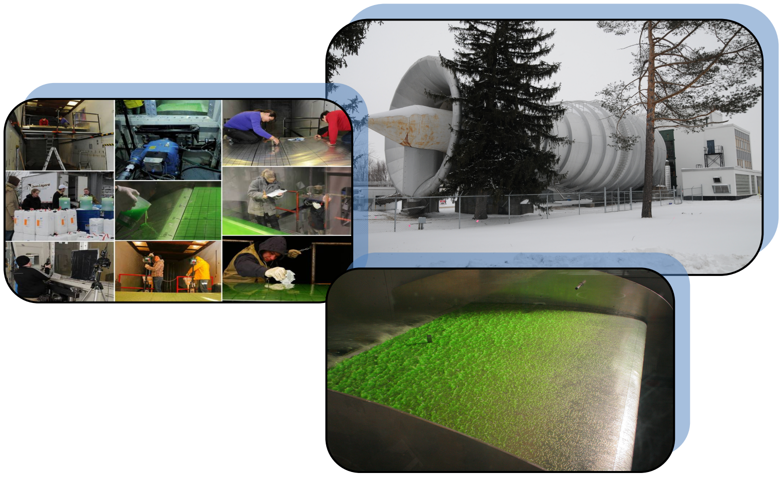
TP15232E

WIND TUNNEL TRIALS TO EXAMINE ANTI-ICING FLUID FLOW-OFF CHARACTERISTICS AND TO SUPPORT THE DEVELOPMENT OF ICE PELLET ALLOWANCE TIMES, WINTERS 2009-10 TO 2012-13

Volume 3



Prepared for
Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Center

Prepared by:

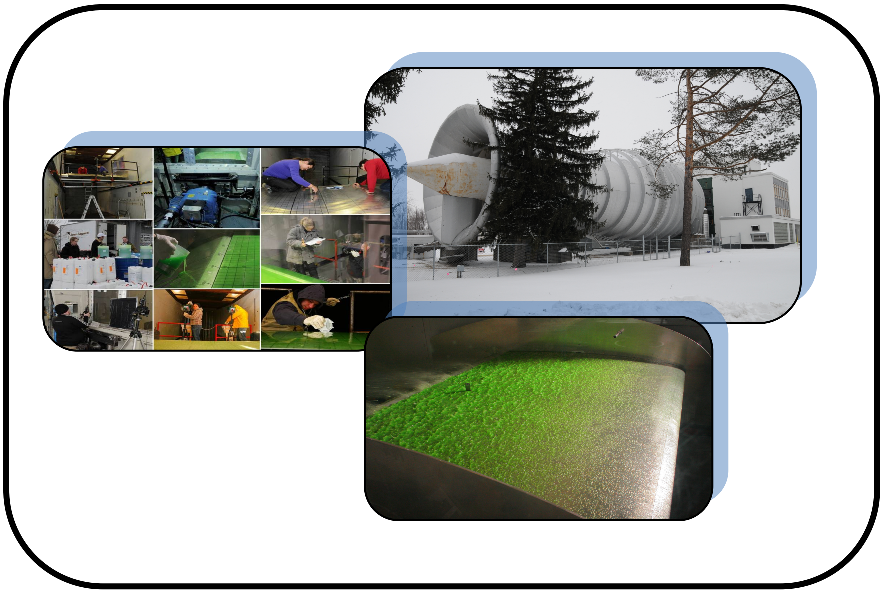
APS
Aviation Inc.

November 2013
Final Version 1.0

TP15232E

WIND TUNNEL TRIALS TO EXAMINE ANTI-ICING FLUID FLOW-OFF CHARACTERISTICS AND TO SUPPORT THE DEVELOPMENT OF ICE PELLET ALLOWANCE TIMES, WINTERS 2009-10 TO 2012-13

Volume 3



By:

Marco Ruggi

Prepared by:

APS Aviation Inc.

November 2013
Final Version 1.0

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by:

Oct 23, 2020

Marco Ruggi, Eng., M.B.A. Date
Project Leader

Reviewed by:

Oct 23, 2020

John D'Avirro, Eng., PBDM Date
Program Manager

Approved by: **

John Detombe Date
Chief Engineer
ADGA Group Consultant Inc.

Un sommaire français se trouve avant la table des matières.

This report was first provided to Transport Canada as Final Draft 1.0 in November 2013.
It has been published as Final Version 1.0 in October 2020.

***Final Draft 1.0 of this report was signed and provided to Transport Canada in November 2013. A Transport Canada technical and editorial review was subsequently completed and the report was finalized in October 2020; John Detombe was not available to participate in the final review or to sign the current version of the report.*

EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC), with financial support from the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology. APS conducted a series of full-scale tests in the National Research Council Canada (NRC) 3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel (PIWT) to determine the flow-off characteristics of anti-icing fluid with and without mixed precipitation conditions with ice pellets.

Background and Objective

Prior to the winter of 2006-07, Holdover Time (HOT) guidance material did not exist for ice pellet conditions, however aircraft could still depart during ice pellet conditions following aircraft deicing and a pre-takeoff contamination check. This protocol was feasible for common air carrier aircraft that provided access to emergency exit windows overlooking the leading edge of the aircraft wings; however, it posed a significant problem for cargo aircraft that have limited visibility of the wings from the cabin.

On December 22, 2004, United Parcel Service (UPS) aircraft in Louisville were grounded for several hours due to extended ice pellet conditions. Due to cargo aircraft configuration, pre-takeoff contamination checks by the onboard crew were not possible. Fed-Ex had been faced with similar problems in Memphis. Following this event, in October 2005, the FAA issued two notices restricting takeoffs in ice pellet conditions.

As a result of this costly incident, UPS set out to obtain experimental data to provide guidance and allow operations to continue in ice pellet conditions. During the winter of 2004-05, aerodynamic and endurance time testing were conducted in simulated ice pellet conditions. APS also conducted some preliminary flat plate research [see Transport Canada (TC) report, TP 14718E, *Preliminary Endurance Time Testing in Simulated Ice Pellet Conditions*, (1)]. Based on the preliminary data, an allowance of 20 minutes in light ice pellet conditions was proposed, however, no changes to the HOT guidelines were made.

During the following winter of 2006-07, the FAA provided a 25 minute allowance as a preliminary guideline; TC issued a note indicating that no changes would be made to the HOT guidelines. This allowance was based on the previous research conducted during the winter of 2005-06, primarily as a result of Falcon 20 aerodynamic research [see TC report, TP 14716E, *Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets* (2)]; these results were presented at the Society of Automotive Engineers (SAE) meeting in Lisbon in May 2006. To address the option of a pre-takeoff contamination check, the 20 minute targeted allowance was extended to 25 minutes; pre-takeoff contamination checks would no longer apply. This allowance was followed by a list of conditions; one restriction was that operations would be limited to ice pellets alone (no mixed conditions).

Due to the high occurrence of ice pellets combined with freezing rain or snow, the industry requested additional guidance material for operations in mixed ice pellet conditions. Additional endurance time testing and aerodynamic research was conducted in simulated ice pellet conditions during the winter of 2006-07.

During the winter of 2007-08, TC and FAA provided allowance time guidance material for operations in mixed conditions with ice pellets guideline. These allowance times were based on the research conducted during the winter of 2006-07 [see TC report, TP 14779E, *Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets* (3)]. The recommended allowance times were based on aerodynamic research conducted using the PIWT and the NRC Falcon 20 aircraft; these results were presented at the SAE meeting in San Diego in May 2007. These allowance time guidelines were followed by a list of restrictions based on the results obtained through the research conducted, and the lack of data in specific conditions.

During the winter of 2007-08, additional endurance time testing and aerodynamic research was conducted to support and further expand the ice pellet allowance times [see TC report, TP 14871E, *Research for Further Development of Ice Pellet Allowance Times: Aircraft Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2007-08,* (4)]. Full-scale testing with the NRC Falcon 20 and T-33 aircraft was conducted in mixed conditions with ice pellets and in non-precipitation conditions. Testing was primarily geared towards simulating low rotation speed aircraft. No changes to the allowance times were made as a result of this work, as aerodynamic data was not available.

During the winter of 2008-09, testing was conducted in the PIWT using a National Aeronautics and Space Administration (NASA) LS-0417 to validate and potentially expand the allowance times. As a result of this testing, a reduction to the light ice pellets mixed with moderate snow allowance time was issued for outside air temperature (OAT) above -5°C: the allowance time was reduced from 25 minutes to 10 minutes. The testing conducted also allowed the expansion of the table to include a new 25 minute allowance time for light ice pellets mixed with moderate rain for above -5°C conditions, as well as a new 15 minute allowance time for light ice pellets mixed with light snow for -5°C to -10°C conditions. A newly updated version of the Type IV allowance time table was developed and adopted for the 2009-10 version of the HOT Guidelines. It was recommended that additional testing be conducted in the PIWT during the winter of 2009-10 using a supercritical airfoil to validate the allowance time for use with newer generation aircraft.

