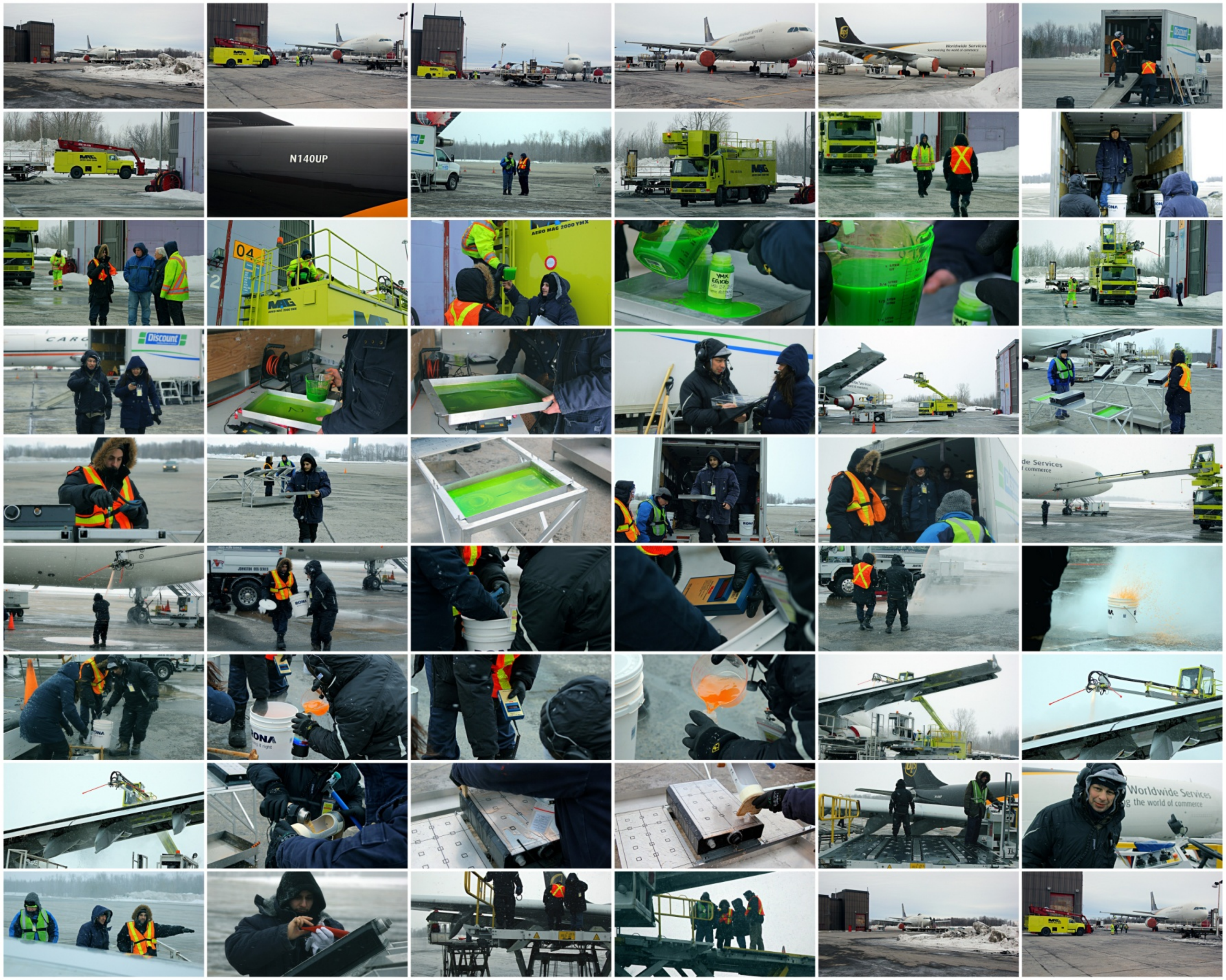
UPS TESTING

MARCH 1, 2012 - RUN 5


RUN
5

UPS TESTING

FEB 27, 2013 - RUN 6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AERO MAG 2000 YMX
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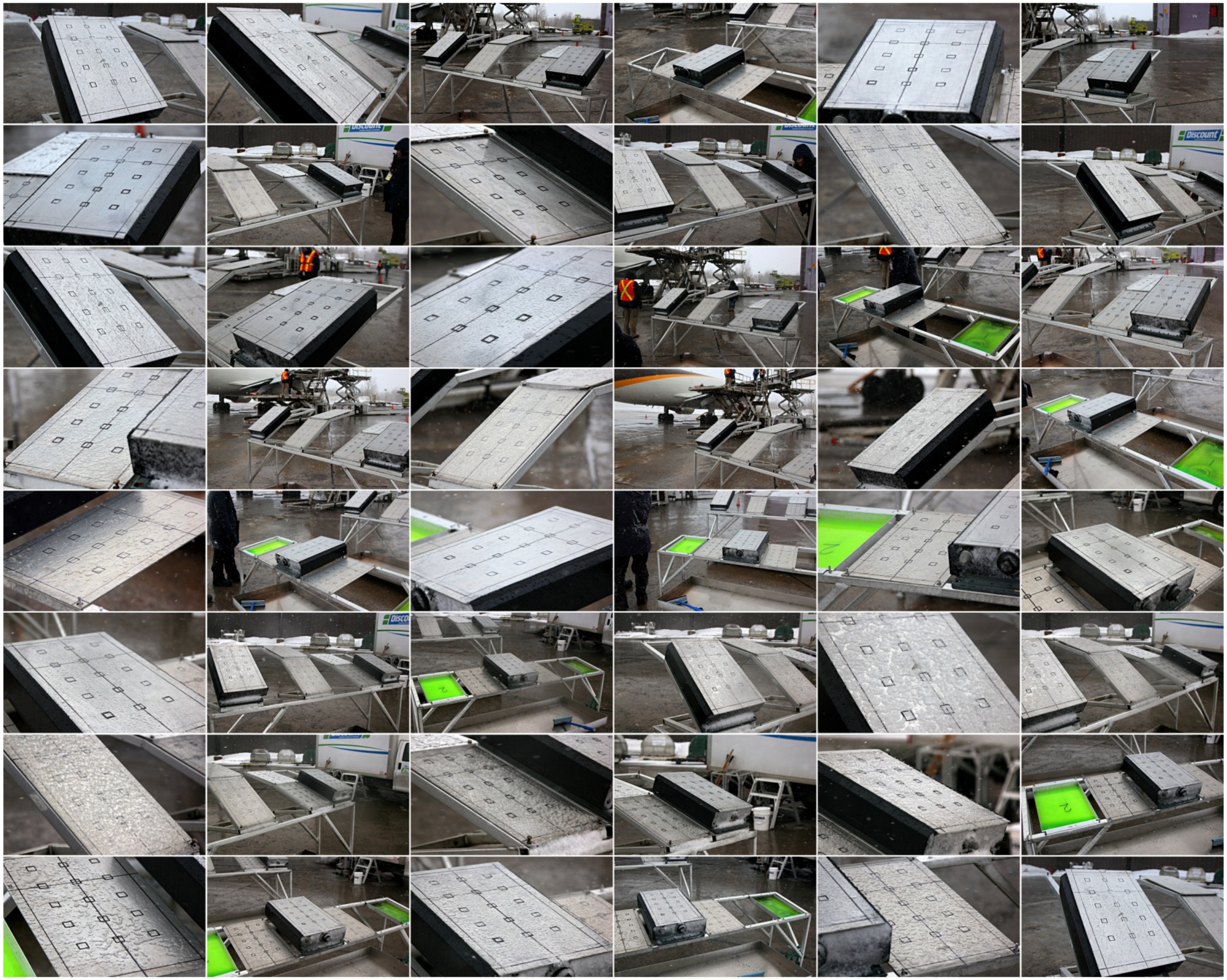

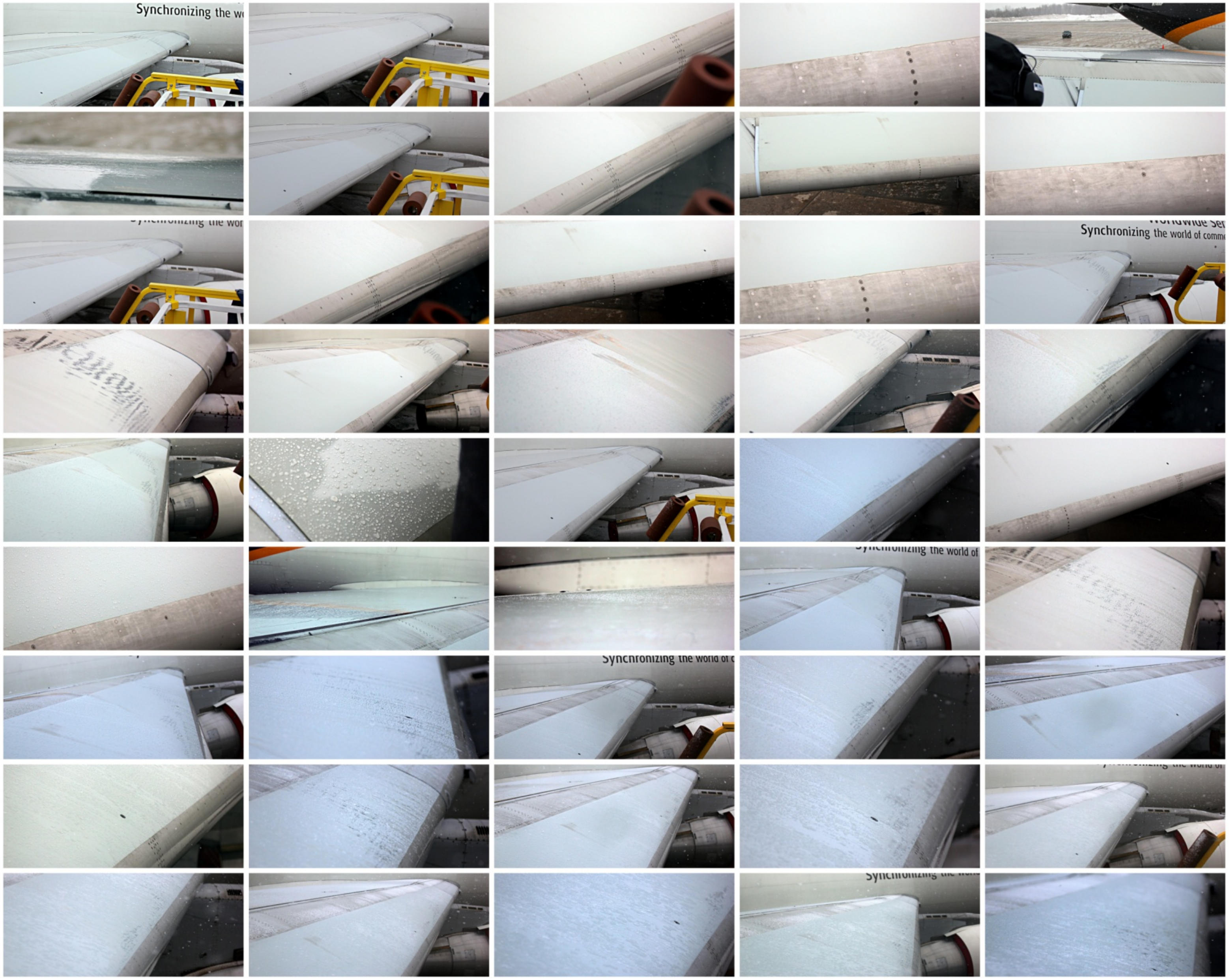
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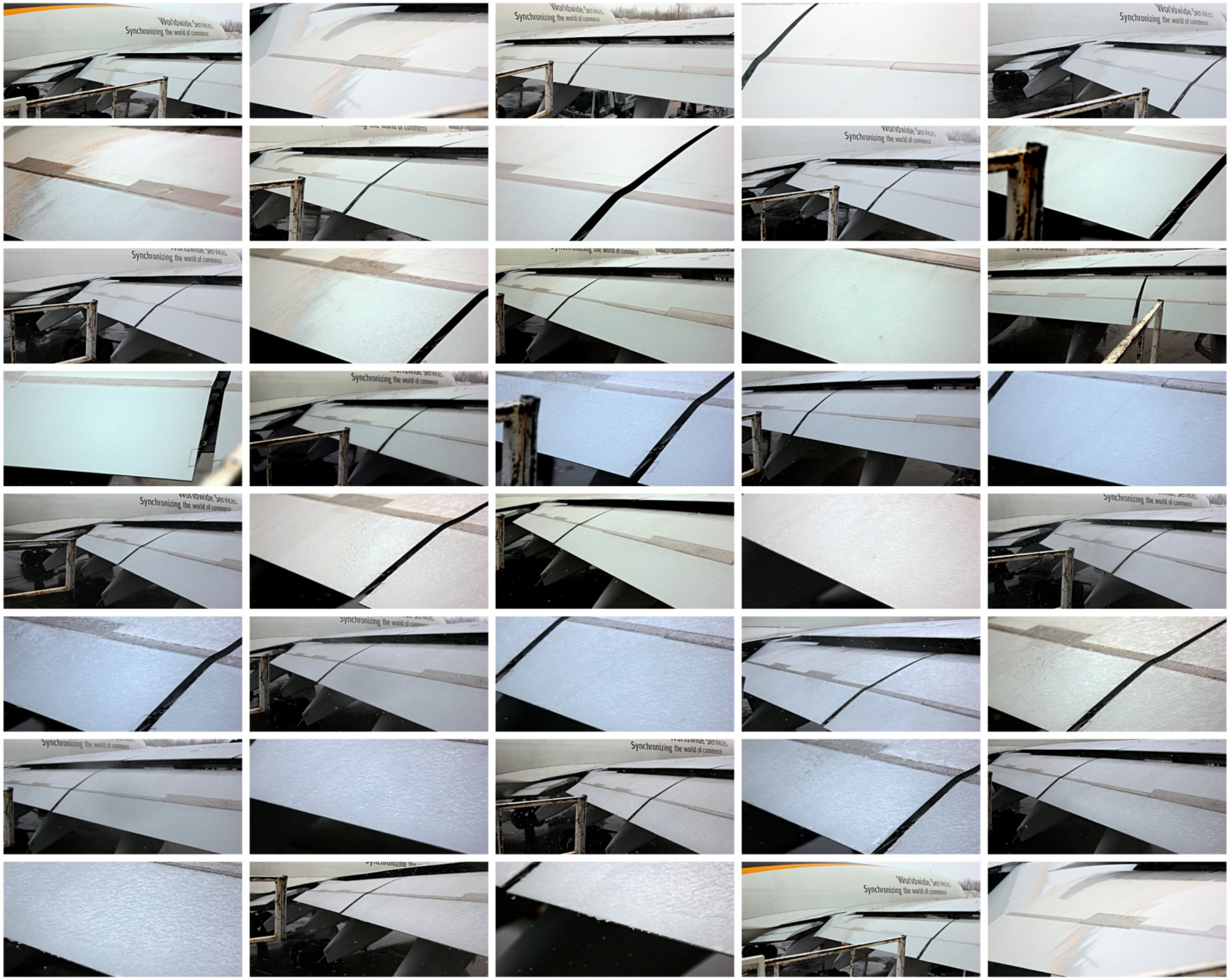
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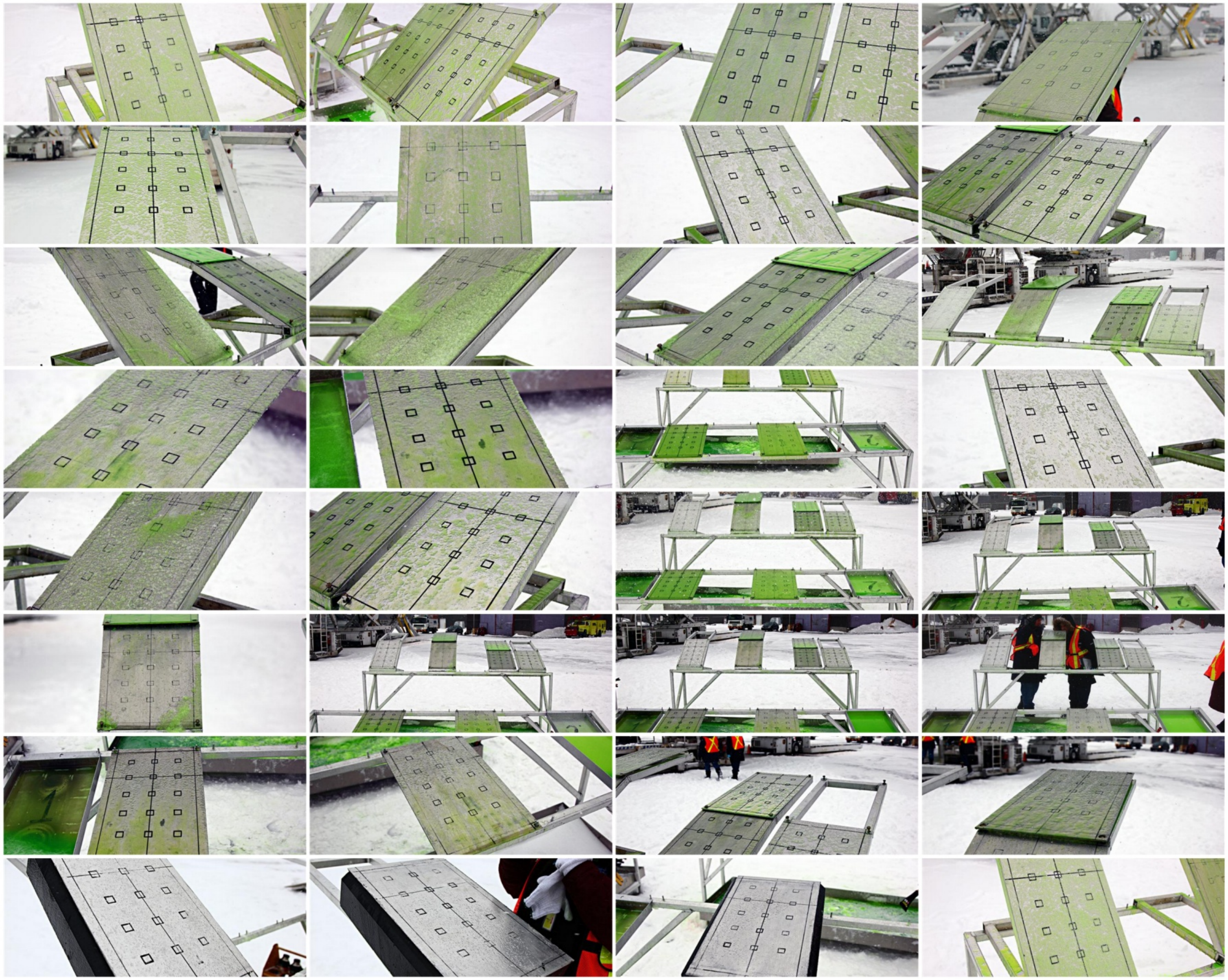
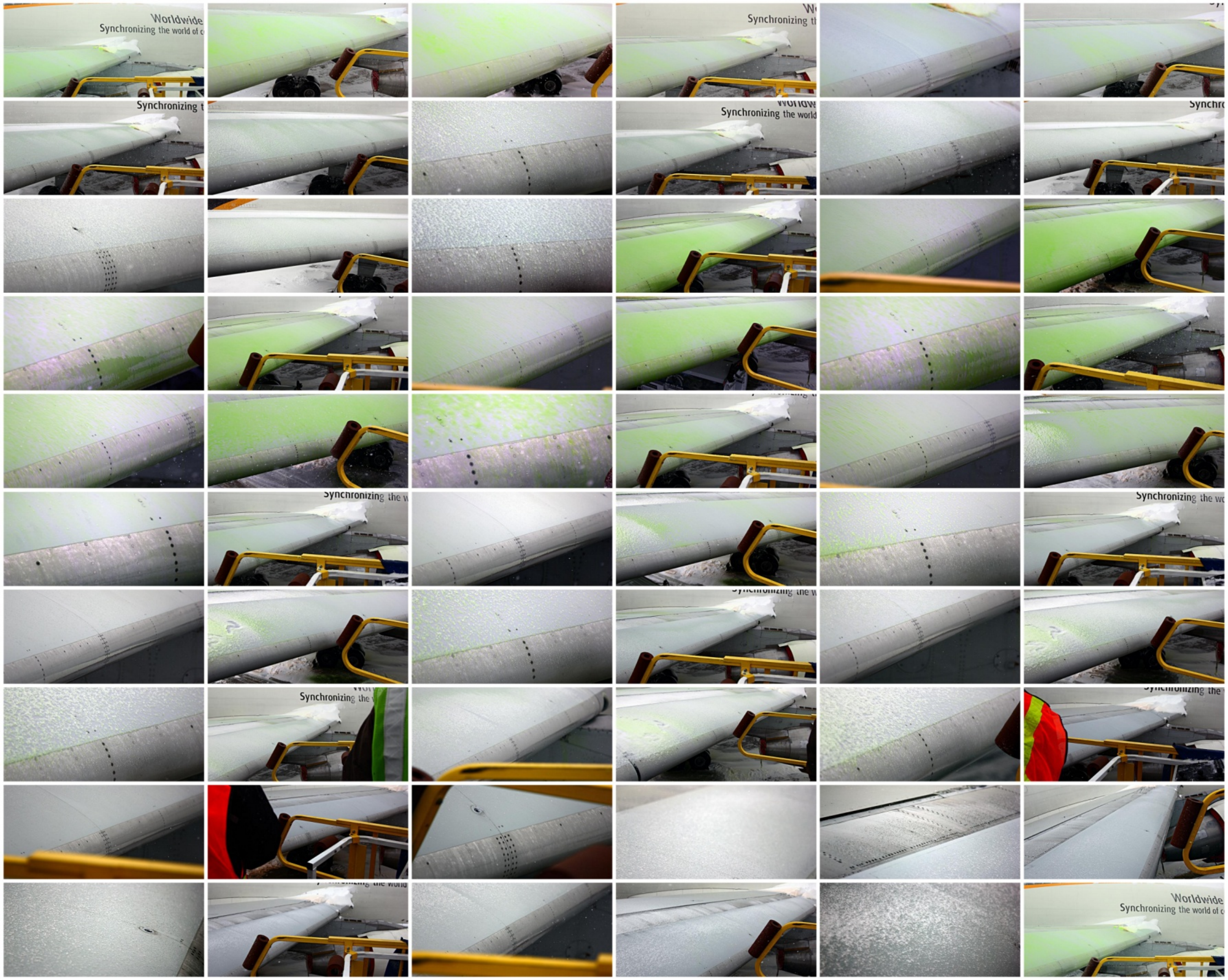
UPS TESTING

March 19, 2013 - RUN 7,8,9

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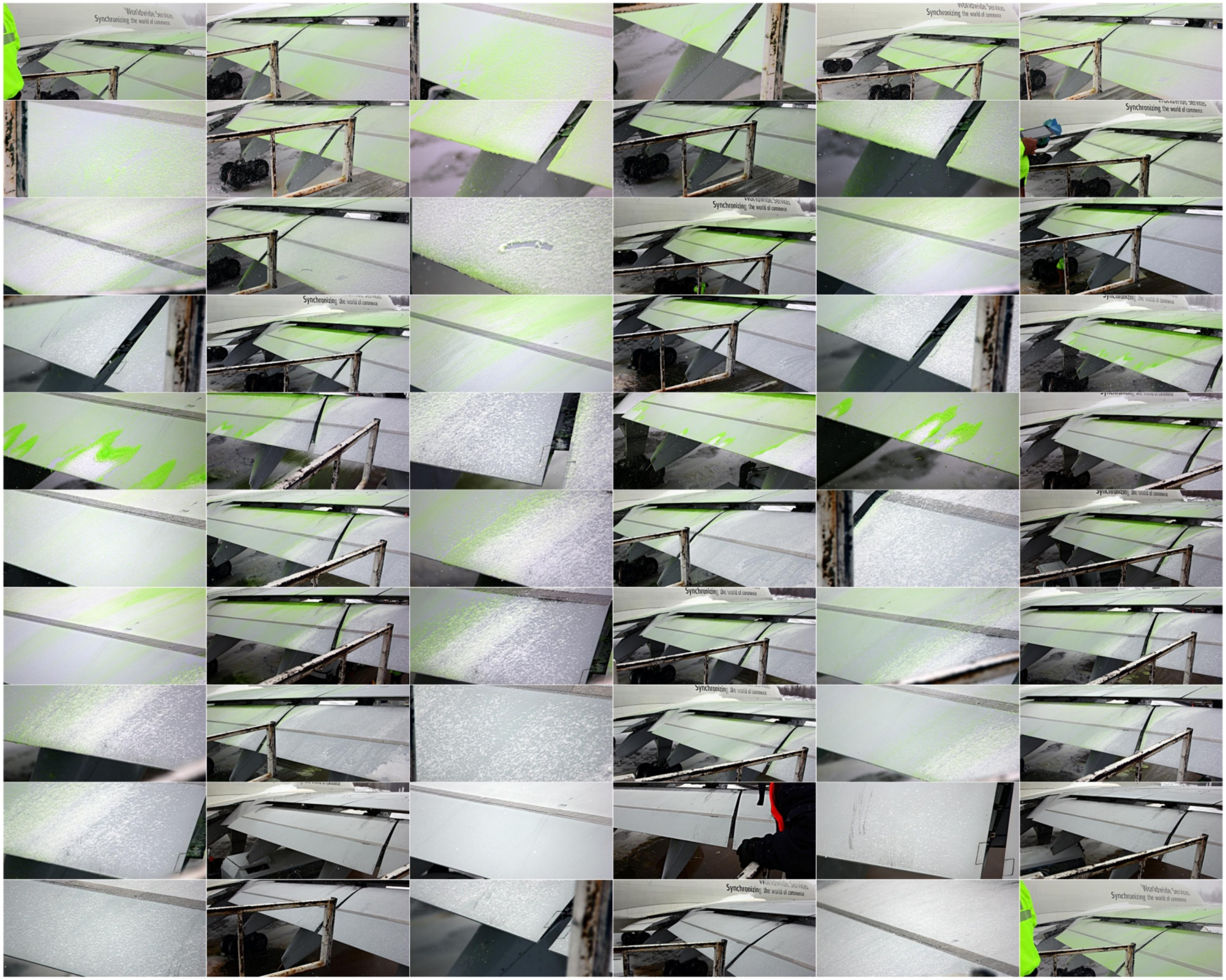
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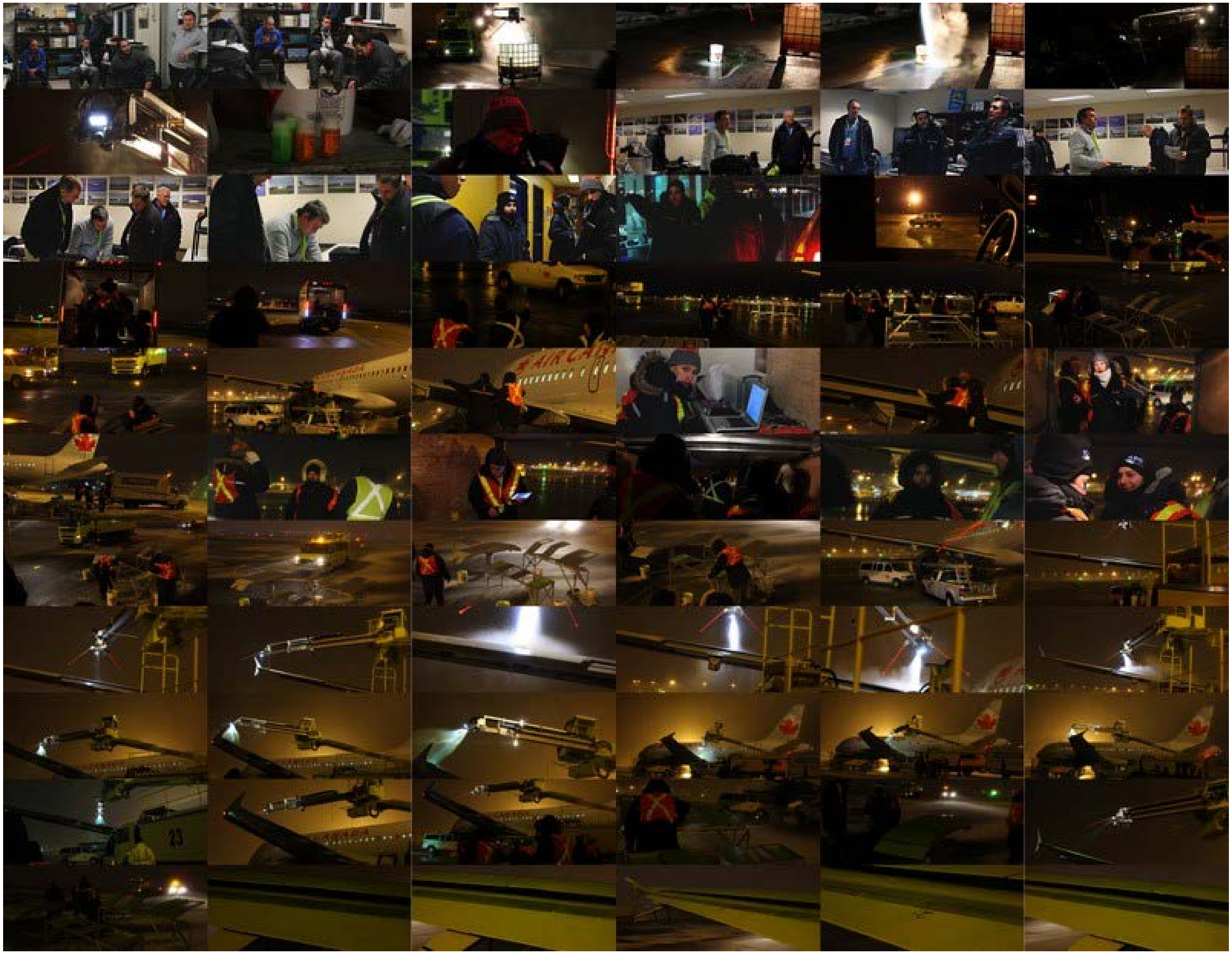
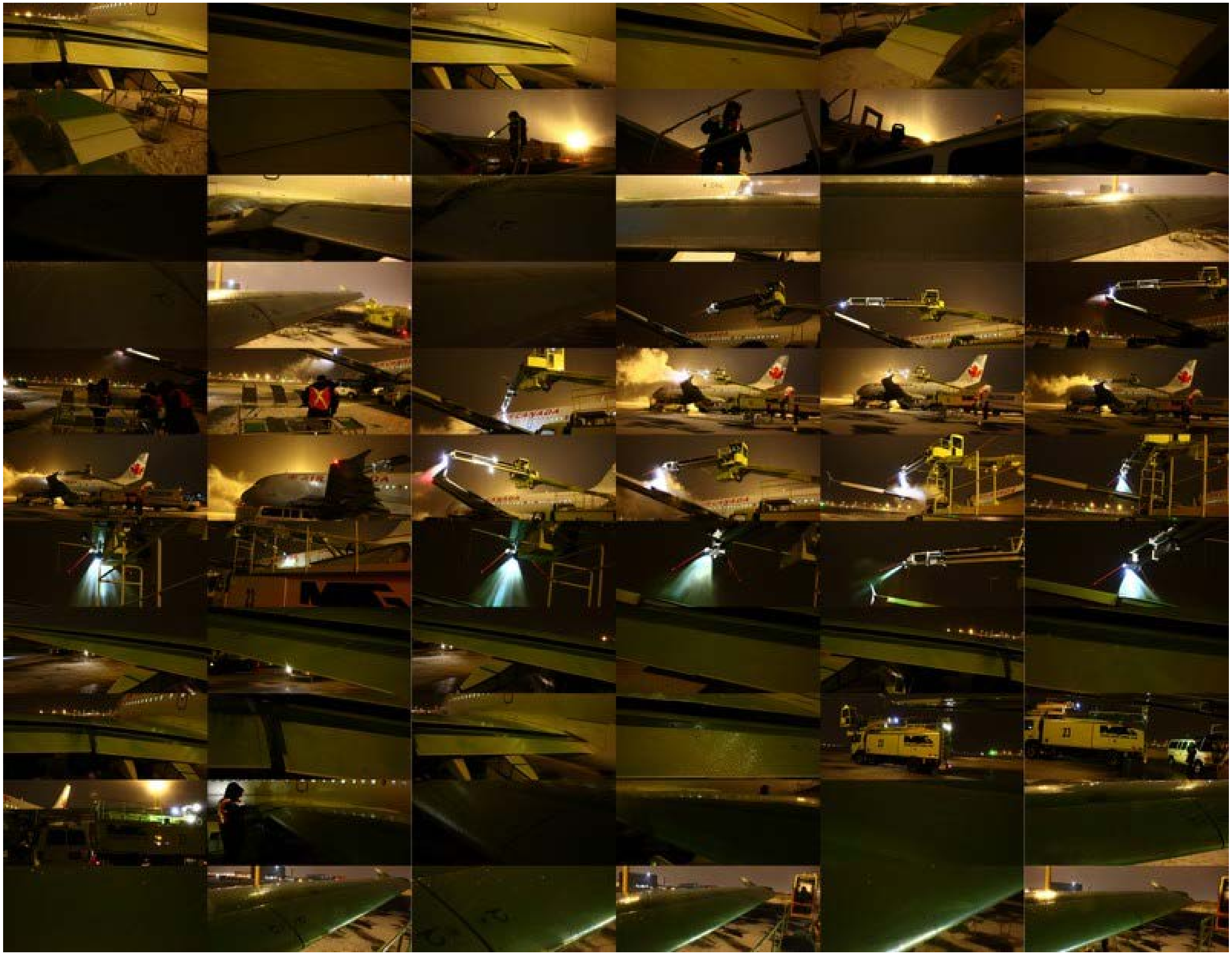
AIR CANADA TESTING

March 2, 2016 - RUN 10 and 11



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APPENDIX G

2010-11 SPECIAL INDOOR FREEZING PRECIPITATION TESTING RESULTS

1. 2010-11 INDOOR FREEZING PRECIPITATION TESTING RESULTS – PHASE 2

The Phase 2 indoor freezing precipitation testing consisted of ad-hoc tests which would provide an initial indication of performance, the results of which would serve as a basis for planning of the winter 2011-12 testing.

1.1 Indoor Freezing Precipitation Testing Setup – Phase 2

Objective #1 – Nested Flap Configurations with Larger Gaps: Conduct flat plate test using the previously used methodology, however simulate larger gaps between the top "feeding" plate and the bottom plate. The gap between the top 10º plate and the lower 20-35º plate will be approximately 4 cm. The baseline tests will simulate minimal to no gap, similar to the methodology described in the previous indoor and outdoor "nested" flap testing. Testing was conducted in precipitation conditions. A hand drawn diagram of the test setup is shown in Figure 1. Photo 1 demonstrates the setup used.

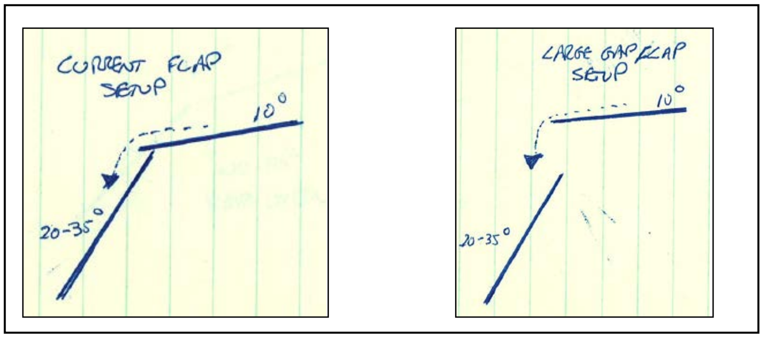

Figure 1: Test Setup to Evaluate Effect of Flap Gap on Endurance Times

Objective #2 – Slat Configurations to Investigate Fluid Flow: It is assumed that fluid will not flow from the main wing section onto the deployed slat, however limited testing should be conducted to determine the minimum gap possible to provide a flow of fluid onto the simulated slat. A similar setup to the deployed flaps tests will be used, however in this setup the bottom plate will be resting on the top plate, rather than vice versa. Overlap gap distances of 0, 0.9, 1.3, and 2.0 mm will be simulated. This testing was conducted in dry conditions as the objective was to investigate fluid flow, and not fluid endurance times. A hand drawn diagram of the test setup is shown in figure 2. Photo 2 demonstrates the setup used.

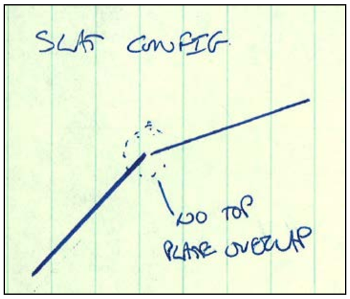

Figure 1: Test Setup to Evaluate Effect of Slat Configuration on Fluid Flow

Objective #3 – Effect of Slat Curvature on Fluid Endurance Time: Conduct testing with a curved surface, simulating a deployed slat, to determine the effects of fluid flow from a curved surface on fluid endurance times. The endurance time recorded on the curved surface will be compared to a highly sloped flat plate to validate the procedure previously used. Testing was conducted in precipitation conditions. A hand drawn diagram of the test setup is shown in figure 3.

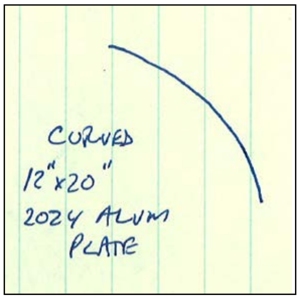

Figure 3: Test Setup to Evaluate Effect of Slat Curvature on Fluid Endurance Time

1.2 Nested Flap Configurations with Larger Gaps

Endurance times measured on a 20° nested plate with a 4 cm gap between overlapping surfaces were equal or shorter than the 20° nested plate with no gap, however were still longer when compared to the baseline 10° plate. Based on the limited results, it is expected that the effect of a gap between overlapping surfaces when simulating a nested flap is minor. Figure 1 demonstrates the results.

It should be noted that these tests were conducted indoors with no wind conditions. Testing would be required in outdoor conditions with wind conditions in order to further substantiate the results as the higher wind component could impact how the fluid flows from the top plate onto the steeper angle bottom plate.

1.3 Slat Configurations to Investigate Fluid Flow

The results indicated that when no gap was simulated, the Type IV fluid flowed from the main test plate section onto the overlapping slat section. It was assumed that this would generate similar endurance times on both surfaces if exposed to precipitation.

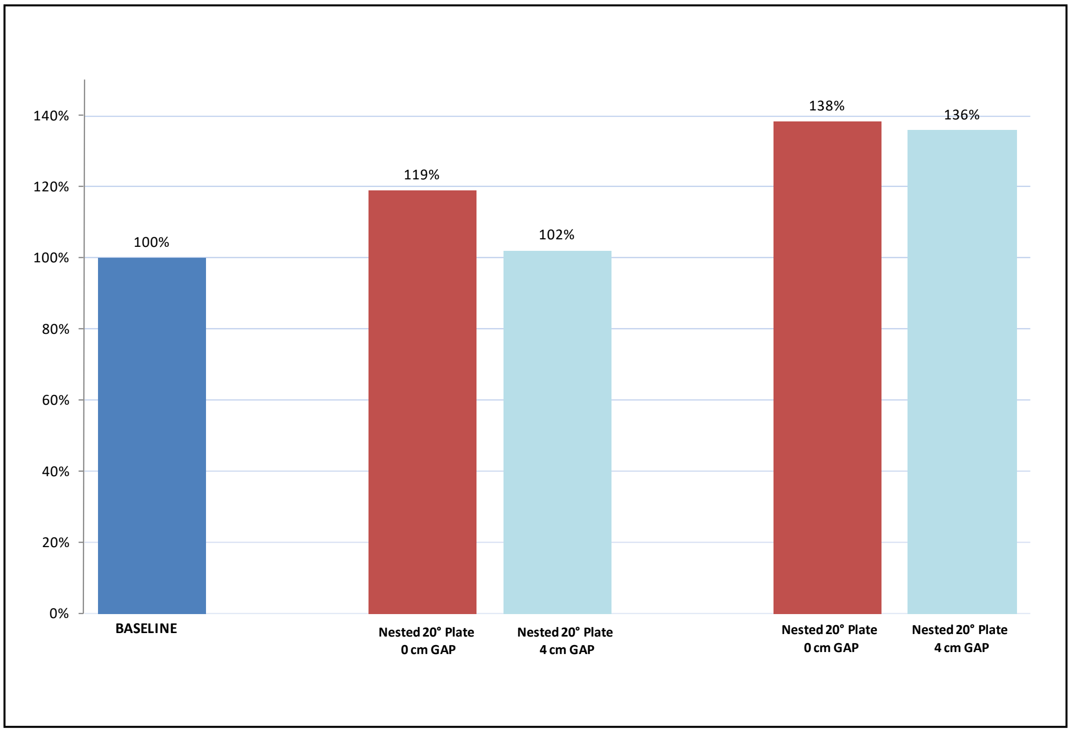

Figure 1: Effect of Flap Gap on Endurance Times

When a gap of 0.9mm was simulated, the Type IV fluid poured onto the main test plate section flowed onto the simulated slat section initially, however as the fluid settled on the main plate section, the fluid thickness reduced and therefore less fluid flowed onto the simulated slat section.

When a gap of 1.3mm was simulated, the results were similar to the previous, however the time required for fluid to stop flowing on the simulated slat was shorter due to the larger gap distance.

When a gap of 2.0mm was simulated, some Type IV fluid flowed onto the simulated slat initially after pour due to the greater thickness of the fluid being poured, however very quickly after, the thickness of the fluid reduced, and the feeding stopped.

In general, the results indicated that even small discontinuities in the surfaces can reduce fluid flow from the main test plate onto the simulated slat. In an operational scenario, the slat would not benefit from fluid feeding, therefore any fluid present on an extended slat would be subject to early fluid failure due to the steeper angle of the surface, but would not benefit from fluid feeding from the main wing section.

1.4 Effect of Slat Curvature on Fluid Endurance Time

Endurance times measured on a curved 35º plate were slightly shorter than the flat 35º plate, however were still significantly shorter when compared to the baseline 10º plate. Based on the limited results, it is expected that the effect of a curved plate when simulating a slat configuration is minor as both configurations (when inclined to higher angles) indicate large reductions in endurance time as compared to the baseline 10º plate. Figure 2 demonstrates the results.