A series of tests were designed and carried out during the winter of 2009-10 using a newly constructed thin high performance airfoil. In general, higher lift losses were observed with the supercritical wing compared to previous wings tested. Although initially 5 percent was used as the initial cut-off for evaluating each test, this was expanded to 8 percent based on the data collected; 8 percent lift loss correlated well with the visual observations recorded. More specifically, lift losses greater than 8 percent on the 2D model were recorded during light ice pellets and moderate ice pellet conditions below -10ºC. The data was re-analysed and extrapolated, and indicated that the allowance times would be acceptable for rotation speeds of 115 knots or greater (compared to 100 knots or greater). It was recommended that a footnote restricting the use of propylene glycol (PG) fluids to aircraft with rotation greater than 115 knots during light ice pellets and moderate ice pellet conditions below -10ºC be included in the allowance time table for the winter of 2010-11. In addition, fluid failure issues with the supercritical wing were observed with PG fluids during moderate ice pellets above - 5ºC. The relatively flat surface of the wing had less fluid flow-off and resulted in an earlier fluid failure for PG fluids. Data collected indicated that an allowance time of 15 minutes would be more appropriate. It was recommended that a footnote reducing the allowance time to 15 minutes for PG fluids during moderate ice pellet conditions above -5ºC be included in the allowance time table for the winter of 2010-11. Additional analysis paired with wind tunnel testing was recommended for the winter of 2010-11 to develop a correlation between the lift losses observed in the wind tunnel and those used as the basis of the aerodynamic acceptance tests (AATs) for fluid certification.

A test program was developed for the winter of 2010-11 in an attempt to continue the previous winter's work and substantiate and possibly expand the current ice pellet allowance times. In addition, testing was conducted to develop a correlation between the lift losses observed in the wind tunnel and those used as the basis of the AATs for fluid certification.

Conclusions and Observations

Type IV High Speed Allowance Times

Results from the 2010-11 testing demonstrated results similar to the 2009-10 testing in that the results indicated fluid flow-off issues with the supercritical wing when using PG fluids at the lower temperatures. During the winter of 2009-10, greater lift losses on the 2D model were recorded during light ice pellets and moderate ice pellet conditions below -10ºC, and changes to the guidance material were made to address this.

During the winter of 2010-11, similar results were obtained, and the data collected indicated that the footnote in the guidance material restricting the use of PG fluids to aircraft with rotation greater than 115 knots during light ice pellets and moderate ice pellet conditions below 10°C was still relevant and should remain in the allowance time table for the winter of 2011-12.

It should be noted that three moderate ice pellet tests conducted at 115 knots and at the very low end of the temperature range demonstrated lift loss results that were marginally above the upper acceptable limit of 9.2 percent, however, the visual observations demonstrated satisfactory results. It was agreed changes would not be made until some additional testing could be conducted to support this work, and until the lift loss limits were further investigated.

The testing conducted during the winters of 2009-10 and 2010-11 also supported the potential expansion of the light ice pellets cells mixed with light or moderate snow. More specifically, the results indicated that for light ice pellets mixed with light snow in above -5°C conditions, the allowance time could potentially be increased from 25 to 40 minutes; for light ice pellets mixed with moderate snow in above -5°C conditions, the allowance time could potentially be increased from 10 to 20 minutes; and that a new allowance time of 7 minutes could potentially be added for light ice pellets mixed with moderate snow in the -5 to -10°C condition. It was agreed changes would not be made until some additional testing could be conducted to support this work, and until the lift loss limits were further investigated.

Correlation of Fluid Certification BLDT Results With NRC Wind Tunnel Lift Loss Results

Based on the work that was conducted by NASA and APS, it was determined that a maximum lift loss of 5.24 percent on the B737-200ADV airplane is equivalent to a lift loss of 7.29 percent on the PIWT model. Due to the scatter in the data, the standard error of the estimate determined an upper limit of lift loss on the PIWT model of 9.17 percent and a lower limit of 5.41 percent.

Currently, the scatter in the "review" range is still large and causes complications when analyzing the data collected. It is anticipated that as future testing progresses, and as more data is collected, a single-value pass/fail cut-off will be developed similar to the AAT and B737-200ADV airplane tests.

Recommendations

Type IV High Speed Allowance Time Table

Based on the 2010-11 wind tunnel test results, no changes were made to the values in the Type IV allowance time table, however, additional guidance was included to explicitly indicate that guidance material does not exist for light ice pellets mixed with light or moderate rain below 0ºC (see newly added Notes 3 and 4).

Additional Testing and Analysis to Further Investigate Supercritical Wing Lift Losses

Additional analysis paired with wind tunnel testing is recommended to further develop a correlation between the lift losses observed in the wind tunnel and AAT which is the basis for the fluid certification process. Currently, the scatter in the data is still large and causes complications when analysing the data collected. It is anticipated that as future testing progresses, and as more data is collected, a single-value pass/fail cut-off will be developed similar to the AAT and B737-200ADV airplane tests.

Testing to Investigate Repeatability and Calibration of the PIWT

A large portion of the work planned for the winter of 2011-12 will focus on the repeatability and calibration of the PIWT. An extensive series of tests are being planned that will include angle of attack sweeps, stall runs, oil flow visualization, boundary layer tripping, and pristine and contaminated fluid testing. This testing will be conducted in cooperation with NASA aerodynamicists to obtain a better understanding of the PIWT characteristics and their effects on the fluid testing, which is the basis of the ice pellet allowance times.

This page intentionally left blank.

SOMMAIRE

Dans le cadre d'un contrat avec le Centre de développement des transports (CDT) et avec l'appui financier de la Federal Aviation Administration (FAA), APS Aviation Inc. (APS) a entrepris des activités de recherche visant à faire progresser les technologies associées au dégivrage et à l'antigivrage d'aéronefs au sol. APS a mené une série d'essais pleine grandeur dans la soufflerie de givrage à propulsion et à circuit ouvert de 3 m sur 6 m du Conseil national de recherches Canada (CNRC), afin de déterminer les caractéristiques de ruissellement du liquide d'antigivrage avec et sans conditions de précipitations mixtes avec granules de glace.

Contexte et objectif

Avant l'hiver 2006-2007, il n'y avait pas de lignes directrices sur les durées d'efficacité (HOT) dans des conditions de granules de glace, mais les aéronefs pouvaient quand même partir dans des conditions de granules de glace, après un dégivrage et une vérification de contamination avant le décollage. Ce protocole était acceptable pour les aéronefs de transport équipés de fenêtres d'issues de secours au-dessus du bord d'attaque de l'aile de l'aéronef ; cependant, il causait un problème important dans le cas d'aéronefs de transport offrant une visibilité limitée des ailes à partir de la cabine.

Le 22 décembre 2004, les aéronefs de United Parcel Service (UPS) à Louisville ont été interdits de vol pendant plusieurs heures en raison de conditions prolongées de granules de glace. Étant donné la configuration des aéronefs cargos, l'équipage ne pouvait effectuer les inspections de contamination avant le décollage. L'entreprise FedEx a connu des problèmes semblables à Memphis. Après cet incident, la FAA a publié, en octobre 2005, deux avis de restriction de décollage dans des conditions de granules de glace.

En raison de cet incident coûteux, UPS s'est efforcée d'obtenir des données expérimentales afin de définir des lignes directrices et de permettre le maintien des activités dans des conditions de granules de glace. Durant l'hiver 2004-2005, des essais aérodynamiques et de durée d'efficacité ont été menés dans des conditions simulées de granules de glace. APS a également mené quelques essais préliminaires sur plaque plane [voir le rapport de Transports Canada (TC), TP 14718E, *Preliminary Endurance Time Testing in Simulated Ice Pellet Conditions* (1)]. À la lumière des données préliminaires, une marge de tolérance de 20 minutes a été proposée pour les conditions de granules de glace légers ; toutefois, aucun changement n'a été apporté aux lignes directrices sur les durées d'efficacité.

Au cours de l'hiver 2006-2007, la FAA a établi une marge de tolérance de 25 minutes à titre de ligne directrice préliminaire ; TC a publié une note selon laquelle aucun changement ne serait apporté aux lignes directrices sur les durées d'efficacité. Cette marge s'appuyait sur des études antérieures menées à l'hiver 2005-2006, principalement à la suite de l'essai aérodynamique sur le Falcon 20 [voir le rapport de TC, TP 14716E, *Falcon 20 Trials to Examine Fluid Removed from Aircraft During Take off with Ice Pellets* (2)] ; ces résultats ont été présentés à la réunion de la Society of Automotive Engineers (SAE) à Lisbonne en mai 2006. Afin de prendre en compte l'option d'inspection de contamination avant le décollage, la marge visée de 20 minutes a été prolongée à 25 minutes ; par conséquent, les vérifications de contamination avant le décollage ne s'appliqueraient plus. Cette marge était suivie d'une liste de conditions ; l'une des restrictions s'appliquait aux manœuvres dans des conditions de granules de glace seulement (et non dans des conditions mixtes).