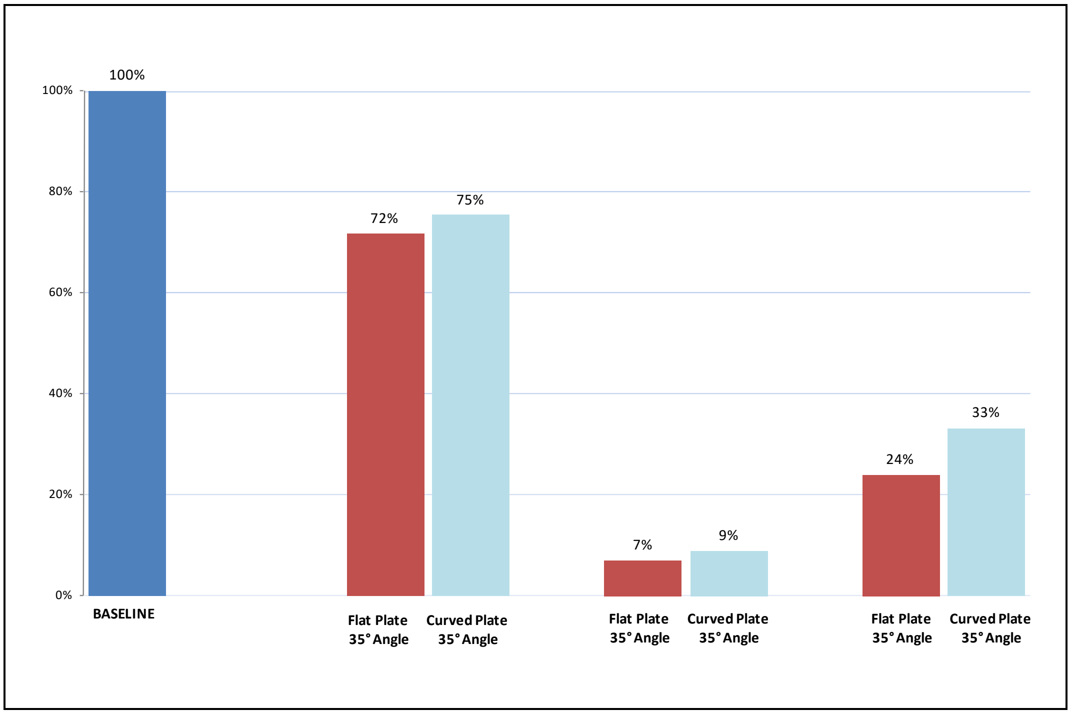

Figure 2: Effect of Curved vs. Flat Plate on Endurance Times

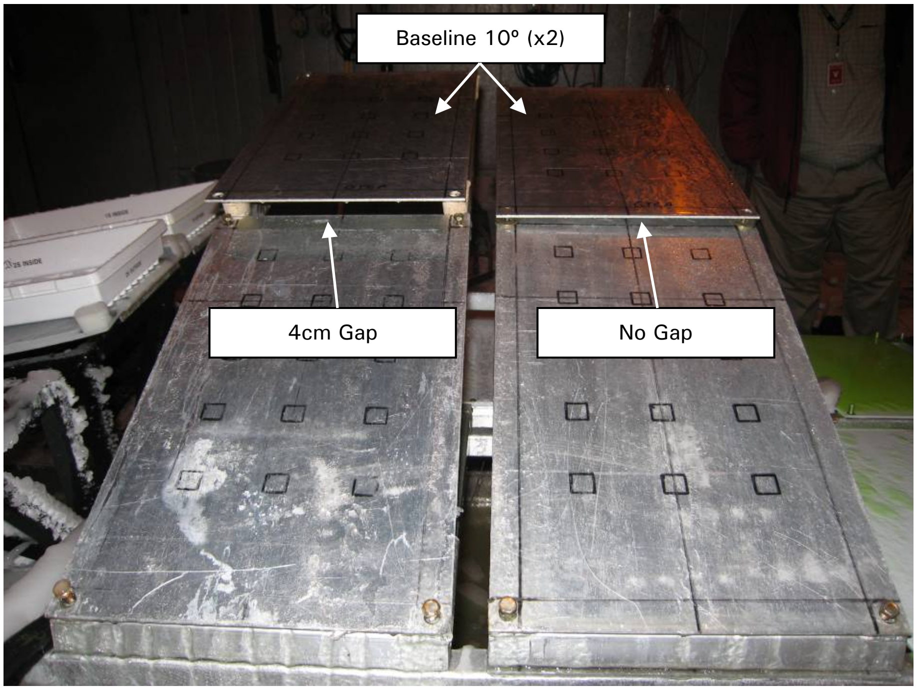

Photo 1: Nested Flap Configurations with Larger Gaps Test Setup

Photo 2: Slat Configurations Test Setup to Investigate Fluid Flow

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APPENDIX H

FULL-SCALE TEST DATA SUMMARIZED AND PLOTTED

Run 1 (Dry Run)

February 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Run # 1 (Dry Run)

Feb 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	- 1.5ºC
Aircraft Skin Temp:(at start of day)	- 0.4ºC
Aircraft/Stand Orientation:	Into wind/Into wind
Wind/Plate Direction:	50 - 60º/50 -60º
Aircraft Direction:	60º
Wind Speed:	15 kph
Precipitation Type:	Dry
Average Rate of 10º Plate:	0 g/dm²/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)	18.7º	21.0º
Mid Slat Angle (middle slat)	21.6º	24.0º
Mid Flap Angle (middle flap):	21.0º	32.0º

Fluid Information

Type I

Type I Fluid:	Type I UCAR ADF (40%) (Brix =25.25)
Application on Wing:	Sprayed from Nozzle
Temperature:	15.1ºC
Quantity of Type I used:	95 litres *

** Estimated as about half of run 2 quantity*

Type IV

Type IV Fluid:	EG 106 (Brix = 33.00)
Application on Wing:	Sprayed from Nozzle
Application on Stand:	Sprayed from Nozzle into bucket and hand-poured onto plates.
Temperature:	15.9ºC
Quantity of Type IV used:	104 litres*

** Estimated the same as run 2 quantity*

Holdover Time Information

Start of Test:	12:11 PM
End of Test:	Approx: 13:10 PM

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Run 2

February 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Run # 2

Feb 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	- 1.2ºC
Aircraft Skin Temp: (at start of day)	- 0.4ºC
Aircraft/Stand Orientation:	Into wind/Into wind
Wind/Plate Direction:	60 - 80º/60 -80º
Aircraft Direction:	60º
Wind Speed:	15 - 20 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	15.2 g/dm^2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)	18.7º	21.0º
Mid Slat Angle (middle slat)	21.6º	24.0º
Mid Flap Angle (middle flap):	21.0º	32.0º

Fluid Information

Type I

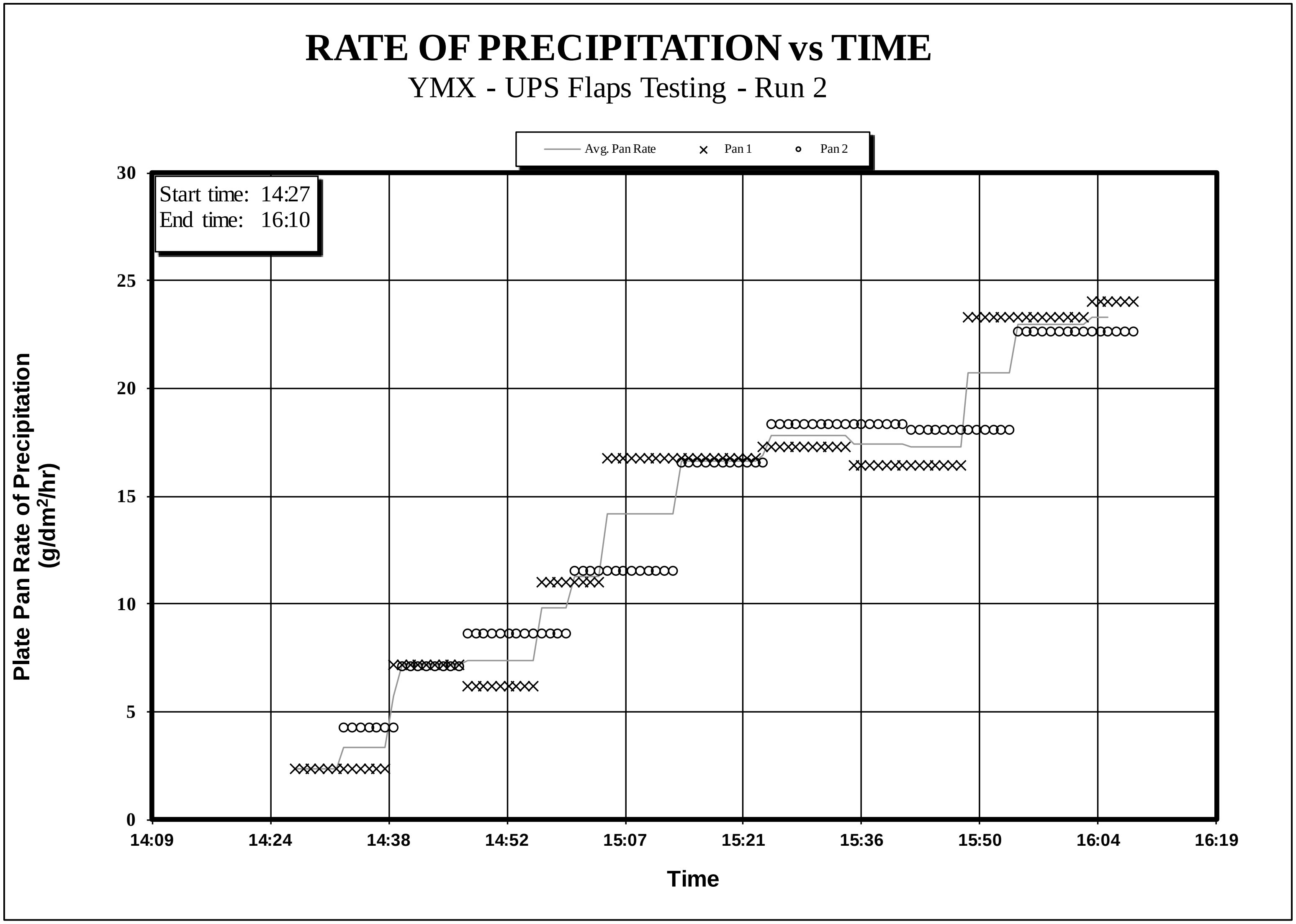
Type I Fluid:	Type I UCAR ADF (40%) (Brix =25.25)
Application on Wing :	Sprayed from Nozzle
Temperature:	Not measured
Quantity of Type I used:	190 litres

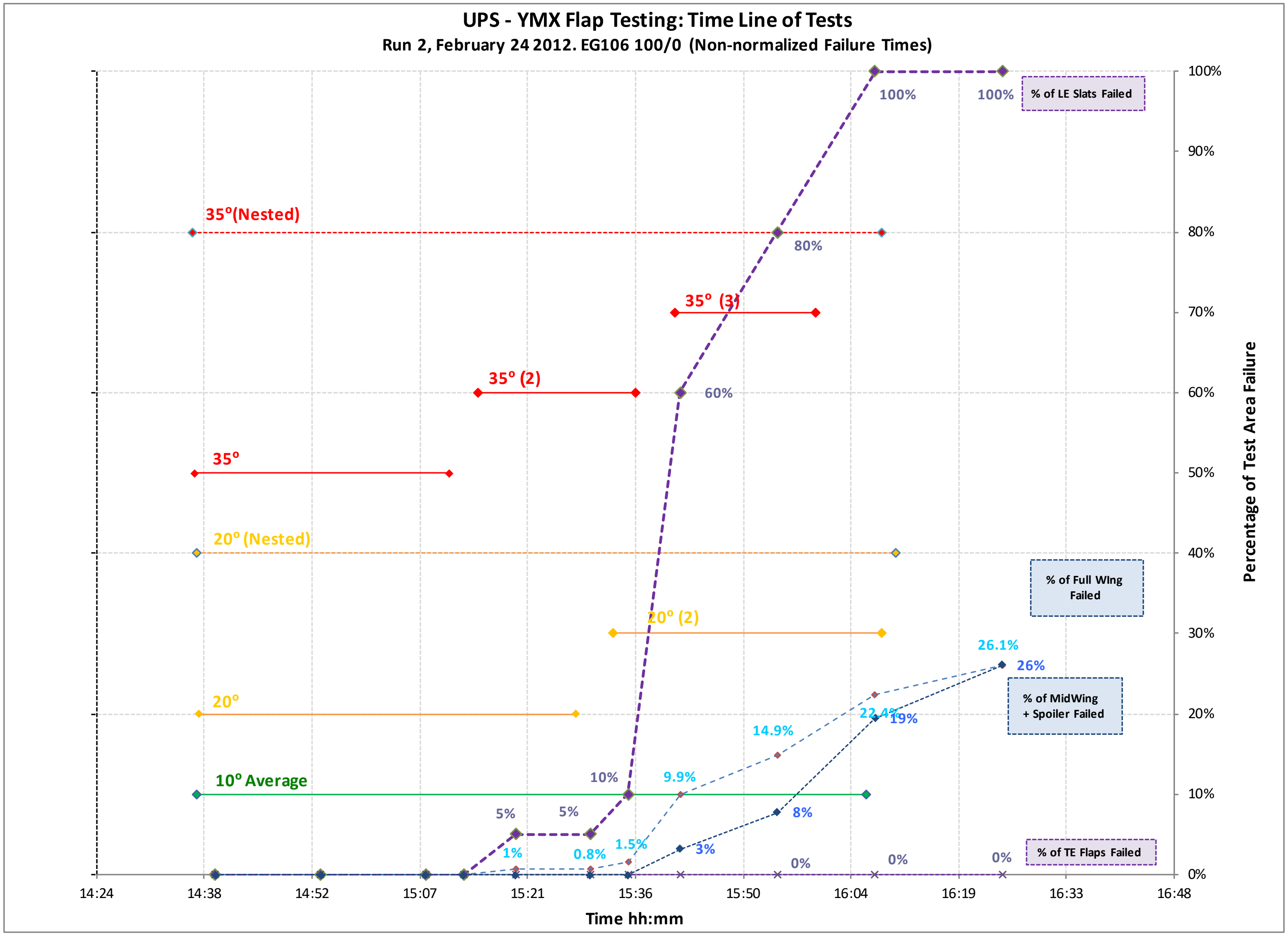
Type IV

Type IV Fluid:	EG 106 (Brix = 33.00)
Application on Wing :	Sprayed from Nozzle
Application on Stand:	Extracted from truck tank and hand-poured onto plates.
Temperature:	Not measured
Quantity of Type IV used:	104 litres

Holdover Time Information

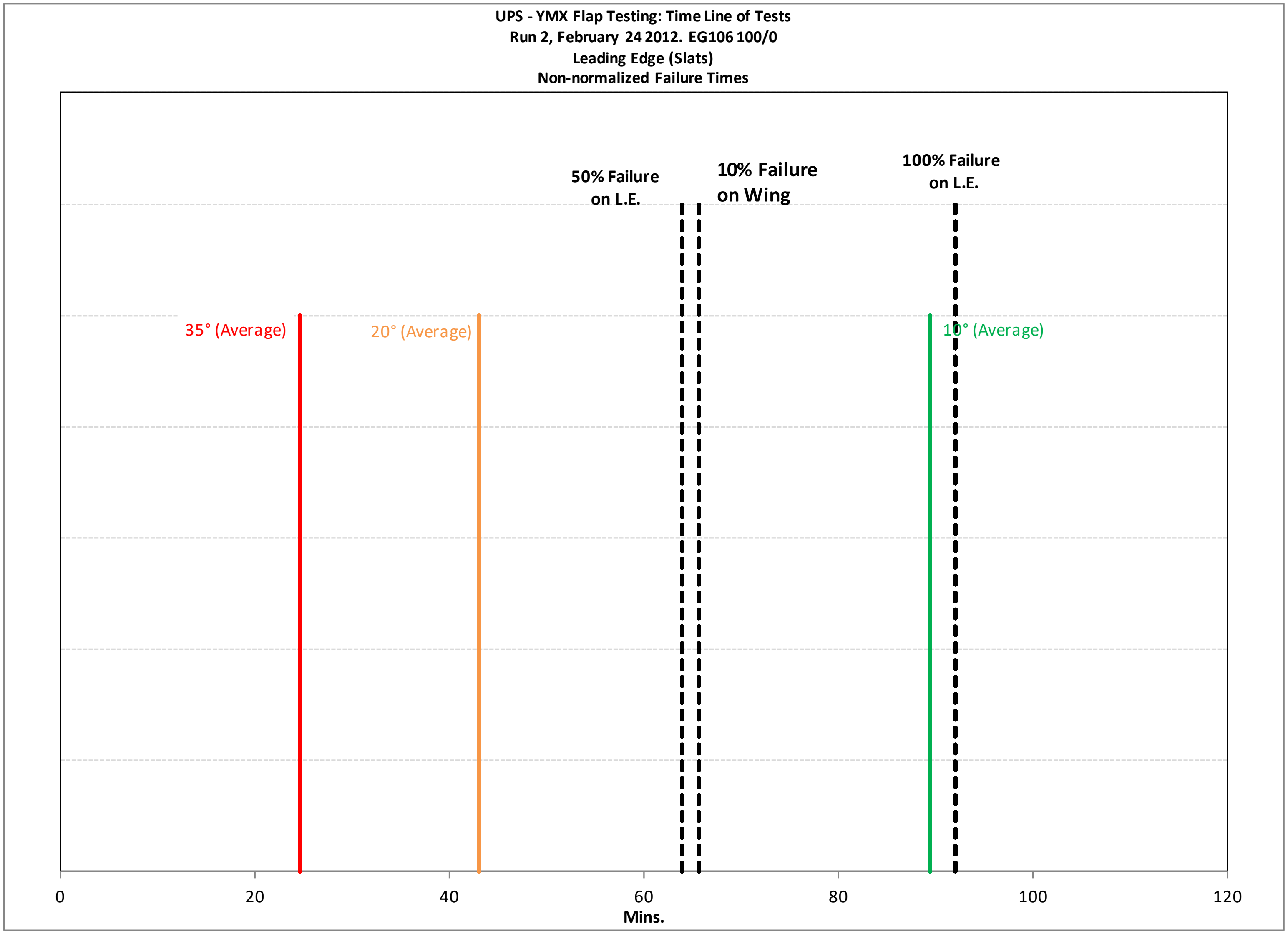
Start of Test:	14:33 PM
End of Test:	16:10 PM

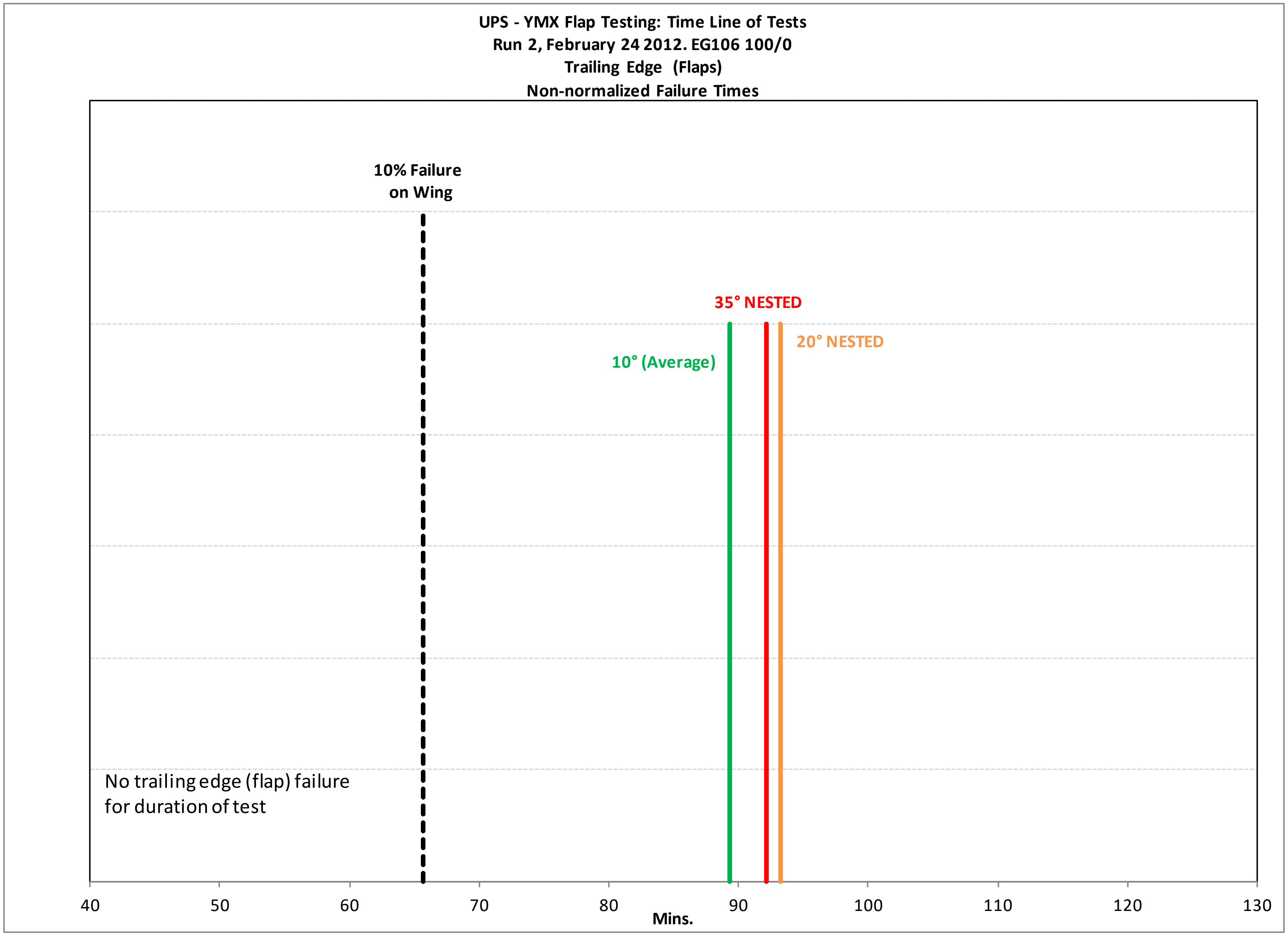

RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 2
Avg. Pan Rate
Pan 1
Pan 2
Start time: 14:27
End time: 16:10
Plate Pan Rate of Precipitation (g/dm²/hr)
30
25
20
15
10
5
0
14:09
14:24
14:38
14:52
15:07
15:21
15:36
15:50
16:04
16:19
Time



UPS - YMX Flap Testing: Time Line of Tests

Run 2, February 24 2012. EG106 100/0 (Non-normalized Failure Times)


UPS - YMX Flap Testing: Time Line of Tests
Run 2, February 24 2012. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
50% Failure on L.E.
10% Failure on Wing
100% Failure on L.E.
35° (Average)
20° (Average)
10° (Average)
0
20
40
60
80
100
120
Mins.


UPS - YMX Flap Testing: Time Line of Tests
Run 2, February 24 2012. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
10% Failure on Wing
35° NESTED
20° NESTED
10° (Average)
No trailing edge (flap) failure for duration of test
40
50
60
70
80
90
100
110
120
130
Mins.

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Run 3

February 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Run # 3

Feb 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	- 0.7ºC
Aircraft Skin Temp: (at start of day)	- 0.4ºC
Aircraft/Stand Orientation:	Into wind/Into wind
Wind/Plate Direction:	60 - 80º/60 -80º
Aircraft Direction:	60º
Wind Speed:	19 - 24 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	30.5 g/dm2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)	18.7º	21.0º
Mid Slat Angle (middle slat)	21.6º	24.0º
Mid Flap Angle (middle flap):	21.0º	32.0º

Fluid Information

Type I

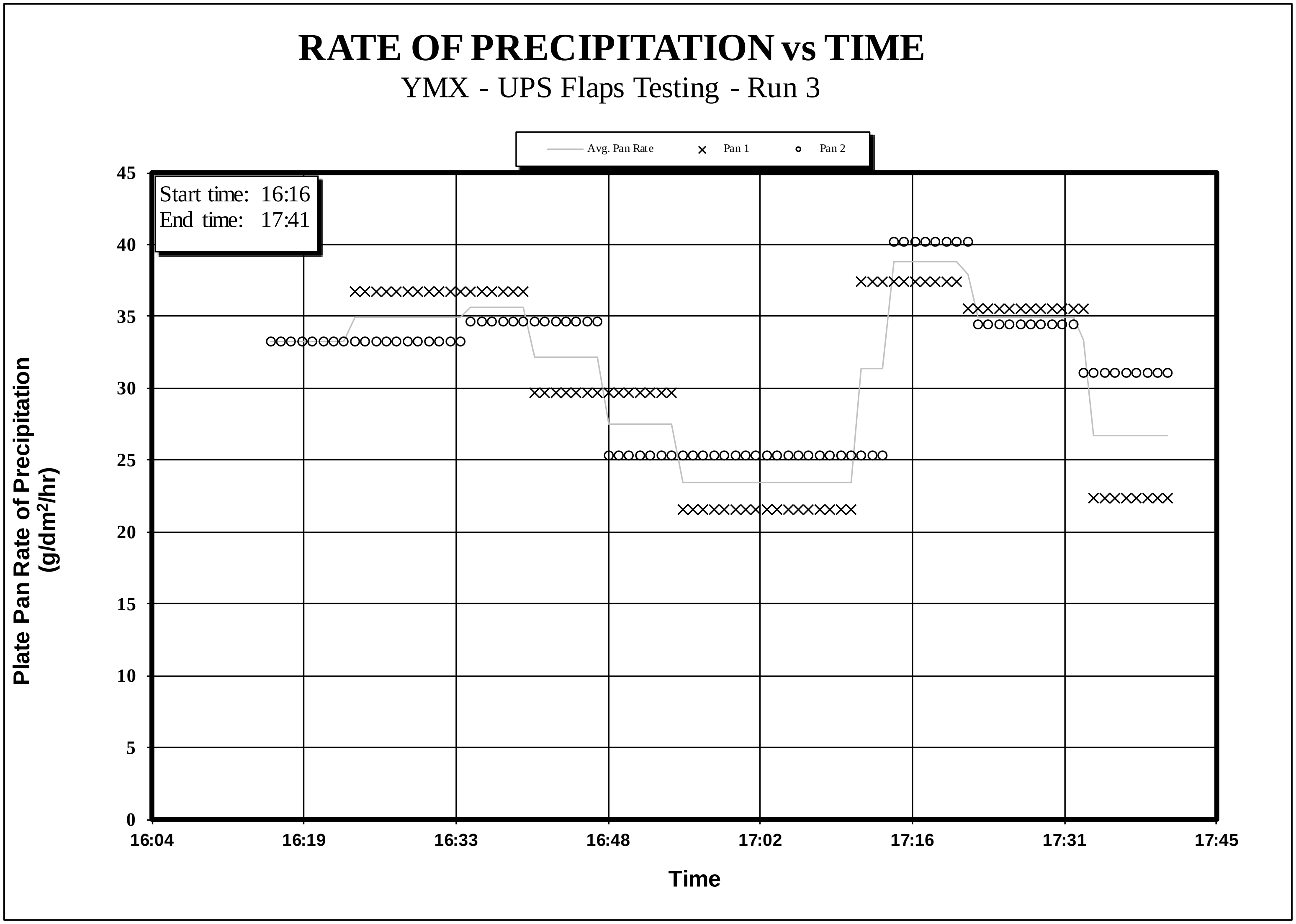
Type I Fluid:	Type I UCAR ADF (40%) (Brix =25.25)
Application on Wing:	Sprayed from Nozzle
Temperature:	Not measured
Quantity of Type I used:	132 litres

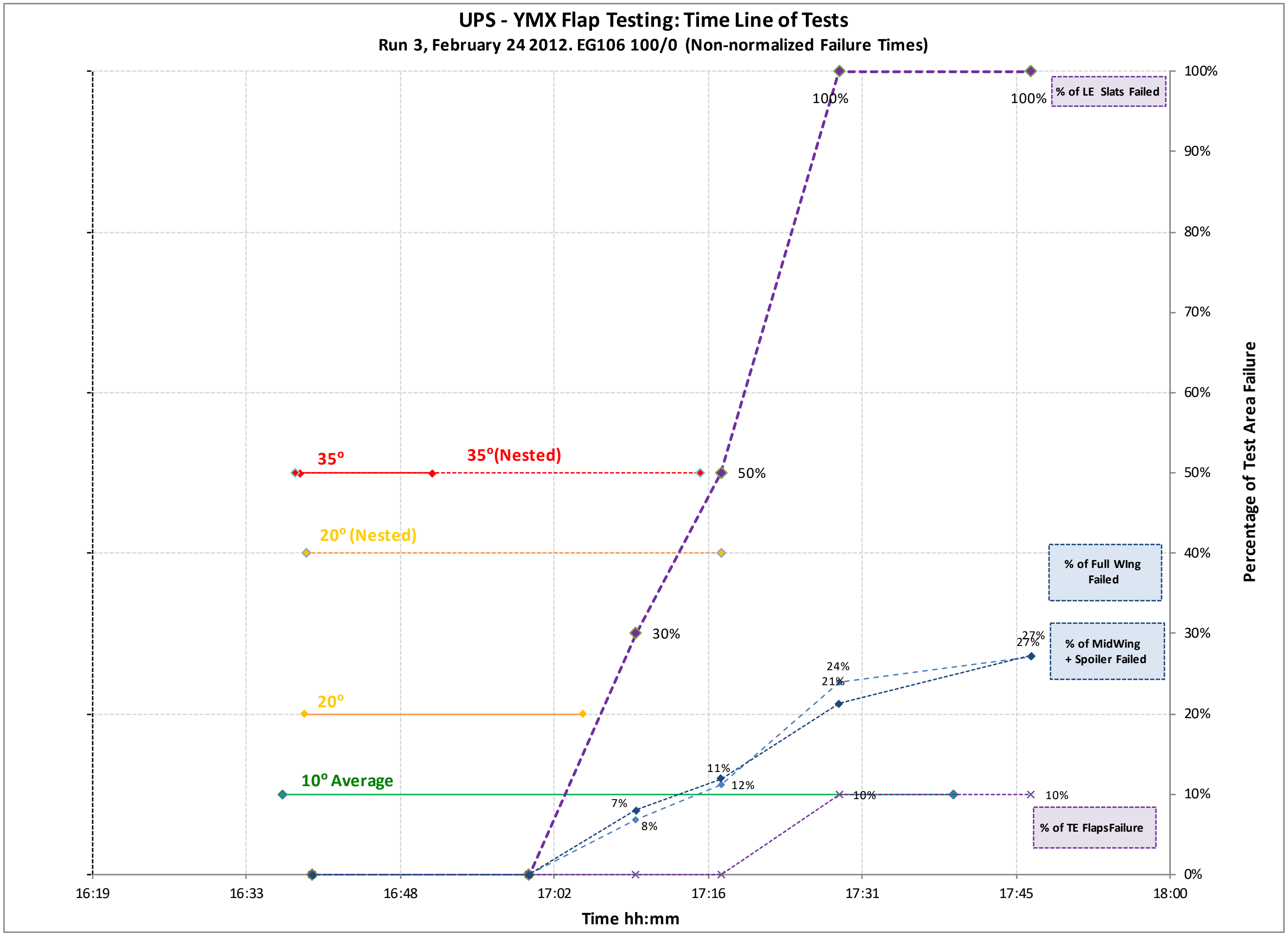
Type IV

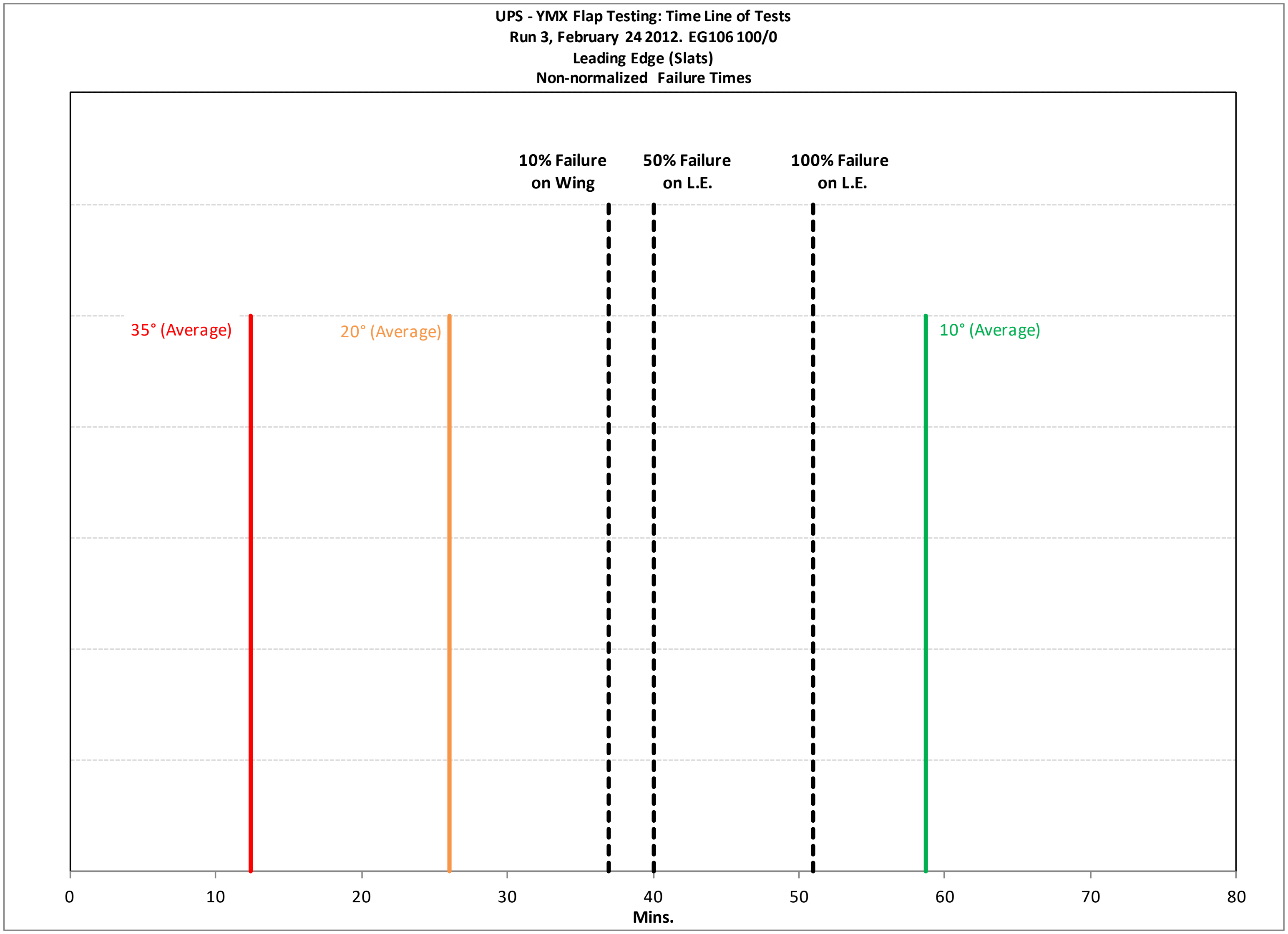
Type IV Fluid:	EG 106 (Brix = 33.00)
Application on Wing:	Sprayed from Nozzle
Application on Stand:	Extracted from truck tank and hand-poured onto plates.
Temperature:	Not measured
Quantity of Type IV used:	112litres

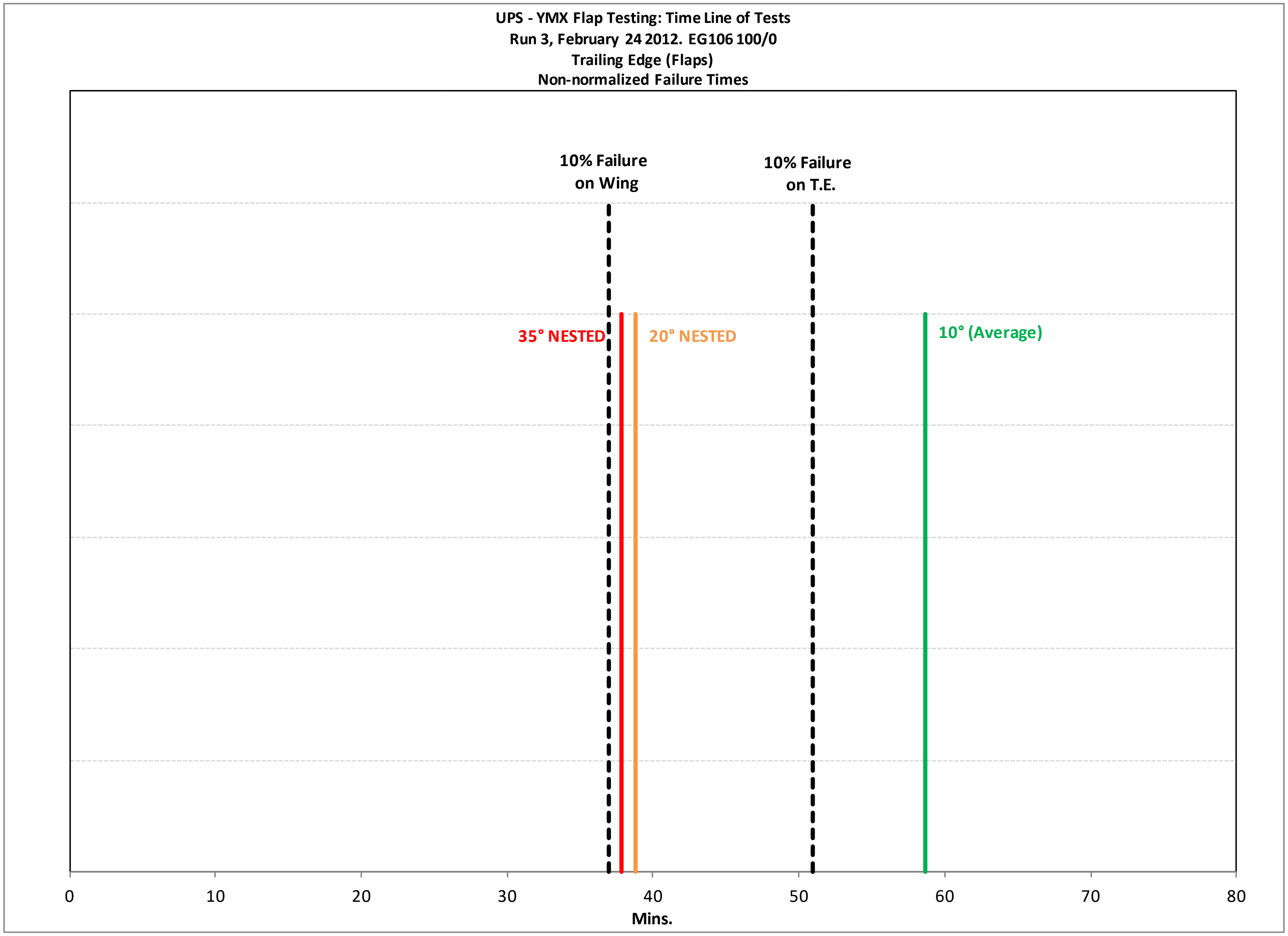
Holdover Time Information

Start of Test:	16:35 PM
End of Test:	17:41 PM


RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 3
Avg. Pan Rate
Pan 1
Pan 2
Start time: 16:16
End time: 17:41
Plate Pan Rate of Precipitation (g/dm²/hr)
0
5
10
15
20
25
30
35
40
45
16:04
16:19
16:33
16:48
17:02
17:16
17:31
17:45
Time


UPS - YMX Flap Testing: Time Line of Tests
Run 3, February 24 2012. EG106 100/0 (Non-normalized Failure Times)
35°
35°(Nested)
20° (Nested)
20°
10° Average
100%
100%
50%
30%
24%
21%
27%
27%
11%
12%
7%
8%
10%
10%
% of LE Slats Failed
% of Full WIng Failed
% of MidWing + Spoiler Failed
% of TE FlapsFailure
16:19
16:33
16:48
17:02
17:16
17:31
17:45
18:00
Time hh:mm
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Test Area Failure


UPS - YMX Flap Testing: Time Line of Tests
Run 3, February 24 2012. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
10% Failure on Wing
50% Failure on L.E.
100% Failure on L.E.
35° (Average)
20° (Average)
10° (Average)
0
10
20
30
40
50
60
70
80
Mins.


UPS - YMX Flap Testing: Time Line of Tests
Run 3, February 24 2012. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
10% Failure on Wing
10% Failure on T.E.
35° NESTED
20° NESTED
10° (Average)
0
10
20
30
40
50
60
70
80
Mins.

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Run 4

March 1, 2012

UPS Airbus A-300 Port Wing

Mirabel Airport

Run # 4

Mar 1, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	- 7.5ºC
Aircraft Skin Temp: (at start of day)	- 5.8ºC
Aircraft/Stand Orientation:	Into wind/Into wind
Wind/Plate Direction:	60 – 80º/60 – 80º
Aircraft Direction:	60º
Wind Speed:	20 – 25 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	9.7g/dm²/h

Slat / Flap Angle Information

Angles Measured*

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)	18.7º	21.0º
Mid Slat Angle (middle slat)	21.6º	24.0º
Mid Flap Angle(middle flap):	21.0º	32.0º

*On the second day of testing (Runs 4 and 5), angles were measured to be 18º, 20º, and 22º for the ¼ slat angle, mid slat angle, and mid flap angle, respectively. It is not known exactly at which chord these angles were taken.