En raison des conditions fréquentes de granules de glace combinées à la pluie verglaçante ou à la neige, l'industrie a demandé des lignes directrices additionnelles pour les opérations dans des conditions mixtes de granules de glace. Au cours de l'hiver 2006-2007, des recherches additionnelles aérodynamiques et sur les durées d'efficacité ont été menées dans des conditions simulées de granules de glace.

Au cours de l'hiver 2007-2008, TC et la FAA ont donné des lignes directrices sur les marges de tolérance pour les opérations dans des conditions mixtes avec granules de glace. Ces marges de tolérance étaient fondées sur la recherche menée au cours de l'hiver 2006-2007 [voir le rapport de TC, TP 14779E, *Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets* (3)]. Les marges de tolérance recommandées étaient fondées sur les essais aérodynamiques menés dans la soufflerie de givrage à propulsion et sur l'aéronef Falcon 20 du CNRC ; ces résultats ont été présentés à la réunion de la SAE à San Diego en mai 2007. Les lignes directrices sur les marges de tolérance ont été suivies d'une liste de restrictions fondées sur les résultats de la recherche et le manque de données dans des conditions précises.

Au cours de l'hiver 2007-2008, des essais additionnels de durées d'efficacité et de la recherche aérodynamique ont été menés pour confirmer et compléter les marges de tolérance dans les granules de glace [voir le rapport de TC, TP 14871E, *Research for Further Development of Ice Pellet Allowance Times: Aircraft Trials to Examine Anti-Icing Fluid Flow-off Characteristics Winter 2007-08* (4)]. Des essais pleine grandeur sur les aéronefs Falcon 20 et T-33 du CNRC ont été menés dans des conditions mixtes avec granules de glace et en absence de précipitation. Les essais visaient principalement la simulation d'aéronefs à basse vitesse de rotation. En l'absence de données aérodynamiques, aucun changement aux marges de tolérance n'a été apporté à la suite de ces travaux.

Au cours de l'hiver 2008-2009, des essais ont été réalisés dans la soufflerie de givrage à propulsion à l'aide d'un profil d'aile LS-0417 de la National Aeronautics and Space Administration (NASA) afin de valider et, possiblement, d'élargir les marges de tolérance. À la suite de ces essais, la marge de tolérance pour les conditions de granules de glace légers avec neige modérée a été réduite pour les températures ambiantes supérieures à -5 °C, passant de 25 minutes à 10 minutes. Les essais ont aussi permis de développer le tableau pour y inclure une nouvelle marge de tolérance de 25 minutes pour les conditions de granules de glace légers avec pluie modérée à des températures supérieures à -5 °C, de même qu'une nouvelle marge de tolérance de 15 minutes pour les conditions de granules de glace légers avec neige légère à des températures de -5 °C à -10 °C. Une nouvelle version actualisée du tableau des marges de tolérance pour les liquides de type IV a été élaborée et adoptée pour la version 2009-2010 des lignes directrices sur les durées d'efficacité. Il a été recommandé de réaliser d'autres essais dans la soufflerie de givrage à propulsion au cours de l'hiver 2009-2010 sur une surface portante supercritique afin de valider la marge de tolérance à utiliser avec les aéronefs de nouvelle génération.

Une série d'essais ont été conçus et réalisés au cours de l'hiver 2009-2010 sur une nouvelle surface portante haute performance à profil mince. En général, les pertes de portance observées sur l'aile supercritique étaient plus importantes que celles observées sur les ailes testées auparavant. Au départ, le seuil initial pour évaluer chaque essai était fixé à 5 pour cent; il a toutefois été augmenté à 8 pour cent à la lumière des données recueillies. Une perte de portance de 8 pour cent concordait bien avec les observations visuelles enregistrées. Plus précisément, des pertes de portance de plus de 8 pour cent ont été enregistrées sur le modèle bidimensionnel dans des conditions de granules de glace légers et modérés à des températures inférieures à -10 °C. Après avoir été analysées de nouveau et extrapolées, les données ont démontré que les marges de tolérance seraient acceptables à des vitesses de rotation de 115 nœuds ou plus (plutôt qu'à des vitesses de 100 nœuds ou plus). Il a été recommandé d'inclure au tableau des marges de tolérance de l'hiver 2010-2011 une note de bas de page limitant l'utilisation de liquides à base de propylène glycol aux aéronefs dont les vitesses de rotation sont supérieures à 115 nœuds dans des conditions de granules de glace légers ou modérés à des températures au-dessous de -10 °C. En outre, des pertes d'efficacité ont été observées sur l'aile supercritique avec les liquides à base de propylène glycol dans des conditions de granules de glace modérés à des températures supérieures à -5 °C. La surface relativement plane de l'aile entravait le ruissellement des liquides à base de propylène glycol, ce qui se soldait par une perte d'efficacité précoce. Les données ont démontré qu'une marge de tolérance de 15 minutes serait plus appropriée. Il a été recommandé d'inclure au tableau des marges de tolérance de l'hiver 2010-2011 une note de bas de page réduisant la marge de tolérance des liquides à base de propylène glycol à 15 minutes dans des conditions de granules de glace modérés à des températures supérieures à -5 °C. D'autres analyses combinées avec des essais en soufflerie ont été recommandées pour l'hiver 2010-2011 afin d'établir une corrélation entre les pertes de portance observées dans la soufflerie et celles utilisées comme base des essais d'acceptabilité sur le plan aérodynamique pour la certification des liquides.

Un programme d'essais a été mis sur pied pour l'hiver 2010-2011 afin de tenter de poursuivre les travaux de l'hiver précédent visant à étayer et possiblement à élargir les marges de tolérance actuelles concernant les granules de glace. En outre, des essais ont été menés afin d'établir une corrélation entre les pertes de portance observées dans la soufflerie et celles utilisées comme base des essais d'acceptabilité sur le plan aérodynamique pour la certification des liquides.

Conclusions et observations

Marges de tolérance pour les liquides de type IV à haute vitesse

Les résultats des tests menés en 2010-2011 se sont avérés semblables à ceux de 2009-2010, démontrant également des problèmes de ruissellement sur l'aile supercritique lors de l'utilisation de liquides à base de propylène glycol à basse température. Au cours de l'hiver 2009-2010, des pertes de portance plus importantes ont été enregistrées sur le modèle bidimensionnel dans des conditions de granules de glace légers et modérés à des températures inférieures à -10 °C; des changements ont été apportés aux lignes directrices dans le but de répondre à cette situation.

L'hiver suivant, des résultats similaires ont été obtenus, et les données recueillies ont permis d'établir que la note de bas de page limitant l'utilisation de liquides à base de propylène glycol aux aéronefs dont les vitesses de rotation sont supérieures à 115 nœuds dans des conditions de granules de glace légers et modérés à des températures au-dessous de -10 °C était toujours pertinente, et devrait continuer d'apparaître dans le tableau des marges de tolérance de l'hiver 2011-2012.

Il convient de noter que trois essais effectués dans des conditions de granules de glace modérés à 115 nœuds et à la valeur la plus basse de la plage de température ont démontré une perte de portance légèrement plus élevée que la limite supérieure acceptable de 9,2 pour cent. Les observations visuelles ont cependant fait état de résultats satisfaisants. Il a été convenu qu'aucune modification ne serait apportée avant que des tests supplémentaires corroborant ces données ne soient menés et que les limites de perte de portance ne fassent l'objet d'examens supplémentaires.

Les essais réalisés au cours des hivers 2009-2010 et 2010-2011 sont également venus appuyer l'élargissement potentiel des cellules associées aux granules de glace légers mélangés à de la neige légère ou modérée. Plus précisément, les résultats obtenus ont démontré que dans des conditions mixtes de granules de glace légers et de neige légère à des températures supérieures à -5 °C, il était possible de faire passer les marges de tolérance de 25 à 40 minutes. Dans des conditions mixtes de granules de glace légers et de neige modérée à des températures supérieures à -5 °C, il a été démontré qu'il était possible de faire passer ces marges de tolérance de 10 à 20 minutes. Enfin, il a été établi qu'une nouvelle marge de tolérance de 7 minutes pouvait être ajoutée pour les conditions de granules de glace légers avec neige modérée à des températures de -5 °C à -10 °C. Il a été convenu qu'aucune modification ne serait apportée avant que des tests supplémentaires corroborant ces données ne soient menés et que les limites de perte de portance ne fassent l'objet d'examens supplémentaires.