Fluid Information

Type I

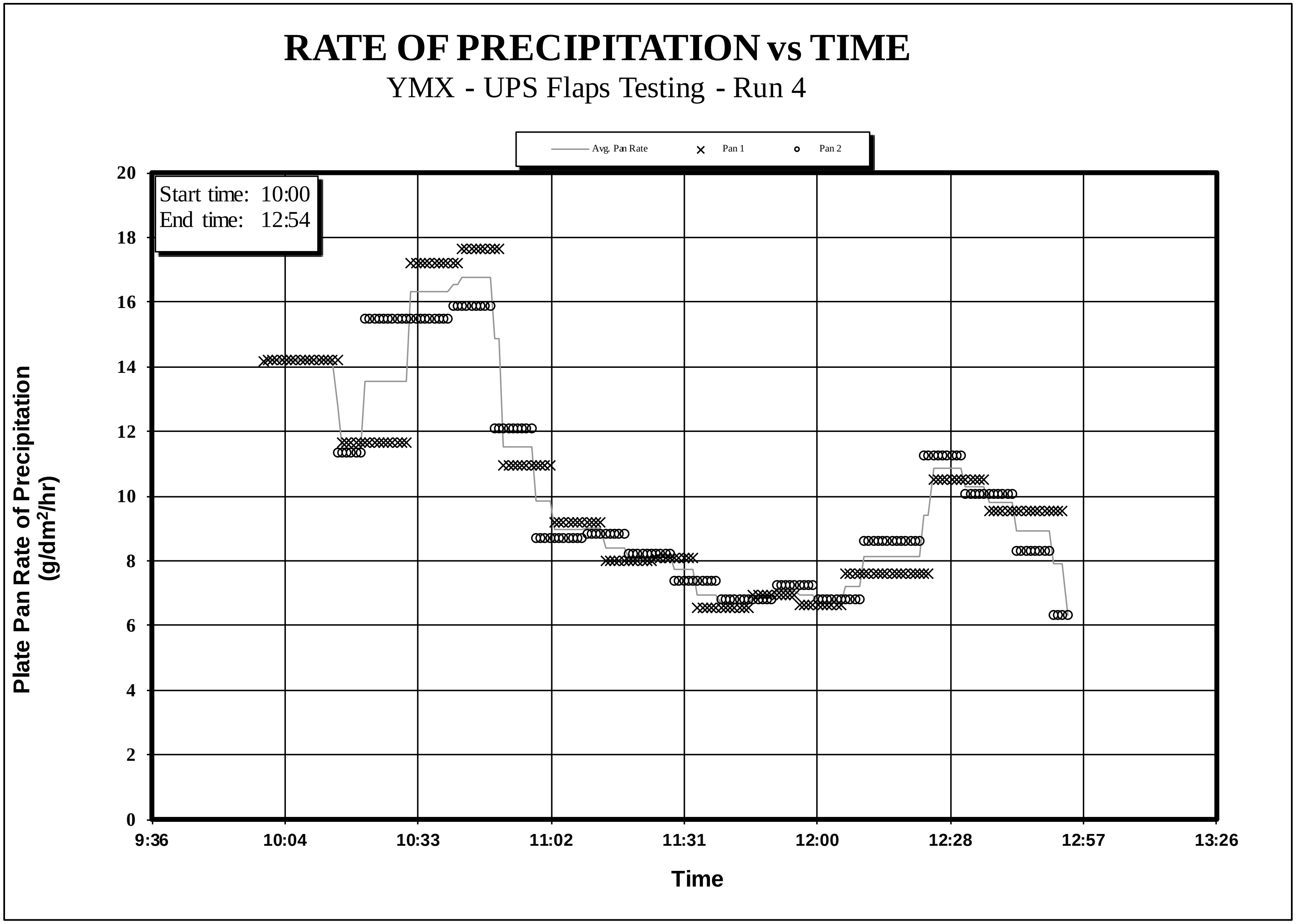
Type I Fluid:	Type I UCAR ADF (40%) (Brix = Not Taken)
Application on Wing:	Sprayed from Nozzle
Temperature:	Not measured
Quantity of Type I used :	127 litres

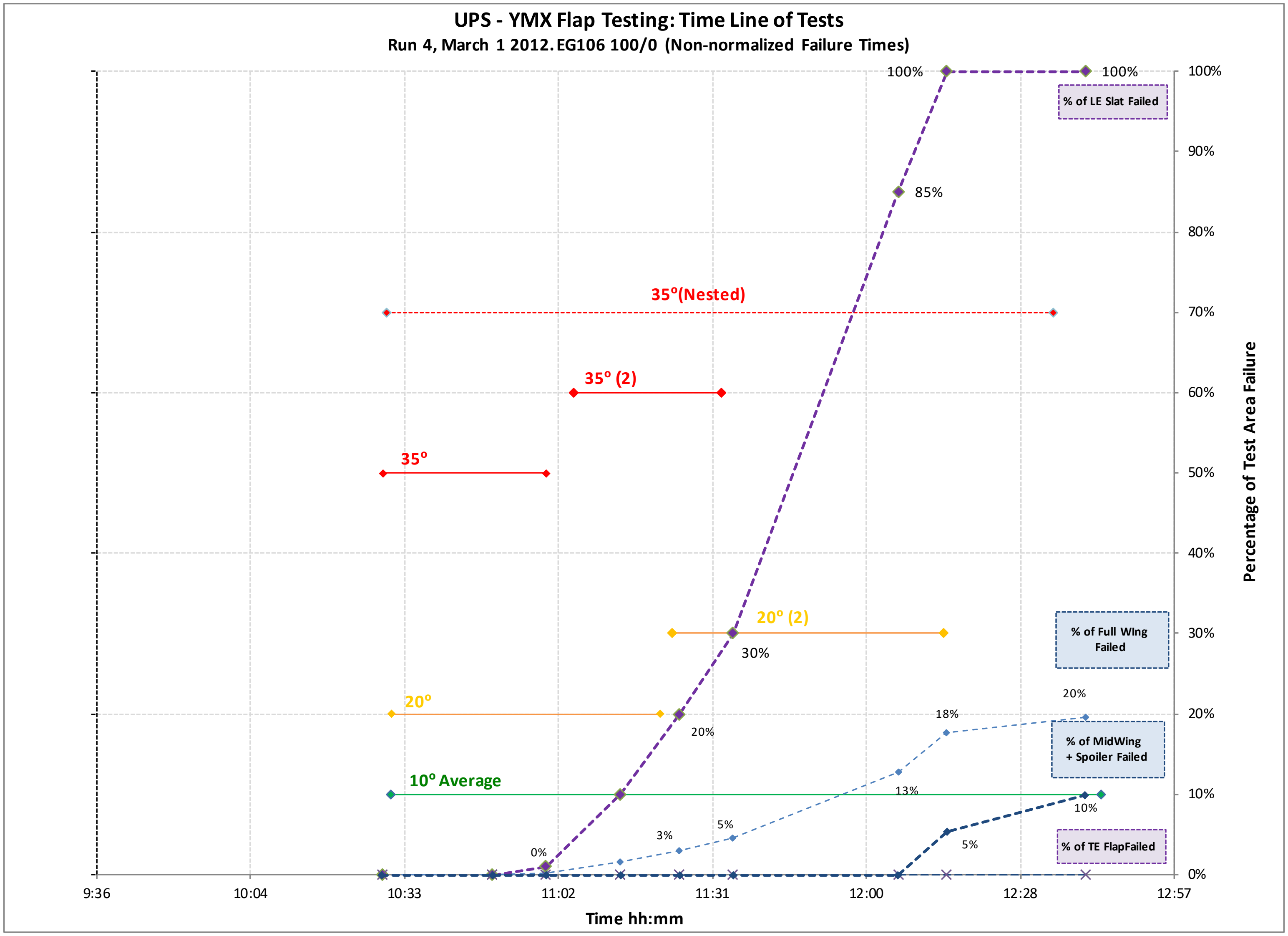
Type IV

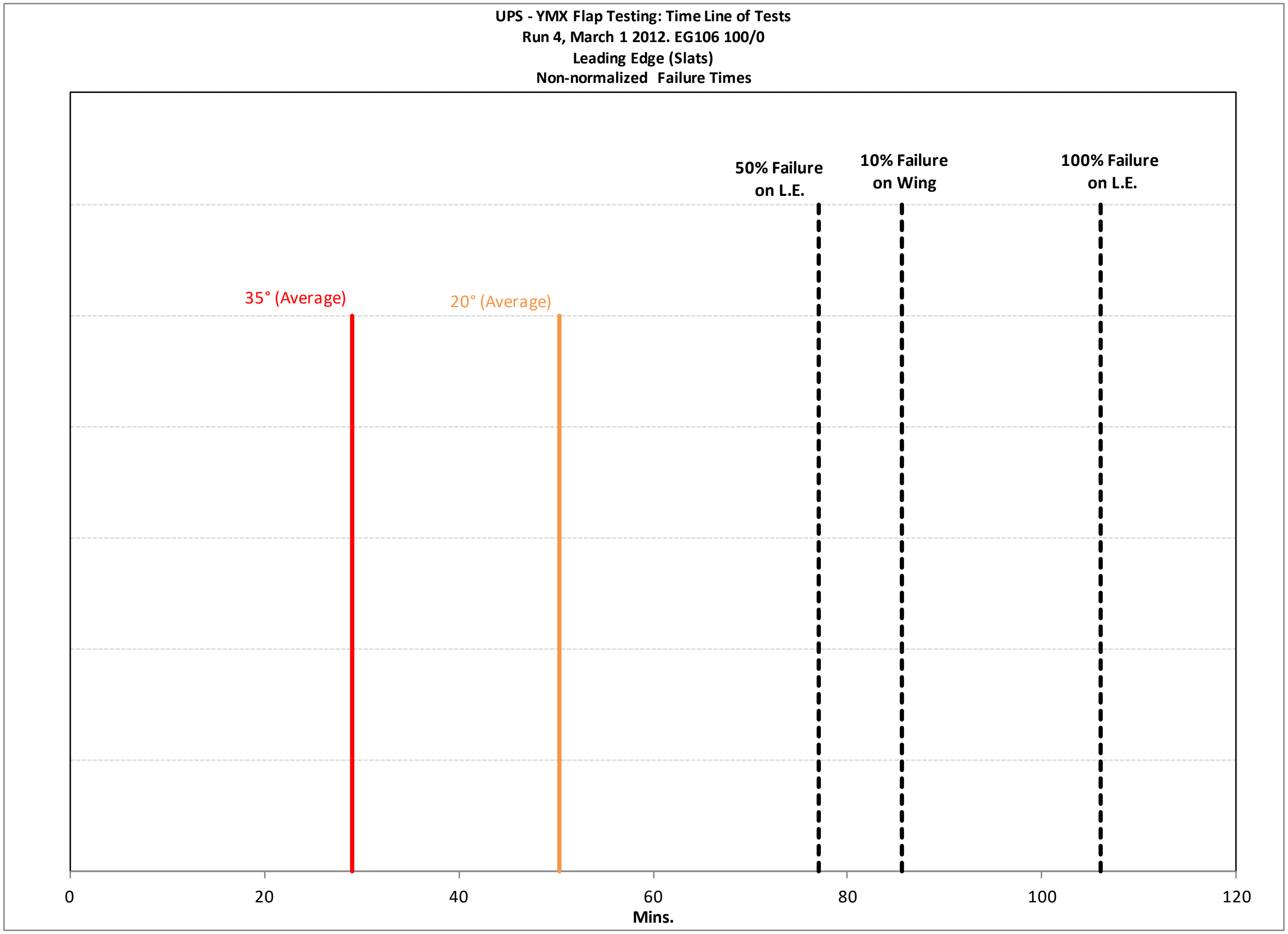
Type IV Fluid:	EG 106 (Brix = Not Taken)
Application on Wing:	Sprayed from Nozzle
Application on Stand:	Extracted from truck tank and hand-poured onto plates.
Temperature:	13.3ºC
Quantity of Type IV used:	156 litres

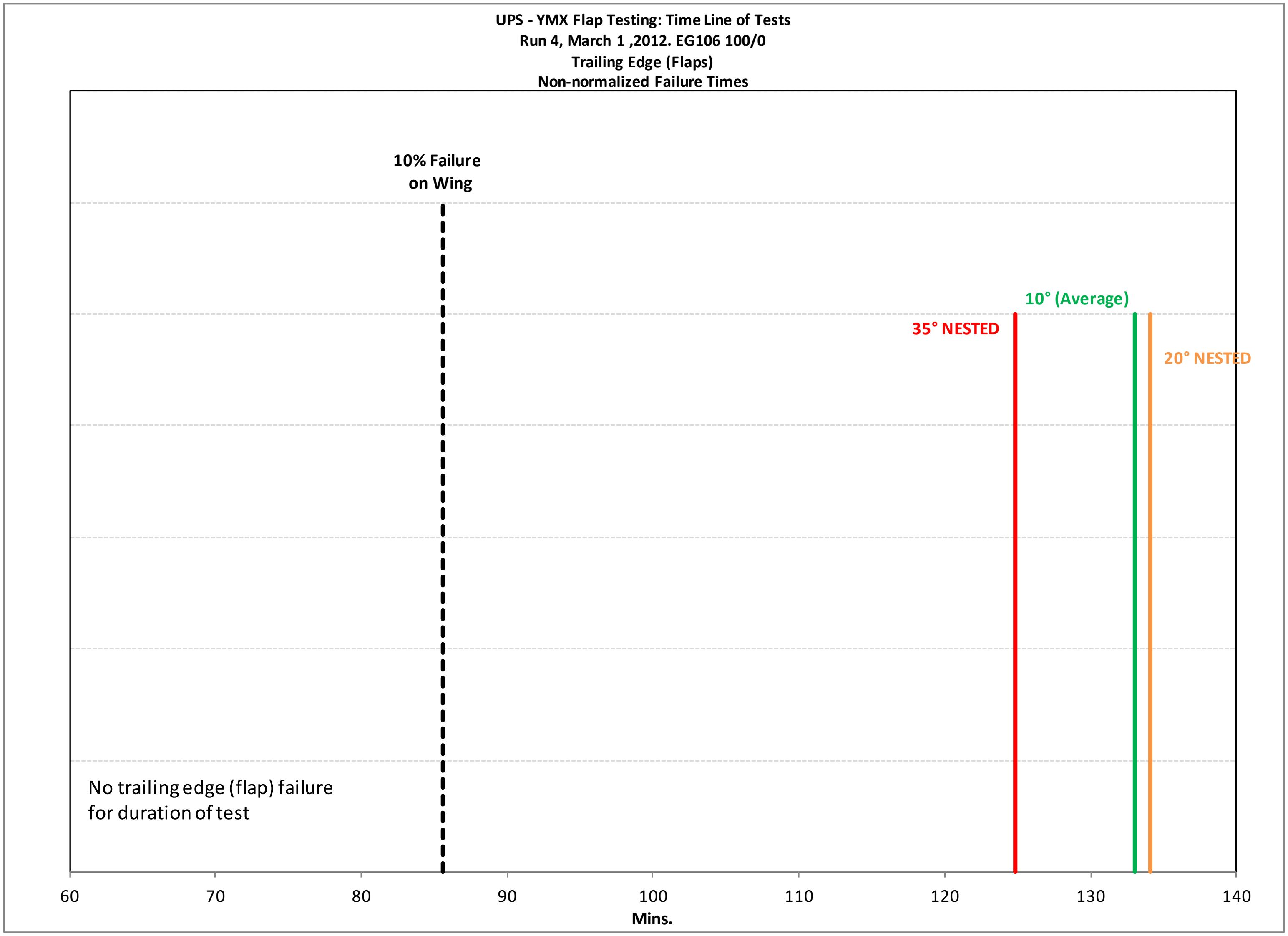
Holdover Time Information

Start of Test:	10:27 AM
End of Test:	13:00 PM


RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 4
Avg. Pan Rate
Pan 1
Pan 2
Start time: 10:00
End time: 12:54
Plate Pan Rate of Precipitation (g/dm²/hr)
0
2
4
6
8
10
12
14
16
18
20
9:36
10:04
10:33
11:02
11:31
12:00
12:28
12:57
13:26
Time


UPS - YMX Flap Testing: Time Line of Tests
Run 4, March 1 2012. EG106 100/0 (Non-normalized Failure Times)
35°(Nested)
35° (2)
35°
20° (2)
20°
10° Average
100%
100%
85%
30%
20%
0%
3%
5%
13%
18%
20%
5%
10%
% of LE Slat Failed
% of Full Wing Failed
% of MidWing + Spoiler Failed
% of TE FlapFailed
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Test Area Failure
9:36
10:04
10:33
11:02
11:31
12:00
12:28
12:57
Time hh:mm


UPS - YMX Flap Testing: Time Line of Tests
Run 4, March 1 2012. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
50% Failure on L.E.
10% Failure on Wing
100% Failure on L.E.
35° (Average)
20° (Average)
0
20
40
60
80
100
120
Mins.


UPS - YMX Flap Testing: Time Line of Tests
Run 4, March 1 ,2012. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
10% Failure on Wing
10° (Average)
35° NESTED
20° NESTED
No trailing edge (flap) failure for duration of test
60
70
80
90
100
110
120
130
140
Mins.

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Run 5

March 1, 2012

UPS Airbus A-300 Port Wing

Mirabel Airport

Including Horizontal Stabilizer

Run # 5

Mar 1, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport
Including Horizontal Stabilizer

Meteorological/Setup Information:

OAT:	- 6.9ºC
Aircraft Skin Temp: (at start of day)	- 5.8ºC
Intended Aircraft/Stand Orientation:	Into wind/Into wind
Wind/Plate Direction :	50º/50º
Aircraft Direction:	60º
Wind Speed:	20-25 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	4.1 g/dm²/h

Slat / Flap Angle Information

Angles Measured*

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)	18.7º	21.0º
Mid Slat Angle (middle slat)	21.6º	24.0º
Mid Flap Angle (middle flap):	21.0º	32.0º

*On the second day of testing (Runs 4 and 5), angles were measured to be 18º, 20º, and 22º for the ¼ slat angle, mid slat angle, and mid flap angle, respectively. It is not known exactly at which chord these angles were taken.

Fluid Information

Type I

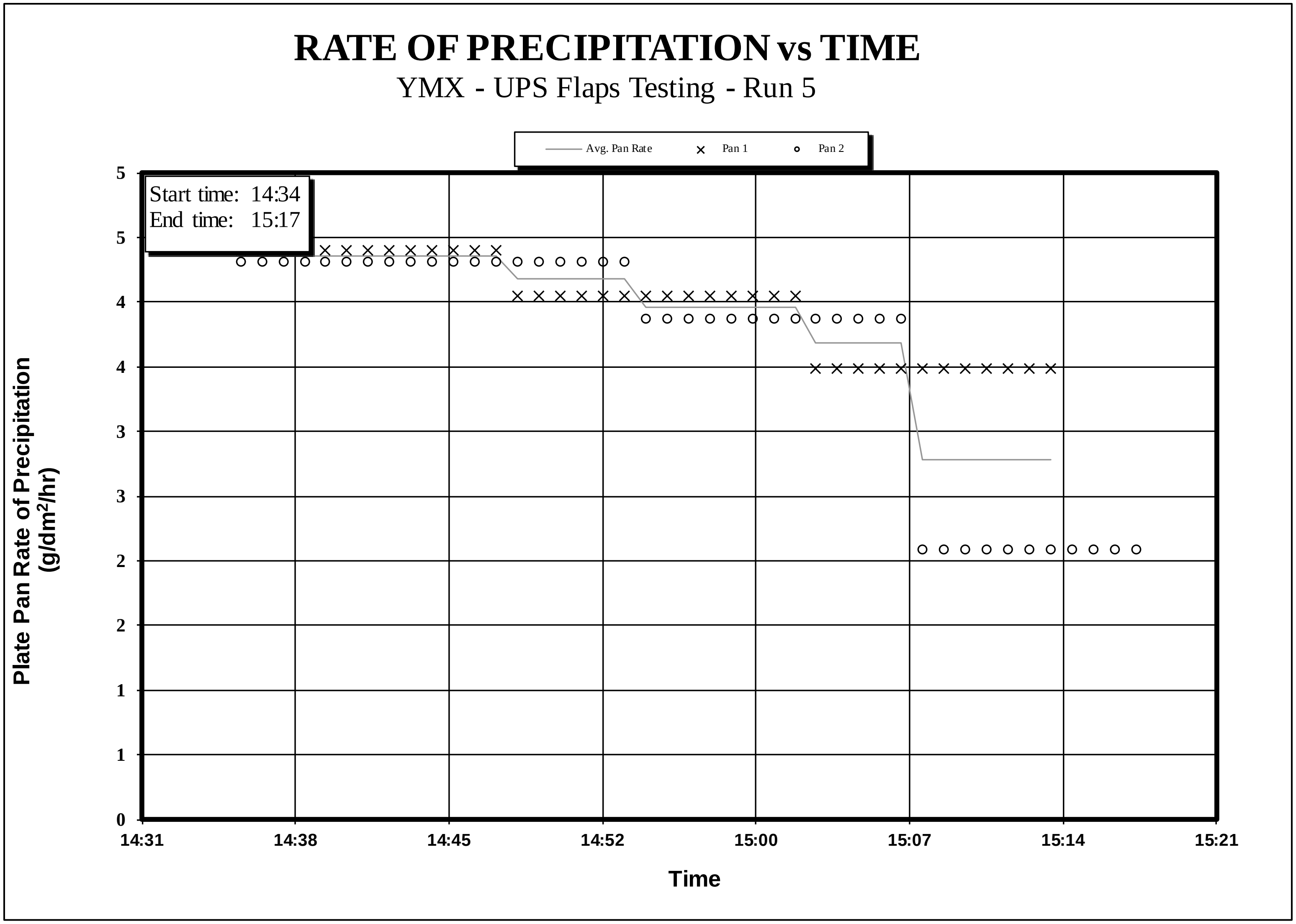
Type I Fluid:	Type I UCAR ADF (40%) (Brix = Not Taken)
Application on Wing:	Sprayed from Nozzle
Temperature:	Not measured
Quantity of Type I applied on wing:	349 litres
Quantity of Type I applied on horizontal stabilizer:	72 litres

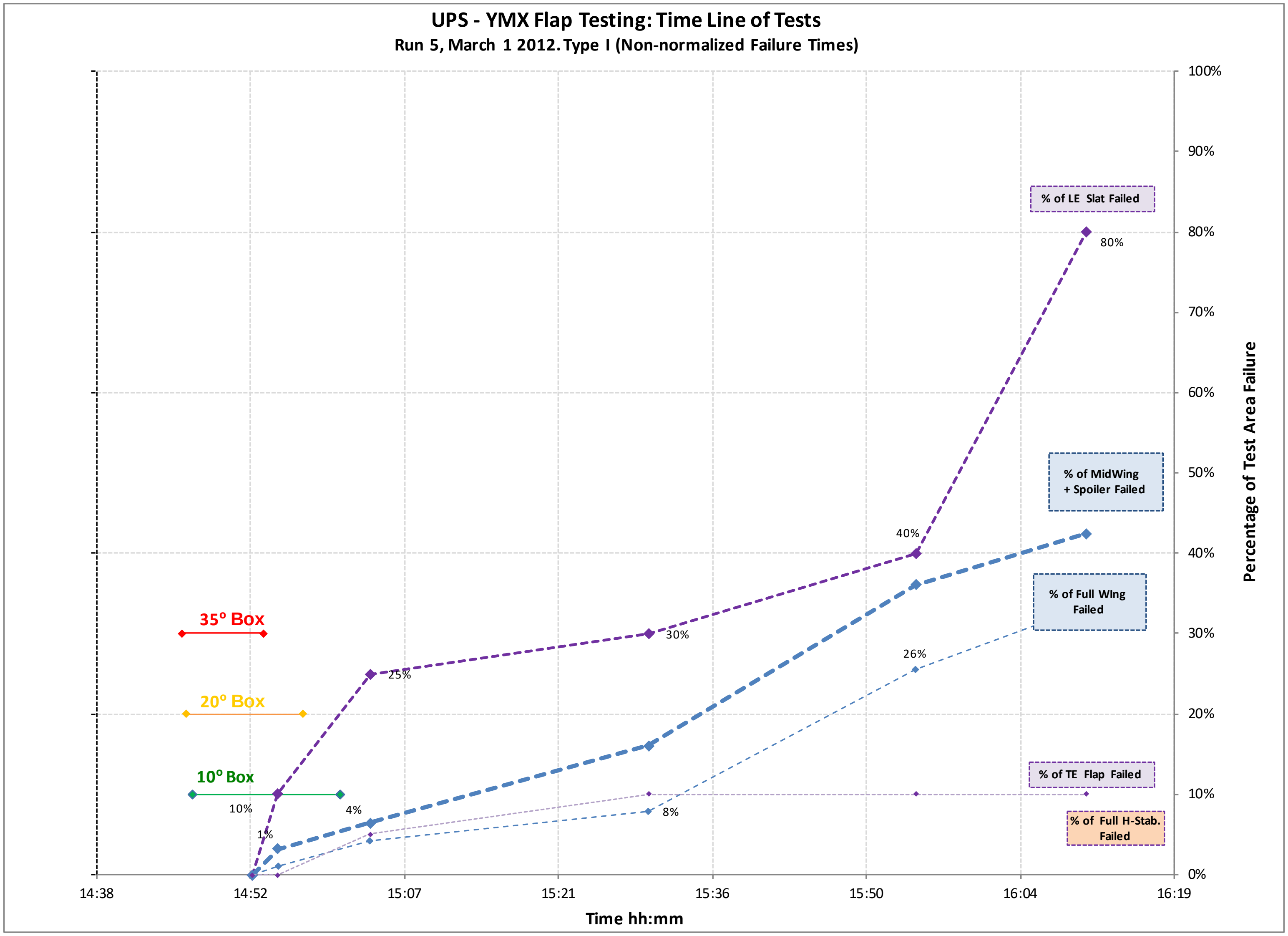
Type IV

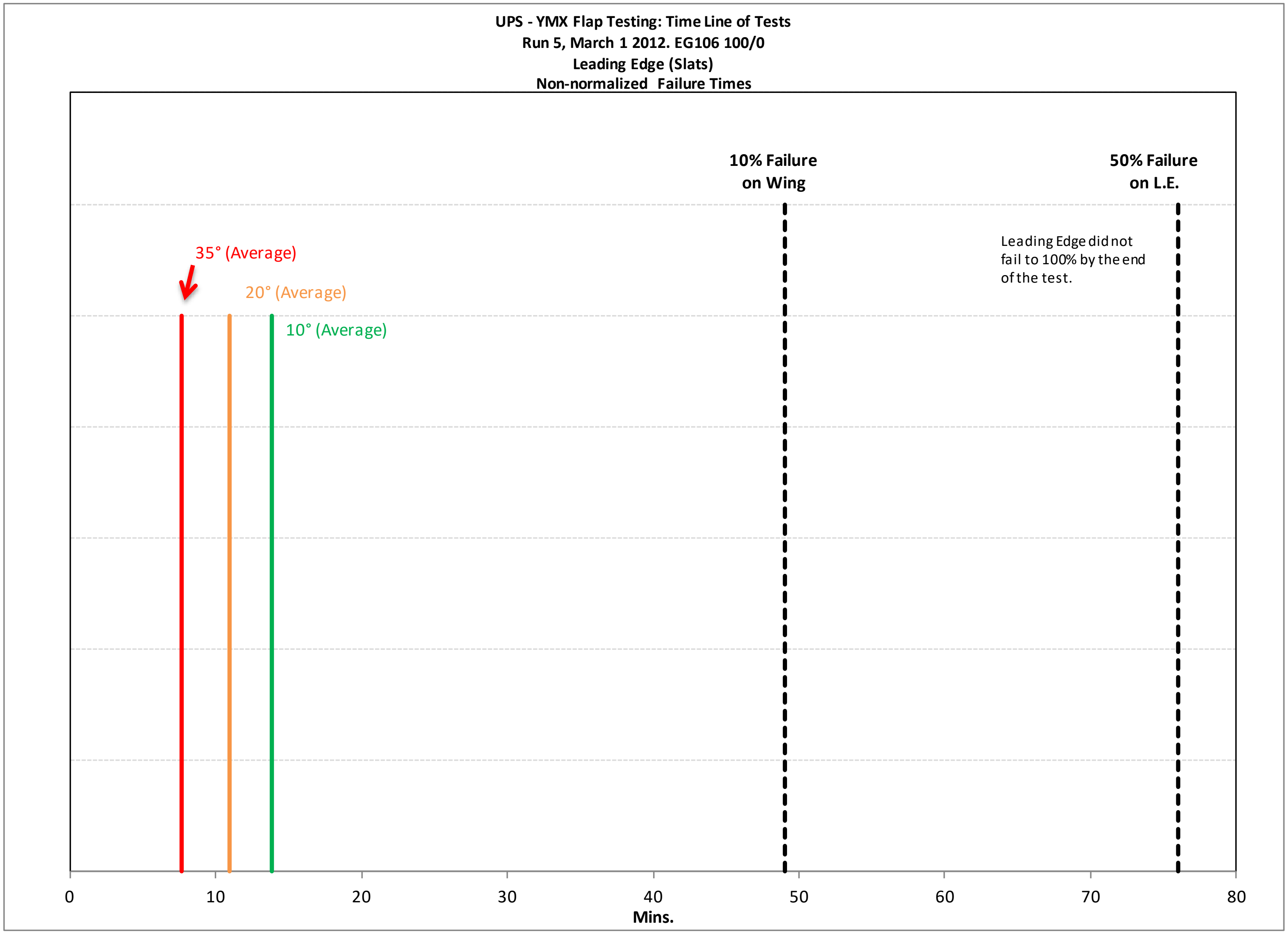
No Type IV fluid applied

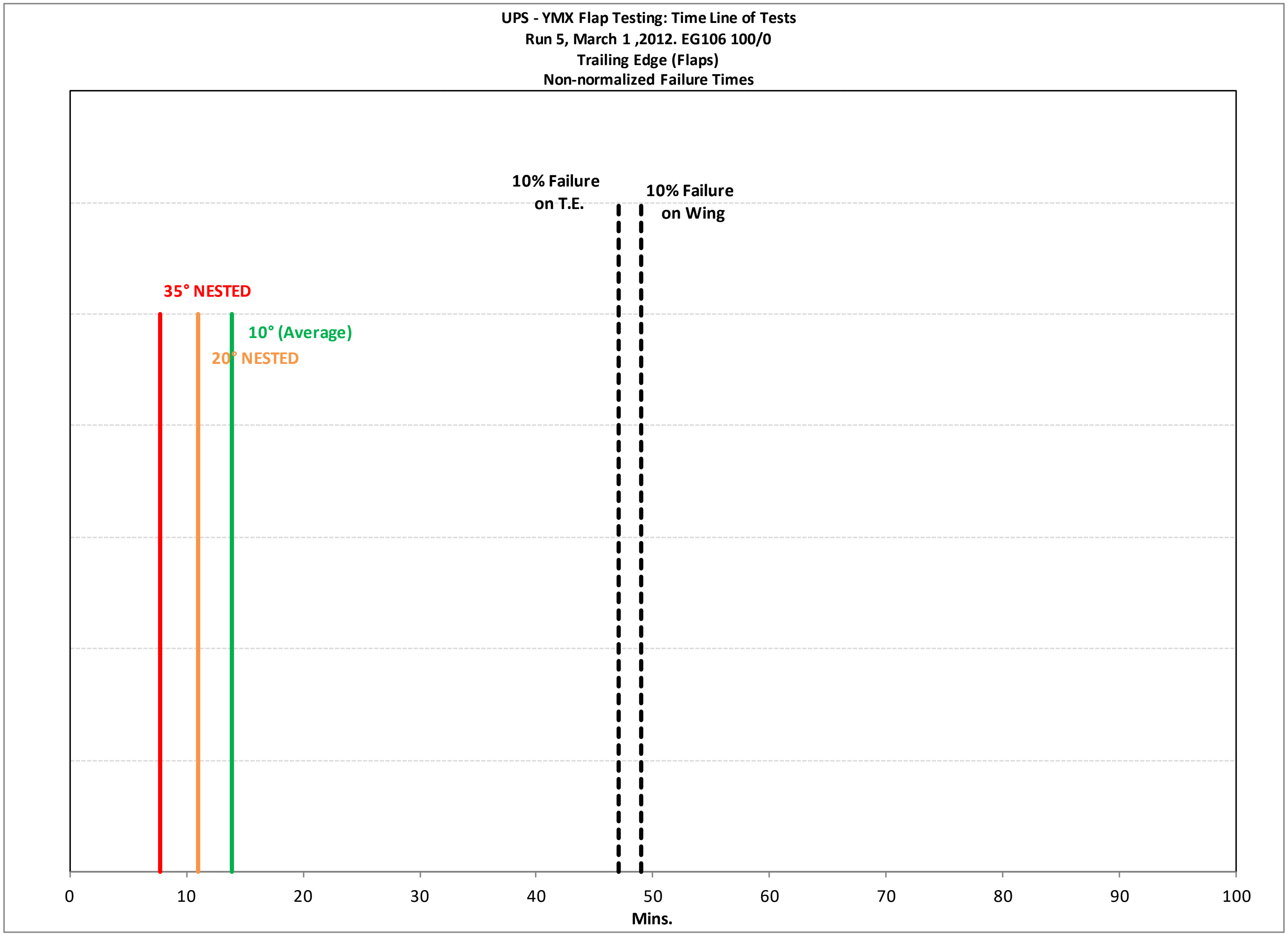
Holdover Time Information

Start of Test:	14:40 PM
End of Test:	15:30 PM


RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 5
Avg. Pan Rate
Pan 1
Pan 2
Start time: 14:34
End time: 15:17
Plate Pan Rate of Precipitation (g/dm²/hr)
5
5
4
4
3
3
2
2
1
1
0
14:31
14:38
14:45
14:52
15:00
15:07
15:14
15:21
Time


UPS - YMX Flap Testing: Time Line of Tests
Run 5, March 1 2012. Type I (Non-normalized Failure Times)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Test Area Failure
14:38
14:52
15:07
15:21
15:36
15:50
16:04
16:19
Time hh:mm
35° Box
20° Box
10° Box
% of LE Slat Failed
% of MidWing + Spoiler Failed
% of Full Wing Failed
% of TE Flap Failed
% of Full H-Stab. Failed
80%
40%
30%
25%
26%
10%
1%
4%
8%


UPS - YMX Flap Testing: Time Line of Tests
Run 5, March 1 2012. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
10% Failure on Wing
50% Failure on L.E.
Leading Edge did not fail to 100% by the end of the test.
35° (Average)
20° (Average)
10° (Average)
0
10
20
30
40
50
60
70
80
Mins.


UPS - YMX Flap Testing: Time Line of Tests
Run 5, March 1 ,2012. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
10% Failure on T.E.
10% Failure on Wing
35° NESTED
10° (Average)
20° NESTED
0
10
20
30
40
50
60
70
80
90
100
Mins.

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Run 6
February 27, 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Run # 6

February 27 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	0.8 to 1.1ºC
Aircraft Skin Temp: (at start of day)	+ 1 ºC
Aircraft/Stand Orientation:	Tail into wind / into wind
Wind/Plate Direction:	50 - 60º/50 -60º
Aircraft Direction:	230º
Wind Speed:	22 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	7.7 g/dm^2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)		19
Mid Slat Angle (middle slat)		22
Mid Flap Angle (middle flap):		21

Fluid Information

Type I

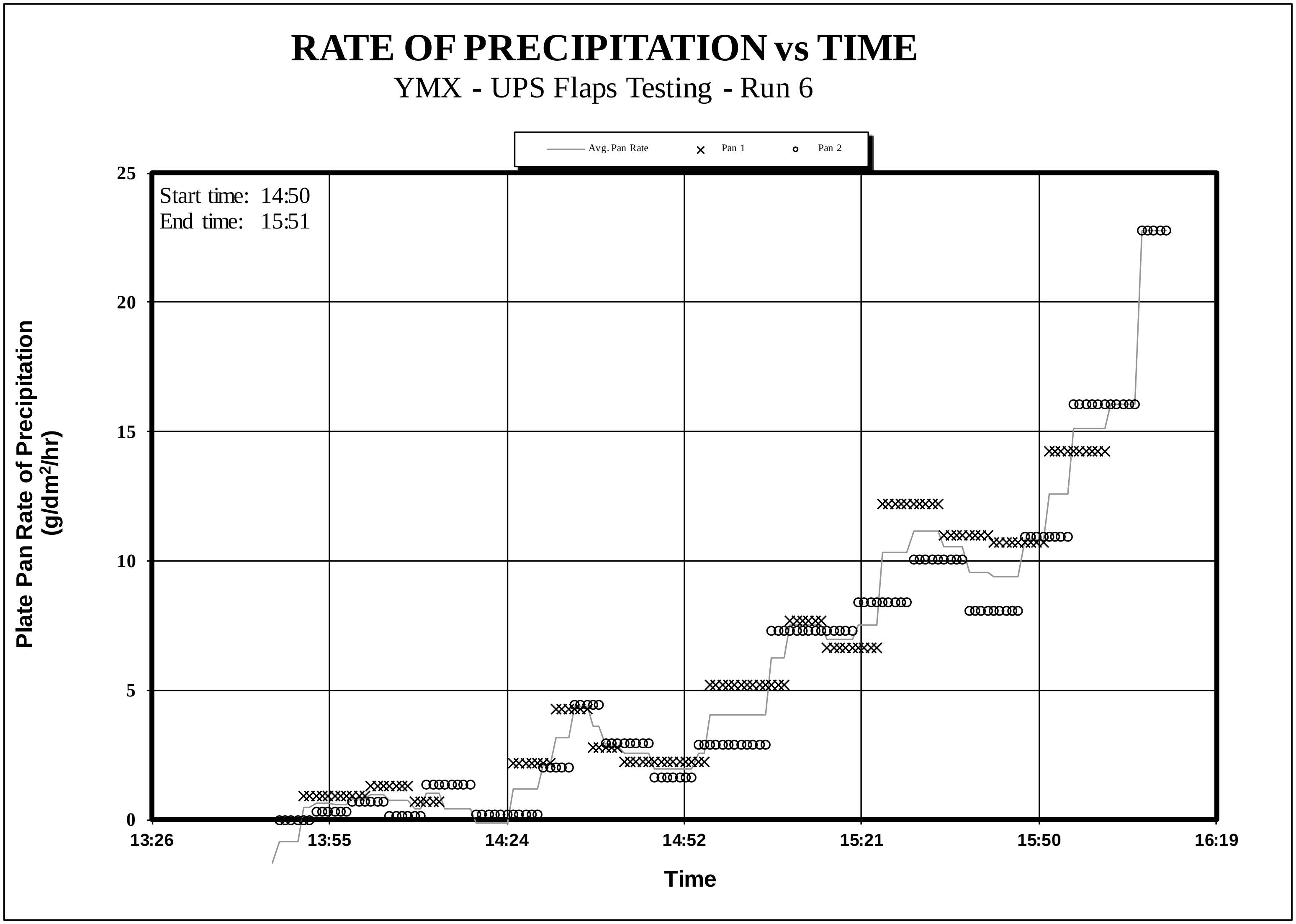
Type I Fluid:	Type I UCAR ADF (40%) (Brix =25.0)
Application on Wing :	Sprayed from Nozzle
Temperature:	50 ºC
Quantity of Type I used:	66 + 48 litres