Corrélation entre les résultats des essais sur l'épaisseur de déplacement de la couche limite pour la certification des liquides et les résultats sur la perte de portance dans la soufflerie du CNRC

Sur la base des travaux menés par la NASA et APS, il a été établi qu'une perte de portance maximale de 5,24 pour cent de l'avion B737-200ADV équivaut à une perte de portance de 7,29 pour cent du modèle de soufflerie de givrage à propulsion. Les données étant dispersées, il a été déterminé que l'erreur type de l'estimation permettait de fixer la limite supérieure de perte de portance du modèle de soufflerie de givrage à propulsion à 9,17 pour cent et sa limite inférieure, à 5,41 pour cent.

À l'heure actuelle, la dispersion des données du modèle « de contrôle » demeure importante et complique l'analyse des résultats recueillis. On prévoit que la réalisation de tests futurs et la collecte d'un plus grand nombre de données permettront l'établissement d'une valeur unique pour le seuil de réussite ou d'échec, à la manière des essais réalisés sur les avions AAT et B737-200ADV.

Recommandations

Tableau des marges de tolérance pour les liquides de type IV à haute vitesse

En fonction des résultats obtenus en soufflerie en 2010-2011, aucun changement n'a été apporté aux valeurs du tableau des marges de tolérance pour les liquides de type IV; toutefois, d'autres lignes directrices ont été ajoutées afin d'indiquer explicitement qu'aucune directive n'existe pour les granules de glace légers mélangés à de la pluie légère ou modérée à des températures inférieures à 0 °C (voir les notes 3 et 4, récemment ajoutées).

Essais et analyses supplémentaires afin d'étudier davantage la diminution de portance sur les ailes supercritiques

D'autres analyses combinées avec des essais en soufflerie sont recommandées afin d'établir de façon plus précise une corrélation entre les pertes de portance observées dans la soufflerie et les essais d'acceptabilité sur le plan aérodynamique, sur lesquels se base le processus de certification des liquides. À l'heure actuelle, la dispersion des données demeure importante et complique l'analyse des résultats recueillis. On prévoit que la réalisation de tests futurs et la collecte d'un plus grand nombre de données permettront l'établissement d'une valeur unique pour le seuil de réussite ou d'échec, à la manière des essais réalisés sur les avions AAT et B737-200ADV.

Essais afin d'étudier la répétabilité et l'étalonnage de la soufflerie de givrage à propulsion

Une bonne partie des travaux menés au cours de l'hiver 2011-2012 porteront sur la répétabilité et l'étalonnage de la soufflerie de givrage à propulsion. Une série de tests sont ainsi prévus, parmi lesquels des balayages des angles d'attaque, des essais de décrochage, une visualisation du ruissellement des liquides, un déclenchement de la couche limite et une évaluation de liquides intacts et contaminés. Ces tests, effectués en collaboration avec des aérodynamiciens de la NASA, devraient permettre de mieux comprendre les caractéristiques de la soufflerie de givrage à propulsion et leurs effets sur l'évaluation des liquides, sur laquelle reposent les marges de tolérance dans des conditions de granules de glace.

CONTENTS Page

LIST OF APPENDICES

LIST OF TABLES Page

LIST OF FIGURES Page

LIST OF PHOTOS Page

GLOSSARY

AAT	Aerodynamic Acceptance Test
AMIL	Anti-icing Materials International Laboratory
APS	APS Aviation Inc.
BLDT	Boundary Layer Displacement Thickness
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
LOUT	Lowest Operational Use Temperature
MSC	Meteorological Service of Canada
NASA	National Aeronautics and Space Administration
NRC	National Research Council Canada
NRCIAR	National Research Council Canada Institute for Aerospace Research
OAT	Outside Air Temperature
PG	Propylene Glycol
PIWT	3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel
RTD	Resistance Temperature Detector
SAE	Society of Automotive Engineers
TC	Transport Canada
TDC	Transportation Development Centre
UPS	United Parcel Service

This page intentionally left blank.

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 an incomplete 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.

Since the early 1990s, the Transportation Development Centre (TDC) of 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 United States Federal Aviation Administration (FAA), the National Research Council Canada (NRC), the Meteorological Service of Canada (MSC), several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

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

As part of a larger research program examining de/anti-icing fluid flow-off during simulated aircraft takeoff, APS conducted a series of full-scale tests in the NRC 3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel (PIWT) using a supercritical wing model to determine the flow-off characteristics of anti-icing fluid with and without mixed precipitation conditions with ice pellets.

NOTE: The documentation of this project has been divided into five separate volumes: one summary report, and four detailed reports on each of the respective testing years' activities. The volumes are as follows:

Volume 1:	*Summary Report*
Volume 2:	*2009-10 Testing Report*
Volume 3:	*2010-11 Testing Report*
Volume 4:	*2011-12 Testing Report*
Volume 5:	*2012-13 Testing Report*

This report is Volume 3 of 5.

1.1 Background

Prior to the winter of 2006-07, Holdover Time (HOT) guidance material did not exist for ice pellet conditions; however aircraft could still depart during ice pellet conditions following aircraft deicing and a pre-takeoff contamination check. This protocol was feasible for common air carrier aircraft that provided access to emergency exit windows overlooking the leading edge of the aircraft wings; however, it posed a significant problem for cargo aircraft that have limited visibility of the wings from the cabin.

On December 22, 2004, United Parcel Service (UPS) aircraft in Louisville were grounded for several hours due to extended ice pellet conditions. Due to cargo aircraft configuration, pre-takeoff contamination checks by the onboard crew were not possible. Fed-Ex had been faced with similar problems in Memphis. Following this event, in October 2005, the FAA issued two notices restricting takeoffs in ice pellet conditions.

As a result of this costly incident, UPS set out to obtain experimental data to provide guidance and allow operations to continue in ice pellet conditions. During the winter of 2004-05, aerodynamic and endurance time testing were conducted in simulated ice pellet conditions. APS also conducted some preliminary flat plate research [see TC report, TP 14718E, *Preliminary Endurance Time Testing in Simulated Ice Pellet Conditions*, (1)]. Based on the preliminary data, an allowance of 20 minutes in light ice pellet conditions was proposed; however, no changes to the HOT Guidelines were made.

During the following winter of 2006-07, the FAA provided a 25-minute allowance as a preliminary guideline; TC issued a note indicating that no changes would be made to the HOT Guidelines. This allowance was based on the previous research conducted during the winter of 2005-06, primarily as a result of the Falcon 20 aerodynamic research [see TC report, TP 14716E, *Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets* (2)]; these results were presented at the Society of Automotive Engineers (SAE) meeting in Lisbon in May 2006. To address the option of a pre-takeoff contamination check, the 20-minute targeted allowance was extended to 25 minutes; pre-takeoff contamination checks would no longer apply. This allowance was followed by a list of conditions; one restriction was that operations would be limited to ice pellets alone (no mixed conditions).

Due to the high occurrence of ice pellets combined with freezing rain or snow, the industry requested additional guidance material for operations in mixed ice pellet conditions. Additional endurance time testing and aerodynamic research was conducted in simulated ice pellet conditions during the winter of 2006-07.

During the winter of 2007-08, TC and the FAA provided allowance time guidance material for operations in mixed conditions with ice pellets. These allowance times were based on the research conducted during the winter of 2006-07 [see TC report, TP 14779E, *Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets* (3)]. The recommended allowance times were based on aerodynamic research conducted using the PIWT and the NRC Falcon 20 aircraft; these results were presented at the SAE meeting in San Diego in May 2007. These allowance time guidelines were followed by a list of restrictions based on the results obtained through the research conducted and on the lack of data in specific conditions.

During the winter of 2007-08, additional endurance time testing and aerodynamic research were conducted to support and further expand the ice pellet allowance times [see TC report, TP 14871E, *Research for Further Development of Ice Pellet Allowance Times: Aircraft Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2007-08,* (4)]. Full-scale testing with the NRC Falcon 20 and T-33 aircraft was conducted in mixed conditions with ice pellets and in non-precipitation conditions. Testing was primarily geared towards simulating low rotation speed aircraft. No changes to the allowance times were made as a result of this work, as aerodynamic data was not available.

During the winter of 2008-09, testing was conducted in the PIWT using a National Aeronautics and Space Administration (NASA) LS-0417 to validate and potentially expand the allowance times. As a result of this testing, a reduction to the light ice pellets mixed with moderate snow allowance time was issued for outside air temperature (OAT) above -5°C: the allowance time was reduced from 25 minutes to 10 minutes. The testing conducted also allowed the expansion of the table to include a new 25-minute allowance time for light ice pellets mixed with moderate rain for above -5°C conditions, as well as a new 15-minute allowance time for light ice pellets mixed with light snow for -5°C to -10°C conditions. A newly updated version of the Type IV allowance time table was developed and adopted for the 2009-10 version of the HOT Guidelines. It was recommended that additional testing be conducted in the PIWT during the winter of 2009-10 using a supercritical airfoil to validate the allowance times for use with newer generation aircraft.

A series of tests were designed and carried out during the winter of 2009-10 using a newly constructed thin high-performance airfoil. In general, higher lift losses were observed with the supercritical wing compared to previous wings tested. Although 5 percent was used as the initial cut-off for evaluating each test, this was expanded to 8 percent based on the data collected; 8 percent lift loss correlated well with the visual observations recorded. More specifically, lift losses greater than 8 percent on the 2D model were recorded during light ice pellet and moderate ice pellet conditions below -10°C. The data was re-analysed and extrapolated, indicating that the allowance times would be acceptable for rotation speeds of 115 knots or greater (compared to 100 knots or greater). It was recommended that a footnote restricting the use of propylene glycol (PG) fluids to aircraft with rotation greater than 115 knots during light ice pellet and moderate ice pellet conditions below -10°C be included in the allowance time table for the winter of 2010-11. In addition, fluid failure issues with the supercritical wing were observed with PG fluids during moderate ice pellets above -5°C. The relatively flat surface of the wing had less fluid flow-off and resulted in an earlier fluid failure for PG fluids. Data collected indicated that an allowance time of 15 minutes would be more appropriate. It was recommended that a footnote reducing the allowance time to 15 minutes for PG fluids during moderate ice pellet conditions above -5°C be included in the allowance time table for the winter of 2010-11. Additional analysis paired with wind tunnel testing was recommended for the winter of 2010-11 to develop a correlation between the lift losses observed in the wind tunnel and those used as the basis of the aerodynamic acceptance tests (AATs) for fluid certification.

Table 1.1 describes the timeline of the developed allowance time guidance material.

Table 1.1: Timeline of Developed Allowance Time Guidance Material

Winter Testing	Research Conducted	FAA Allowance Time	TC Allowance Time	Report TP #	Related Winter HOT Guidelines
2004-05	UPS Research APS PMG Research	October 2005 Notices 8000.309 and 8000.313 (no takeoff in IP)	No Changes to Guidelines	Data available through UPS & TP 14718	2005-06
2005-06	APS Falcon 20	20 minutes targeted, 25 minutes recomended *(to include 5 min PTCC)*	Note include indicating no changes to guidelines	TP 14716E	2006-07
2006-07	APS Wind Tunnel & Falcon 20	Allowance Time Table 1st Version	Allowance Time Table 1st Version (October 2007)	TP 14779E	2007-08
2007-08	APS Falcon 20	Allowance Time Table 1st Version	Allowance Time Table 1st Version	TP 14871E	2008-09
2008-09	APS Wind Tunnel	Allowance Time Table 2nd Version	Allowance Time Table 2nd Version	TP 14935E	2009-10
2009-10	APS Wind Tunnel	Allowance Time Table 3rd Version	Allowance Time Table 3rd Version	TP 15232 (Vol 2)	2010-11
2010-11	APS Wind Tunnel	No Changes to Guidelines	No Changes to Guidelines	TP 15232 (Vol 3)	2011-12

1.2 Program Objectives

A test program was developed for the winter of 2010-11 in an attempt to continue the previous winter's work and substantiate and possibly expand the current ice pellet allowance times. In addition, testing was conducted to develop a correlation between the lift losses observed in the wind tunnel and those used as the basis of the AATs for fluid certification.

A series of tests were designed and carried out during the winter of 2010-11. Testing was conducted with and without contamination. Research was conducted to validate and develop allowance times for the following application:

- Type IV Fluid – High-Speed Ramp (Allowance times currently exist).

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

1.3 Previous Falcon 20 Full-Scale Testing

Previous trials to examine the elimination of failed SAE Type IV fluids from aircraft wings during takeoff were conducted during the 1997-98 and 1998-99 winter seasons. These trials, based on simulated takeoff tests using the NRC Falcon 20 aircraft, showed that the test approach was a viable one. The Falcon 20 test program conducted during the winters of 2001-02 and 2002-03 addressed the effects of unshed anti-icing fluid on aircraft takeoff performance.

This research is documented in detail in a series of five reports written by APS for TC:

- TP 13316E, *Contaminated Aircraft Takeoff Test for the 1997/98 Winter* (5);
- TP 13479E, *Contaminated Aircraft Takeoff Tests for the 1998-99 Winter* (6);
- TP 13666E, *Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures* (7);
- TP 13995E, *Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid* (8); and
- TP 14147E, *Aircraft Takeoff Test Program for Winter 2002-03: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid* (9).

Research was conducted during the winter of 2005-06 using the Falcon 20 aircraft to determine the maximum amount of ice pellet contamination that will flow-off an anti-iced aircraft at takeoff. This research is documented in detail in a report written by APS for TC [see TP 14716E (2)].

During the winter of 2006-07, extensive testing was conducted in mixed ice pellet conditions in the NRC PIWT. The Falcon 20 aircraft was used to validate the results obtained in the NRC PIWT by conducting a limited number of validation tests. This research is documented in detail in a report written by APS for TC [see TP 14779E (3)].

The details of the methodology used for this testing are documented in a report written by APS for TC:

- TP 14778E, *Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report* (10).

During the winter of 2007-08, the NRC PIWT was not available for testing during the winter months. The Falcon 20 aircraft was used to conduct simulated low rotation speed tests in mixed conditions with ice pellets. Two tests were also conducted with the NRC T-33 aircraft to validate the low rotation speed results obtained with the Falcon 20. This research is documented in detail in a report written by APS for TC [see TP 14871E (4)].

1.4 Previous NRC Wind Tunnel Full-Scale Testing

Previous trials to examine aerodynamic performance effects of de/anti-icing fluids that had been contaminated by varying quantities of freezing precipitation were conducted over three winter seasons at the NRC PIWT. The airfoil tested was a full-scale NASA LS(1)-0417 section with a Fowler flap deployed at 15 degrees. A spray bar located in the wind tunnel settling chamber produced artificial snow. Takeoff was simulated by accelerating the test section wind speed, and aerodynamic data was obtained while pitching the airfoil to the stall. These trials, based on takeoff simulations, showed that the test approach was a viable one.

This research is documented in detail in a report written in May 1999 by the National Research Council Canada Institute for Aerospace Research (NRCIAR) for TC, TP 13426E, *Air-Flap Performance with De-Anti-Icing Fluids and Freezing Precipitation* (11).

During the winter of 2006-07, extensive testing was conducted in simulated mixed ice pellet conditions in the NRC PIWT using a NACA 23012 wing section. Testing was primarily geared towards expansion of the 25-minute allowance time for ice pellets. Testing included mixed ice pellet conditions as well as preliminary testing in heavy snow conditions. This research is documented in detail in a report written by

APS for TC, TP 14779E (3). The details of the methodology used for this testing are documented in a report written by APS for TC, TP 14778E (10).

During the winter of 2008-09, aerodynamic research was conducted in the NRC PIWT using a NASA LS(1)-0417 section to investigate fluid flow-off of contaminated fluid following simulated ice pellet and mixed conditions to substantiate and further develop the current ice pellet allowance times. High-speed and low-speed ramp testing were conducted using Type IV fluid, as well as limited testing with Type II and III fluids. This research is documented in detail in a report written by APS for TC, [see TC report, TP 14935E, *Research for Further Development of Ice Pellet Allowance Times: Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09 (12)]*.

During the winter of 2009-10, a series of tests were designed and carried out using a newly constructed thin high-performance airfoil. In general, higher lift losses were observed with the supercritical wing compared to previous wings tested. The intent was to validate the allowance times for use with newer generation aircraft. The new wing section demonstrated greater sensitivity to lift losses, especially at colder temperatures. This research is documented in detail in a report written by APS for TC, [see TC report, TP 15232E, *Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winters 2009-10 to 2012-13* (Vol. 2) (13)].

1.5 Overview of 2010-11 Testing

Full-scale testing during the winter of 2010-11 was conducted using the NRC PIWT. The primary testing conducted aimed at validating the current allowance times for use with newer generation aircraft with supercritical wing designs and to develop a correlation between the lift losses observed in the wind tunnel and boundary layer displacement thickness (BLDT) results used as the basis of the aerodynamic acceptance for fluid certification.

In addition, some preliminary work was conducted as a lower priority to address current industry concerns. This work has been documented in the TC report, TP 15160E, *Exploratory Wind Tunnel Aerodynamic Research: Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2010-11* (14).

Table 1.2 demonstrates the groupings for the global set of tests conducted at the wind tunnel during the winter of 2010-11. Only tests pertaining to ice pellet allowance times and the BLDT correlation work (groups 1 to 3) are described in this report. Table 1.3 demonstrates in greater detail the groupings for the secondary R&D objective tests (groups 4 and 5 from Table 1.1).