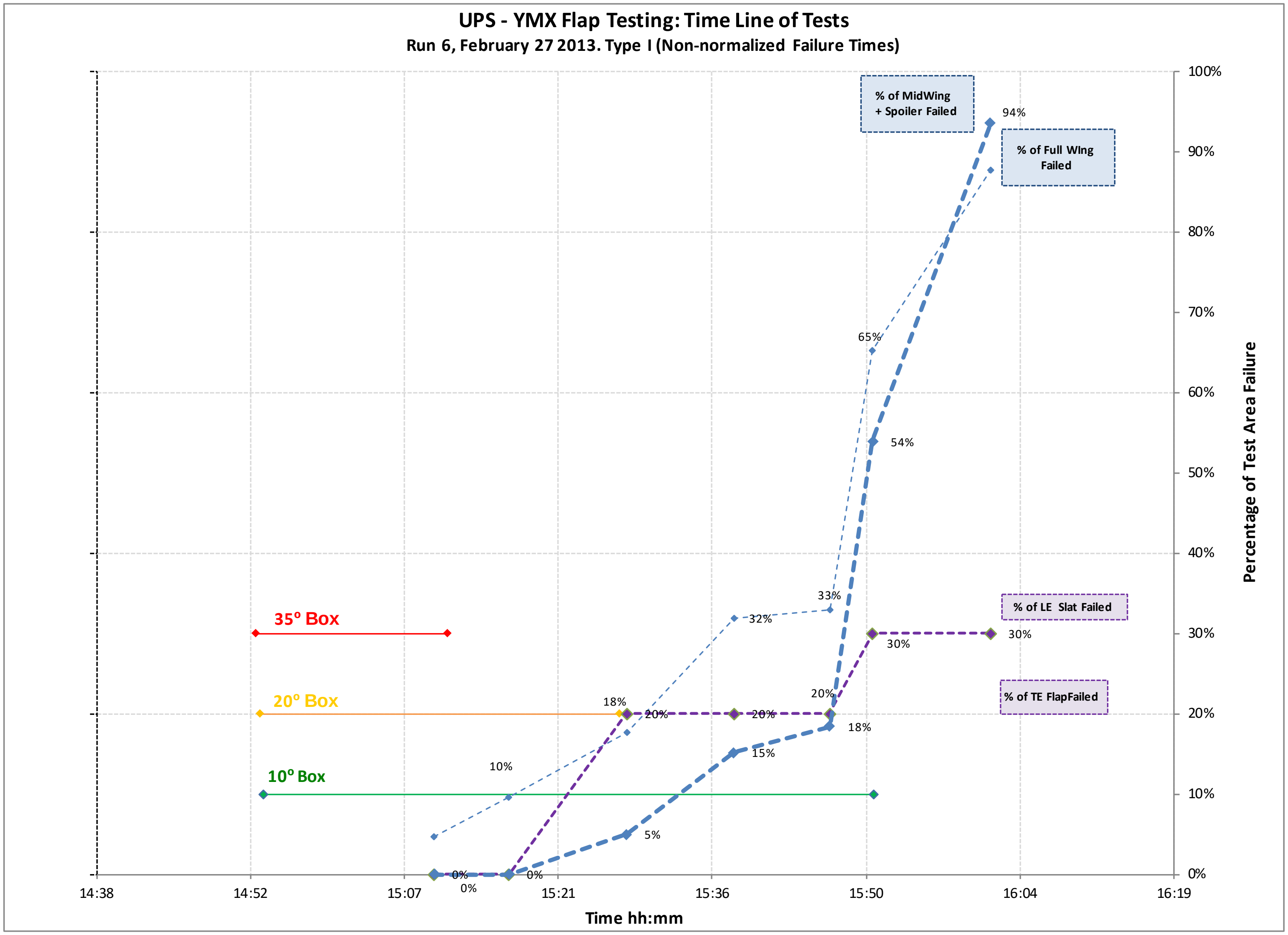
Type IV

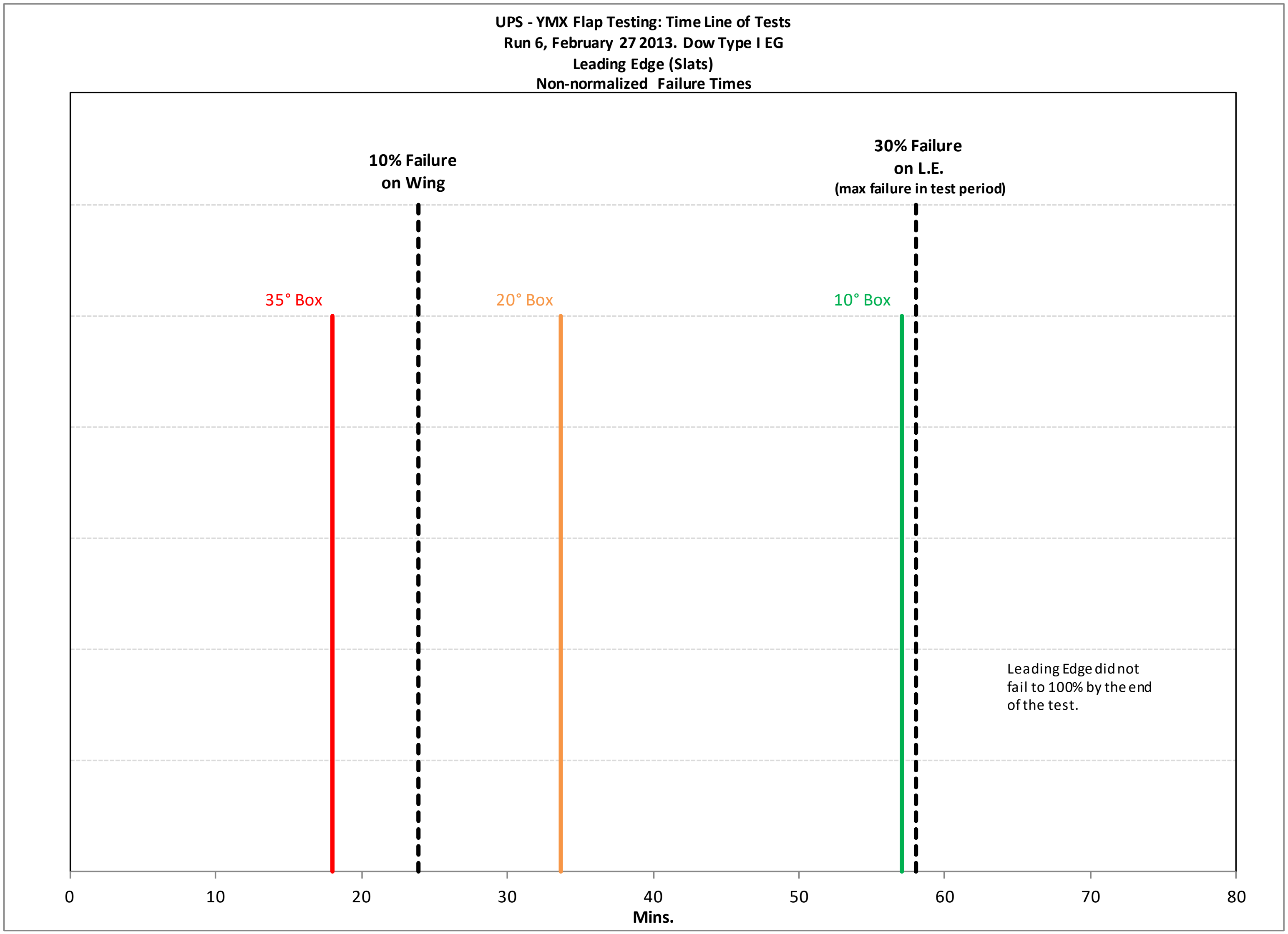
No Type IV fluid applied

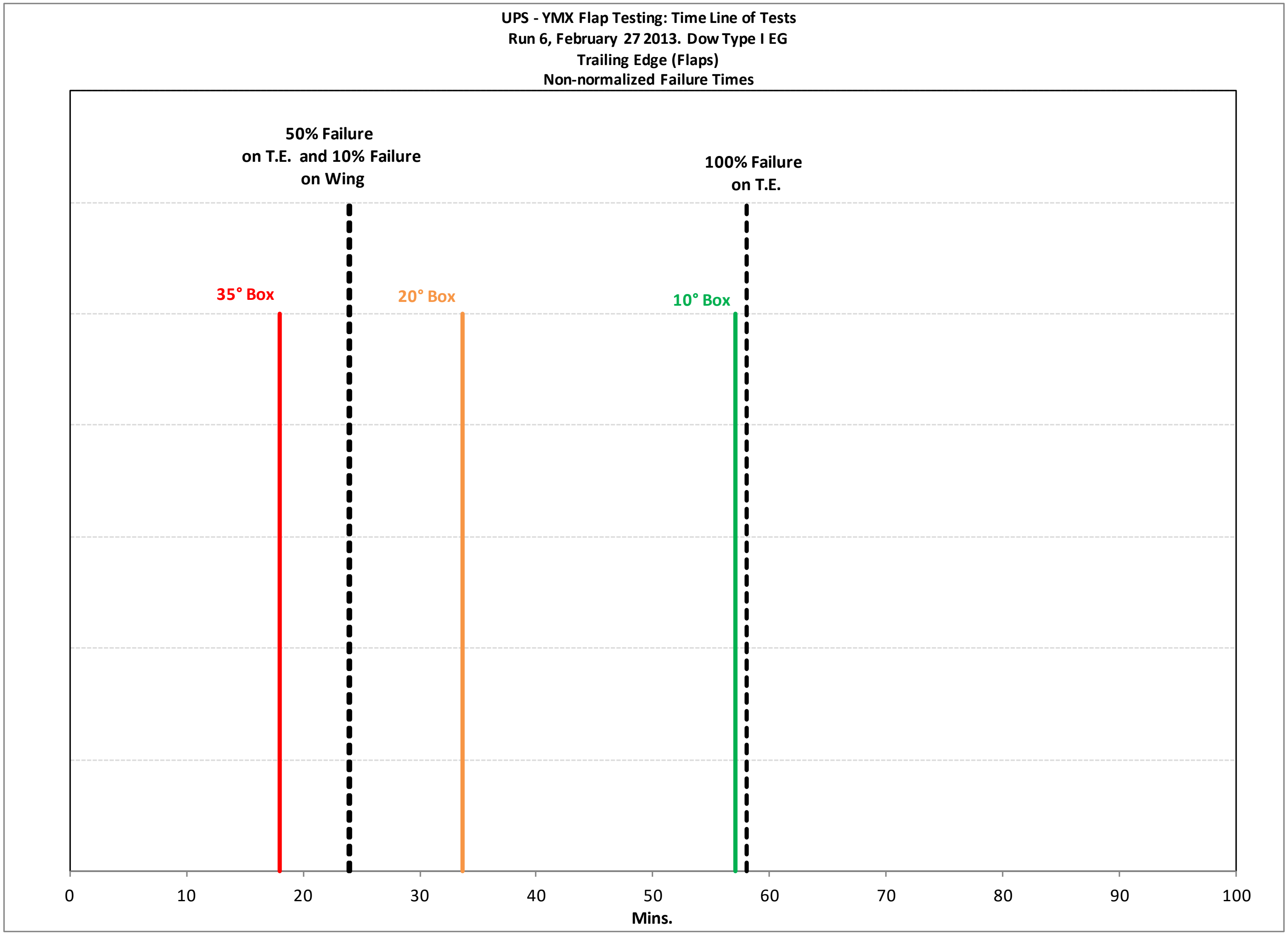
Holdover Time Information

Start of Test:	14:50PM
End of Test:	15:51PM


RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 6
Avg. Pan Rate
Pan 1
Pan 2
Start time: 14:50
End time: 15:51
Plate Pan Rate of Precipitation (g/dm²/hr)
25
20
15
10
5
0
13:26
13:55
14:24
14:52
15:21
15:50
16:19
Time


UPS - YMX Flap Testing: Time Line of Tests
Run 6, February 27 2013. Type I (Non-normalized Failure Times)
% of MidWing + Spoiler Failed
% of Full Wing Failed
% of LE Slat Failed
% of TE FlapFailed
35° Box
20° Box
10° Box
94%
65%
54%
33%
32%
30%
30%
20%
20%
20%
18%
18%
15%
10%
5%
0%
0%
0%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Test Area Failure
14:38
14:52
15:07
15:21
15:36
15:50
16:04
16:19
Time hh:mm


UPS - YMX Flap Testing: Time Line of Tests
Run 6, February 27 2013. Dow Type I EG
Leading Edge (Slats)
Non-normalized Failure Times
10% Failure on Wing
30% Failure on L.E.
(max failure in test period)
35° Box
20° Box
10° Box
Leading Edge did not fail to 100% by the end of the test.
0
10
20
30
40
50
60
70
80
Mins.


UPS - YMX Flap Testing: Time Line of Tests
Run 6, February 27 2013. Dow Type I EG
Trailing Edge (Flaps)
Non-normalized Failure Times
50% Failure on T.E. and 10% Failure on Wing
100% Failure on T.E.
35° Box
20° Box
10° Box
0
10
20
30
40
50
60
70
80
90
100
Mins.

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Run 7
March 19, 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Run # 7

March 19 , 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	-4.1 to -4.2 ºC
Aircraft Skin Temp:(at start of day)	Not Recorded
Aircraft/Stand Orientation:	Tail Into wind/Into wind
Wind/Plate Direction:	60º-70º
Aircraft Direction:	240º
Wind Speed:	15-20 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	21.4 g/dm^2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)		19º
Mid Slat Angle (middle slat)		22º
Mid Flap Angle (middle flap):		21º

Fluid Information

Type I

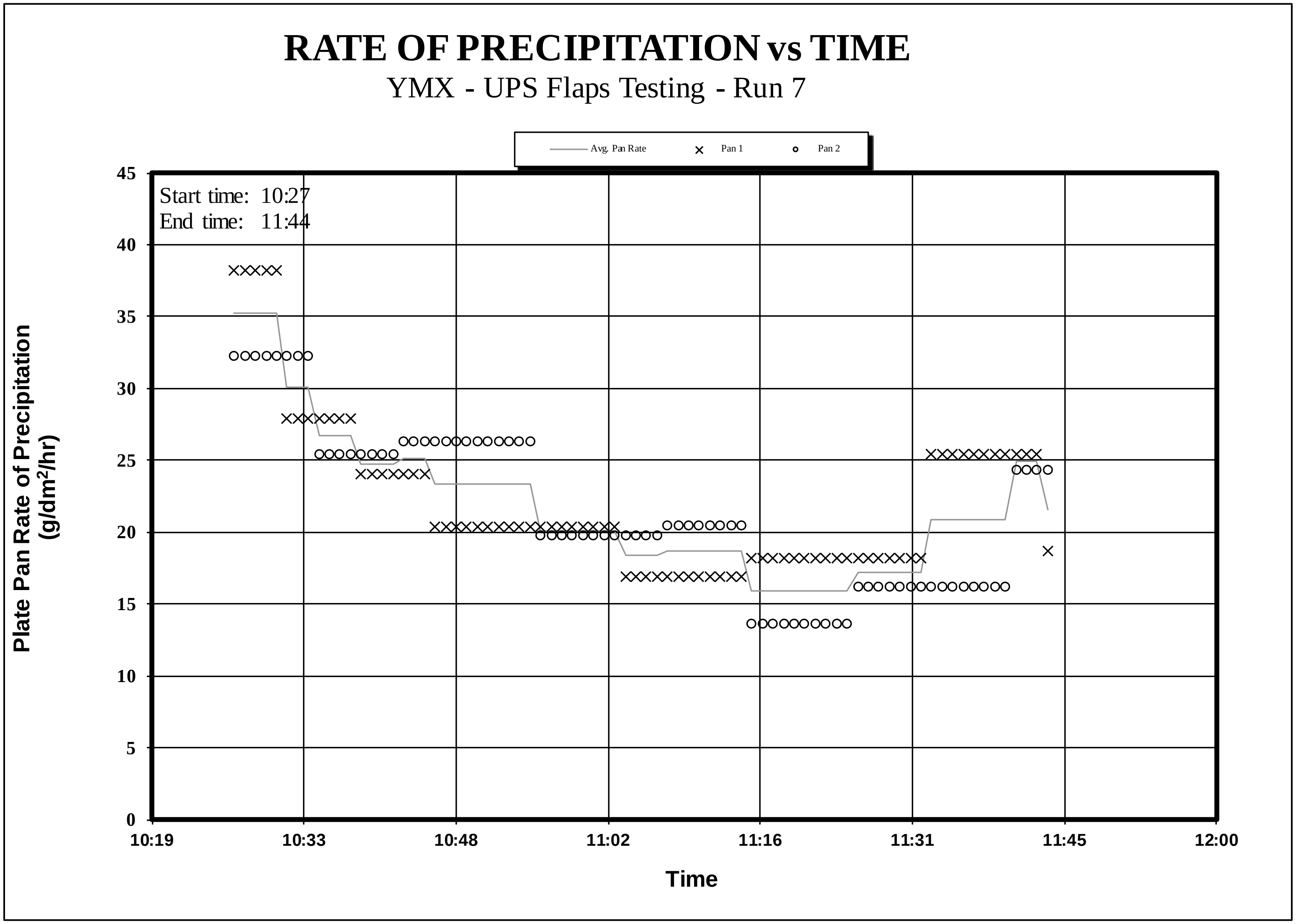
Type I Fluid:	Type I UCAR ADF (40%) (Brix =32.50)
Application on Wing:	Sprayed from Nozzle
Temperature:	53.1ºC
Quantity of Type I used:	24 litres

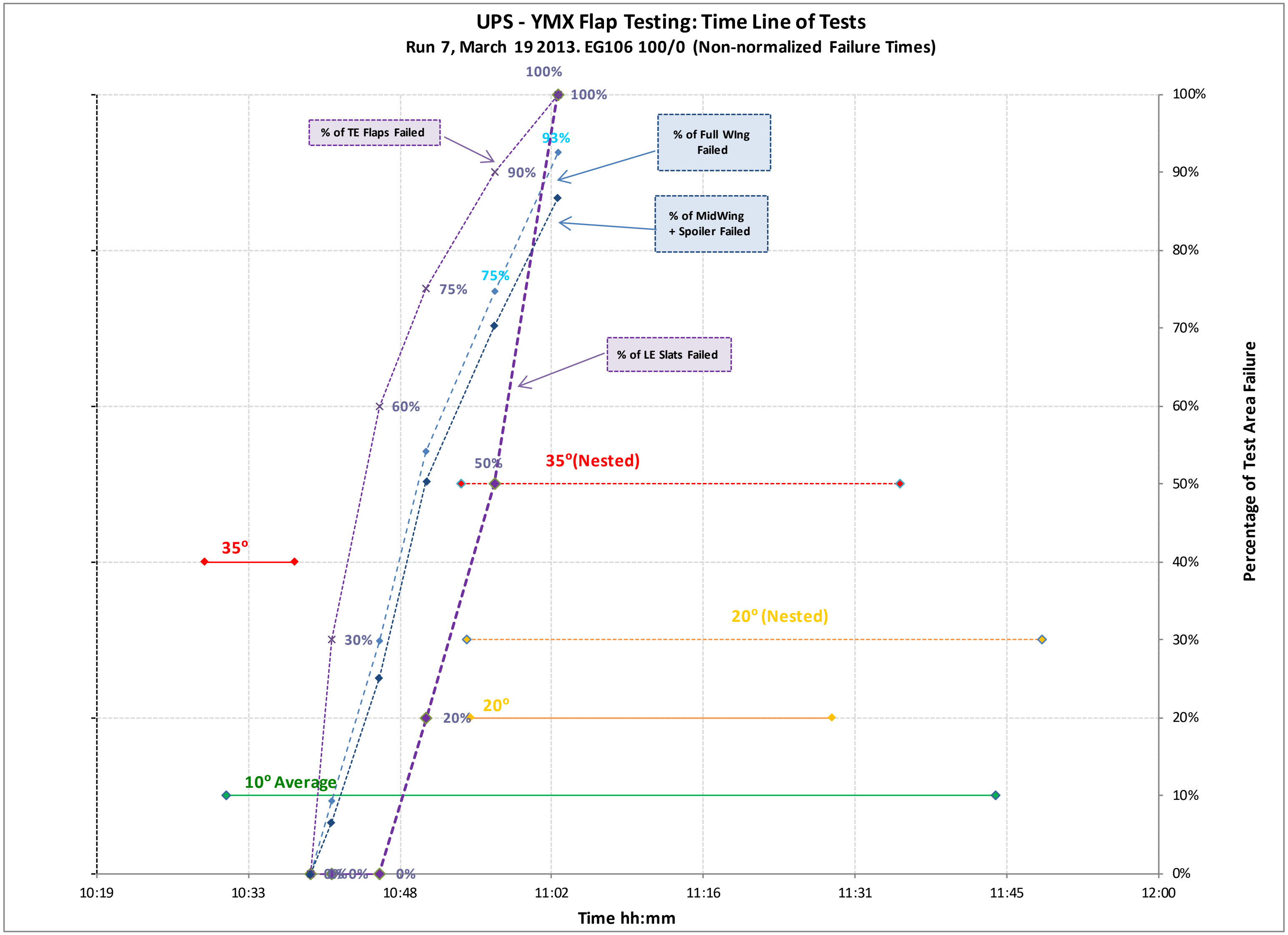
Type IV

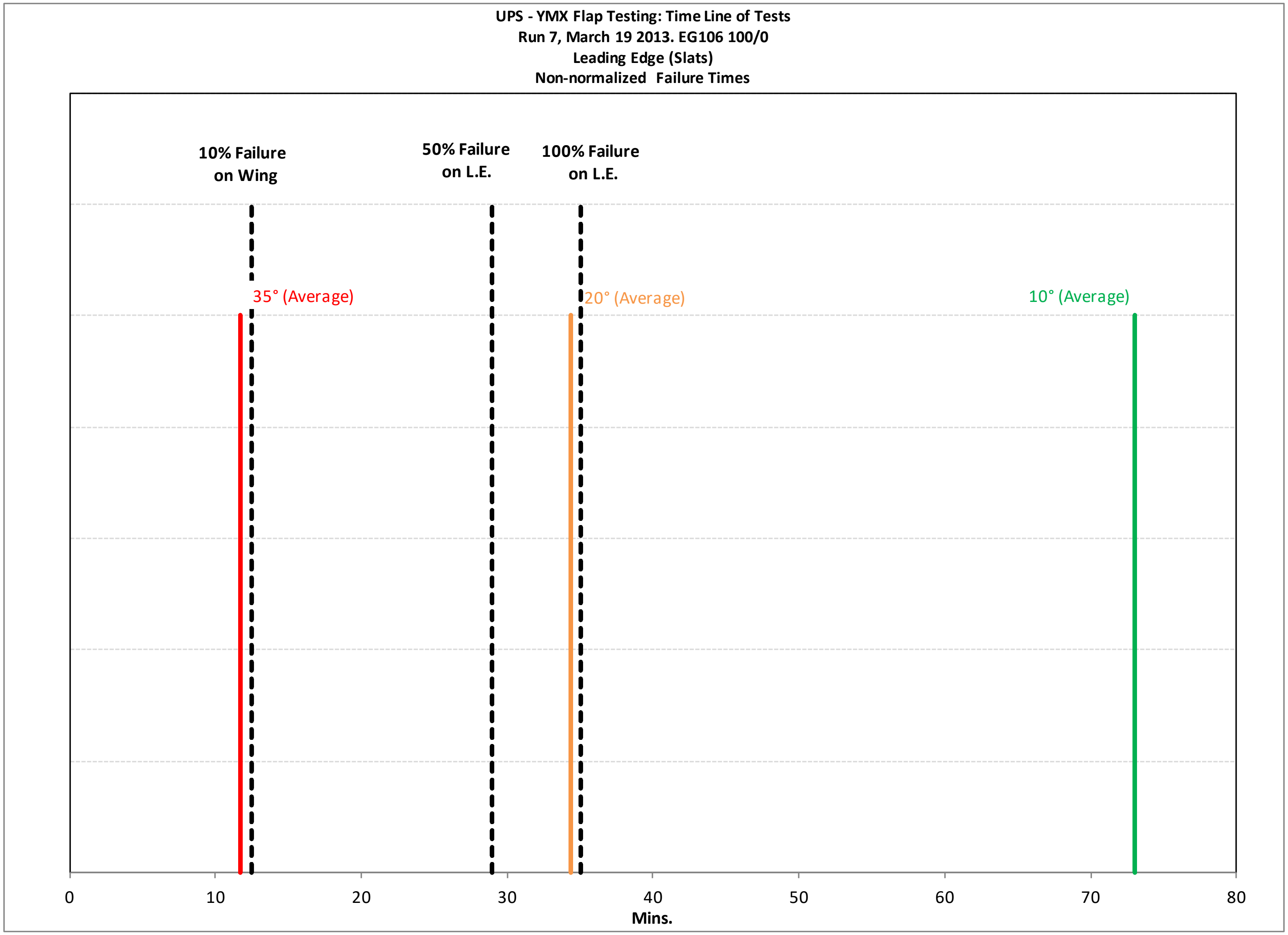
Type IV Fluid:	EG 106 (Brix = ukn)
Application on Wing:	Sprayed from Nozzle
Application on Stand:	Sprayed from Nozzle into bucket and hand-poured onto plates.
Temperature:	Not measured
Quantity of Type IV used:	68 litres

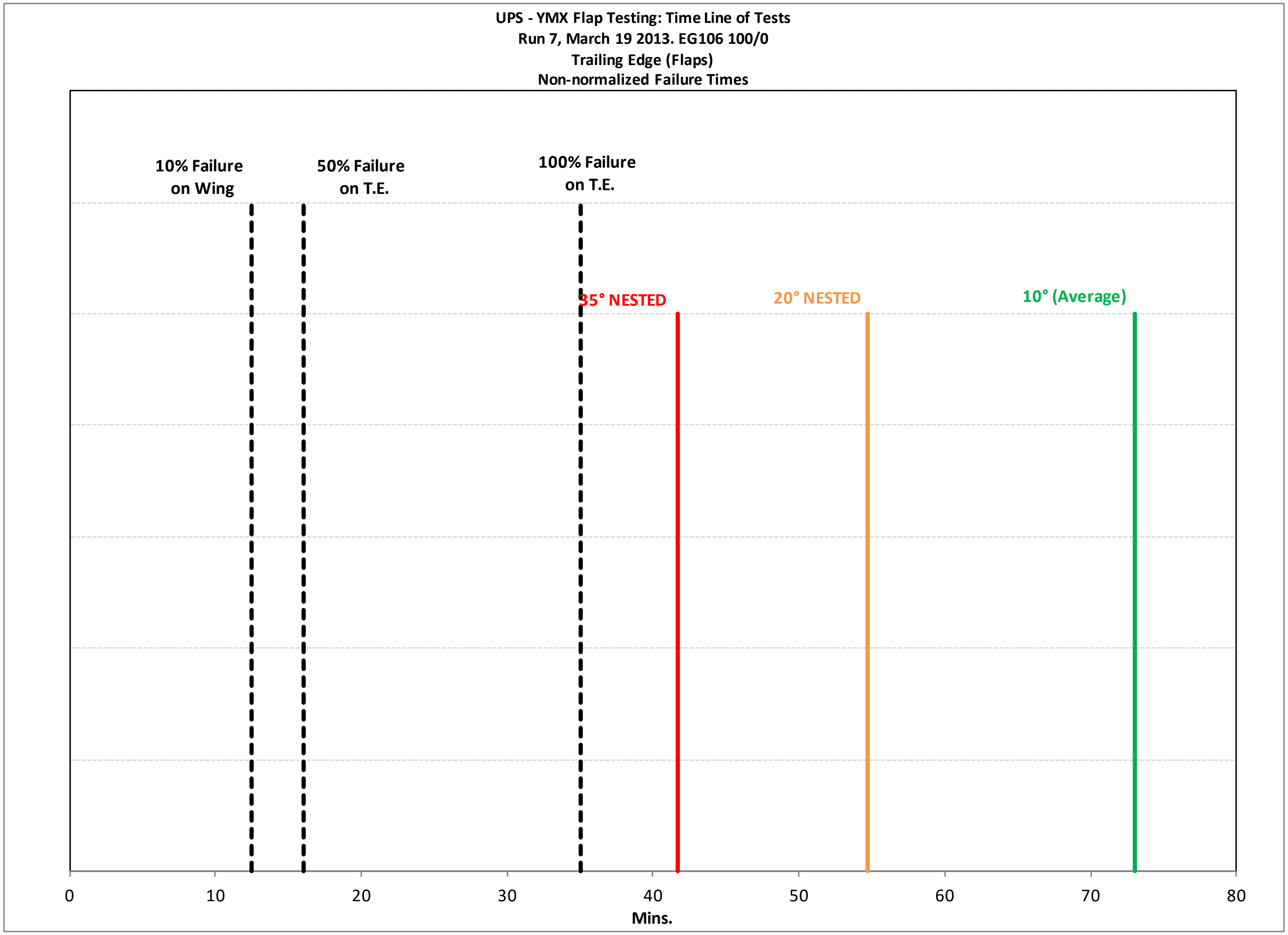
Holdover Time Information

Start of Test:	10:27 AM
End of Test:	11:44 AM


RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 7
Avg. Pan Rate
Pan 1
Pan 2
Start time: 10:27
End time: 11:44
Plate Pan Rate of Precipitation (g/dm²/hr)
45
40
35
30
25
20
15
10
5
0
10:19
10:33
10:48
11:02
11:16
11:31
11:45
12:00
Time


UPS - YMX Flap Testing: Time Line of Tests
Run 7, March 19 2013. EG106 100/0 (Non-normalized Failure Times)
% of TE Flaps Failed
% of Full Wing Failed
% of MidWing + Spoiler Failed
% of LE Slats Failed
100%
100%
93%
90%
75%
75%
60%
50%
35°(Nested)
35°
30%
20°(Nested)
20°
20%
10° Average
0%
0%
0%
0%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Test Area Failure
10:19
10:33
10:48
11:02
11:16
11:31
11:45
12:00
Time hh:mm


UPS - YMX Flap Testing: Time Line of Tests
Run 7, March 19 2013. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
10% Failure on Wing
50% Failure on L.E.
100% Failure on L.E.
35° (Average)
20° (Average)
10° (Average)
0
10
20
30
40
50
60
70
80
Mins.


UPS - YMX Flap Testing: Time Line of Tests
Run 7, March 19 2013. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
10% Failure on Wing
50% Failure on T.E.
100% Failure on T.E.
35° NESTED
20° NESTED
10° (Average)
0
10
20
30
40
50
60
70
80
Mins.

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Run 8
March 19, 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Run # 8

March 19 , 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	-3.7 to -4.1ºC
Aircraft Skin Temp:(at start of day)	Not Taken
Aircraft/Stand Orientation:	Tail Into wind/Into wind
Wind/Plate Direction:	60º-70º
Aircraft Direction:	240º
Wind Speed:	15-20 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	10.0 g/dm^2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	**Edge of Test Area Closest to Fuselage**	**Edge of Test Area Closest to Wing Tip**
¼ Slat Angle (top quarter)		19º
Mid Slat Angle (middle slat)		22º
Mid Flap Angle (middle flap):		21º

Fluid Information

Type I

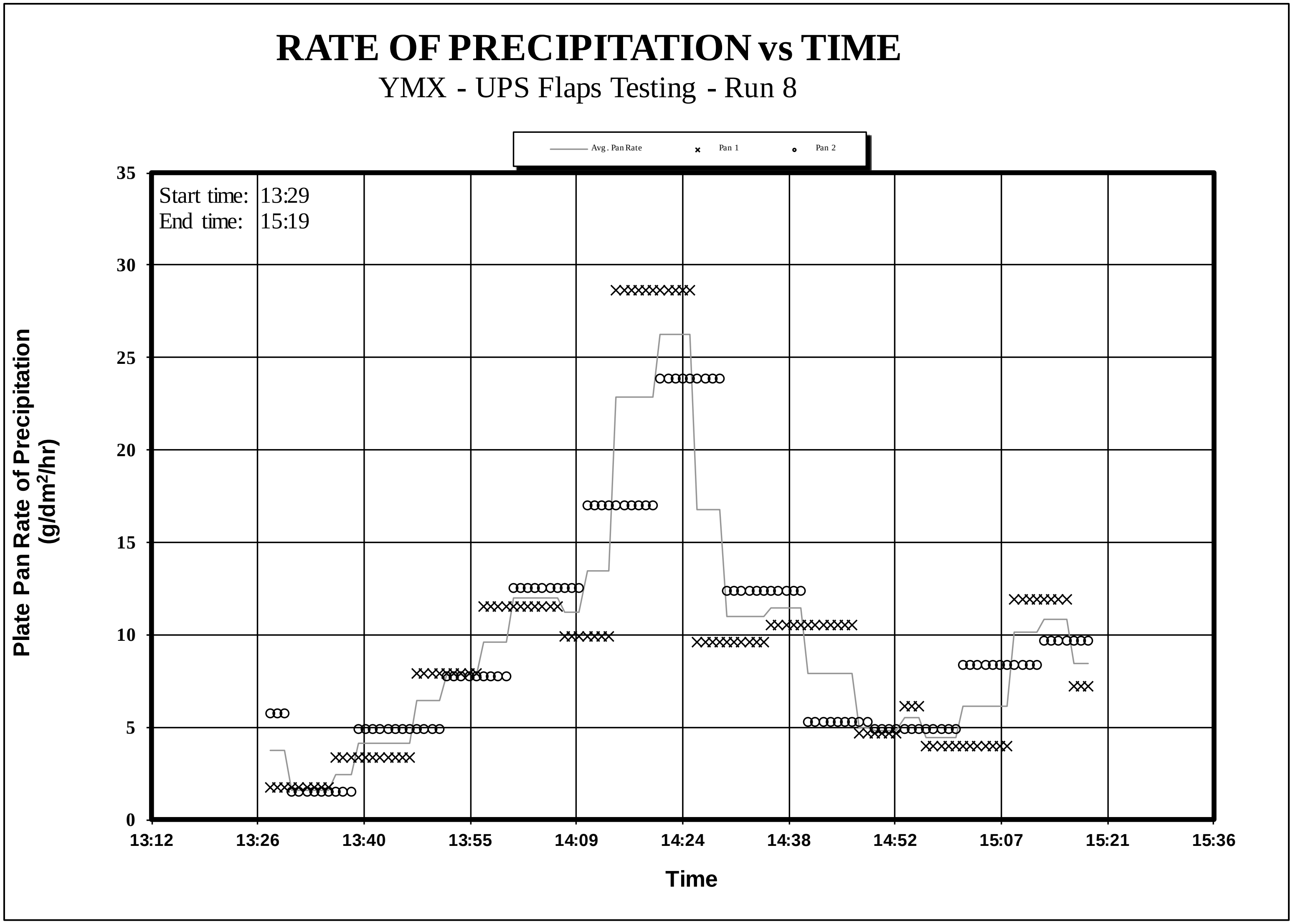
Type I Fluid:	Type I UCAR ADF (40%) (Brix = 32.50)
Application on Wing:	Sprayed from Nozzle
Temperature:	50ºC
Quantity of Type I used:	323 litres

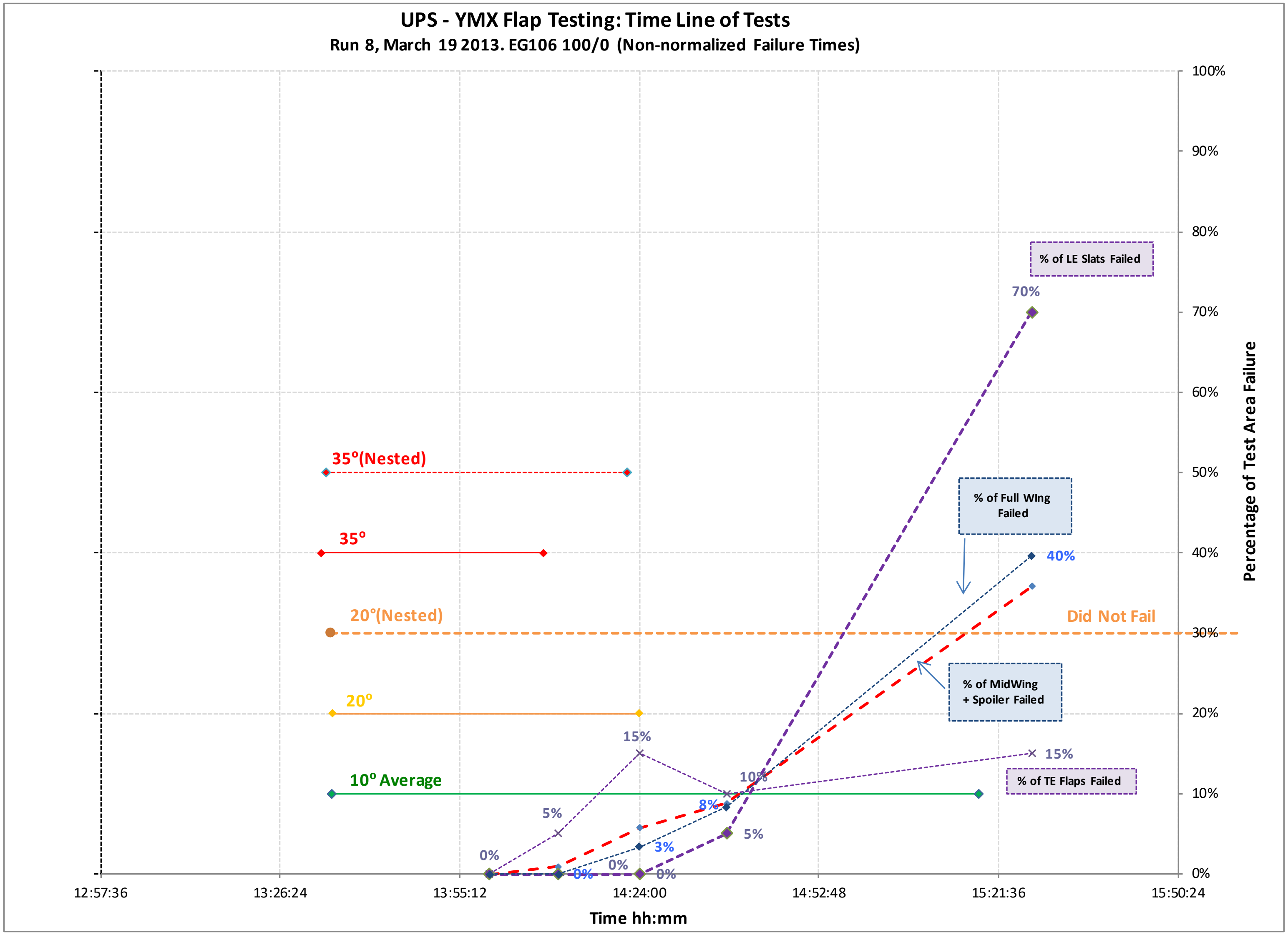
Type IV

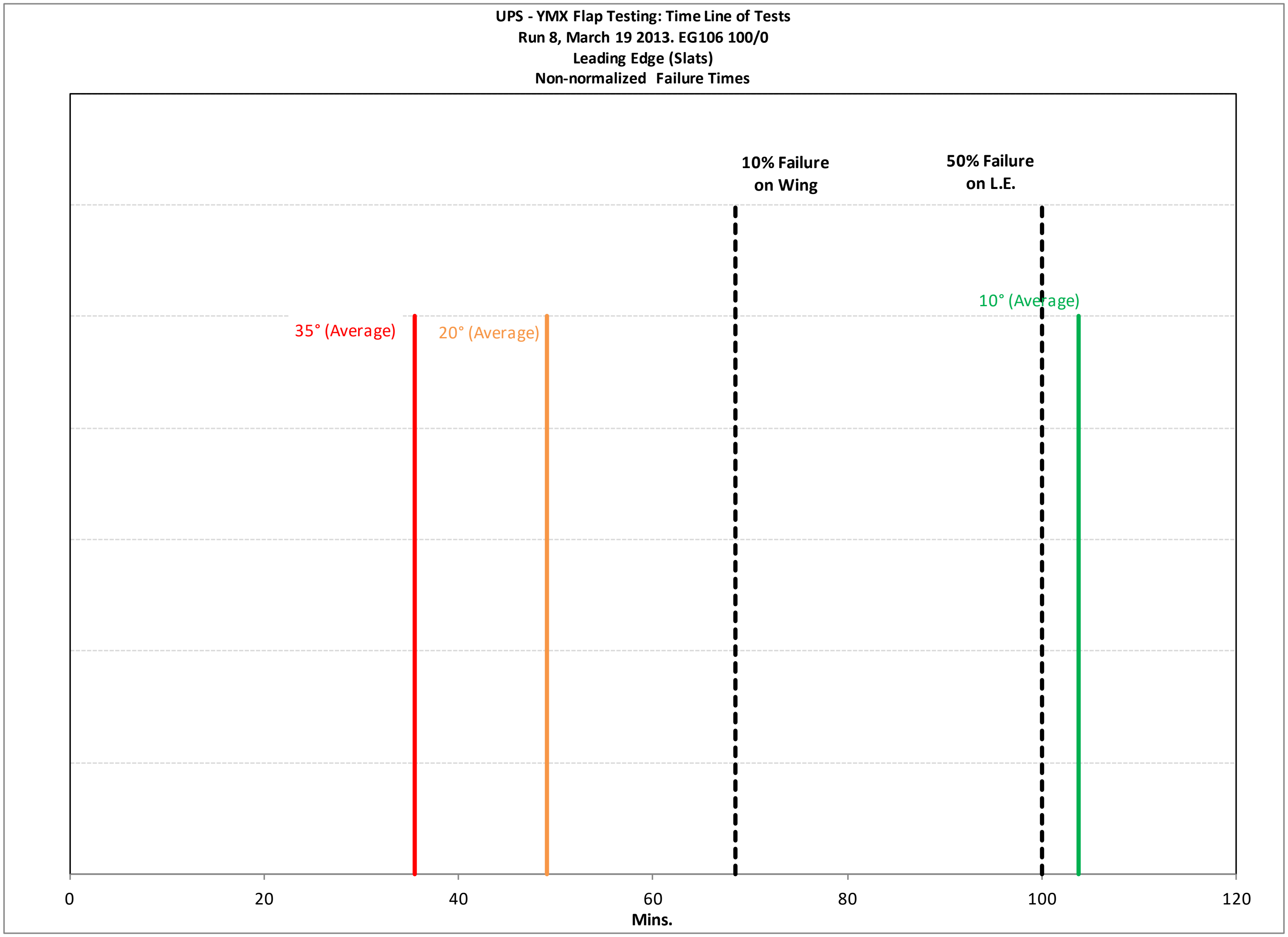
Type IV Fluid:	EG 106 (Brix = 33.00)
Application on Wing:	Sprayed from Nozzle
Application on Stand:	Sprayed from Nozzle into bucket and hand-poured onto plates.
Temperature:	18.4
Quantity of Type IV used:	92 litres

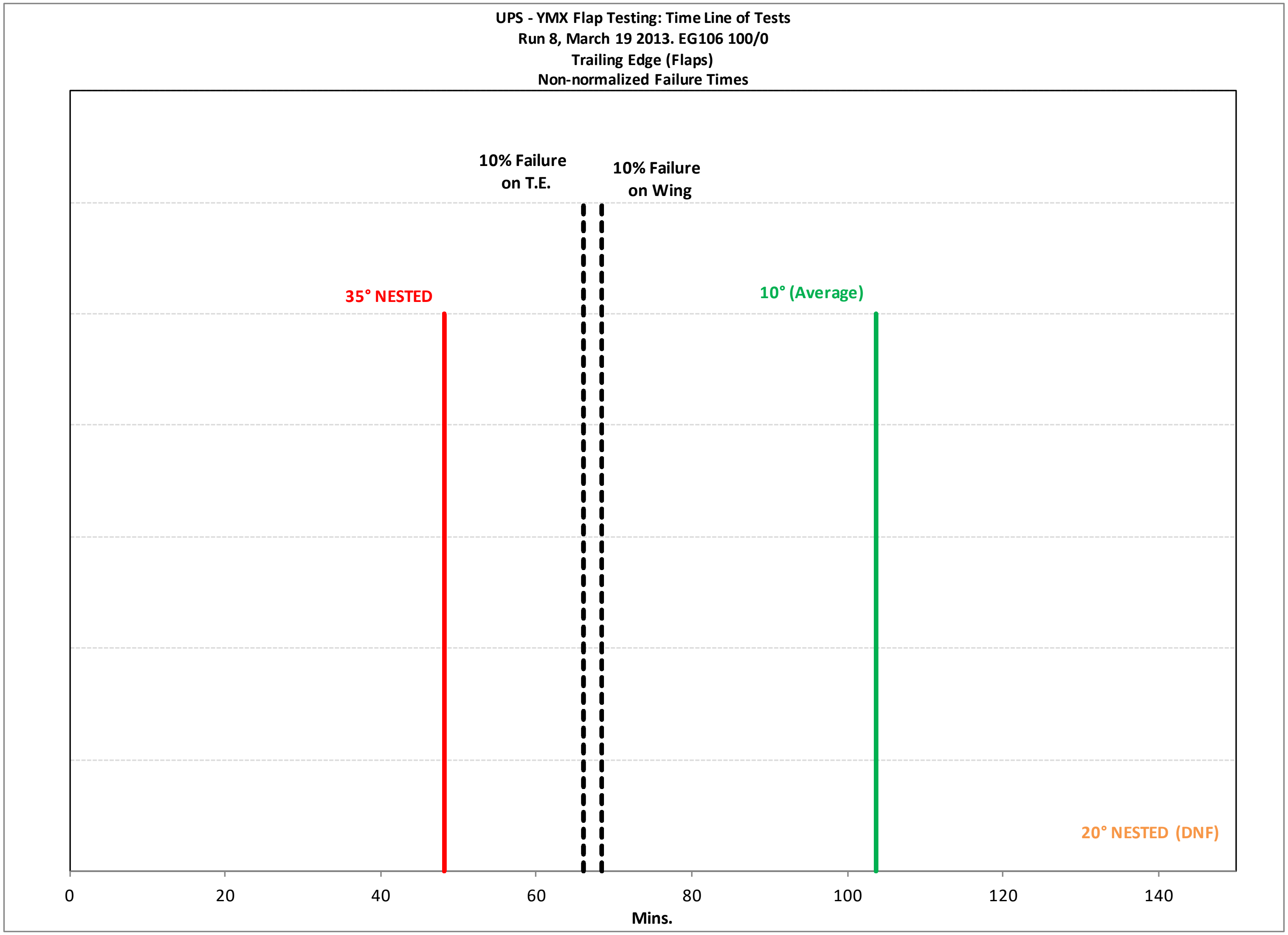
Holdover Time Information

Start of Test:	13:29 PM
End of Test:	15:19 PM


RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 8
Avg. Pan Rate
Pan 1
Pan 2
Start time: 13:29
End time: 15:19
Plate Pan Rate of Precipitation (g/dm²/hr)
0
5
10
15
20
25
30
35
13:12
13:26
13:40
13:55
14:09
14:24
14:38
14:52
15:07
15:21
15:36
Time


UPS - YMX Flap Testing: Time Line of Tests
Run 8, March 19 2013. EG106 100/0 (Non-normalized Failure Times)
35°(Nested)
35°
20°(Nested)
20°
10° Average
Did Not Fail
% of LE Slats Failed
% of Full Wing Failed
% of MidWing + Spoiler Failed
% of TE Flaps Failed
70%
40%
15%
10%
8%
5%
3%
0%
100%
90%
80%
60%
50%
30%
20%
12:57:36
13:26:24
13:55:12
14:24:00
14:52:48
15:21:36
15:50:24
Time hh:mm
Percentage of Test Area Failure


UPS - YMX Flap Testing: Time Line of Tests
Run 8, March 19 2013. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
10% Failure on Wing
50% Failure on L.E.
10° (Average)
35° (Average)
20° (Average)
0
20
40
60
80
100
120
Mins.