Table 1.2: Summary of 2010-11 Wind Tunnel Tests by Objective

1. ICE PELLET ALLOWANCE TIMES

TOTAL RUNS: 61

6, 7, 8, 10, 13, 14, 15, 15A, 15B, 20, 22, 23, 24, 25, 26, 27, 28, 31, 35, 37, 38, 40, 41, 41A, 44, 45, 46, 47, 51, 53, 56, 58, 59, 59A, 69, 70, 72, 73, 74, 78, 79, 82, 83, 84, 85, 92, 92A, 93, 102, 103, 104, 105, 106, 115, 116, 117, 121, 128, 129, 131, 132

3. BASELINE (BLDT)

TOTAL RUNS: 42

5, 5A, 9, 12, 21, 29, 30, 32, 33, 34, 36, 39, 42, 43, 48, 49, 50, 52, 54, 55, 57, 60, 61, 62, 63, 66, 67, 68, 71, 75, 76, 77, 80, 81, 86, 86A, 94, 95, 95A, 96, 97, 107

2. DRY WING

TOTAL RUNS: 8

1, 2, 3, 65, 100, 112, 119, 120

4. RESEARCH & DEVELOPMENT

TOTAL RUNS: 37

4, 11, 16, 17, 18, 19, 64, 64A, 87, 88, 89, 90, 91, 98, 99. 101, 108, 108A, 109, 110, 111, 113, 114, 118, 122, 123, 124, 125, 126, 127, 127A, 130, 133, 134, 135, 136, 137

TOTAL NUMBER OF RUNS

148

1.6 Report Format

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

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

b) Section 3 describes data collected during the full-scale testing conducted;

c) Section 4 describes the analysis methodology used to evaluate the wind tunnel tests conducted;

d) Section 5 includes details of additional data analysis that was conducted while developing the ice pellet allowance times for the winter of 2010-11;

e) Section 6 describes the data, results, and observations for testing conducted in Light Ice Pellet conditions;

f) Section 7 describes the data, results, and observations for testing conducted in Moderate Ice Pellet conditions;

g) Section 8 describes the data, results, and observations for testing conducted in Light Ice Pellets Mixed with Light Freezing Rain;

h) Section 9 describes the data, results, and observations for testing conducted in Light Ice Pellets Mixed with Moderate Rain;

i) Section 10 describes the data, results, and observations for testing conducted in Light Ice Pellets Mixed with Light Snow;

j) Section 11 describes the data, results, and observations for testing conducted in Light Ice Pellets Mixed with Moderate Snow;

k) Section 12 describes the data, results, and observations for testing conducted in Light Ice Pellets Mixed with Light Rain;

l) Section 13 presents a summary of the conclusions and observations; and

m) Section 14 lists the recommendations for future testing.

Table 1.3: Summary of 2010-11 Secondary R&D Objectives

OBJECTIVE	RUN #	TOTAL RUNS
Surface Roughness and Heavy Contamination	64, 64A, 111, 125, 127, 127A, 137	**7**
LE Heater (Clean LE)	99	**1**
Inadequate Fluid Application	98	**1**
Effect of Ramp-up Time	11, 13, 122, 123, 124	**5**
Mixed Precipitation	114, 118, 133, 134, 135, 136	**6**
Snow or Rain with No Fluid	101, 113	**2**
Wing Geometry	130	**1**
Heavy Snow	16, 17, 18, 19, 87, 88, 89, 108, 108A, 109, 110	**11**
Multiple Fluids	90, 91	**2**
Type III	4	**1**
	TOTAL	**37**

This page intentionally left blank.

2. METHODOLOGY

This section describes the test methodology and equipment specific to the full-scale aerodynamic tests conducted at the NRC PIWT, as well as general testing methodology and equipment.

2.1 Wind Tunnel Test Site

The 2010-11 PIWT tests were performed at the NRC Aerospace Facilities, Building M-46, at the NRC Montreal Road campus, located in Ottawa, Canada. Figure 2.1 provides a schematic of the NRC Montreal Road campus showing the location of the NRC PIWT. Photo 2.1 shows an outside view of the wind tunnel test facility. Photo 2.2 shows an inside view of the wind tunnel test section. The open-circuit layout, with a fan at entry, permits contaminants associated with the test articles (such as heat or de/anti-icing fluid) to discharge directly, without recirculating or contacting the fan. The fan is normally driven electrically, but high-speed operations can be accommodated by a gas turbine drive system. Due to the requirements of both high-speed and low-speed operations during the testing, the gas turbine was selected to allow for greater flexibility, as it can perform both low- and high-speed operations, whereas the electric drive is limited to low-speed operations.

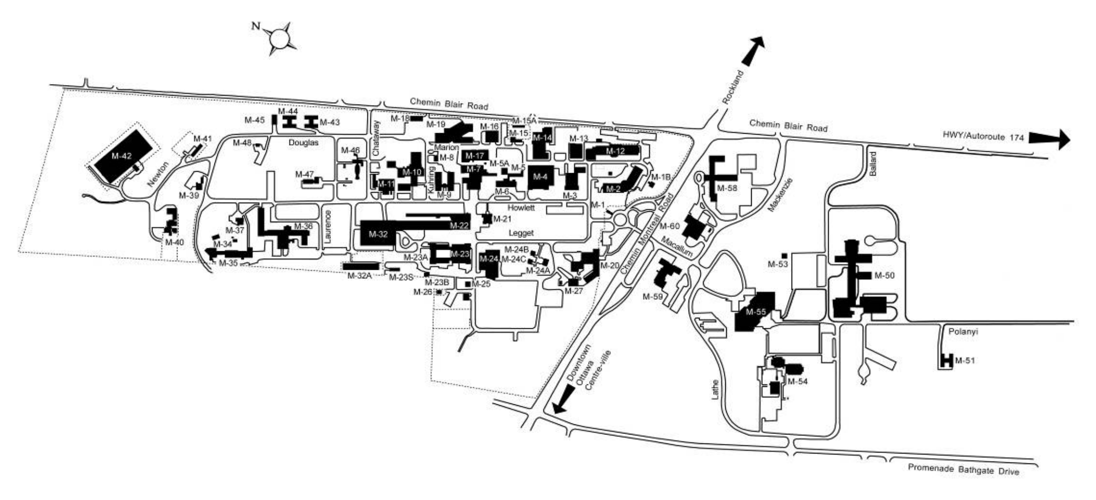


Figure 2.1: Schematic of NRC Montreal Road Campus

2.2 Test Schedule

Testing was conducted over a period of four weeks starting January 17, 2011, and ending February 11, 2011. One day was dedicated to setup and calibration prior to the start of the actual testing, and one day was required for teardown and packing. Testing was conducted during 22 days over the four-week period; testing days were selected based on weather. Table 2.1 presents the calendar of wind tunnel tests performed in 2010-11. It should be noted that the tests listed comprise all the tests conducted, including the tests not pertaining to the ice pellet allowance time objectives. At the beginning of each test day, a plan was developed that included the list of tests (taken from the global test plan) to be completed based on the weather conditions and testing priorities. This daily plan was discussed, approved, and modified (if necessary) by TC, the FAA, and APS.

Table 2.1: Calendar of Tests

Date	Number of Test Runs	Test Numbers
17-Jan-11	Setup and Calib.	n/a
18-Jan-11	4	1, 2, 3, 4
19-Jan-11	7	5, 5A, 6, 7, 8, 9, 10
20-Jan-11	7	11, 12, 13, 14, 15, 15A, 15B
21-Jan-11	1	16
22-Jan-11	3	17,18, 19
23-Jan-11	8	20, 21, 22, 23, 24, 25, 26, 27
24-Jan-11	13	28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40
25-Jan-11	13	41, 41A, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52
26-Jan-11	10	53, 54, 55, 56, 57, 58, 59, 60, 61
27-Jan-11	9	62, 63, 64, 64A, 65, 66, 67, 68, 69
28-Jan-11	7	70, 71, 72, 73, 74, 75, 76
29-Jan-11	No Tests Conducted	n/a
30-Jan-11	2	77, 78
31-Jan-11	10	79, 80, 81, 82, 83, 84, 85, 86, 86A, 87
01-Feb-11	9	88, 89, 90, 91, 92, 92A, 93, 94, 95
02-Feb-11	10	95A, 96, 97, 98, 99, 100, 101, 102, 103, 104
03-Feb-11	8	105, 106, 107, 108, 108A, 109, 110, 111
04-Feb-11	No Tests Conducted	n/a
05-Feb-11	No Tests Conducted	n/a
06-Feb-11	No Tests Conducted	n/a
07-Feb-11	8	112, 113, 114, 115, 116, 117, 118, 119
08-Feb-11	9	120, 121, 122, 123, 124, 125, 126, 127, 127A
09-Feb-11	7	128, 129, 130, 131, 132, 133, 134
10-Feb-11	3	135, 136, 137
11-Feb-11	Teardown	n/a

2.3 Wind Tunnel Procedure

To satisfy the program objective, simulated takeoff and climb-out tests were performed with the supercritical wing section, and different parameters, including fluid thickness, wing temperature, and fluid freezing point, were recorded at designated times during the tests. The supercritical wing section was constructed by the NRC specifically to conduct these tests following extensive consultations with an airframe manufacturer to ensure a representative supercritical design.