UPS - YMX Flap Testing: Time Line of Tests
Run 8, March 19 2013. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
10% Failure on T.E.
10% Failure on Wing
35° NESTED
10° (Average)
20° NESTED (DNF)
0
20
40
60
80
100
120
140
Mins.

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Run 9
March 19, 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Run # 9

March 19 , 2013
UPS Airbus A-300 Port Wing
Mirabel Airport

Meteorological/Setup Information:

OAT:	-3.4ºC
Aircraft Skin Temp:(at start of day)	Not Taken
Aircraft/Stand Orientation:	Tail Into wind/Into wind
Wind/Plate Direction:	60º-70º
Aircraft Direction:	240º
Wind Speed:	15-20 kph
Precipitation Type:	Snow
Average Rate of 10º Plate:	9.4 g/dm^2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	**Edge of Test Area Closest to Fuselage**	**Edge of Test Area Closest to Wing Tip**
¼ Slat Angle (top quarter)		19º
Mid Slat Angle (middle slat)		22º
Mid Flap Angle (middle flap):		21º

Fluid Information

Type I

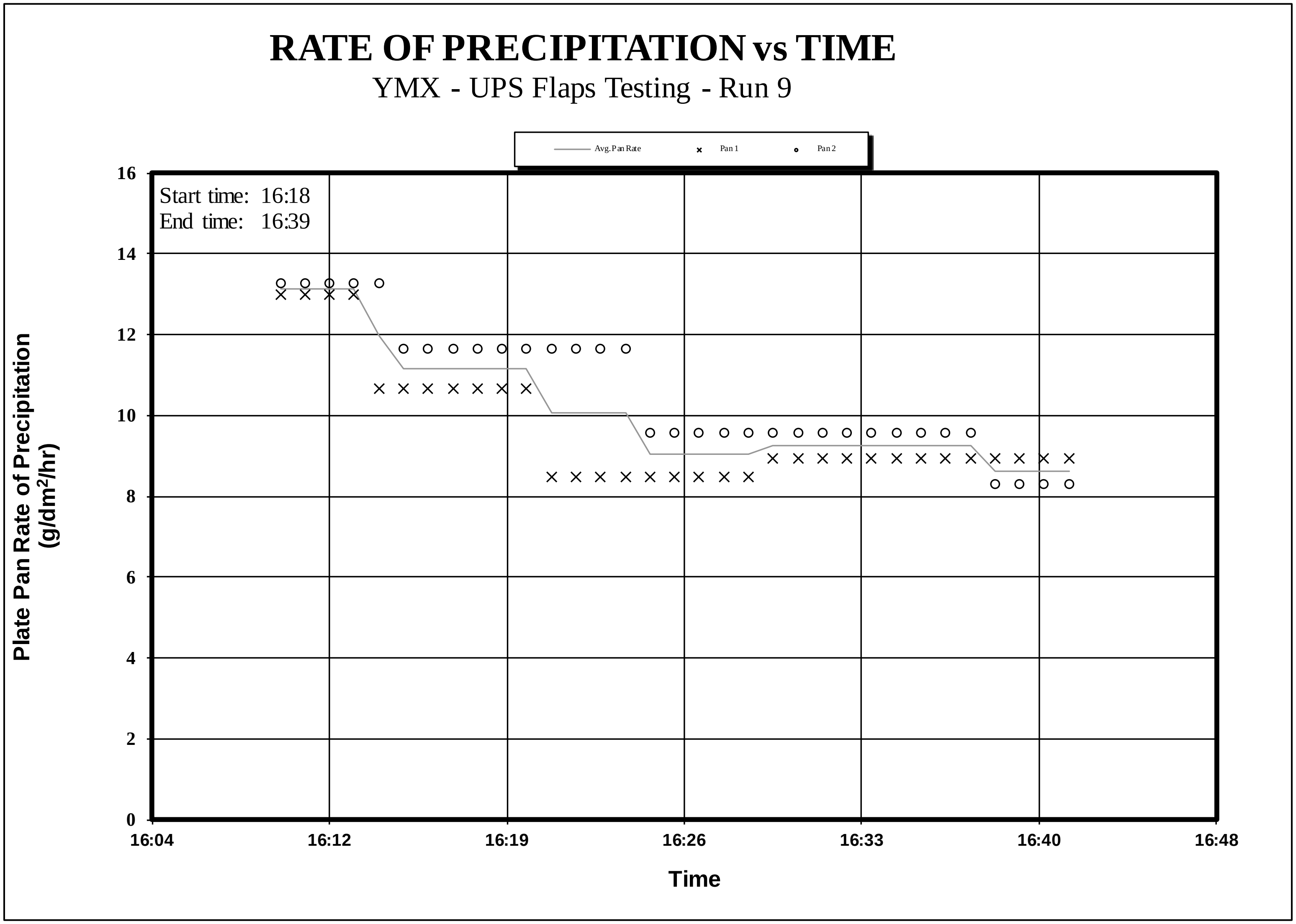
Type I Fluid:	Type I UCAR ADF (40%) (Brix = 24.5)
Application on Wing:	Sprayed from Nozzle
Temperature:	54ºC
Quantity of Type I used:	366 + 164 litres

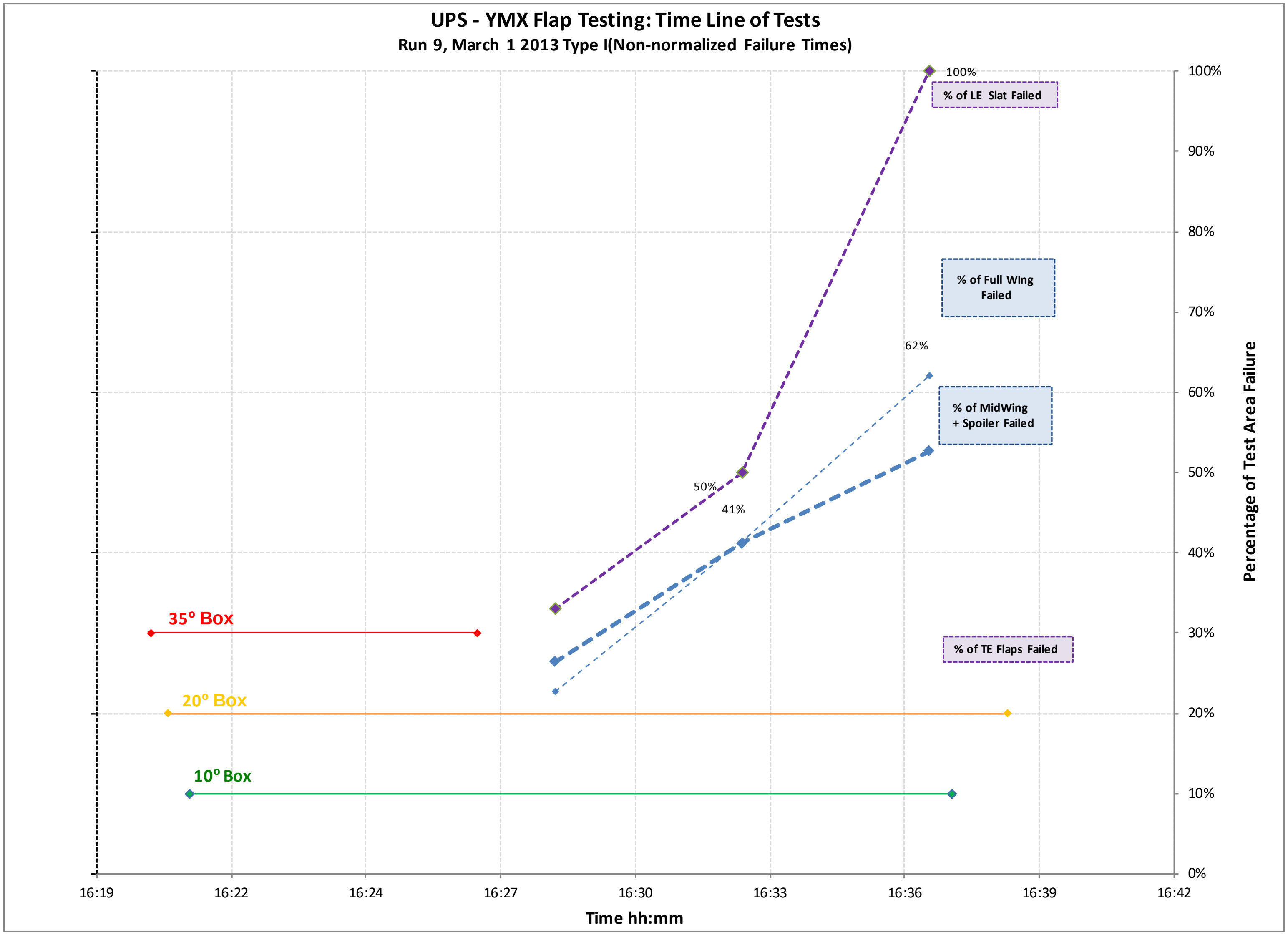
Type IV

No Type IV fluid applied

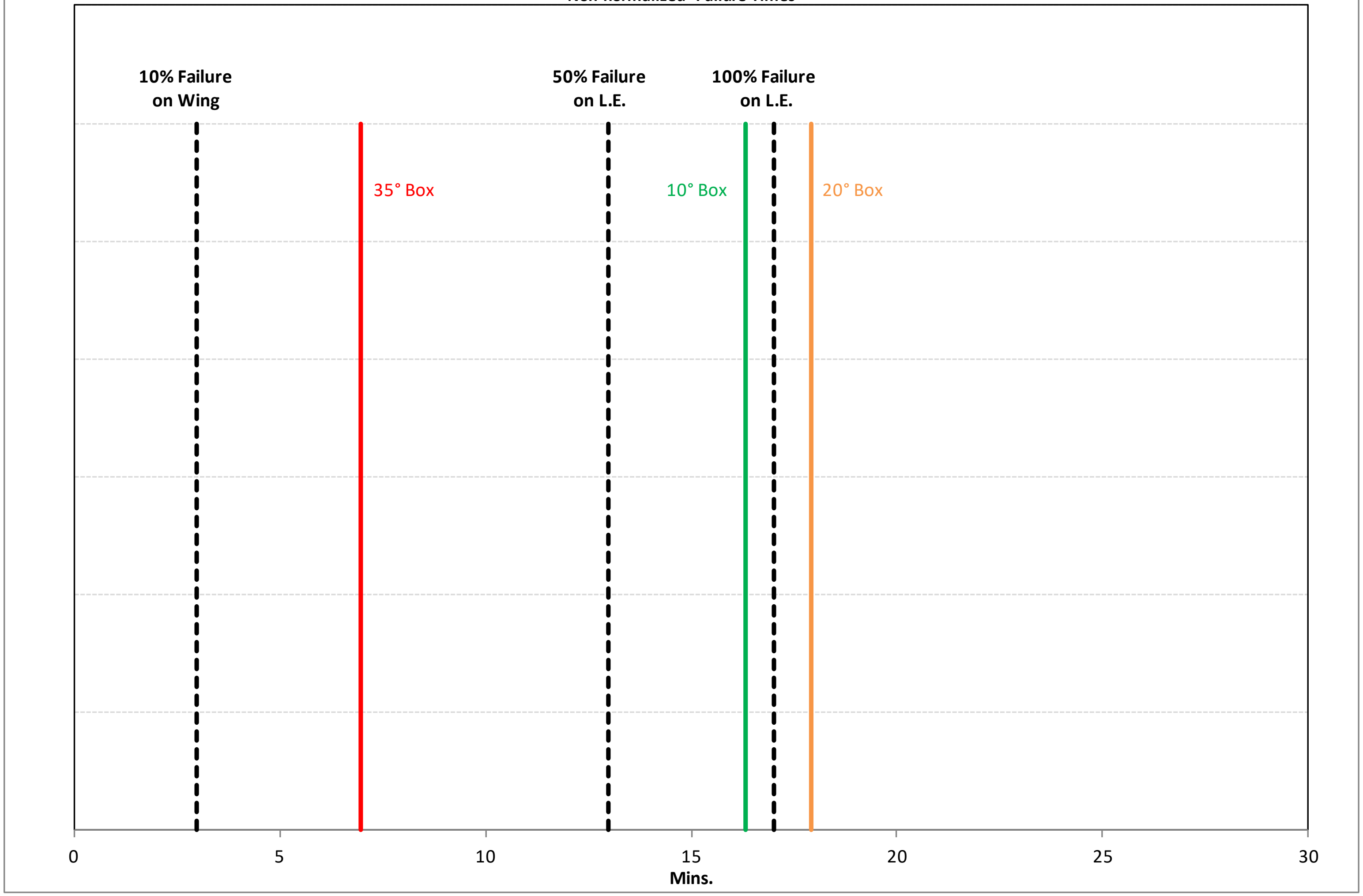
Holdover Time Information

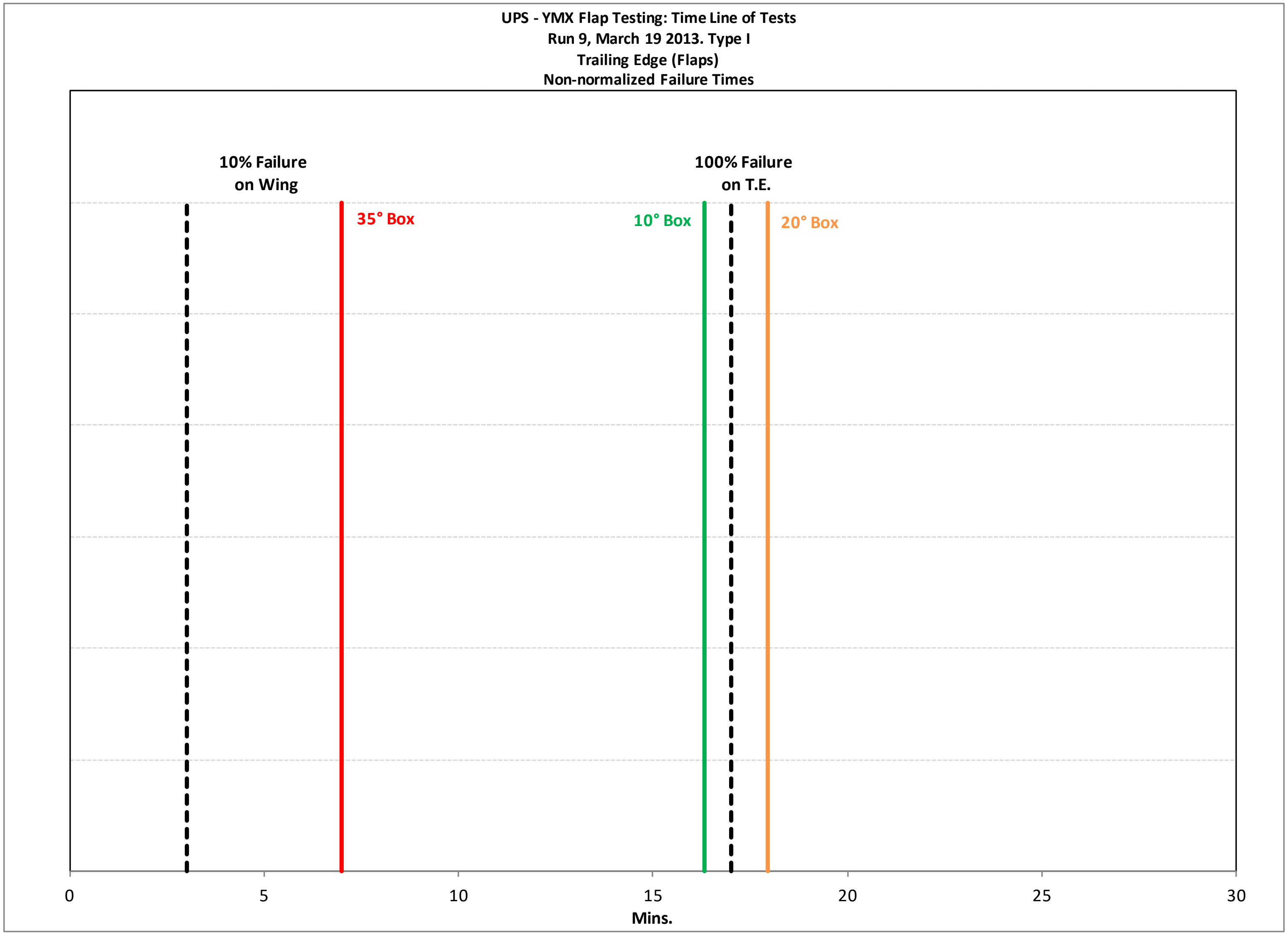
Start of Test:	16:18 PM
End of Test:	16:39 PM


RATE OF PRECIPITATION vs TIME
YMX - UPS Flaps Testing - Run 9
Avg. Pan Rate
Pan 1
Pan 2
Start time: 16:18
End time: 16:39
Plate Pan Rate of Precipitation (g/dm²/hr)
0
2
4
6
8
10
12
14
16
16:04
16:12
16:19
16:26
16:33
16:40
16:48
Time


UPS - YMX Flap Testing: Time Line of Tests
Run 9, March 1 2013 Type I(Non-normalized Failure Times)
100%
% of LE Slat Failed
% of Full Wing Failed
62%
% of MidWing + Spoiler Failed
50%
41%
35° Box
% of TE Flaps Failed
20° Box
10° Box
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Test Area Failure
16:19
16:22
16:24
16:27
16:30
16:33
16:36
16:39
16:42
Time hh:mm

UPS - YMX Flap Testing: Time Line of Tests
Run 9, March 19 2013. Type I
Leading Edge (Slats)
Non-normalized Failure Times




UPS - YMX Flap Testing: Time Line of Tests
Run 9, March 19 2013. Type I
Trailing Edge (Flaps)
Non-normalized Failure Times
10% Failure on Wing
100% Failure on T.E.
35° Box
10° Box
20° Box
0
5
10
15
20
25
30
Mins.

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Run 10
March 2, 2016
Air Canada Airbus A-3149 Port Wing
YUL Airport

Run # 10

March 2, 2016
Air Canada Airbus A-319 Port Wing
YUL Airport

Meteorological/Setup Information:

OAT:	-10.1 to -10.3ºC
Aircraft Skin Temp:(at start of day)	-9.0 to -9.2ºC
Aircraft/Stand Orientation:	Tail Into wind/Into wind
Wind/Plate Direction:	45º
Aircraft Direction:	225º
Wind Speed:	40-45 kph
Precipitation Type:	Ice Pellets
Average Rate of 10º Plate:	19.1 g/dm²/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	**Edge of Test Area Closest to Fuselage**	**Edge of Test Area Closest to Wing Tip**
¼ Slat Angle (top quarter)	24.2º	23.9º
Mid Slat Angle (middle slat)	26.5º	27º
Mid Flap Angle (middle flap):	23º	25º

Fluid Information

Type I

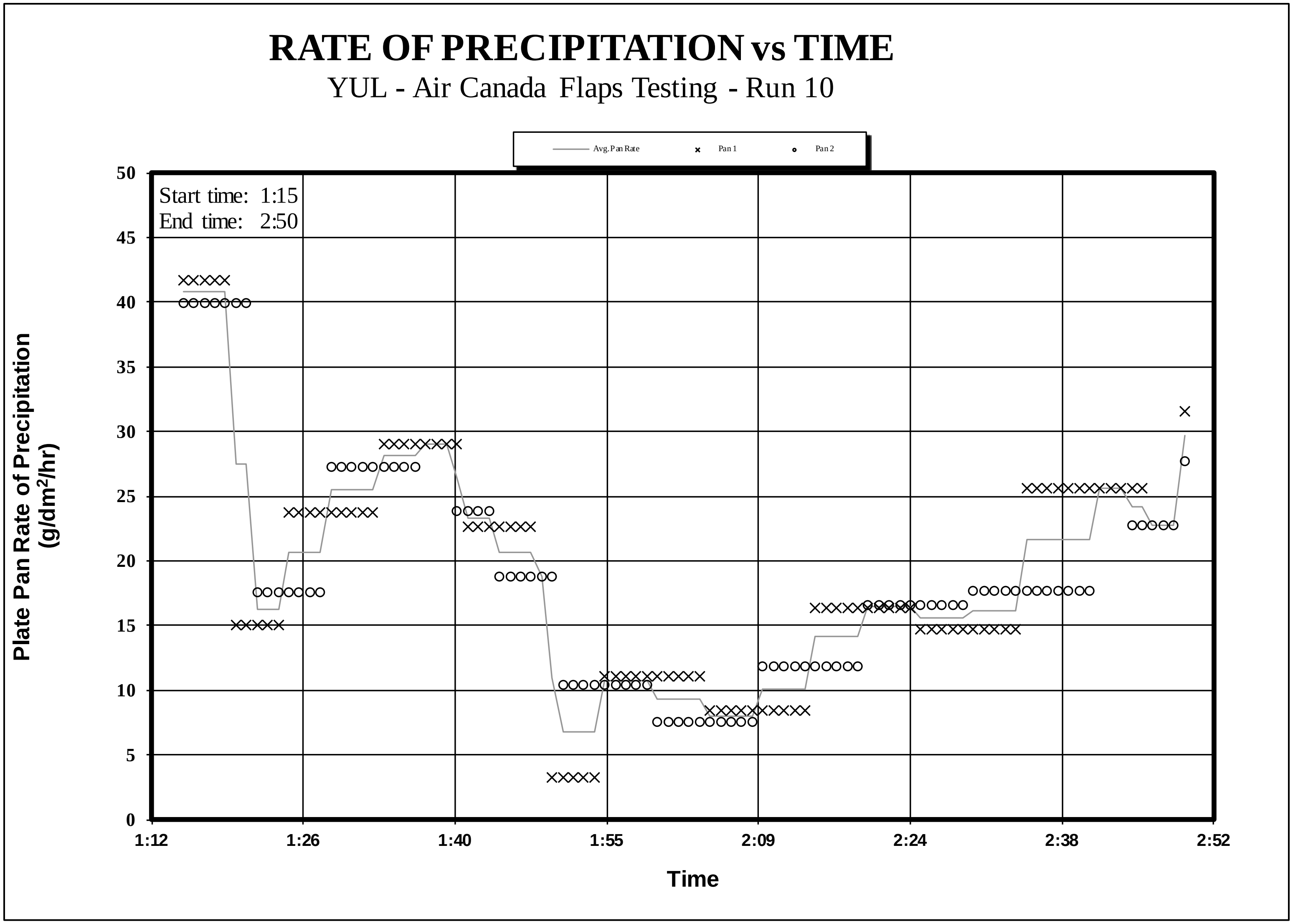
Type I Fluid:	Type I LNT E188(40%) (Brix = 25.75)
Application on Wing:	Sprayed from Nozzle
Temperature:	60ºC (not measured)
Quantity of Type I used:	133 litres

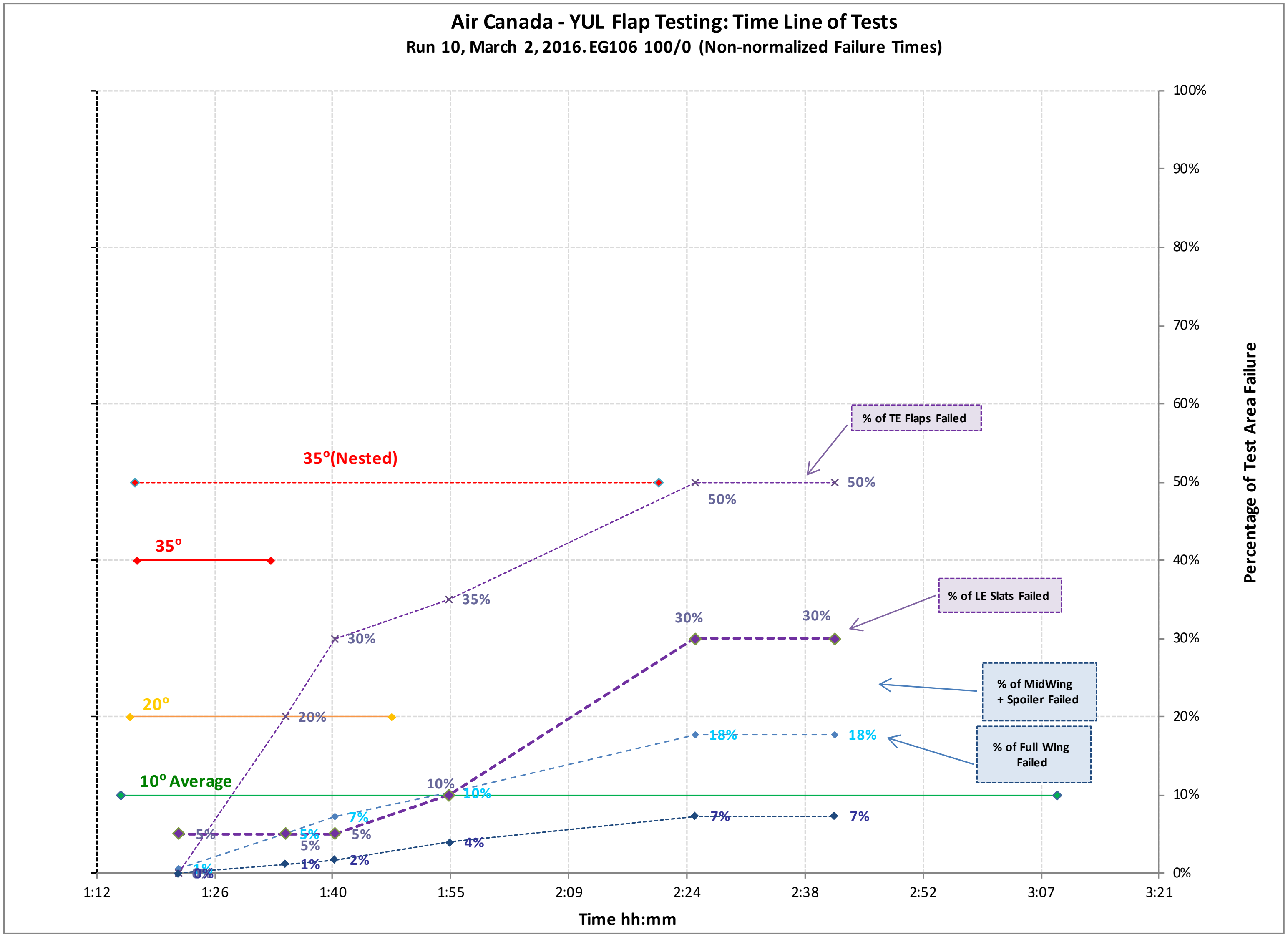
Type IV

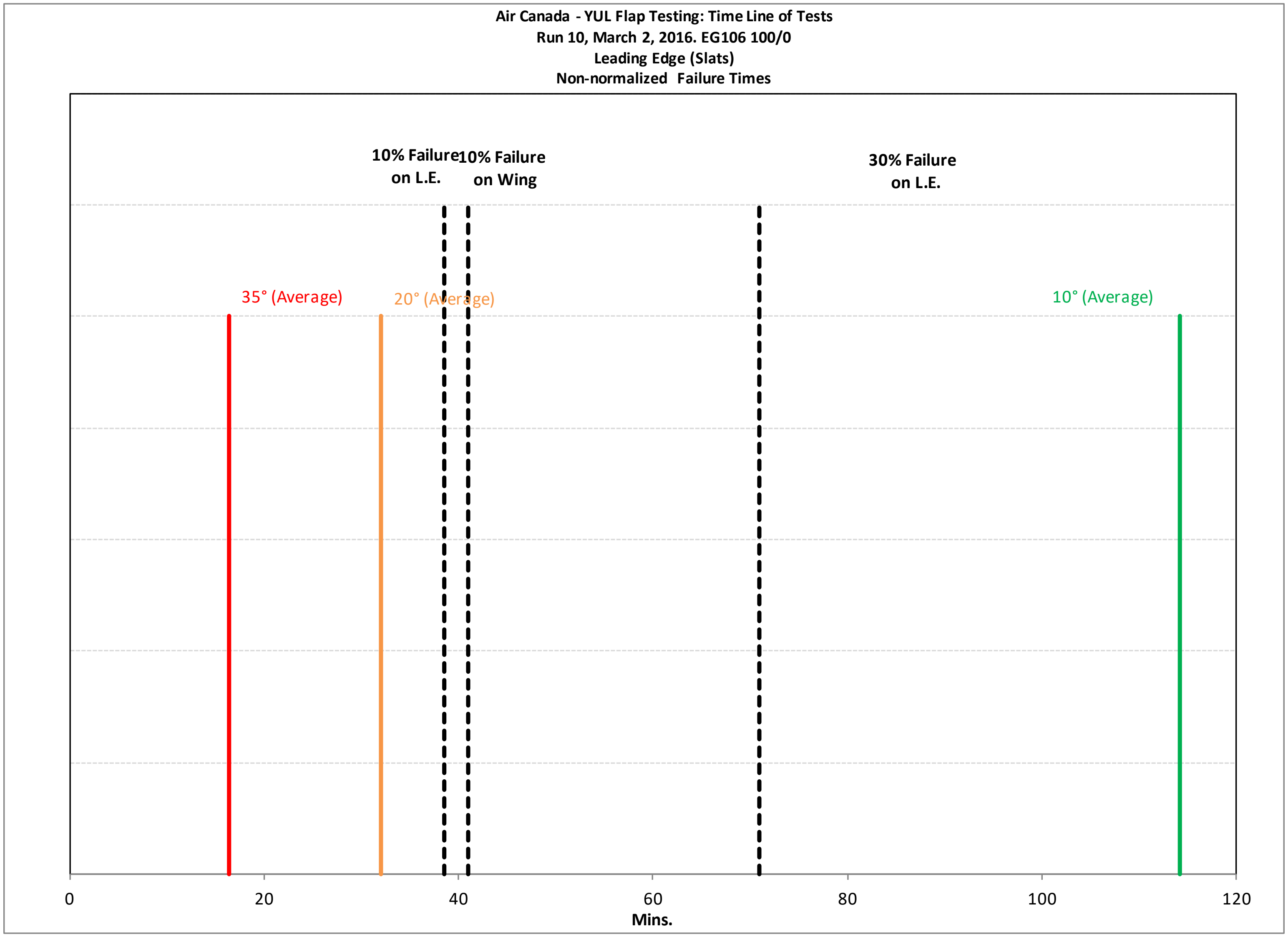
Type IV Fluid:	EG 106 (Brix = 34.00)
Application on Wing:	Sprayed from Nozzle
Application on Stand:	Sprayed from Nozzle into bucket and hand-poured onto plates.
Temperature:	10ºC
Quantity of Type IV used:	108 litres

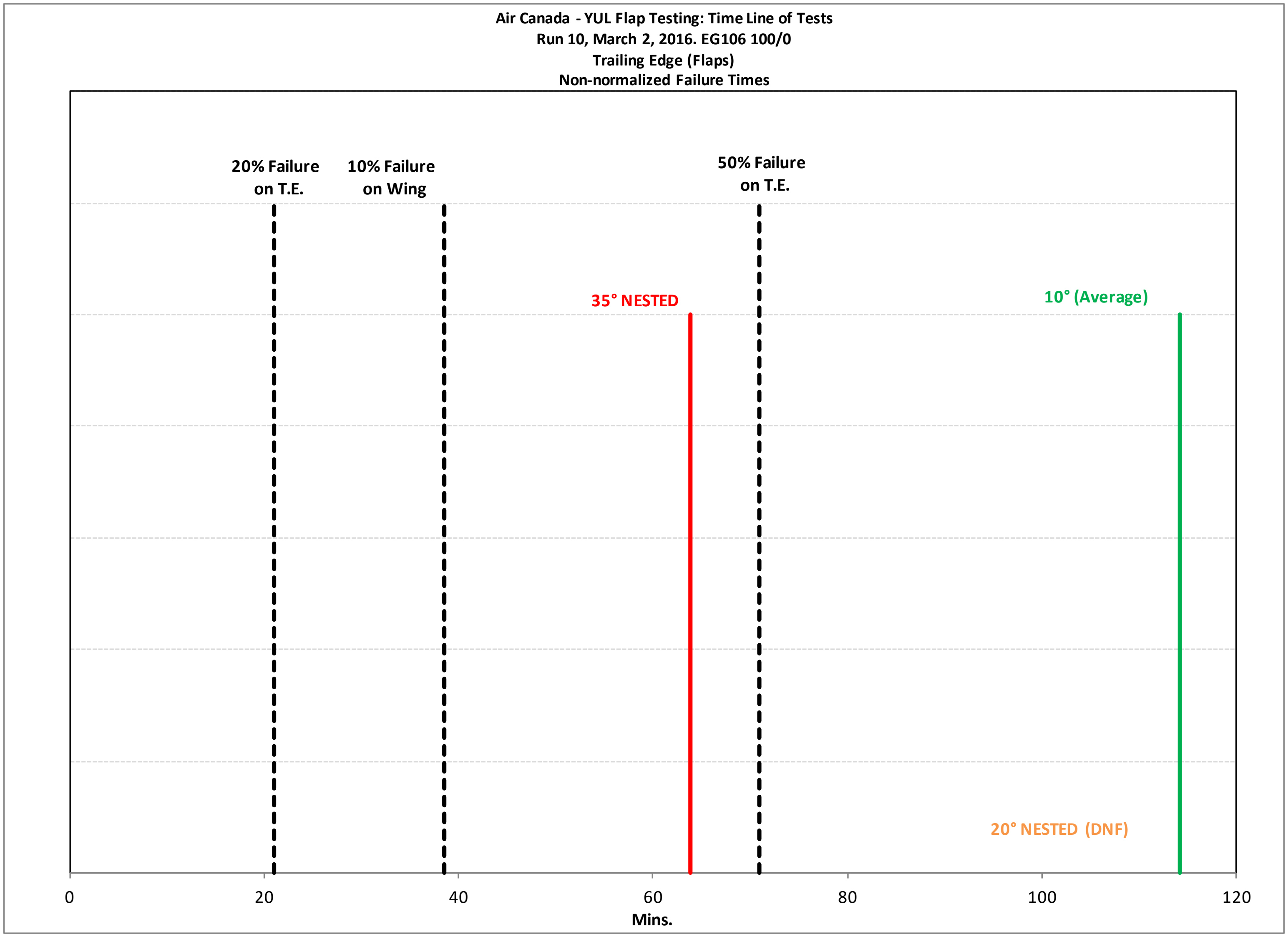
Holdover Time Information

Start of Test:	1:14 AM
End of Test:	2:50 AM


RATE OF PRECIPITATION vs TIME
YUL - Air Canada Flaps Testing - Run 10
Avg. Pan Rate
Pan 1
Pan 2
Start time: 1:15
End time: 2:50
Plate Pan Rate of Precipitation (g/dm²/hr)
50
45
40
35
30
25
20
15
10
5
0
1:12
1:26
1:40
1:55
2:09
2:24
2:38
2:52
Time


Air Canada - YUL Flap Testing: Time Line of Tests
Run 10, March 2, 2016. EG106 100/0 (Non-normalized Failure Times)
35°(Nested)
35°
20°
10° Average
% of TE Flaps Failed
% of LE Slats Failed
% of MidWing + Spoiler Failed
% of Full Wing Failed
50%
50%
35%
30%
20%
30%
30%
18%
18%
10%
10%
7%
7%
7%
5%
5%
5%
5%
4%
2%
1%
1%
0%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Test Area Failure
1:12
1:26
1:40
1:55
2:09
2:24
2:38
2:52
3:07
3:21
Time hh:mm


Air Canada - YUL Flap Testing: Time Line of Tests
Run 10, March 2, 2016. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
10% Failure on L.E.
10% Failure on Wing
30% Failure on L.E.
35° (Average)
20° (Average)
10° (Average)
0
20
40
60
80
100
120
Mins.


Air Canada - YUL Flap Testing: Time Line of Tests
Run 10, March 2, 2016. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
20% Failure on T.E.
10% Failure on Wing
50% Failure on T.E.
35° NESTED
10° (Average)
20° NESTED (DNF)
0
20
40
60
80
100
120
Mins.