The procedure for each test was as follows:

a) The wing section was treated with anti-icing fluid, poured in a one-step operation (no Type I fluid was used during the tests);

b) Contamination, in the form of simulated ice pellets, freezing rain, and/or snow, was applied to the wing section. Test parameters were measured at the beginning and end of the exposure to contamination; and

c) At the end of the contamination period, the tunnel was cleared of all equipment and scaffolding.

The wind tunnel was subsequently operated through a simulated takeoff and climb-out test. The behaviour of the fluid during takeoff and climb-out was recorded with digital high-speed still cameras. In addition, windows overlooking the wing section allowed observers to document the fluid elimination performance in real-time.

The procedure for the wind tunnel trials is included in Appendix B. The procedure includes details regarding the test objectives, test plan, procedure and methodology, and pertinent information and documentation.

2.4 Test Sequence

The length of each test (from start of setup to end of last measurement) varied largely due to the length of exposure to precipitation (if applicable). Time required for setup and teardown as well as preparing and configuring the wing section was relatively the same from test to test. Figure 2.2 demonstrates a sample timeline for a typical wind tunnel test. It should be noted that a precipitation exposure time of 30 minutes was used for demonstration purposes; this time varied for each test depending on the objective.

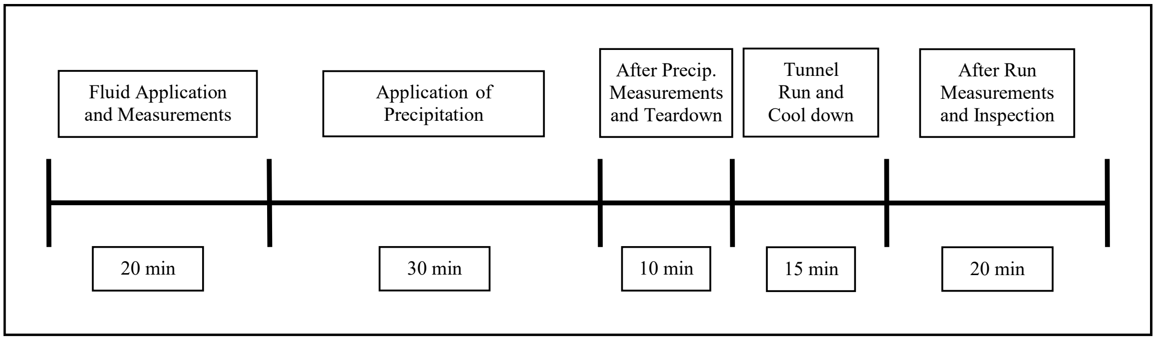


Figure 2.2: Typical Wind Tunnel Test Timeline

2.5 Wind Tunnel

The following sections describe the wind tunnel and major components.

2.5.1 Propulsion Icing Wind Tunnel

The experiments were performed in the NRC PIWT. This facility is an open-circuit wind tunnel with a fan at the entry, drawing air from and exhausting to the outdoors; this design is ideal for de/anti-icing tests as it prevents contaminants from recirculating within the tunnel. This design also permits sub-freezing air to be drawn in during the Ottawa winter, thereby providing test section temperatures appropriate for these experiments. The test section is 3 m (10 ft.) wide by 6 m (20 ft.) high by 12 m (40 ft.) long, with a maximum wind speed of 78 knots when using the electrical turbine drive and with a maximum wind speed of just over 115 knots when using the gas turbine drive. Scaffolding was constructed to allow access to the wing section, which facilitated the application of fluids and the subsequent inspection and cleaning of the airfoil.

2.5.2 Generic High-Performance “Supercritical” Commuter Airfoil

The wing section used for testing was a generic high-performance commuter airfoil, also referred to as “supercritical.” This wing section was constructed by the NRC in 2009 specifically to conduct these tests following extensive consultations with an airframe manufacturer to ensure a representative supercritical design. The original wing design was representative of an outboard section and did not include a flap; the flap was later added at the request of TC, the FAA, and APS. A CFD analysis of the modified wing section was conducted by the airframe manufacturer, and it was confirmed that the wing section provided a good representation of a flapped section of an operational supercritical wing. Photo 2.3 shows the wing section used for testing.

2.5.3 Generic "Supercritical" Wing Design Characteristics

A cross sectional view of the supercritical wing section used for testing has been included in Figure 2.3; the dimensions indicated are in metres. Some of the pertinent dimensions of the wing section are:

a) Chord length not including flap: 1.4 m (4.6 ft.); and
b) Width: 2.4 m (8 ft.).

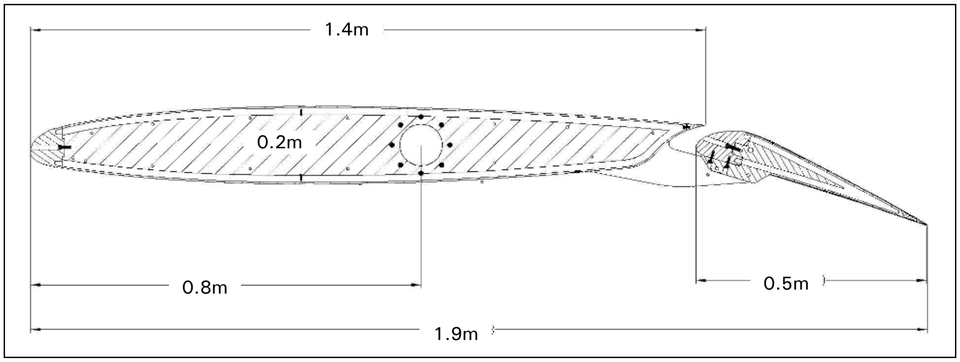


Figure 2.3: Generic "Supercritical" Wing Section

An analysis of the wing section model was conducted by the airframe manufacturer to determine the typical rest position of this type of wing section. It was determined that on a typical commuter aircraft, this section of wing would typically be pitched forward by 2° when sitting on the ground. As a result, the NRC ensured the rest position of the wing model was set to -2° for each test.

The wing section was fitted with a hinged flap. The flap position was fixed at 20° and was not intended to be changed during testing. The top surface of the flap wing section had a steeper angle; a flap setting of 20° created close to a 26° slope on the top surface of the flap (with the wing pitched forward by 2°). As testing progressed, the ability to change the flap setting from 0° to 20° was necessary; contrary to a nested flap, which is typically protected during precipitation, a hinged flap is always exposed, and results indicated earlier failures were due to the shallower angle of the hinged flap. Modifications were made by the NRC to allow the flap setting to alternate between 0° and 20° for the fluid application and contamination periods; however, all takeoff simulations were conducted with the flap set to 20°. No moveable devices were available on the wing section. Detailed coordinates for this airfoil are included in Appendix C.

End plates were installed on the wing section to eliminate the "wall effects" from the wind tunnel walls and to provide a better aerodynamic flow above the test area. Figure 2.4 demonstrates the end plates installed on the supercritical wing section (note: the wing section is depicted without the top wing skin).

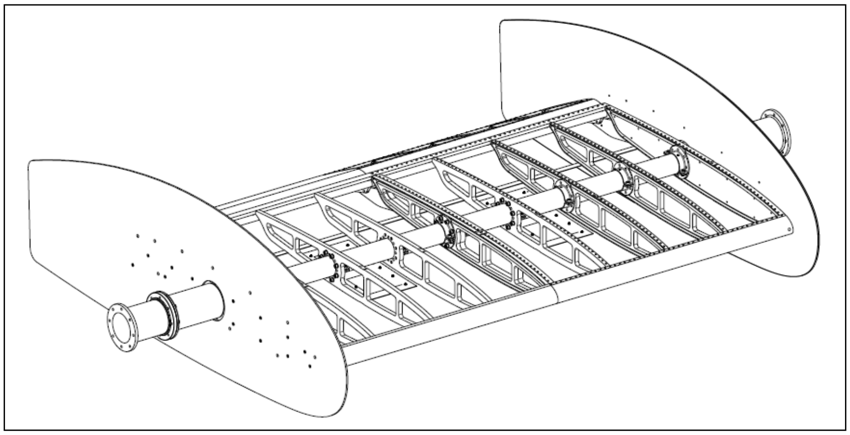


Figure 2.4: End Plates Installed on Supercritical Wing Section

2.5.4 Wind Tunnel Measurement Capabilities

The supercritical wing section was supported on either side by 2-axis weigh scales capable of measuring drag and lift forces generated on the wing section. The lift data collected for each test described in this report has been plotted as a function of time and is included in Appendix D. The wing section was attached to servo-systems capable of pitching the wing section to a static angle or generating dynamic movements. The servo-system was programmed to simulate pitch angles during takeoff and climb-out based on operational aircraft flight profiles.