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Run 11
March 2, 2016
Air Canada Airbus A-319 Port Wing
YUL Airport

Run # 11

March 2, 2016
Air Canada Airbus A-319 Port Wing
YUL Airport

Meteorological/Setup Information:

OAT:	-9.8 to -9.9ºC
Aircraft Skin Temp:(at start of day)	-9.0 to -9.2ºC
Aircraft/Stand Orientation:	Tail Into wind/Into wind
Wind/Plate Direction:	45º
Aircraft Direction:	225º
Wind Speed:	40-50 kph
Precipitation Type:	Ice Pellets and Snow
Average Rate of 10º Plate:	18.8 g/dm^2/h

Slat / Flap Angle Information

Angles Measured

Aircraft Flap Setting 15/20 (highest)	Edge of Test Area Closest to Fuselage	Edge of Test Area Closest to Wing Tip
¼ Slat Angle (top quarter)	24.2º	23.9º
Mid Slat Angle (middle slat)	26.5º	27º
Mid Flap Angle (middle flap):	23º	25º

Fluid Information

Type I

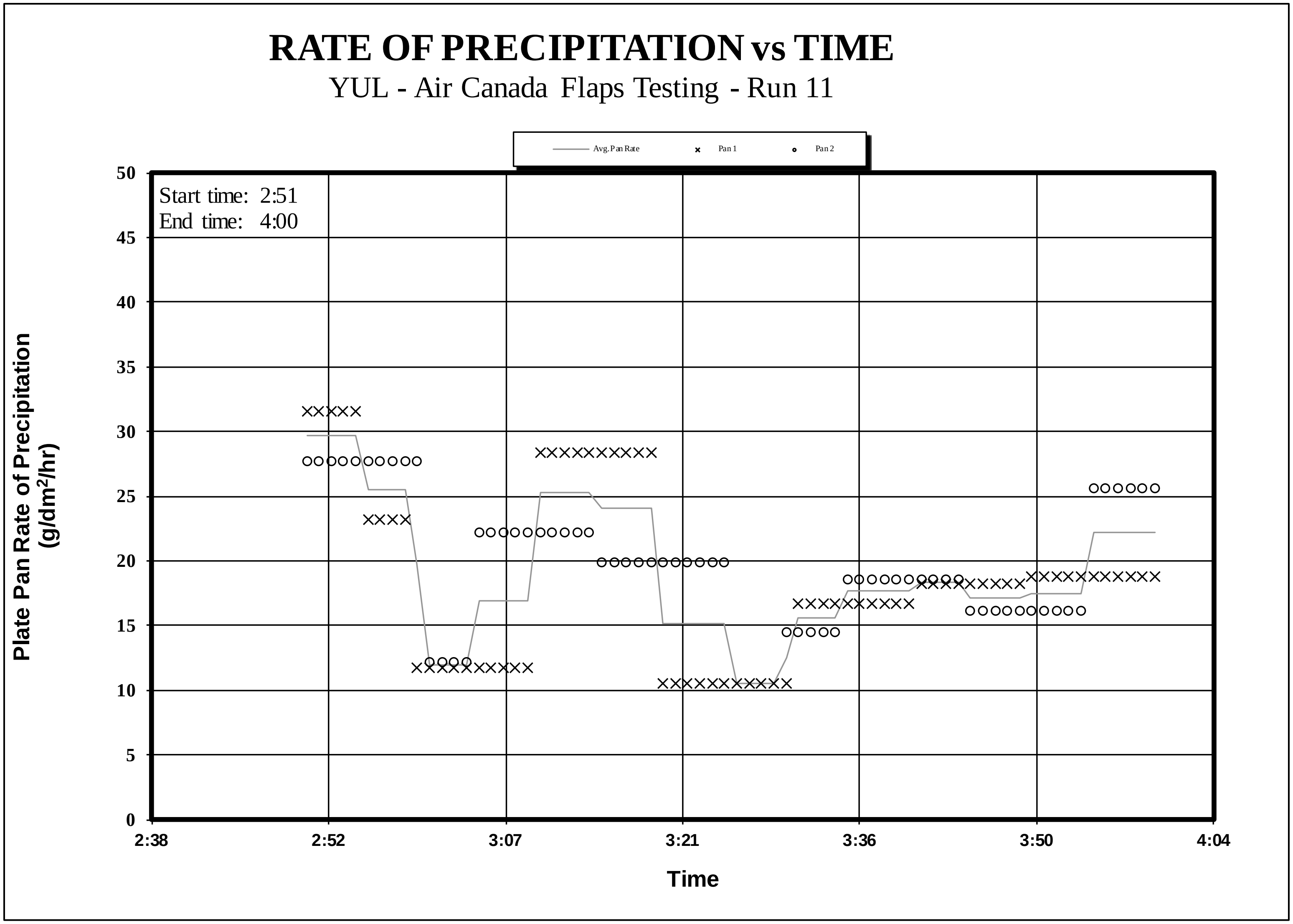
Type I Fluid:	Type I LNT E188(40%) (Brix = 25.75)
Application on Wing:	Sprayed from Nozzle
Temperature:	60ºC (not measured)
Quantity of Type I used:	431 litres

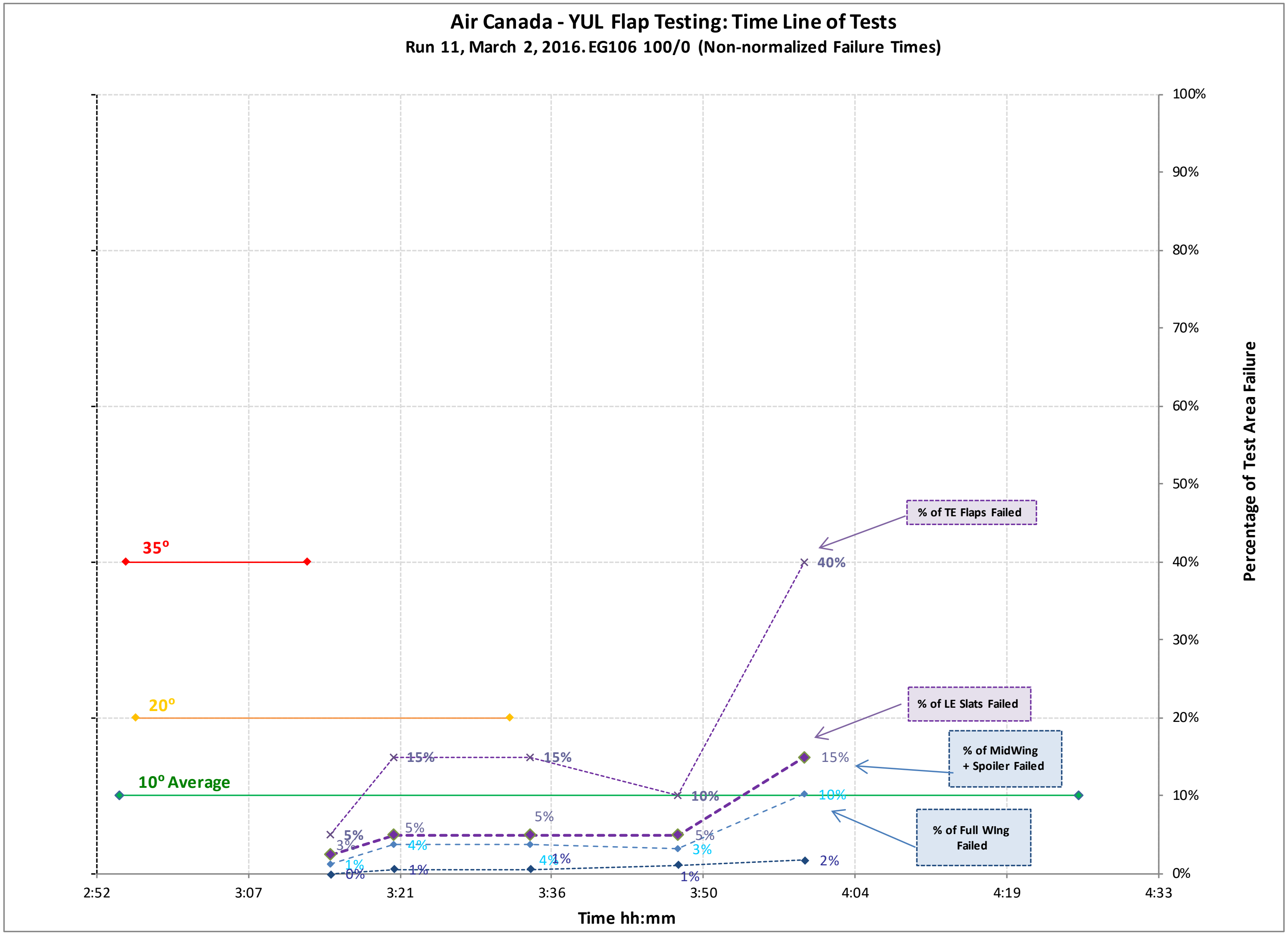
Type IV

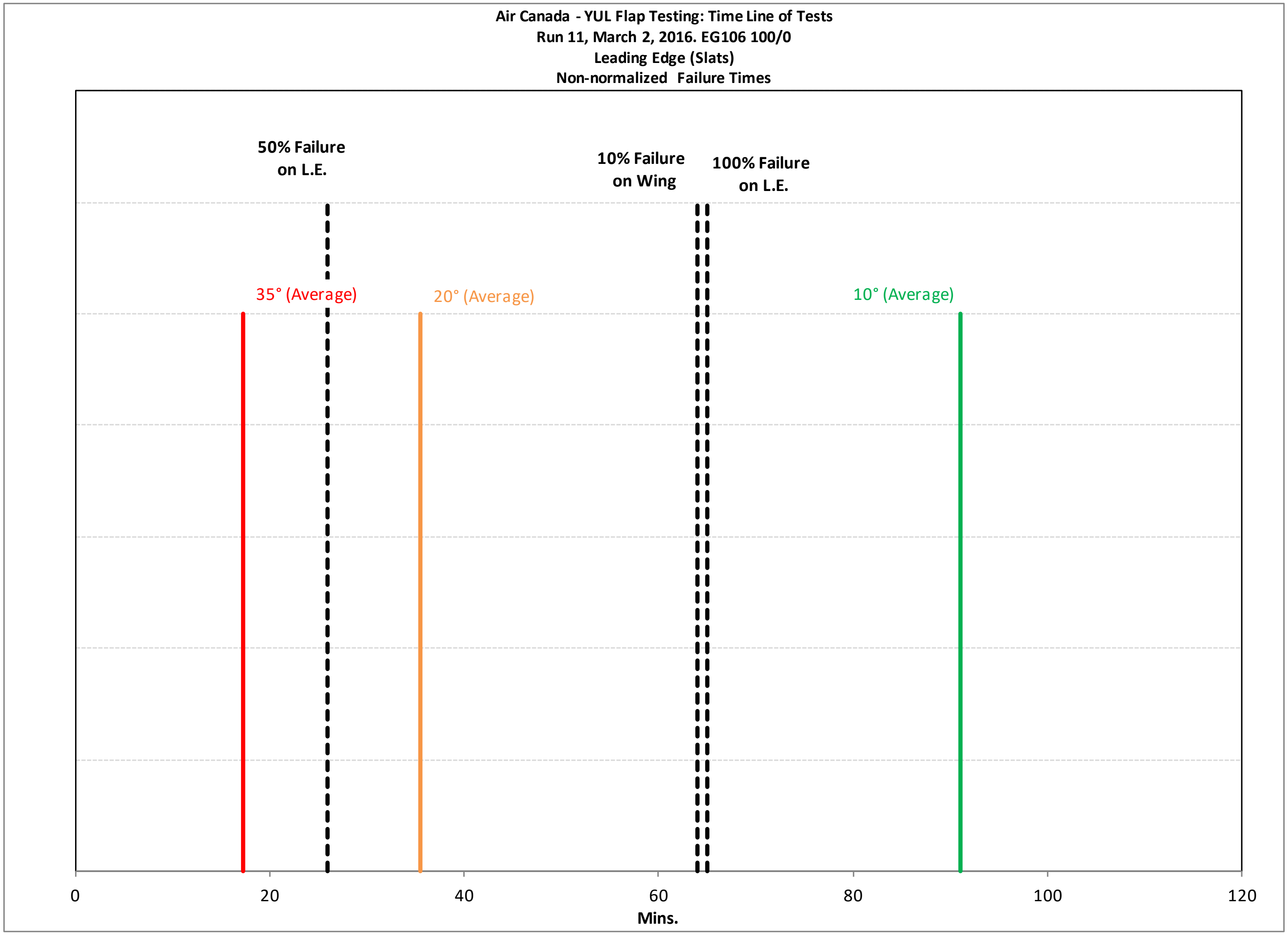
Type IV Fluid:	EG 106 (Brix = 34.00)
Application on Wing:	Sprayed from Nozzle
Application on Stand:	Sprayed from Nozzle into bucket and hand-poured onto plates.
Temperature:	3.2ºC
Quantity of Type IV used:	166 litres

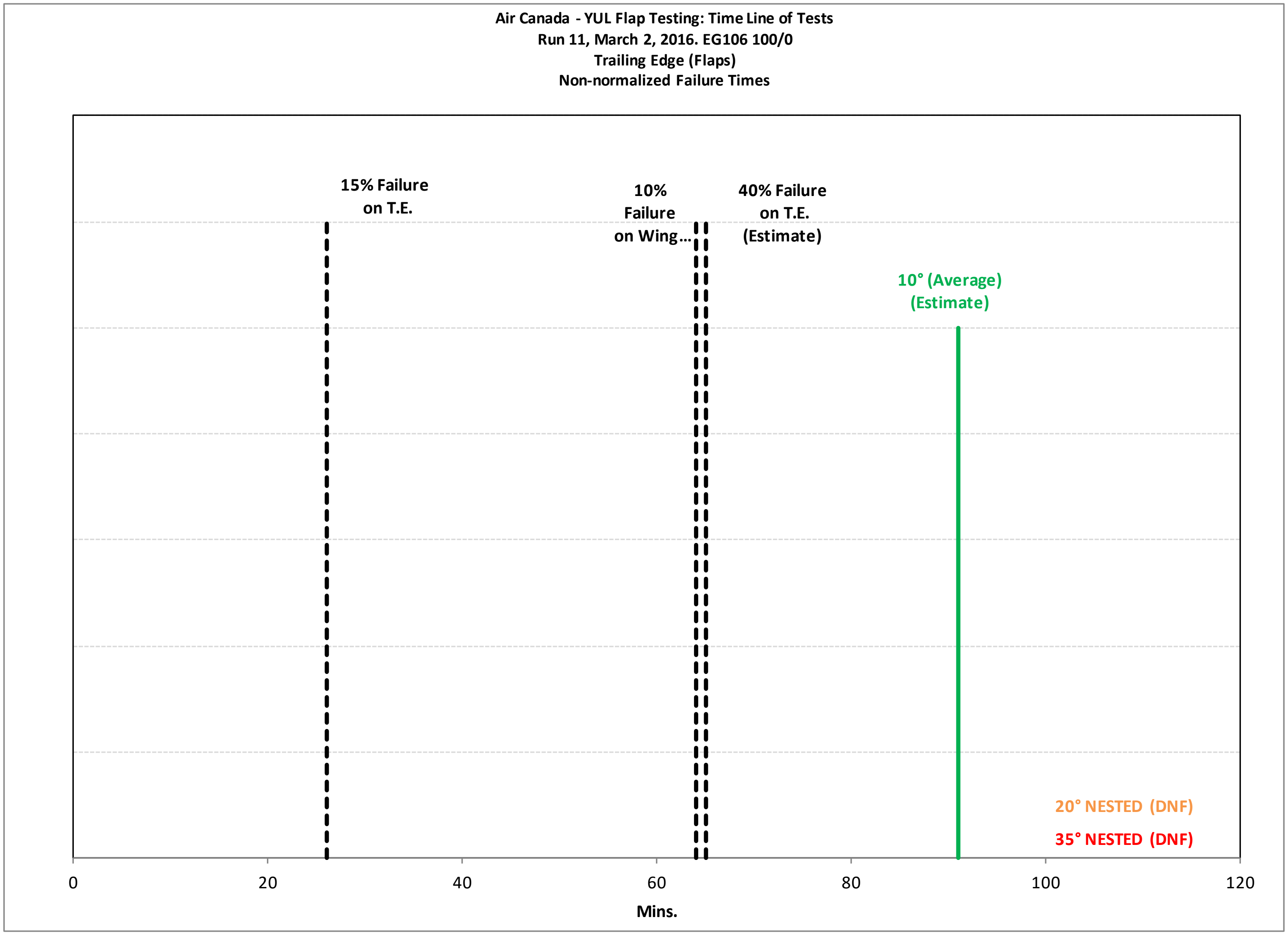
Holdover Time Information

Start of Test:	2:55 AM
End of Test:	4:00 AM


RATE OF PRECIPITATION vs TIME
YUL - Air Canada Flaps Testing - Run 11
Avg. Pan Rate
Pan 1
Pan 2
Start time: 2:51
End time: 4:00
Plate Pan Rate of Precipitation (g/dm²/hr)
0
5
10
15
20
25
30
35
40
45
50
2:38
2:52
3:07
3:21
3:36
3:50
4:04
Time


Air Canada - YUL Flap Testing: Time Line of Tests
Run 11, March 2, 2016. EG106 100/0 (Non-normalized Failure Times)
35°
20°
10° Average
% of TE Flaps Failed
% of LE Slats Failed
% of MidWing + Spoiler Failed
% of Full Wing Failed
5%
3%
1%
0%
15%
5%
4%
1%
15%
5%
4%
1%
10%
5%
3%
1%
40%
15%
10%
2%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Test Area Failure
2:52
3:07
3:21
3:36
3:50
4:04
4:19
4:33
Time hh:mm


Air Canada - YUL Flap Testing: Time Line of Tests
Run 11, March 2, 2016. EG106 100/0
Leading Edge (Slats)
Non-normalized Failure Times
50% Failure on L.E.
10% Failure on Wing
100% Failure on L.E.
35° (Average)
20° (Average)
10° (Average)
0
20
40
60
80
100
120
Mins.


Air Canada - YUL Flap Testing: Time Line of Tests
Run 11, March 2, 2016. EG106 100/0
Trailing Edge (Flaps)
Non-normalized Failure Times
15% Failure on T.E.
10% Failure on Wing…
40% Failure on T.E. (Estimate)
10° (Average) (Estimate)
20° NESTED (DNF)
35° NESTED (DNF)
0
20
40
60
80
100
120
Mins.

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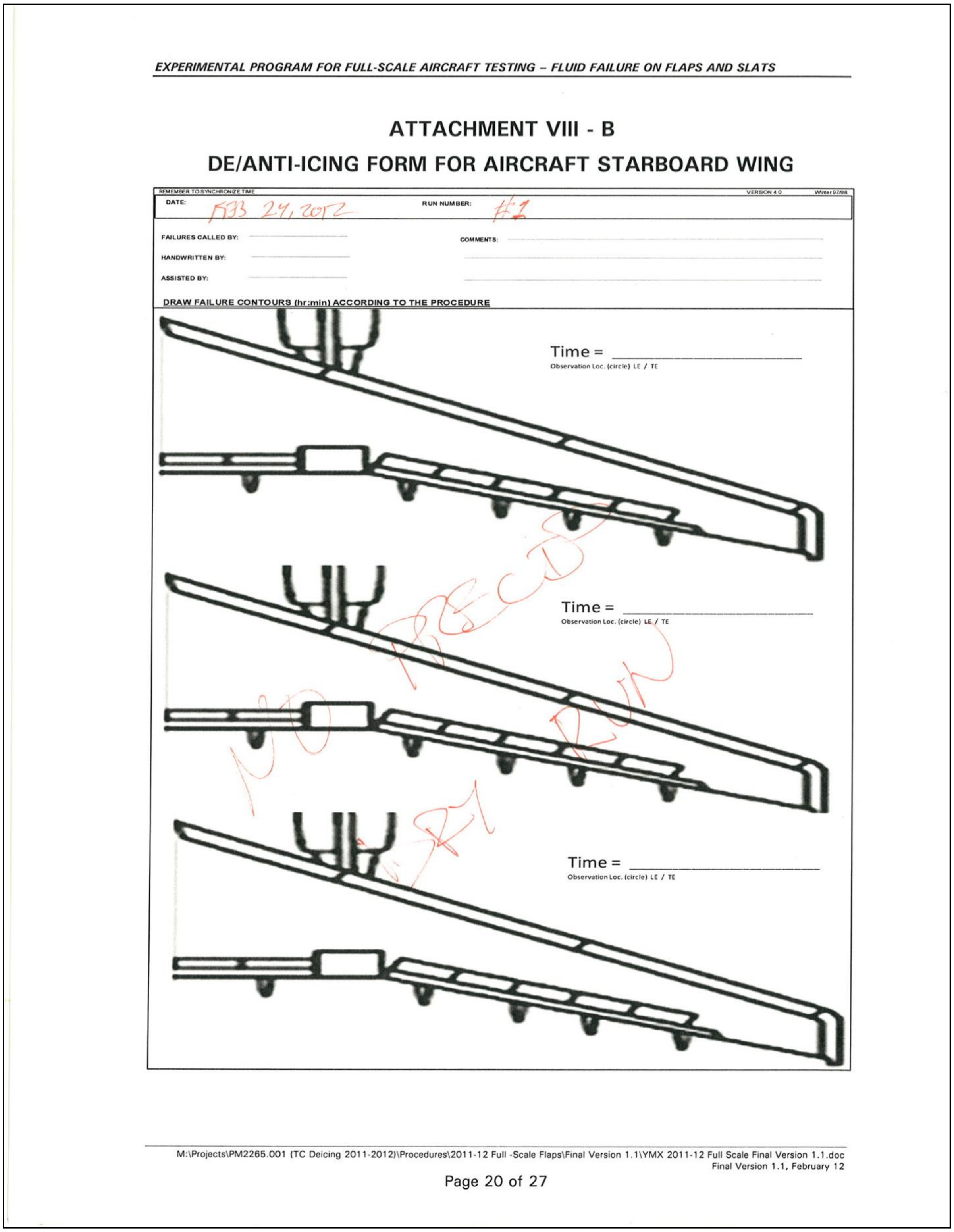
APPENDIX I

WING FLUID FAILURE VISUAL OBSERVATION DATA

Run 1 (Dry Run)

February 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport



EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIII - B

DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

REMEMBER TO SYNCHRONIZE TIME VERSION 4.0 Winter 97/98

DATE: FEB 24, 2012 RUN NUMBER: #1

FAILURES CALLED BY:

HANDWRITTEN BY:

ASSISTED BY:

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = ____________________

Observation Loc. (circle) LE / TE

Time = ____________________

Observation Loc. (circle) LE / TE

Time = ____________________

Observation Loc. (circle) LE / TE

NO PRECIP RUN

DRY

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
Final Version 1.1, February 12

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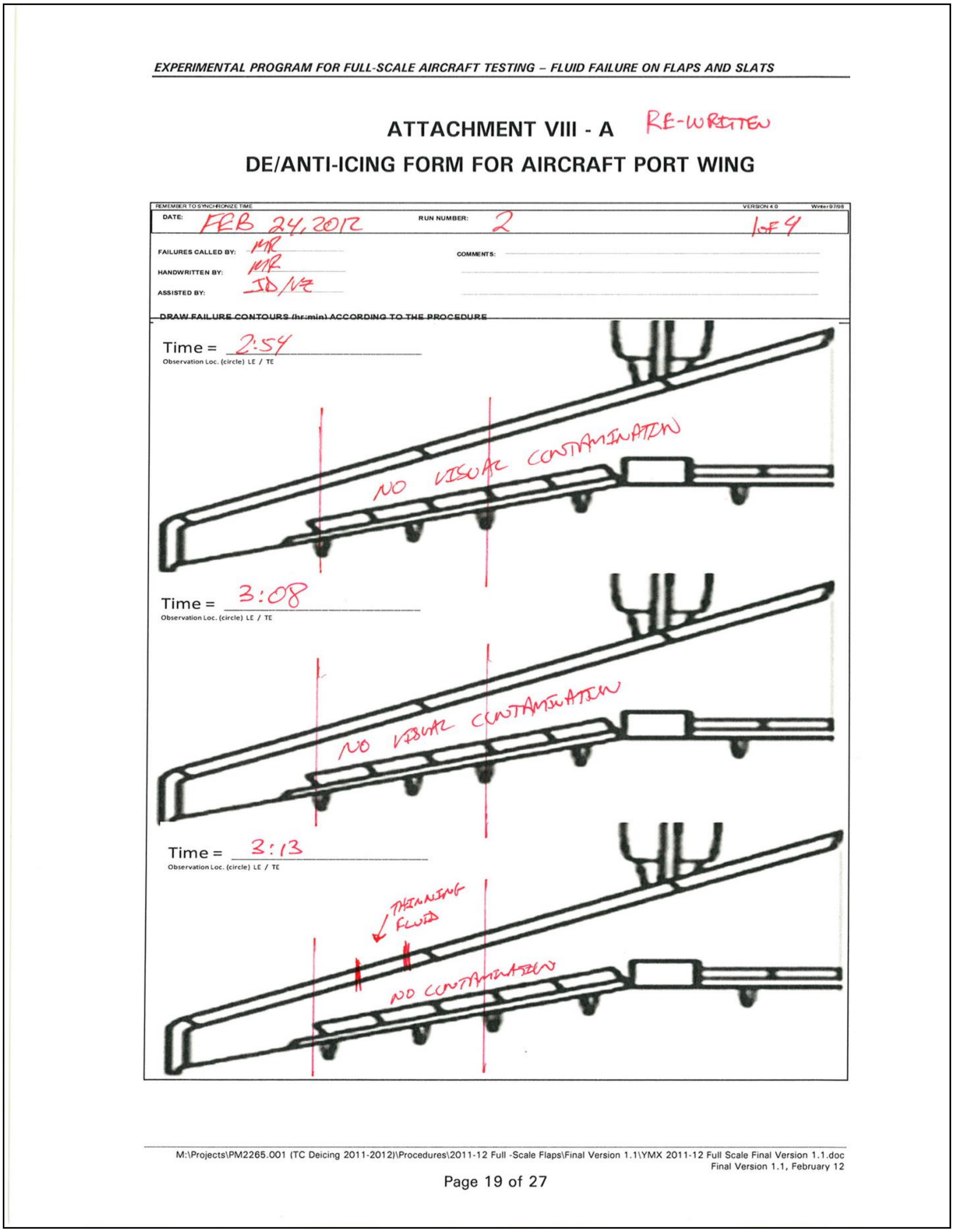
Run 2

February 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport



EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIII - A RE-WRITTEN

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME VERSION 4.0 Winter 97/98

DATE: FEB 24, 2012 RUN NUMBER: 2 1 of 4

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: JD/VZ

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 2:54
Observation Loc. (circle) LE / TE

NO VISUAL CONTAMINATION

Time = 3:08
Observation Loc. (circle) LE / TE

NO VISUAL CONTAMINATION

Time = 3:13
Observation Loc. (circle) LE / TE

THINNING FLUID

NO CONTAMINATION

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
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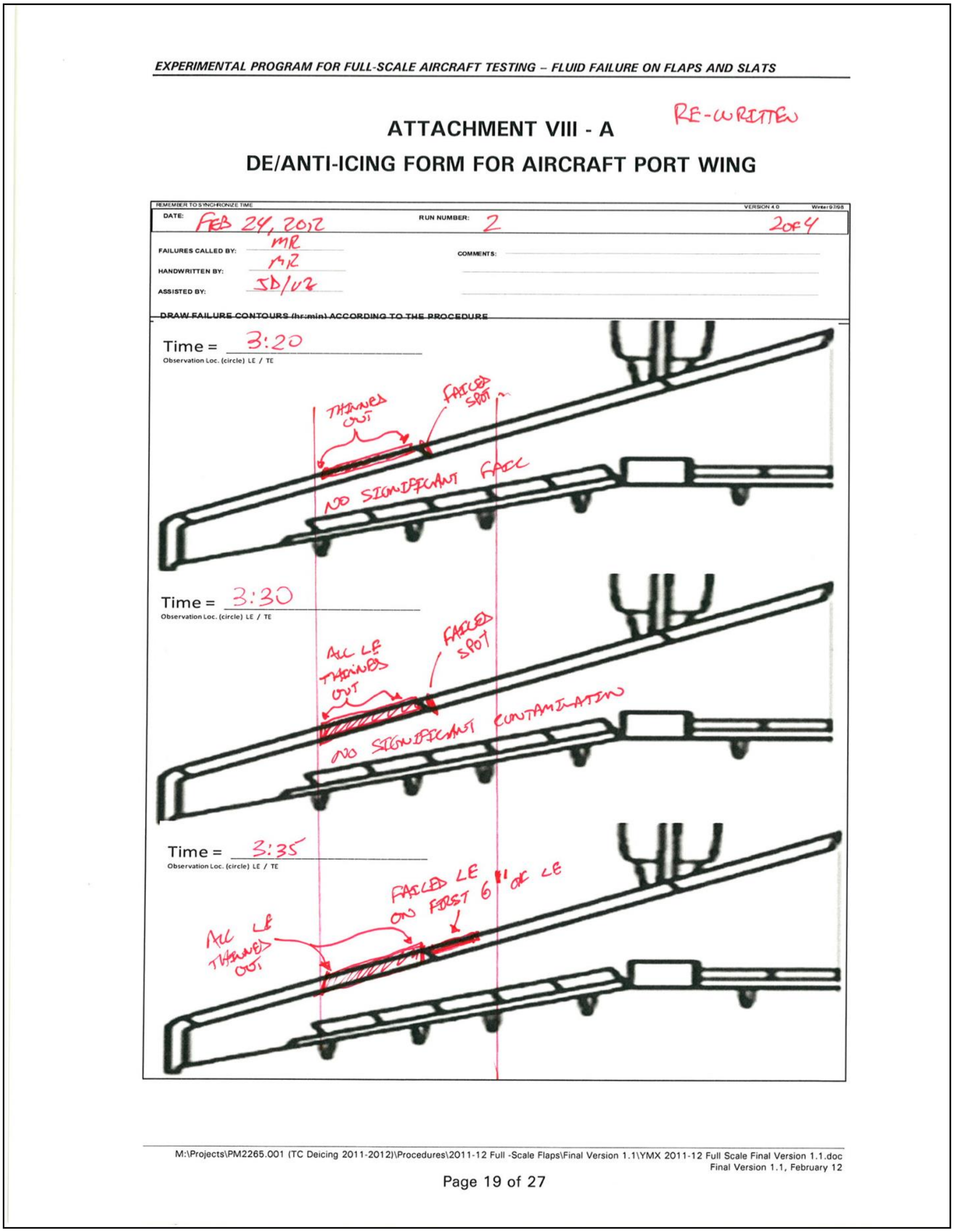

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

RE-WRITTEN

ATTACHMENT VIII - A

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0

Winter 97/98

DATE: FEB 24, 2012

RUN NUMBER: 2

2 OF 4

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: JD/VZ

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 3:20

Observation Loc. (circle) LE / TE

Time = 3:30

Observation Loc. (circle) LE / TE

Time = 3:35

Observation Loc. (circle) LE / TE

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
Final Version 1.1, February 12

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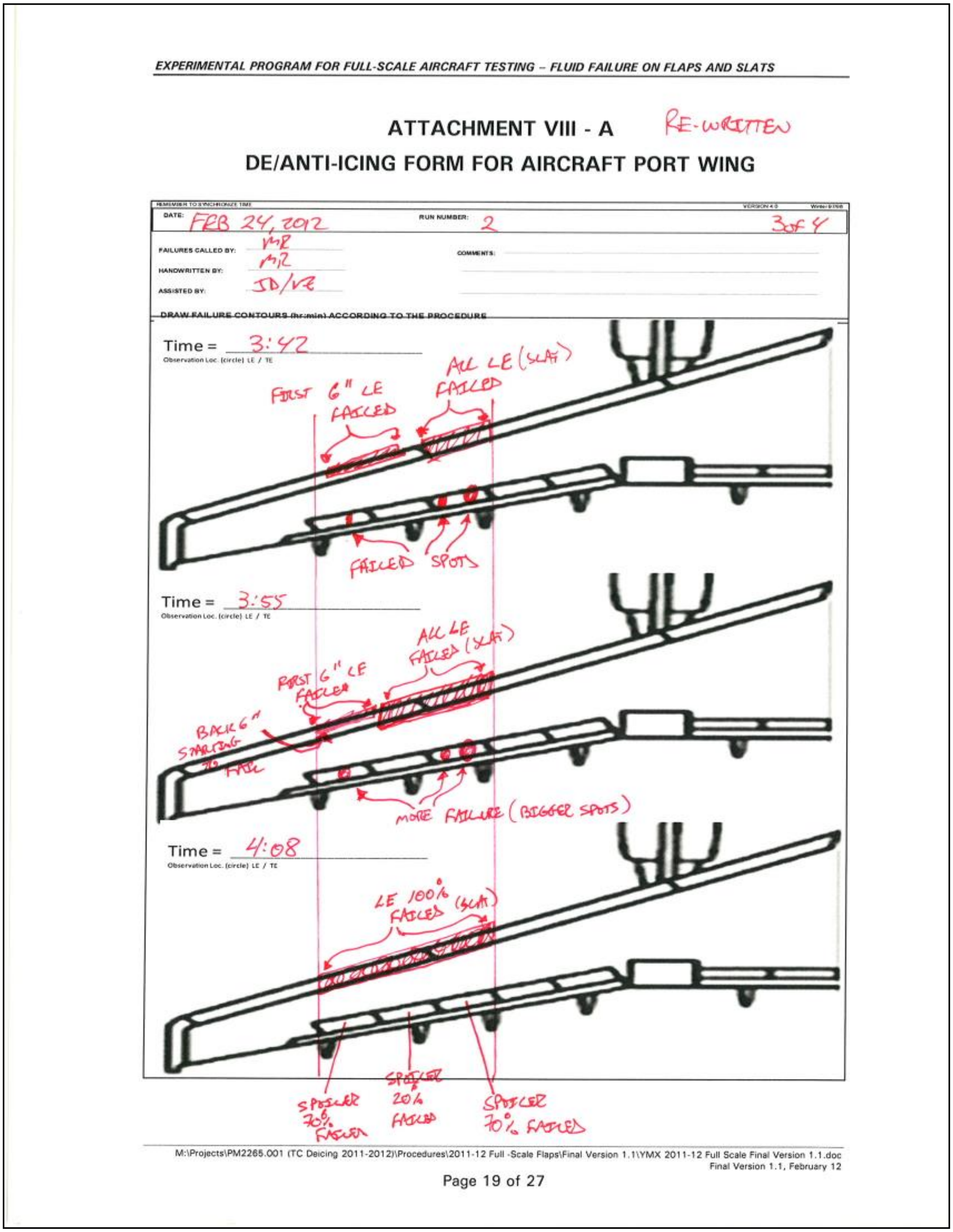

ATTACHMENT VIII - A

RE-WRITTEN

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0

DATE: FEB 24, 2012

RUN NUMBER: 2

3 of 4

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: JD/VE

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 3:42

Observation Loc. (circle) LE / TE

FIRST 6" LE FAILED

ALL LE (SLAT) FAILED

FAILED SPOTS

Time = 3:55

Observation Loc. (circle) LE / TE

BACK 6" STARTING TO FAIL

FIRST 6" LE FAILED

ALL LE FAILED (SLAT)

MORE FAILURE (BIGGER SPOTS)

Time = 4:08

Observation Loc. (circle) LE / TE

LE 100% FAILED (SLAT)

SPOILER 70% FAILED

SPOILER 20% FAILED

SPOILER 70% FAILED

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
Final Version 1.1, February 12

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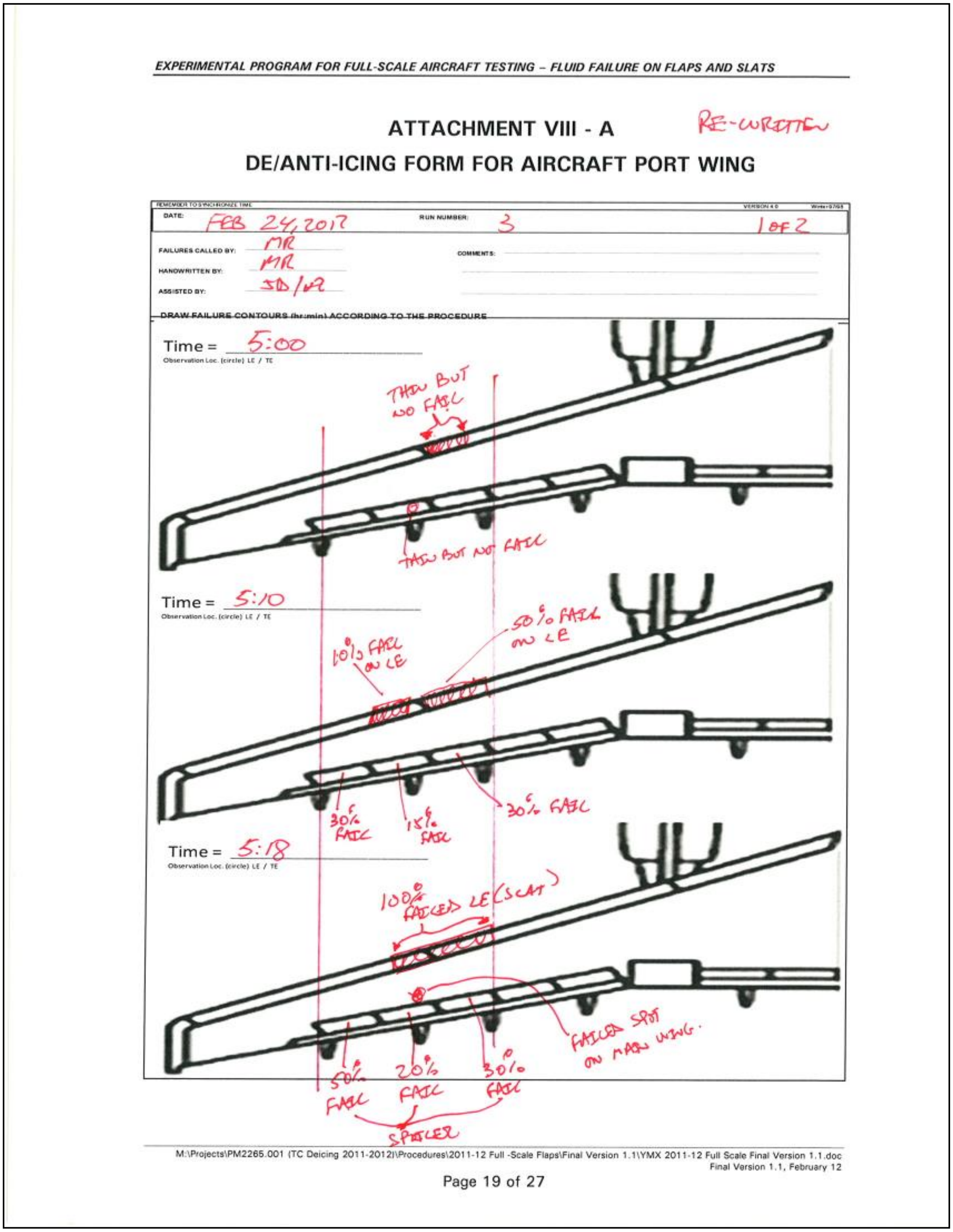
Run 3

February 24, 2012
UPS Airbus A-300 Port Wing
Mirabel Airport



EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIII - A

RE-WRITTEN

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0

Winter 07/08

DATE: FEB 24, 2017

RUN NUMBER: 3

1 OF 2

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: SD/VR

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 5:00

Observation Loc. (circle) LE / TE

Time = 5:10

Observation Loc. (circle) LE / TE

Time = 5:18

Observation Loc. (circle) LE / TE

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
Final Version 1.1, February 12

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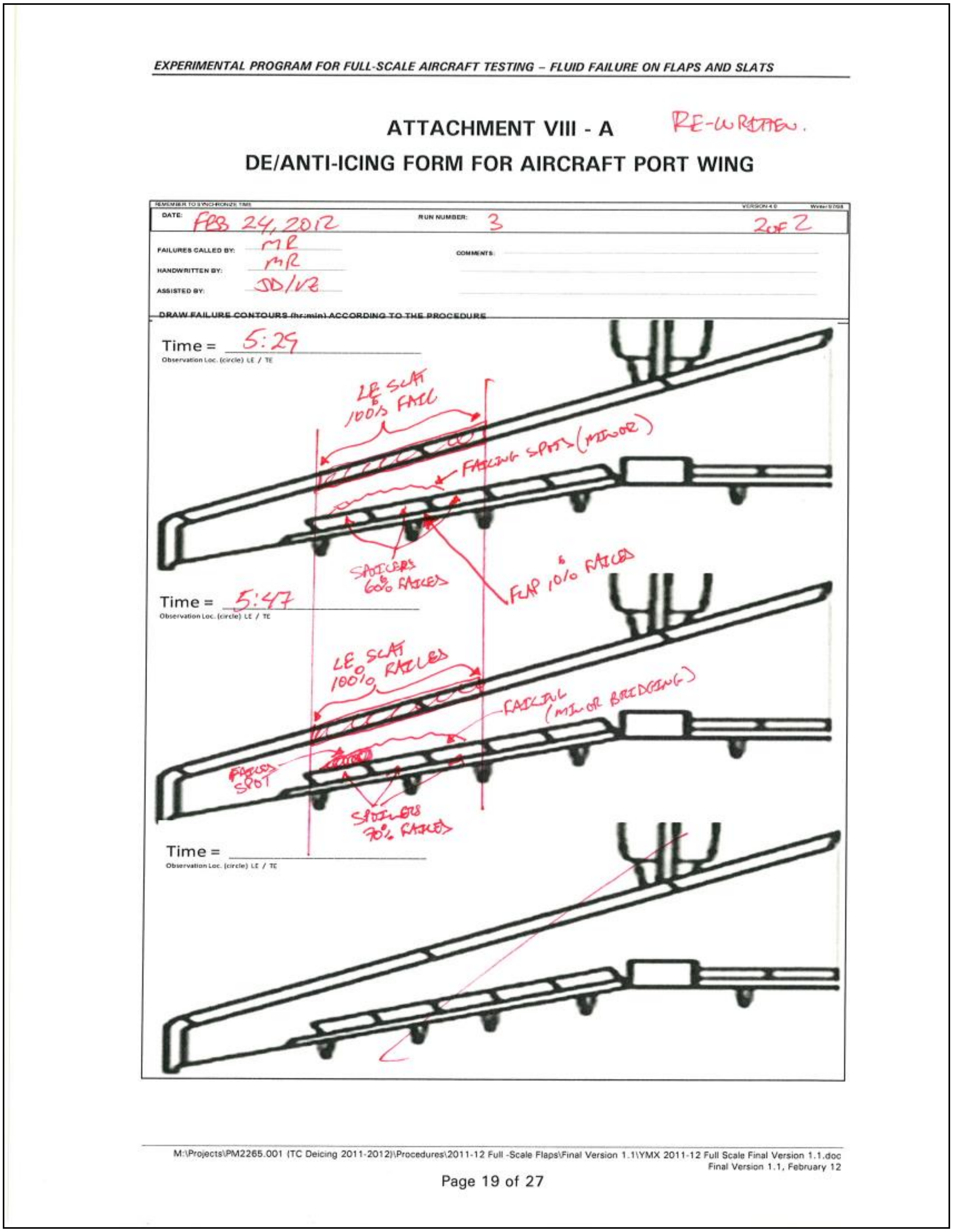


ATTACHMENT VIII - A

RE-WRITTEN.

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0

Winter 07/08

DATE: FEB 24, 2012

RUN NUMBER: 3

2of 2

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: JD/VZ

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 5:29

Observation Loc. (circle) LE / TE

Time = 5:47

Observation Loc. (circle) LE / TE

Time =

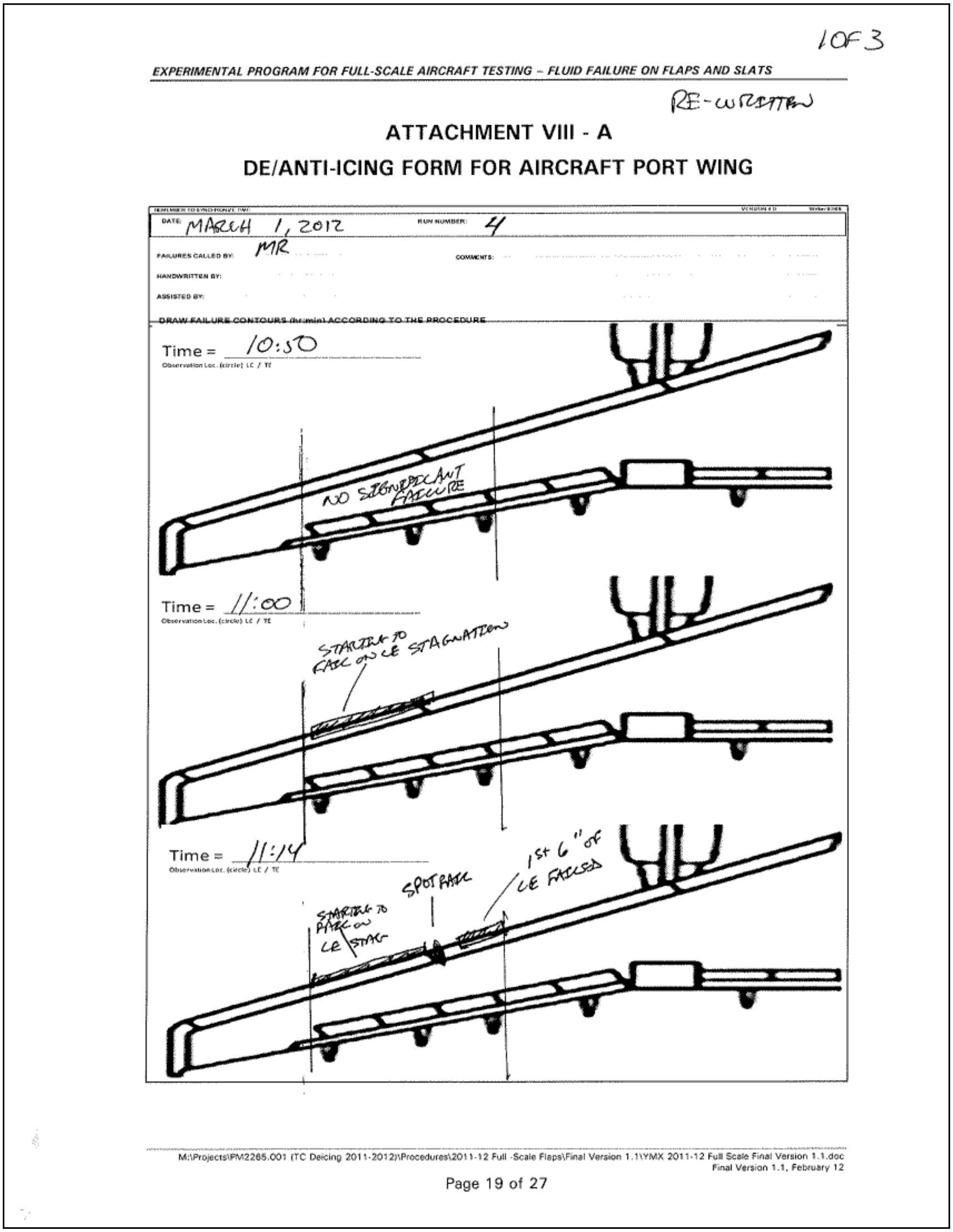
Observation Loc. (circle) LE / TE

Run 4

March 1, 2012

UPS Airbus A-300 Port Wing

Mirabel Airport



1OF3

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

RE-WRITTEN

ATTACHMENT VIII - A

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME

DATE: MARCH 1, 2012

RUN NUMBER: 4

FAILURES CALLED BY: MR

COMMENTS:

HANDWRITTEN BY:

ASSISTED BY:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 10:50

Observation Loc. (circle) LE / TE

NO SIGNIFICANT FAILURE

Time = 11:00

Observation Loc. (circle) LE / TE

STARTING TO FAIL ON LE STAGNATION

Time = 11:14

Observation Loc. (circle) LE / TE

STARTING TO FAIL ON LE STAG

SPOT FAIL

1st 6" OF LE FAILED

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
Final Version 1.1, February 12

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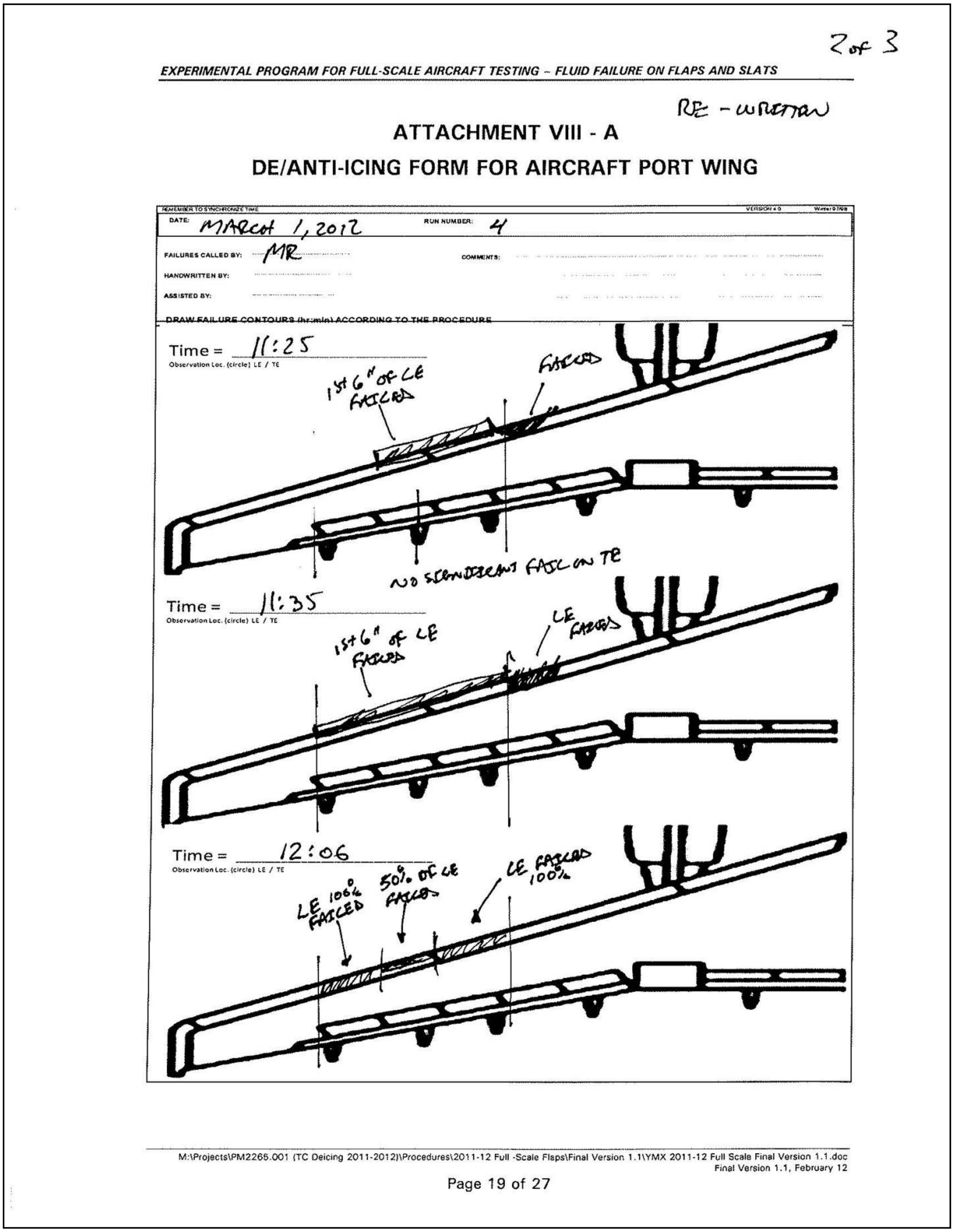

2 of 3

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

RE-WRITTEN

ATTACHMENT VIII - A

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0

Winter 97/98

DATE: MARCH 1, 2012

RUN NUMBER: 4

FAILURES CALLED BY: MR

COMMENTS:

HANDWRITTEN BY:

ASSISTED BY:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 11:25

Observation Loc. (circle) LE / TE

1st 6" OF LE FAILED

FAILED

NO SIGNIFICANT FAIL ON TE

Time = 11:35

Observation Loc. (circle) LE / TE

1st 6" OF LE FAILED

LE FAILED

Time = 12:06

Observation Loc. (circle) LE / TE

LE 100% FAILED

50% OF LE FAILED

LE FAILED 100%

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
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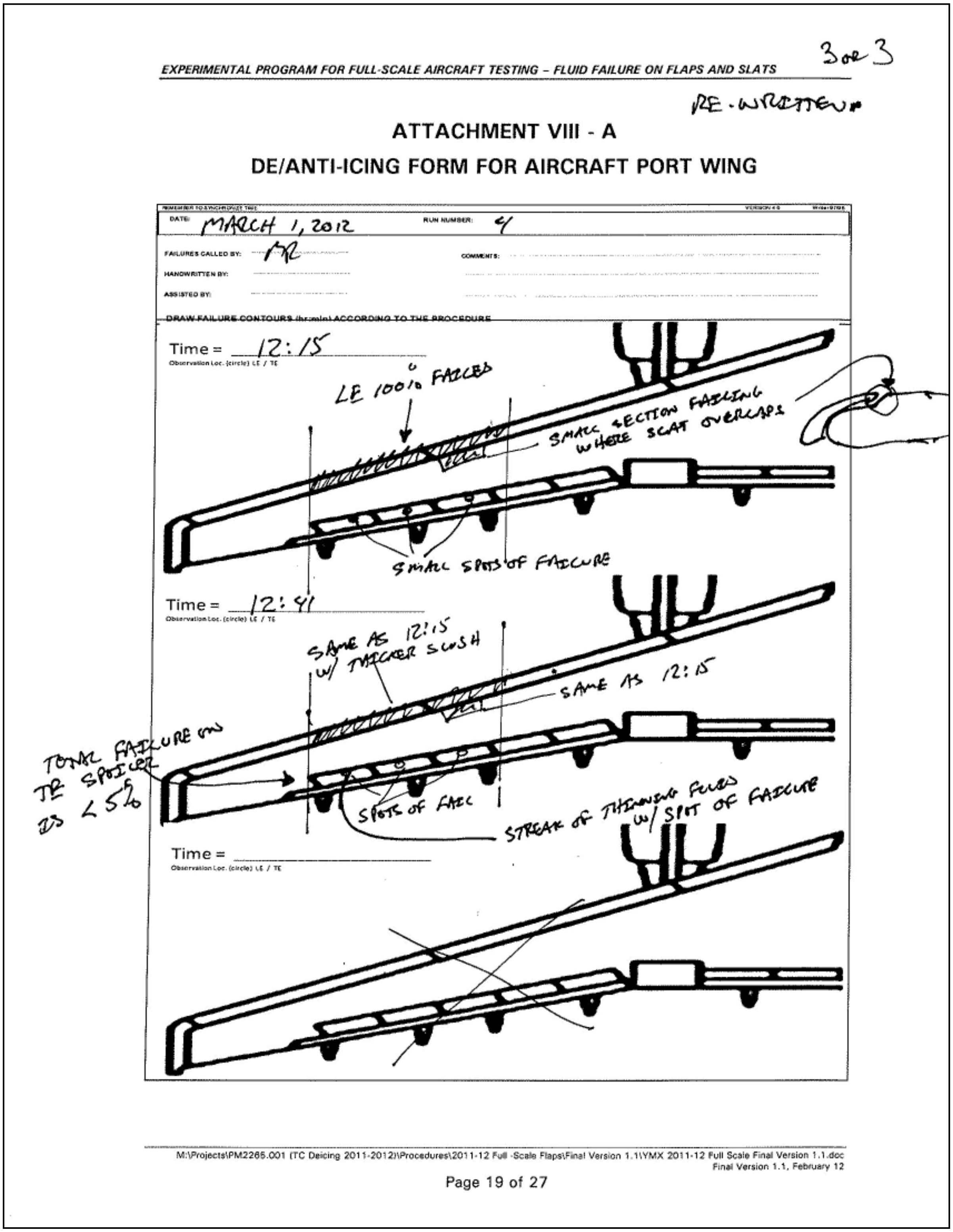

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

3 of 3

RE-WRITTEN

ATTACHMENT VIII - A

DE/ANTI-ICING FORM FOR AIRCRAFT PORT WING

REMEMBER TO SYNCHRONIZE TIME

DATE: MARCH 1, 2012

RUN NUMBER: 4

FAILURES CALLED BY: MR

COMMENTS:

HANDWRITTEN BY:

ASSISTED BY:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 12:15

Observation Loc. (circle) LE / TE

LE 100% FAILED

SMALL SECTION FAILING WHERE SLAT OVERLAPS

SMALL SPOTS OF FAILURE

Time = 12:41

Observation Loc. (circle) LE / TE

SAME AS 12:15 W/ THICKER SLUSH

SAME AS 12:15

TOTAL FAILURE ON TE SPOILER IS < 5%

SPOTS OF FAIL

STREAK OF THINNING FLUID W/ SPOT OF FAILURE

Time =

Observation Loc. (circle) LE / TE

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\2011-12 Full -Scale Flaps\Final Version 1.1\YMX 2011-12 Full Scale Final Version 1.1.doc
Final Version 1.1, February 12

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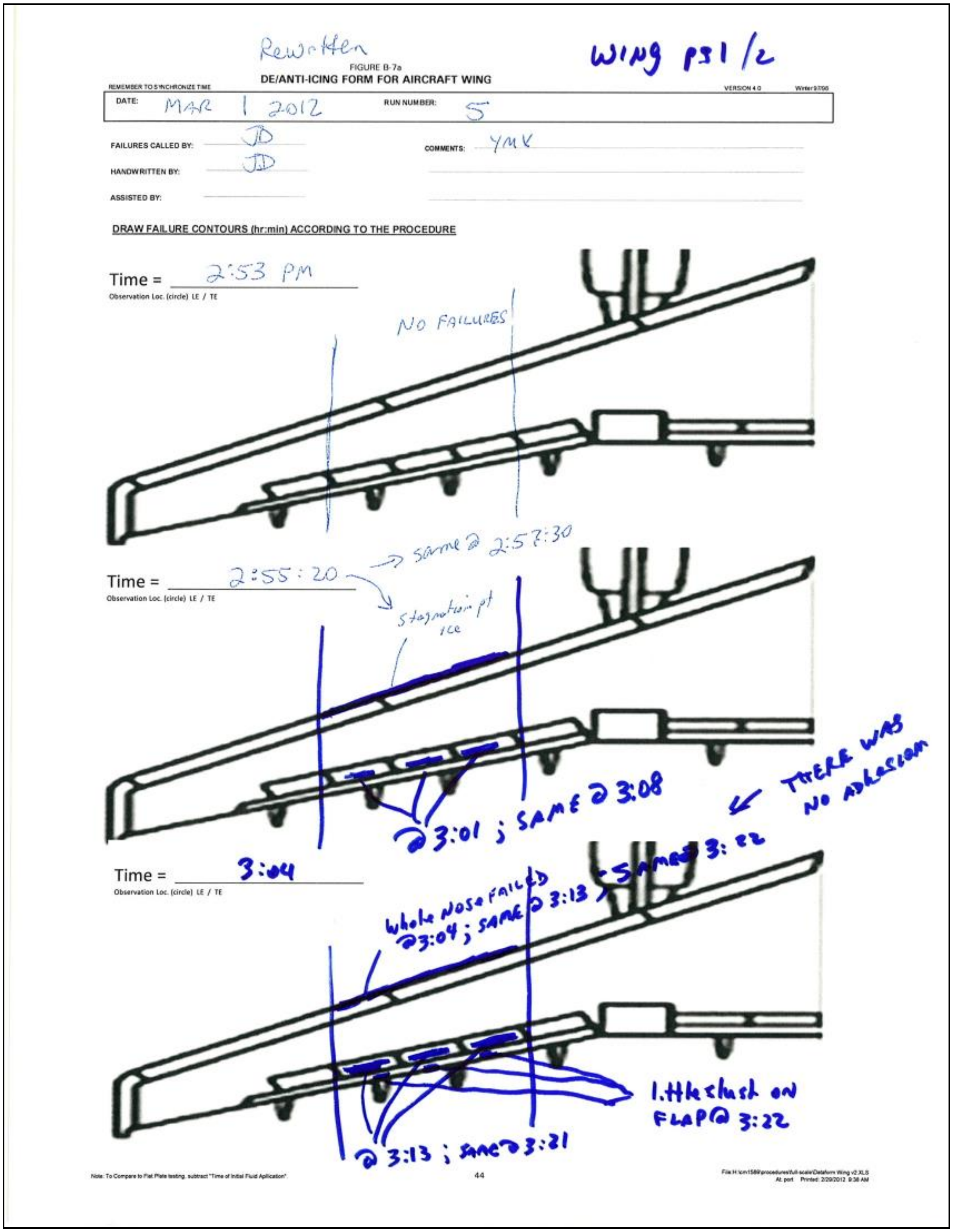
Run 5

March 1, 2012

UPS Airbus A-300 Port Wing

Mirabel Airport

Including Horizontal Stabilizer



Rewritten

WING pg 1/2

FIGURE B-7a

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Winter 97/98

DATE: MAR 1 2012

RUN NUMBER: 5

FAILURES CALLED BY: JD

COMMENTS: YMK

HANDWRITTEN BY: JD

ASSISTED BY:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 2:53 PM

Observation Loc. (circle) LE / TE

NO FAILURES

Time = 2:55:20 → same @ 2:57:30

Observation Loc. (circle) LE / TE

Stagnation pt ice

@3:01 ; SAME @ 3:08

THERE WAS NO ADHESION

Time = 3:04

Observation Loc. (circle) LE / TE

whole NOSE FAILED @3:04 ; SAME @ 3:13 ; SAME @ 3:22

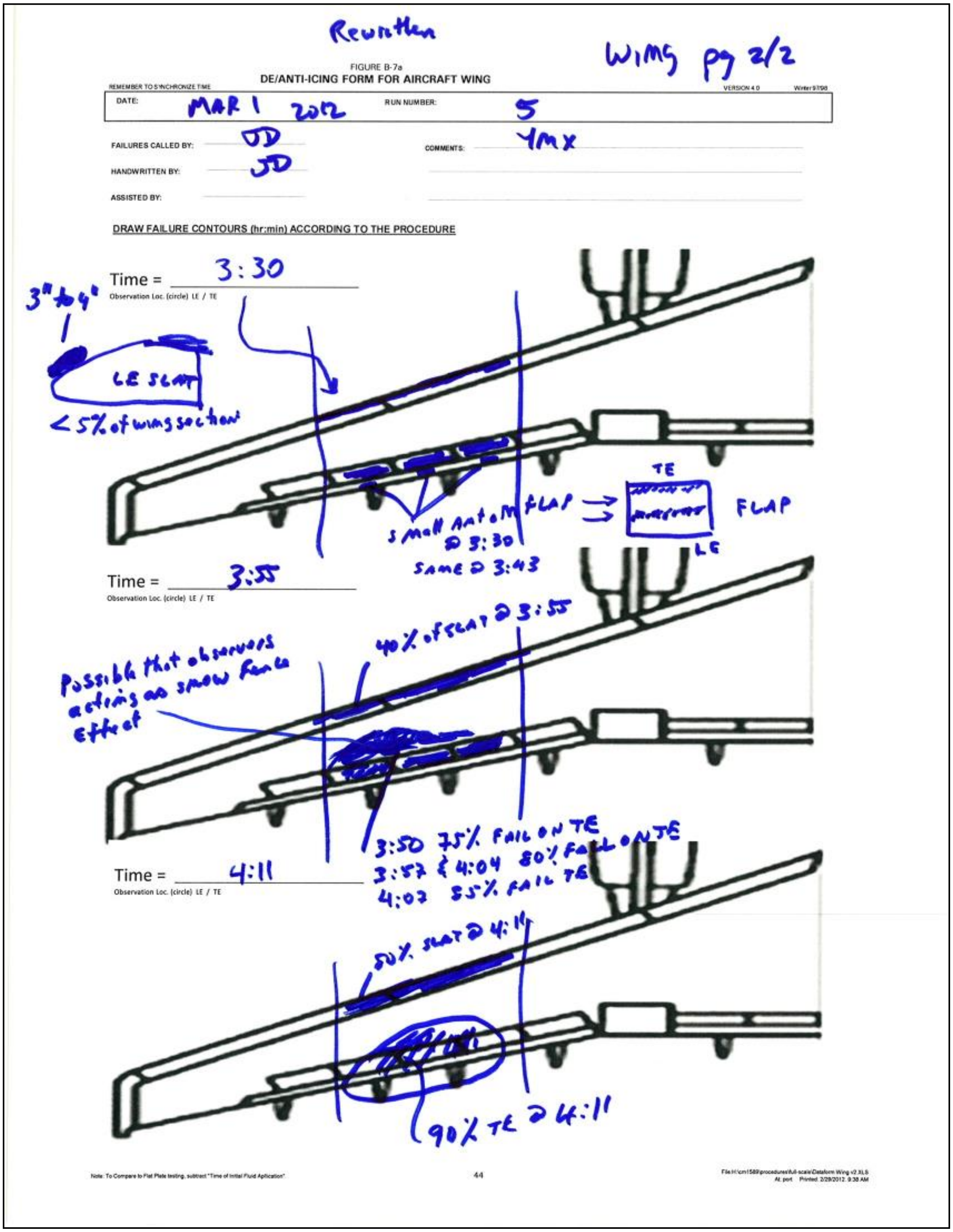
little slush on FLAP @ 3:22

@ 3:13 ; same @ 3:21

Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Aplication".

44

File:H:\cm1589\procedures\full-scale\Dataform Wing v2.XLS
At: port Printed: 2/29/2012 9:38 AM



Rewritten

Wing pg 2/2

FIGURE B-7a

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Winter 97/98

DATE: MAR 1 2012

RUN NUMBER: 5

FAILURES CALLED BY: JD

COMMENTS: YMX

HANDWRITTEN BY: JD

ASSISTED BY:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 3:30

Observation Loc. (circle) LE / TE

3" to 4"

LE SLAT

< 5% of wing section

small Ant on flap @ 3:30

same @ 3:43

TE

FLAP

LE

Time = 3:55

Observation Loc. (circle) LE / TE

40% of slat @ 3:55

Possible that observers acting as snow fence effect

3:50 75% fail on TE

3:57 & 4:04 80% fail on TE

4:07 85% fail TE

Time = 4:11

Observation Loc. (circle) LE / TE

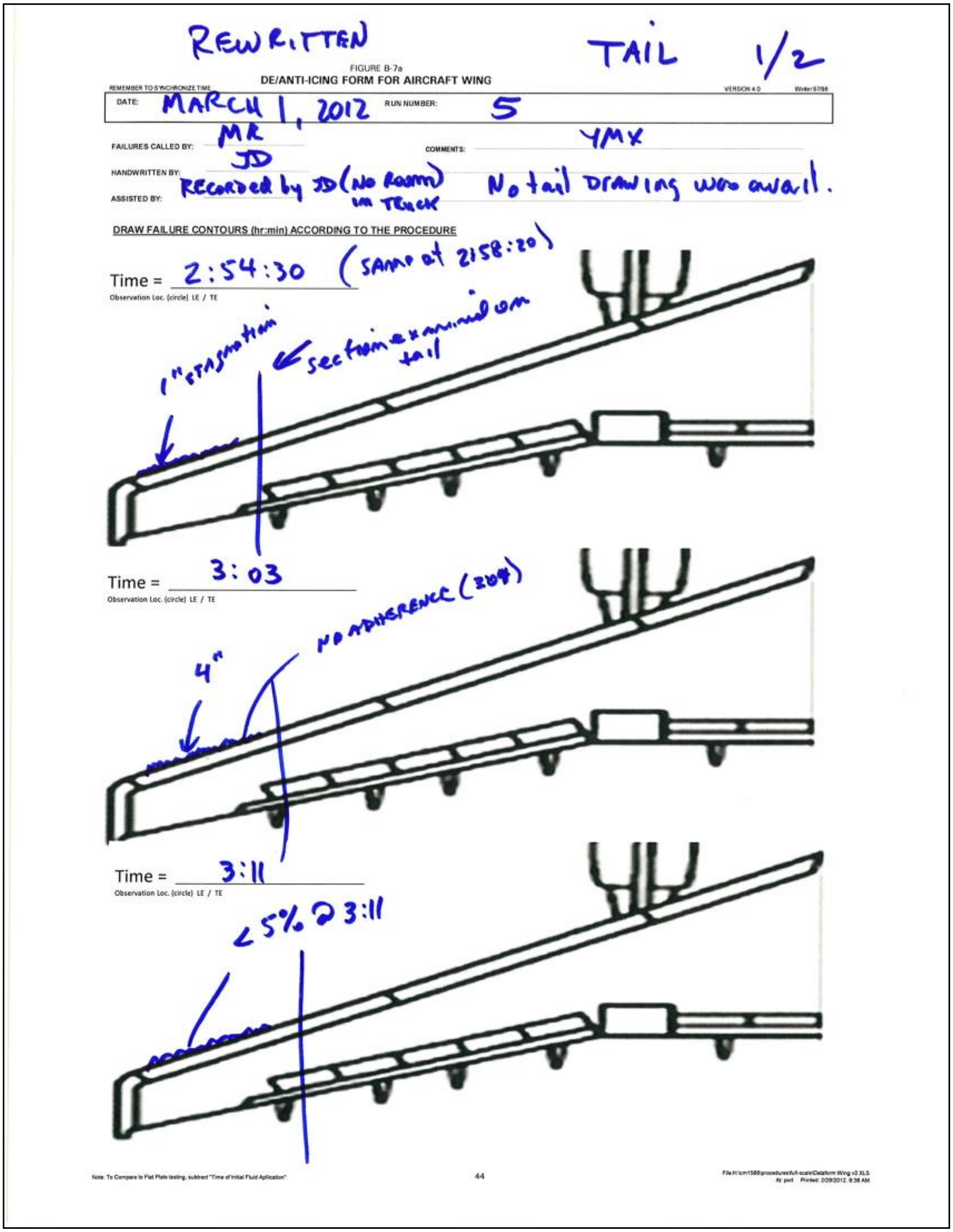
50% slat @ 4:11

90% TE @ 4:11

Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Aplication".

44

File:H:\cm1589\procedures\full-scale\Dataform Wing v2.XLS
At. port Printed: 2/29/2012. 9:38 AM



REWRITTEN

TAIL 1/2

FIGURE B-7a

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Winter 97/98

DATE: MARCH 1, 2012 RUN NUMBER: 5

FAILURES CALLED BY: MR

HANDWRITTEN BY: JD

ASSISTED BY: RECORDED by JD (NO ROOM in TRUCK)

COMMENTS: YMX No tail DRAWING was avail.

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 2:54:30 (SAME at 2158:20)

Observation Loc. (circle) LE / TE

1" stagnation

section examined on tail

Time = 3:03

Observation Loc. (circle) LE / TE

4"

NO ADHERENCE (304)

Time = 3:11

Observation Loc. (circle) LE / TE

<5% @ 3:11

Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Application".

44

File:H:\cm1589\procedures\full-scale\Dataform Wing v2.XLS
At: port Printed: 2/29/2012, 9:38 AM

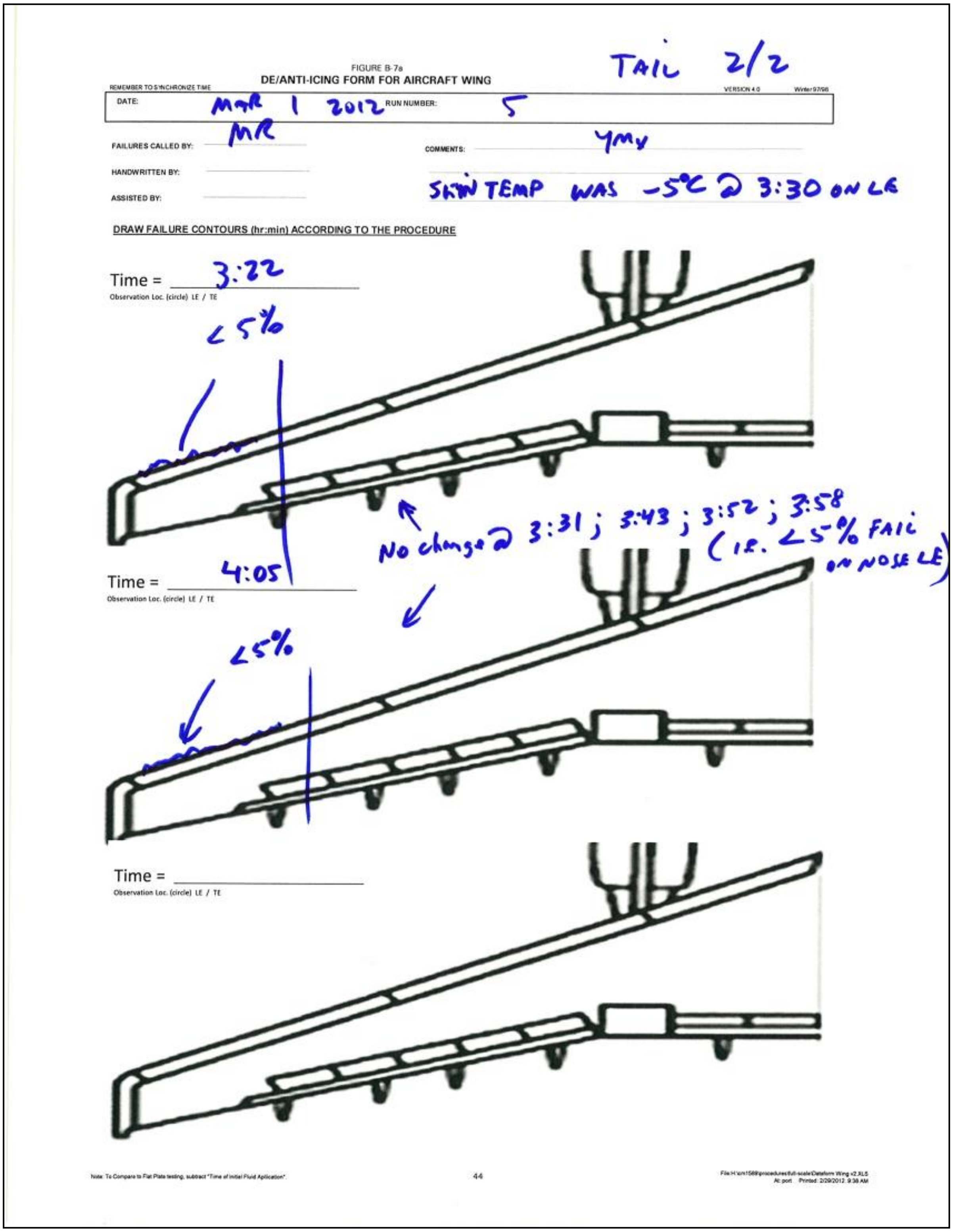


FIGURE B-7a

DE/ANTI-ICING FORM FOR AIRCRAFT WING

TAIL 2/2

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Winter 97/98

DATE: MAR 1 2012 RUN NUMBER: 5

FAILURES CALLED BY: MR

HANDWRITTEN BY:

ASSISTED BY:

COMMENTS: YMY

SKIN TEMP WAS -5°C @ 3:30 ON LE

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 3:22

Observation Loc. (circle) LE / TE

< 5%

No change @ 3:31; 3:43; 3:52; 3:58 (IE. < 5% FAIL ON NOSE LE)

Time = 4:05

Observation Loc. (circle) LE / TE

< 5%

Time =

Observation Loc. (circle) LE / TE

Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Application".

44

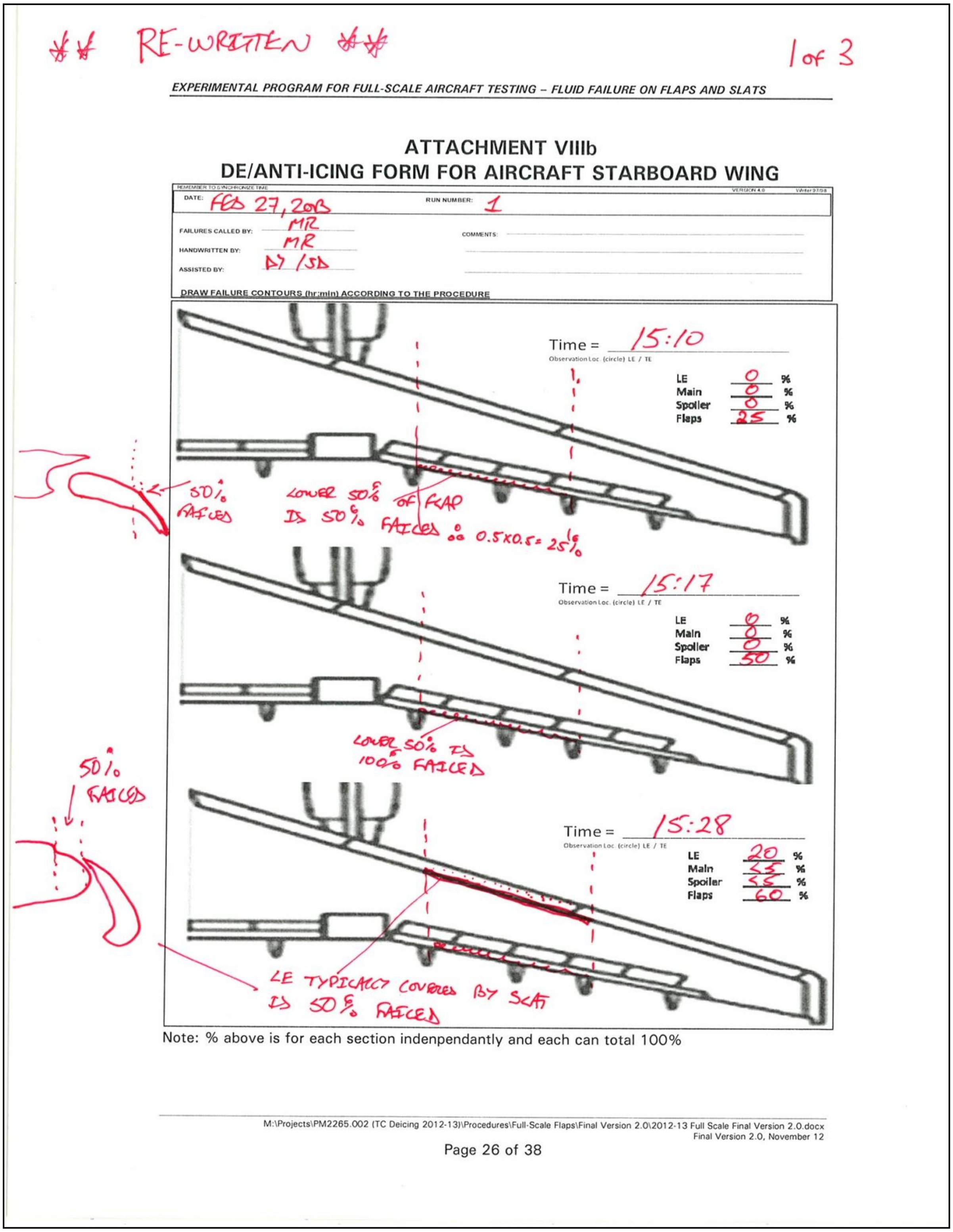
File:H:\cm1589\procedures\full-scale\Dataform Wing v2.XLS
At: port Printed: 2/29/2012 9:38 AM

Run 6

February 27, 2013

UPS Airbus A-300 Starboard Wing

Mirabel Airport



** RE-WRITTEN **

1 of 3

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb
DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Writer 97/98

DATE: FEB 27, 2013

RUN NUMBER: 1

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: AJ /SD

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 15:10

Observation Loc. (circle) LE / TE

LE 0 %
Main 0 %
Spoiler 0 %
Flaps 25 %

50% FAILED

LOWER 50% OF FLAP IS 50% FAILED ∴ 0.5X0.5= 25%

Time = 15:17

Observation Loc. (circle) LE / TE

LE 0 %
Main 0 %
Spoiler 0 %
Flaps 50 %

LOWER 50% IS 100% FAILED

50% FAILED

Time = 15:28

Observation Loc. (circle) LE / TE

LE 20 %
Main 55 %
Spoiler 55 %
Flaps 60 %

LE TYPICALLY COVERED BY SLAT IS 50% FAILED

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
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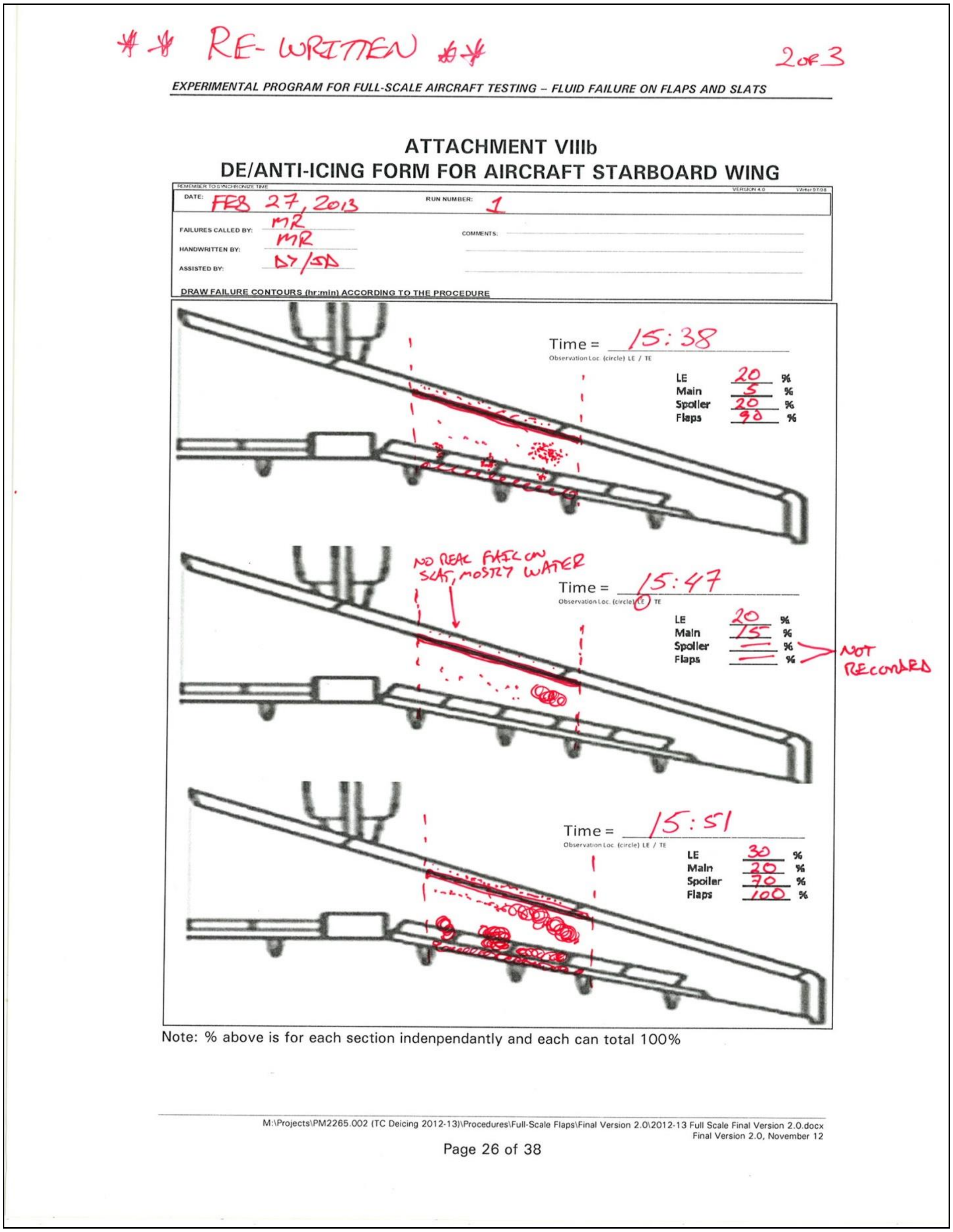

** RE-WRITTEN **

2 of 3

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb
DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 VAter 97/98

DATE: FEB 27, 2013

RUN NUMBER: 1

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: DY/SD

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 15:38

Observation Loc. (circle) LE / TE

LE	20	%
Main	5	%
Spoiler	20	%
Flaps	90	%

NO REAL FAIL ON SLAT, MOSTLY WATER

Time = 15:47

Observation Loc. (circle) [✓ LE] / TE

LE	20	%
Main	15	%
Spoiler	—	%
Flaps	—	%

NOT RECORDED

Time = 15:51

Observation Loc. (circle) LE / TE

LE	30	%
Main	20	%
Spoiler	70	%
Flaps	100	%

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
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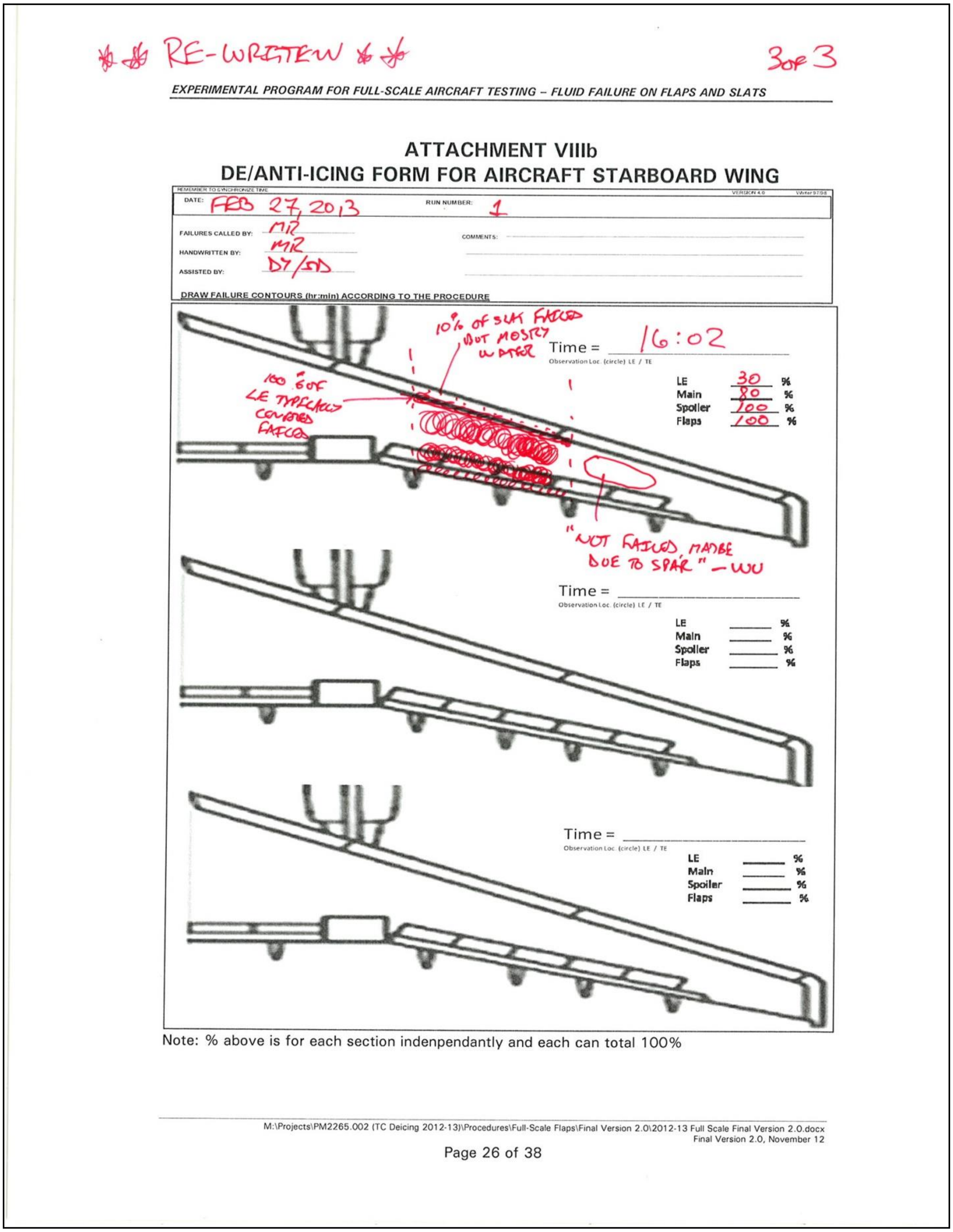

** RE-WRITTEN **

3 of 3

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb

DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0

Winter 97/98

DATE: FEB 27, 2013

RUN NUMBER: 1

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY: DY/SD

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

10% OF SLAT FAILED BUT MOSTLY WATER

100% OF LE TYPICALLY COVERED FAILED

Time = 16:02

Observation Loc. (circle) LE / TE

LE 30 %
Main 80 %
Spoiler 100 %
Flaps 100 %

"NOT FAILED MAYBE DUE TO SPAR" – WU

Time = ______

Observation Loc. (circle) LE / TE

LE ______ %
Main ______ %
Spoiler ______ %
Flaps ______ %

Time = ______

Observation Loc. (circle) LE / TE

LE ______ %
Main ______ %
Spoiler ______ %
Flaps ______ %

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
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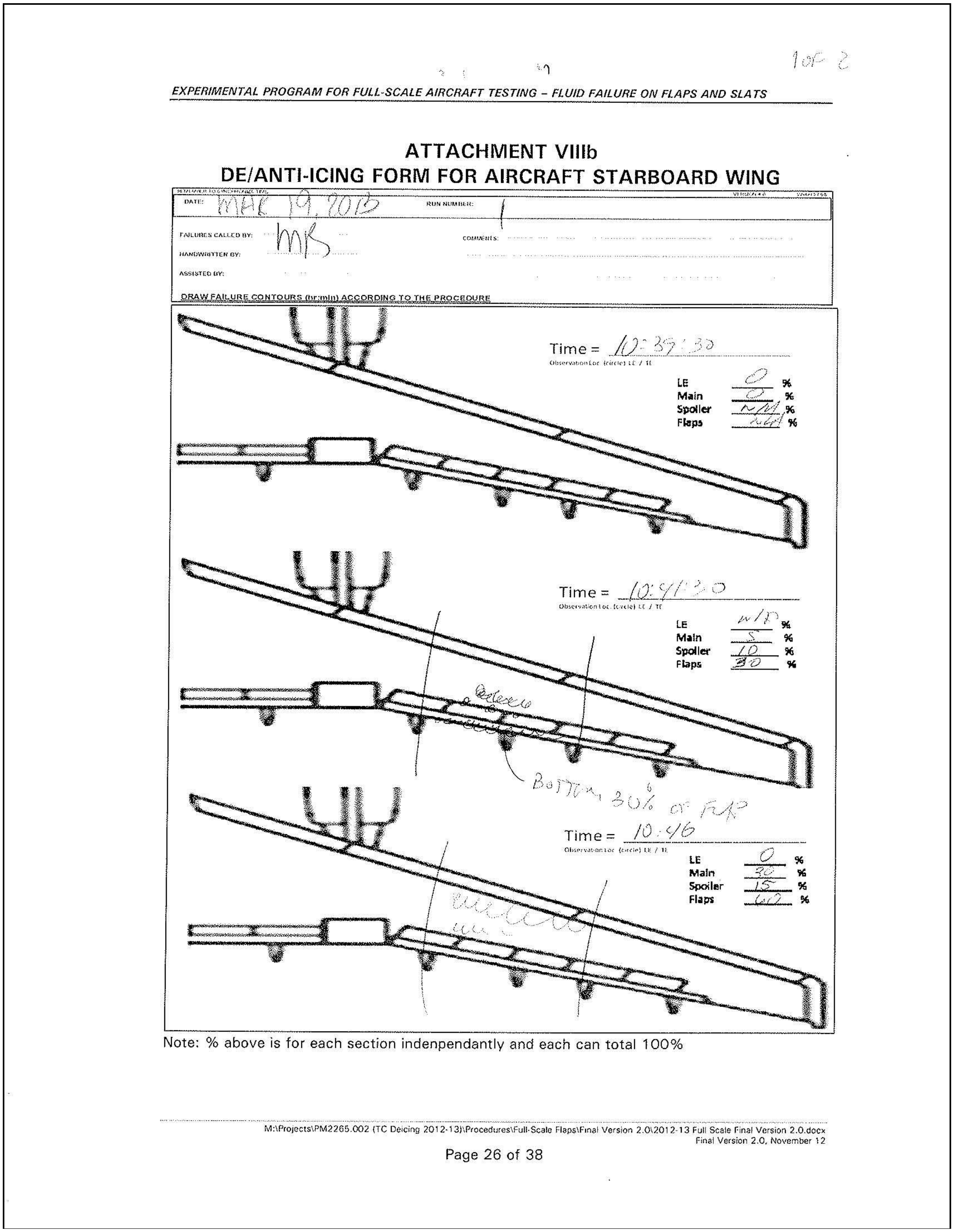
Run 7

March 19, 2013

UPS Airbus A-300 Starboard Wing

Mirabel Airport



1 of 2

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb
DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

DATE: MAR 19, 2013
RUN NUMBER: 1
FAILURES CALLED BY: MB
HANDWRITTEN BY:
ASSISTED BY:
COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 10:39:30
Observation Loc. (circle) LE / TE

LE	0 %
Main	0 %
Spoiler	N/M %
Flaps	N/A %

Time = 10:41:30
Observation Loc. (circle) LE / TE

LE	w/D %
Main	5 %
Spoiler	10 %
Flaps	30 %

BOTTOM 30% OF FLAP

Time = 10:46
Observation Loc. (circle) LE / TE

LE	0 %
Main	30 %
Spoiler	15 %
Flaps	60 %

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
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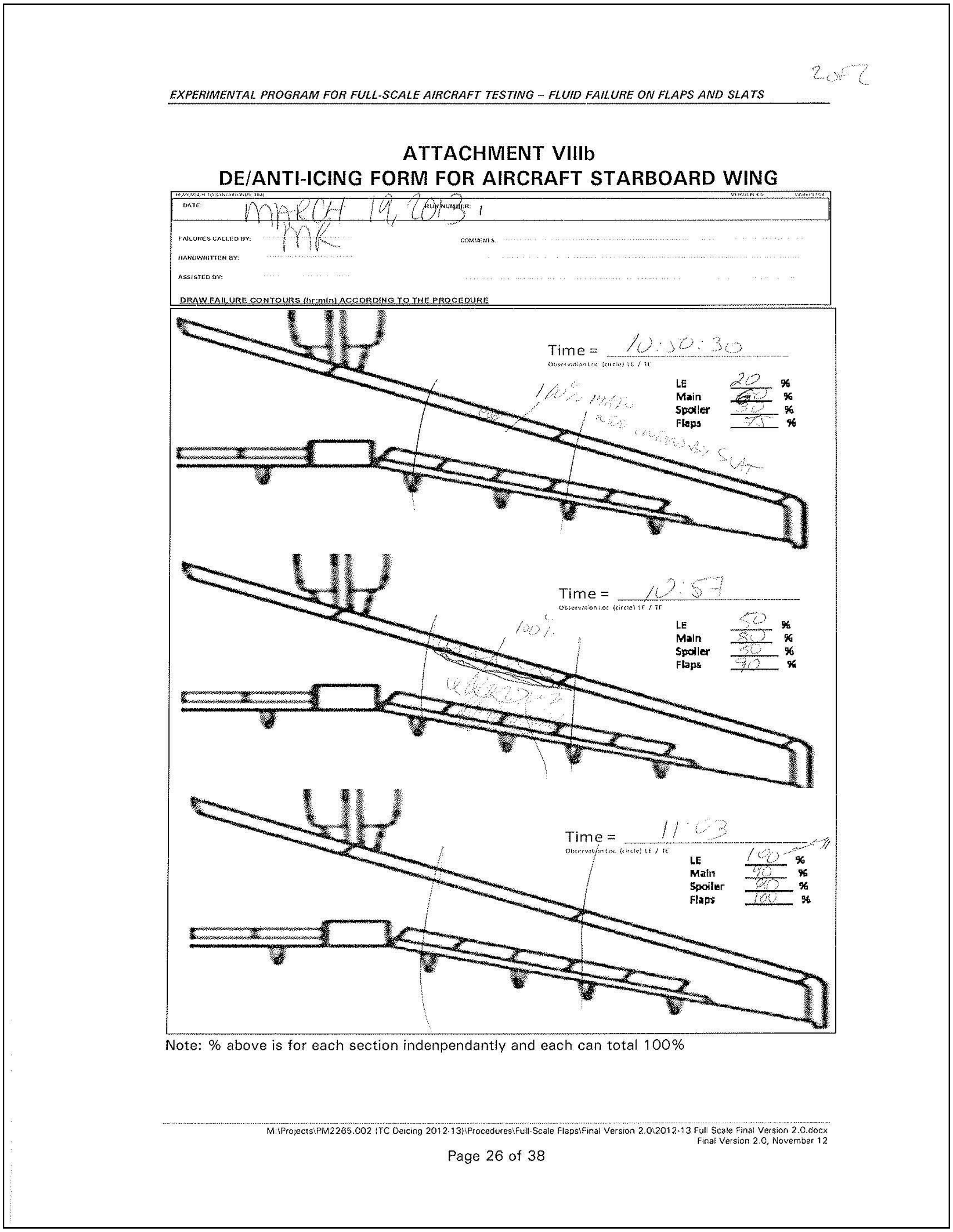

2 of 7

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb
DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

REMEMBER TO SYNCHRONIZE TIME

DATE: MARCH 19, 2013

RUN NUMBER: 1

FAILURES CALLED BY: MK

HANDWRITTEN BY:

ASSISTED BY:

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 10:50:30

Observation Loc (circle) LE / TE

LE 20 %
Main 60 %
Spoiler 30 %
Flaps 75 %

100% MAIN

& TE covered by SLAT

Time = 10:57

Observation Loc (circle) LE / TE

LE 50 %
Main 80 %
Spoiler 50 %
Flaps 90 %

100%

Time = 11:03

Observation Loc (circle) LE / TE

LE 100 %
Main 90 %
Spoiler 90 %
Flaps 100 %

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
Final Version 2.0, November 12

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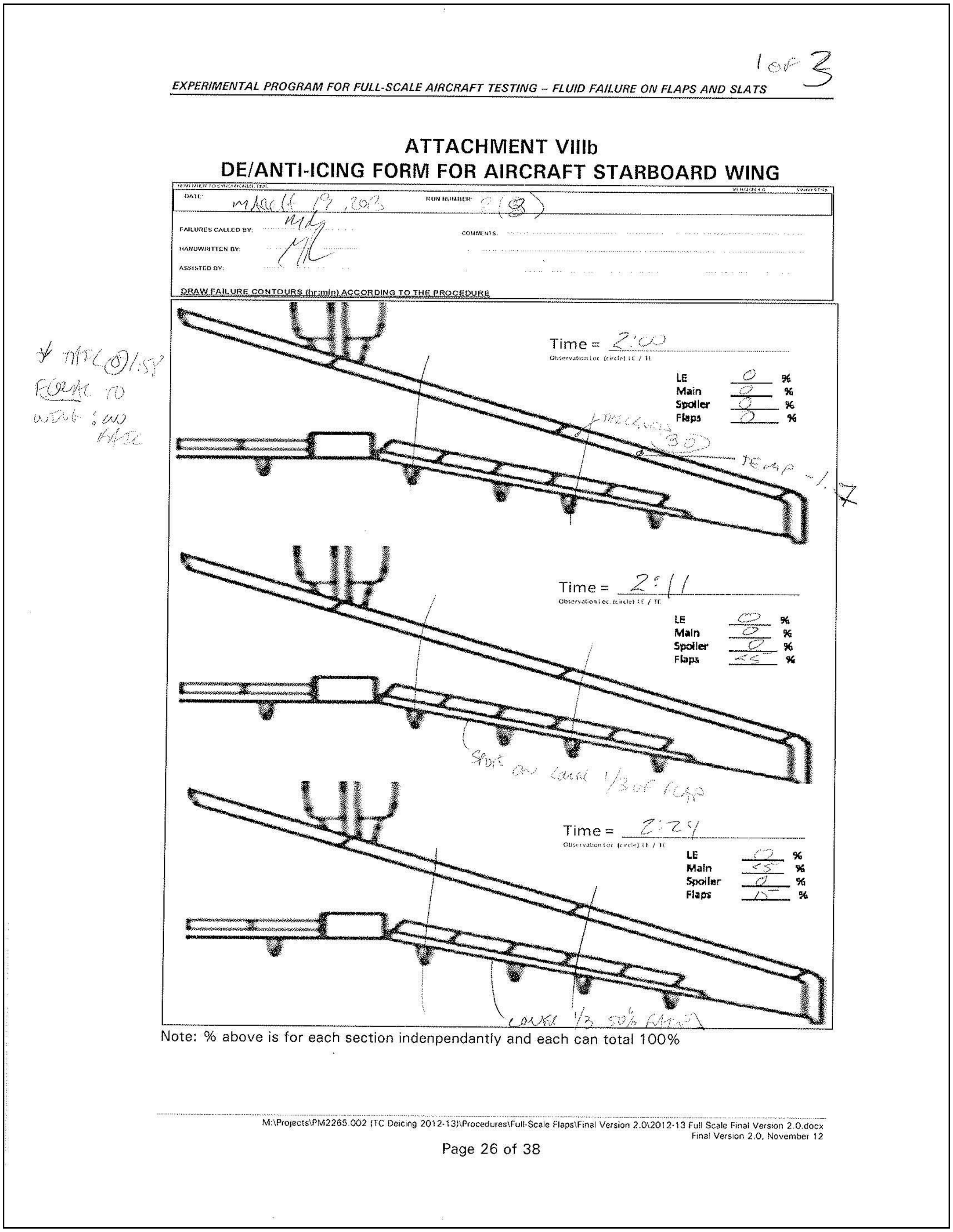
Run 8

March 19, 2013

UPS Airbus A-300 Starboard Wing

Mirabel Airport

Including Horizontal Stabilizer



1 of 3

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb
DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

DATE: MARCH 19, 2013 RUN NUMBER: 2 (3)

FAILURES CALLED BY: ML

HANDWRITTEN BY: ML

ASSISTED BY:

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

* NATC @ 1:54
FORM TO
WING : 00
HAIR

Time = 2:00

Observation Loc (circle) LE / TE

LE	0	%
Main	0	%
Spoiler	0	%
Flaps	0	%

MAGNUS (30)

TEMP -1.7

Time = 2:11

Observation Loc (circle) LE / TE

LE	0	%
Main	0	%
Spoiler	0	%
Flaps	<5	%

SPOTS ON LOWER 1/3 OF FLAP

Time = 2:24

Observation Loc (circle) LE / TE

LE	0	%
Main	<5	%
Spoiler	0	%
Flaps	15	%

LOWER 1/3 50% FAILED

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
Final Version 2.0, November 12

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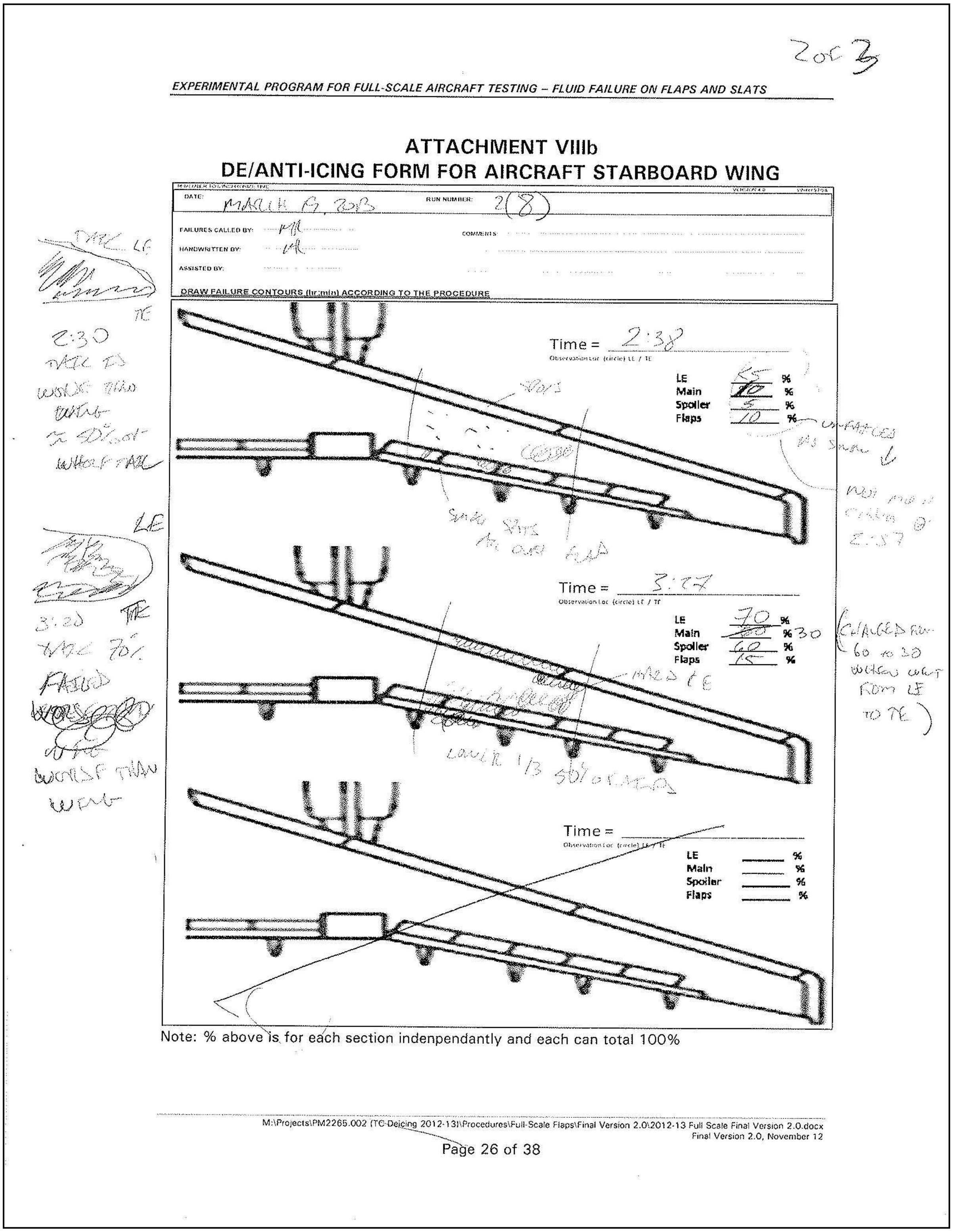

2 of 3

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb
DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

DATE: MARCH 8, 2013 RUN NUMBER: 2(8)

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY:

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

DARK LE

TE

2:30 DARK IS WORSE THAN [illegible] ~ 50% OF WHOLE TAIL

Time = 2:38

Observation Loc (circle) LE / TE

LE 55 %

Main 10 %

Spoiler 5 %

Flaps 10 % UNCHANGED AS SHOWN

SPOTS

SNOW BITS ALL OVER FLAP

NOT MUCH CHANGE @ 2:57

LE

3:20 TE DARK 70% FAILED WORSE THAN WING

Time = 3:27

Observation Loc (circle) LE / TE

LE 70 %

Main ~~60~~ % 30

Spoiler 60 %

Flaps 15 %

(CHANGED FROM 60 TO 30 WHEN WENT FROM LE TO TE)

HARD LE

LOWER 1/3 50% OF FLAP

Time =

Observation Loc (circle) LE / TE

LE %

Main %

Spoiler %

Flaps %

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
Final Version 2.0, November 12

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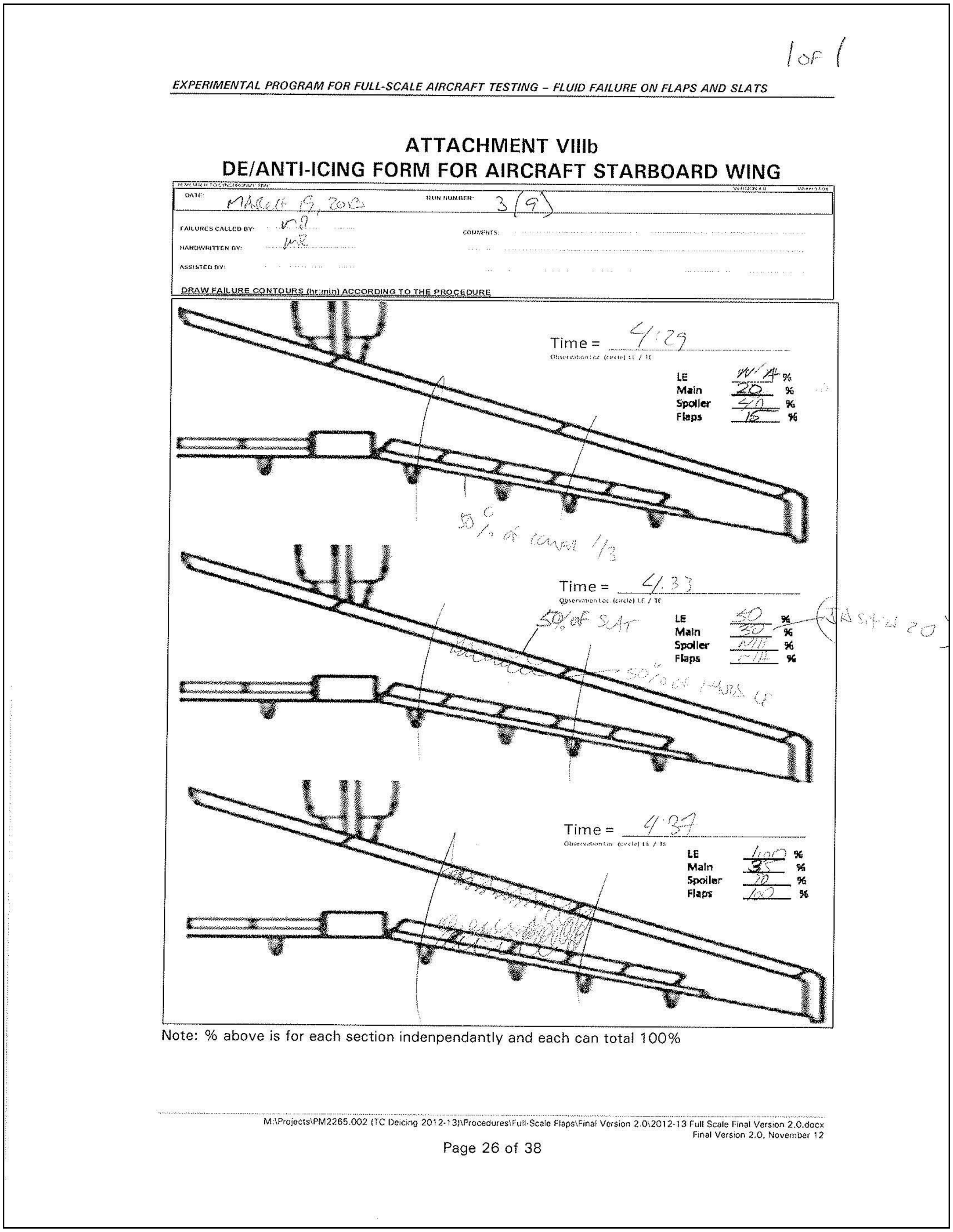
Run 9

March 19, 2013

UPS Airbus A-300 Starboard Wing

Mirabel Airport



1 of 1

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

ATTACHMENT VIIIb
DE/ANTI-ICING FORM FOR AIRCRAFT STARBOARD WING

DATE: MARCH 19, 2013

RUN NUMBER: 3 (9)

FAILURES CALLED BY: MR

HANDWRITTEN BY: MR

ASSISTED BY:

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

Time = 4:29

Observation Loc. (circle) LE / TE

LE N/A %
Main 20 %
Spoiler 40 %
Flaps 15 %

50% of lower 1/3

Time = 4:33

Observation Loc. (circle) LE / TE

LE 50 %
Main 30 %
Spoiler Nil %
Flaps Nil %

(JA SP 4:20)

50% of SLAT

50% of FLAPS LE

Time = 4:37

Observation Loc. (circle) LE / TE

LE 100 %
Main 35 %
Spoiler 70 %
Flaps 100 %

Note: % above is for each section indenpendantly and each can total 100%

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Full-Scale Flaps\Final Version 2.0\2012-13 Full Scale Final Version 2.0.docx
Final Version 2.0, November 12

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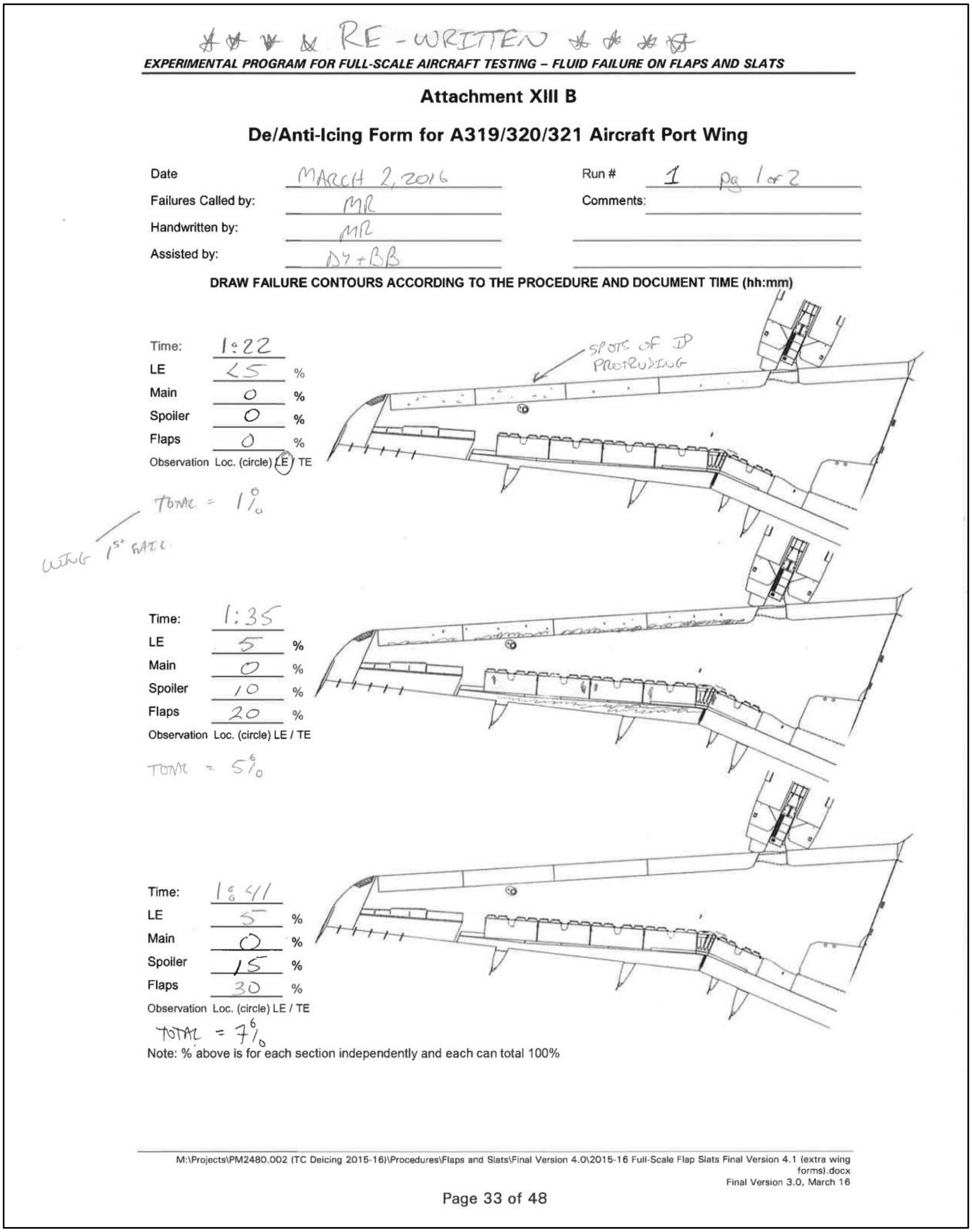
Run 10

March 2, 2016

Air Canada Airbus A-319 Port Wing

YUL Airport



**** RE-WRITTEN ****

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

Attachment XIII B

De/Anti-Icing Form for A319/320/321 Aircraft Port Wing

Date MARCH 2, 2016

Run # 1 pg 1 of 2

Failures Called by: MR

Comments:

Handwritten by: MR

Assisted by: DY+BB

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)

Time: 1:22

LE <5 %

Main 0 %

Spoiler 0 %

Flaps 0 %

Observation Loc. (circle) [✓ LE] / TE

TOTAL = 1%

WING 1st FAIL

SPOTS OF ID PROTRUDING

Time: 1:35

LE 5 %

Main 0 %

Spoiler 10 %

Flaps 20 %

Observation Loc. (circle) LE / TE

TOTAL = 5%

Time: 1:41

LE 5 %

Main 0 %

Spoiler 15 %

Flaps 30 %

Observation Loc. (circle) LE / TE

TOTAL = 7%

Note: % above is for each section independently and each can total 100%

M:\Projects\PM2480.002 (TC Deicing 2015-16)\Procedures\Flaps and Slats\Final Version 4.0\2015-16 Full-Scale Flap Slats Final Version 4.1 (extra wing forms).docx
Final Version 3.0, March 16

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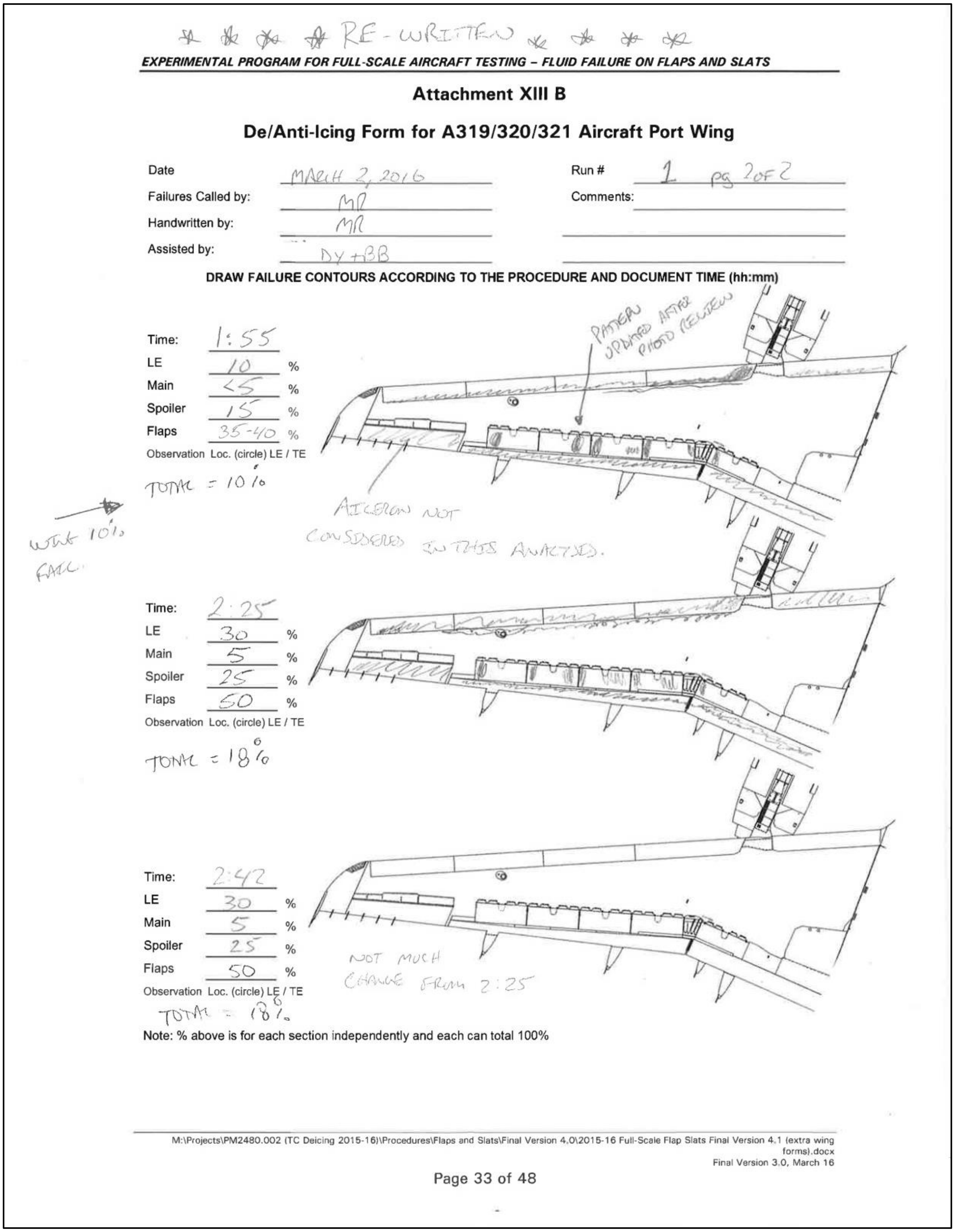

* * * * RE-WRITTEN * * * *

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

Attachment XIII B

De/Anti-Icing Form for A319/320/321 Aircraft Port Wing

Date: MARCH 2, 2016

Run #: 1 pg 2 of 2

Failures Called by: MR

Comments:

Handwritten by: MR

Assisted by: DY + BB

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)

PATTERN UPDATED AFTER PHOTO REVIEW

Time: 1:55
LE 10 %
Main <5 %
Spoiler 15 %
Flaps 35-40 %
Observation Loc. (circle) LE / TE

TOTAL = 10%

AILERON NOT CONSIDERED IN THIS ANALYSIS.

WING 10% FAIL.

Time: 2:25
LE 30 %
Main 5 %
Spoiler 25 %
Flaps 50 %
Observation Loc. (circle) LE / TE

TOTAL = 18%

Time: 2:42
LE 30 %
Main 5 %
Spoiler 25 %
Flaps 50 %
Observation Loc. (circle) LE / TE

NOT MUCH CHANGE FROM 2:25

TOTAL = 18%

Note: % above is for each section independently and each can total 100%

M:\Projects\PM2480.002 (TC Deicing 2015-16)\Procedures\Flaps and Slats\Final Version 4.0\2015-16 Full-Scale Flap Slats Final Version 4.1 (extra wing forms).docx
Final Version 3.0, March 16

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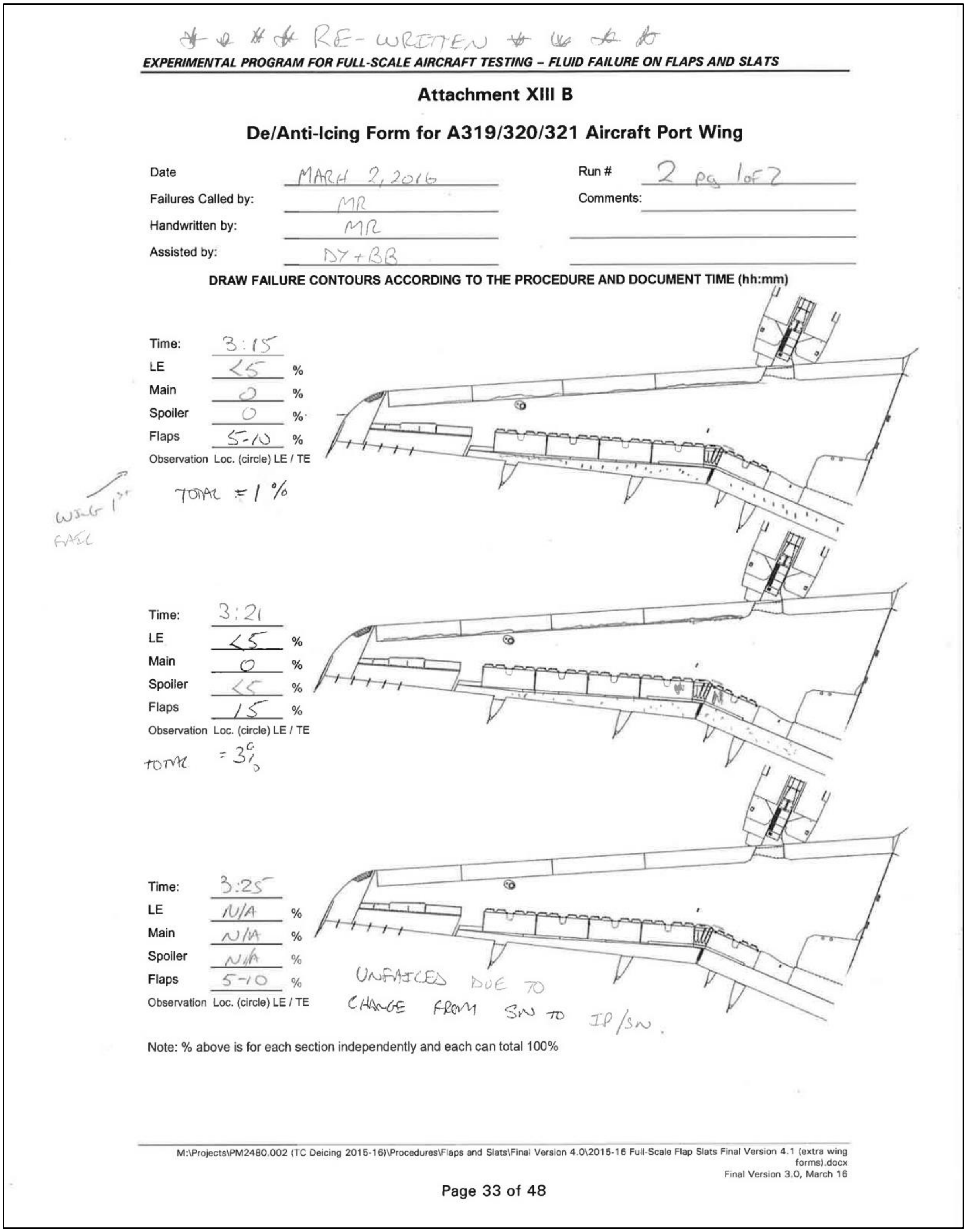
Run 11

March 2, 2016

Air Canada Airbus A-319 Port Wing

YUL Airport



RE-WRITTEN

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

Attachment XIII B

De/Anti-Icing Form for A319/320/321 Aircraft Port Wing

Date MARH 2, 2016

Failures Called by: MR

Handwritten by: MR

Assisted by: DY + BB

Run # 2 pg 1 of 2

Comments:

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)

Time: 3:15

LE <5 %

Main 0 %

Spoiler 0 %

Flaps 5-10 %

Observation Loc. (circle) LE / TE

TOTAL = 1 %

WING 1st FAIL

Time: 3:21

LE <5 %

Main 0 %

Spoiler <5 %

Flaps 15 %

Observation Loc. (circle) LE / TE

TOTAL = 3%

Time: 3:25

LE N/A %

Main N/A %

Spoiler N/A %

Flaps 5-10 %

Observation Loc. (circle) LE / TE

UNFAILED DUE TO CHANGE FROM SN TO IP/SN.

Note: % above is for each section independently and each can total 100%

M:\Projects\PM2480.002 (TC Deicing 2015-16)\Procedures\Flaps and Slats\Final Version 4.0\2015-16 Full-Scale Flap Slats Final Version 4.1 (extra wing forms).docx
Final Version 3.0, March 16

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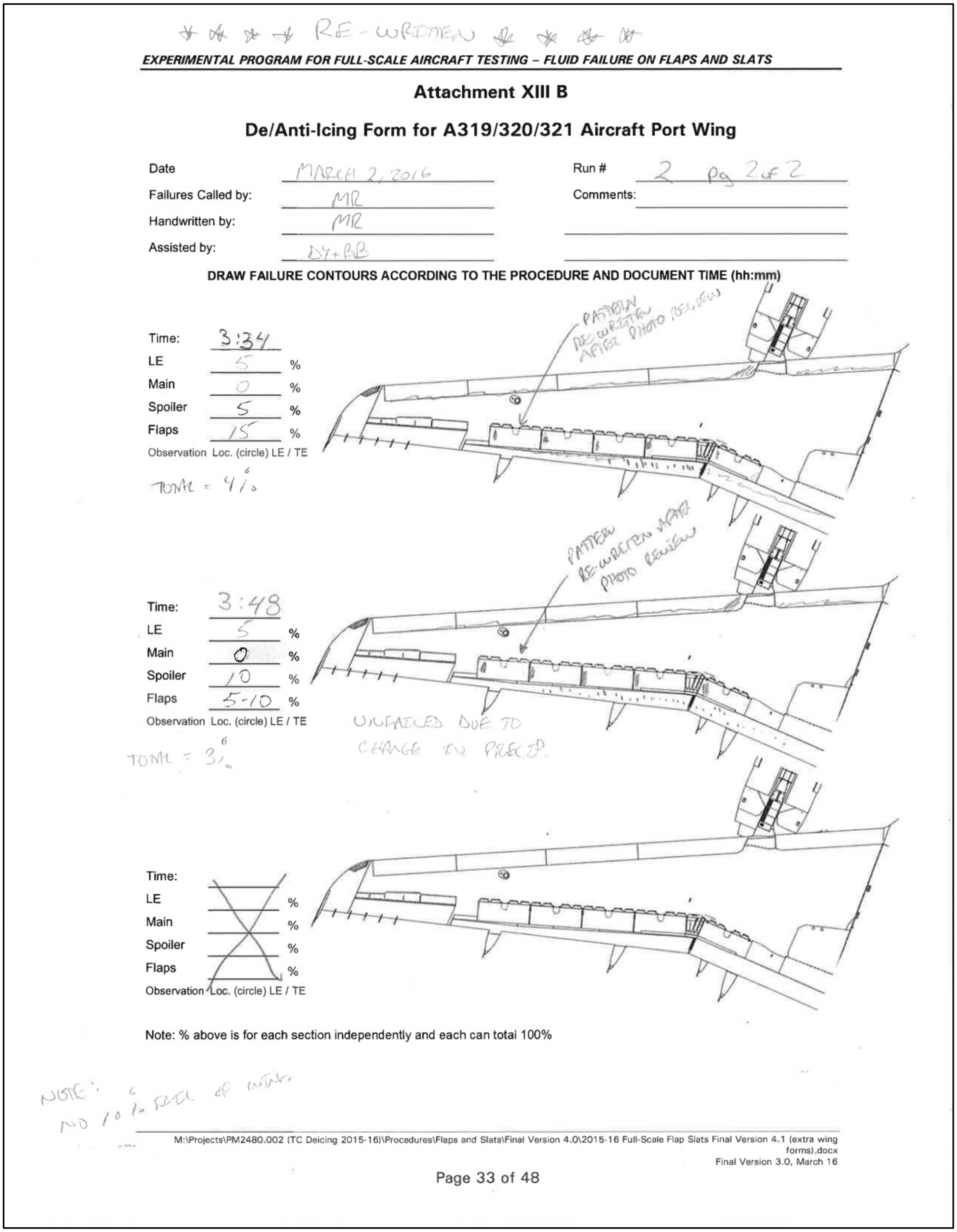

RE-WRITTEN

EXPERIMENTAL PROGRAM FOR FULL-SCALE AIRCRAFT TESTING – FLUID FAILURE ON FLAPS AND SLATS

Attachment XIII B

De/Anti-Icing Form for A319/320/321 Aircraft Port Wing

Date: MARCH 2, 2016
Run #: 2 pg 2 of 2
Failures Called by: MR
Comments:
Handwritten by: MR
Assisted by: DY+BB

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE AND DOCUMENT TIME (hh:mm)

Time: 3:34
LE 5 %
Main 0 %
Spoiler 5 %
Flaps 15 %
Observation Loc. (circle) LE / TE

6
TOTAL = 4%

PATTERN RE-WRITTEN AFTER PHOTO REVIEW

Time: 3:48
LE 5 %
Main 0 %
Spoiler 10 %
Flaps 5-10 %
Observation Loc. (circle) LE / TE

6
TOTAL = 3%

PATTERN RE-WRITTEN AFTER PHOTO REVIEW

UNFAILED DUE TO CHANGE IN PRECIP.

Time:
LE %
Main %
Spoiler %
Flaps %
Observation Loc. (circle) LE / TE

Note: % above is for each section independently and each can total 100%

6
NOTE: NO 10% FAIL OF WING

M:\Projects\PM2480.002 (TC Deicing 2015-16)\Procedures\Flaps and Slats\Final Version 4.0\2015-16 Full-Scale Flap Slats Final Version 4.1 (extra wing forms).docx
Final Version 3.0, March 16

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