The wing section was also equipped with eight Resistance Temperature Detectors (RTDs); these were installed by NRC personnel to record the skin temperature on the leading edge (LE), mid chord (MID), trailing edge (TE), and under-wing (UND). RTDs were placed along a chord 0.5 m (1.5 ft.) in pairs to the left and to the right of the wing centreline. The following are the locations of the RTDs:

- RTD LE located approximately 25 cm from the leading edge (as measured along wing skin curvature);
- RTD MID located approximately 70 cm from the leading edge (as measured along wing skin curvature);
- RTD TE located approximately 30 cm from the trailing edge (as measured along wing skin curvature); and
- RTD UND located approximately 45 cm from the leading edge.

Figure 2.5 demonstrates the general location of the RTDs. These RTDs were primarily used to monitor the skin temperature in real-time through the NRC data display system and were recorded by APS personnel as described in Section 2.15.3.

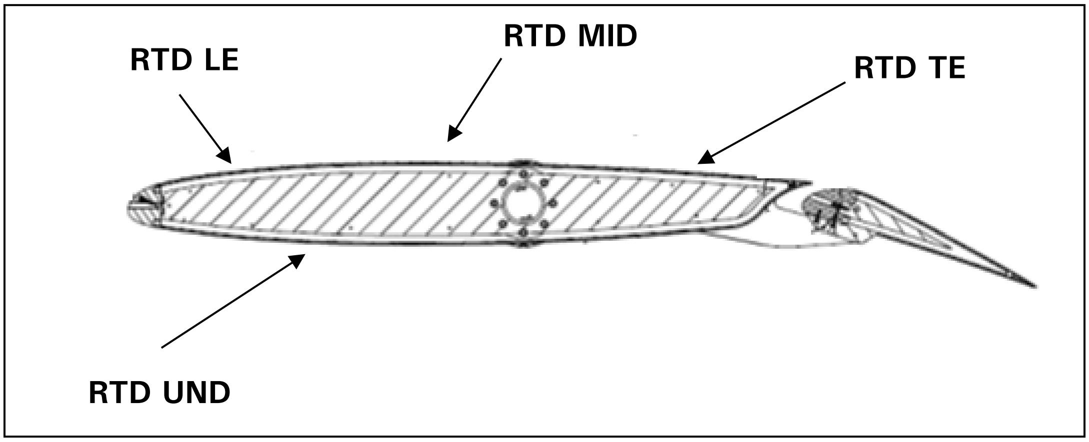


Figure 2.5: Location of RTDs Installed Inside Supercritical Wing

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

- Air temperature inside the tunnel;
- Outside air temperature;
- Air pressure;
- Wind speed; and
- Relative humidity.

2.5.5 Test Area Grid

Prior to the testing, APS personnel used markers to draw a grid on the wing upper surface (excluding the flap). Each grid cell measured 5.1 cm x 5.1 cm (2 in. x 2 in.) with the cell axis positioned perpendicular and parallel to the leading edge (see Photo 2.4). The grid section was 2.4 m (8 ft.), which covered the entire wing section. The grid markings began approximately 10.1 cm (4 in.) aft of the leading edge stagnation point and were continued along the length of the main chord; grid markings were not drawn on the flap section. The grid was used to facilitate observations of the fluid shearing off the wing and the movement of ice pellets during takeoff. Additional notes can be found in Appendix E.

2.6 Equipment

A considerable amount of test equipment was required to perform these tests. Key items are described in the following subsections; a full list of equipment is provided in the test procedure, which is included in Appendix B.

2.7 Simulated Precipitation

2.7.1 Ice Pellets

In a previous analysis of natural ice pellet events, the diameter of ice pellets was measured. It was found that ice pellets generally ranged from 1 mm to 3 mm. During moderate to heavy ice pellet conditions, the diameter of the ice pellets measured up to 5 mm. Based on this observation, ice pellets were produced with diameters ranging from 1.4 mm to 4.0 mm to represent the most common ice pellet sizes observed during natural events.

The ice pellets were manufactured inside a refrigerated truck (see Photo 2.5). Cubes of ice were crushed and passed through calibrated sieves (see Photo 2.6) to obtain the required ice pellet size range. Hand-held motorized dispensers were used to dispense the ice pellets. The ice pellets were applied to the leading and trailing edges of the wing at the same time.

2.7.2 Snow

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

The snow was manufactured inside a refrigerated truck. Cubes of ice were crushed and passed through calibrated sieves to obtain the required snow size range. Hand-held motorized dispensers were used to dispense the snow. The snow was applied to the leading and trailing edges of the wing at the same time.

2.7.3 Freezing Rain/Rain

The same sprayer head and scanner used for HOT testing at the NRC Climatic Engineering Facility was employed for testing. The sprayer system uses compressed air and distilled water to produce freezing rain. The temperature of the water is controlled and is kept just above freezing temperature in order to produce freezing rain. To produce rain, the temperature of the water is raised until the precipitation no longer freezes on the test surfaces.

2.8 Simulated Precipitation Related Equipment

2.8.1 Ice Pellet and Snow Dispenser

Calibration work was performed on the modified ice pellet/snow dispensers during the winter of 2007-08. The purpose of this calibration work was to determine the dispensers' distribution footprint when dispensing both ice pellets and snow. A series of tests were performed in various conditions:

1. Ice Pellets, Low Winds (0 km/h to 5 km/h);
2. Ice Pellets, Moderate Winds (10 km/h);
3. Snow, Low Wind (0 km/h to 5 km/h); and
4. Snow, Moderate Wind (10 km/h).

These tests were conducted using 121 collection pans, each measuring 15 cm x 15 cm, over an area 3.4 m x 3.4 m. Pre-measured amounts of IP/Snow were dispersed over this area, and the amount collected by each pan was recorded. A distribution footprint of the dispenser was attained, and efficiency for the dispenser was computed.

Using the results from these calibration tests, it was determined that the most appropriate distribution for the wind tunnel tests would be attained by using four dispensers (two on the leading edge, and two on the trailing edge) and by moving them through a cycle of four positions 0.3 m (1 ft.) apart; this essentially simulated sixteen dispensers positioned 0.3 m (1 ft.) apart along the leading and trailing edge of the wing.

Dispensing was done by placing known quantities of simulated ice pellets or snow into the dispensing bucket and allowing the dispenser to completely empty the contents over a set period of time (usually 1 minute). After the dispensing bucket was emptied, the dispenser was shifted over to the next of four positions per dispenser. The dispensers were re-filled every minute for the duration of the test (see Photo 2.7). The calculated efficiencies were accounted for when weighing the required amounts of ice pellets and snow. Details regarding the distribution pattern can be found in Attachments XI and XII of the wind tunnel procedure found in Appendix B.

During the winter of 2009-10, the methodology for dispensing snow was modified for tests requiring heavier snow intensities. Snow was dispensed manually by sifting snow directly onto the wing using calibrated sieves. This method was found to be more efficient and provided a more even application for cases where higher intensity snow precipitation rates were required.

2.8.2 Freezing Rain Sprayer

Simulated freezing rain was generated by the NRC freezing rain sprayer system. The same sprayer head and scanner used for HOT testing at the NRC Climatic Engineering Facility was employed for testing. The sprayer system uses compressed air and distilled water to produce freezing rain. Two hypodermic needles are mounted onto a sprayer head whose movement is controlled by a 2-axis scanner. Approximately 2 seconds are required for the sprayer to disperse across the 2.4 m (8 ft.) width of the wing. The spray pattern is an “S” shape form, and a total of 54 seconds is required to complete a full cycle. Two full cycles are required to completely cover the wing (the second cycle is offset to generate a more even distribution). The freezing rain sprayer is shown in Photo 2.8.

2.9 Definition of Precipitation Rates

When simulating precipitation rates for full-scale and plate testing, the rate limits defined for standard HOT testing were referenced. Figure 2.5 demonstrates the HOT testing rate precipitation breakdown.

HOT testing protocol for ice pellets does not currently exist. As a result, ice pellet precipitation rate limits were based upon the freezing rain rate breakdown. The following precipitation rates were used for the full-scale and flat plate testing conducted during the winter of 2010-11:

- Light Ice Pellets: 13-25 g/dm^2/h;
- Moderate Ice Pellets: 25-75 g/dm^2/h;
- Light Freezing Rain: 13-25 g/dm^2/h;
- Moderate Freezing Drizzle: 5-13 g/dm^2/h;
- Light Rain: 13-25 g/dm^2/h;
- Moderate Rain: 25-75 g/dm^2/h;
- Light Snow: 4-10 g/dm^2/h; and
- Moderate Snow 10-25 g/dm^2/h.

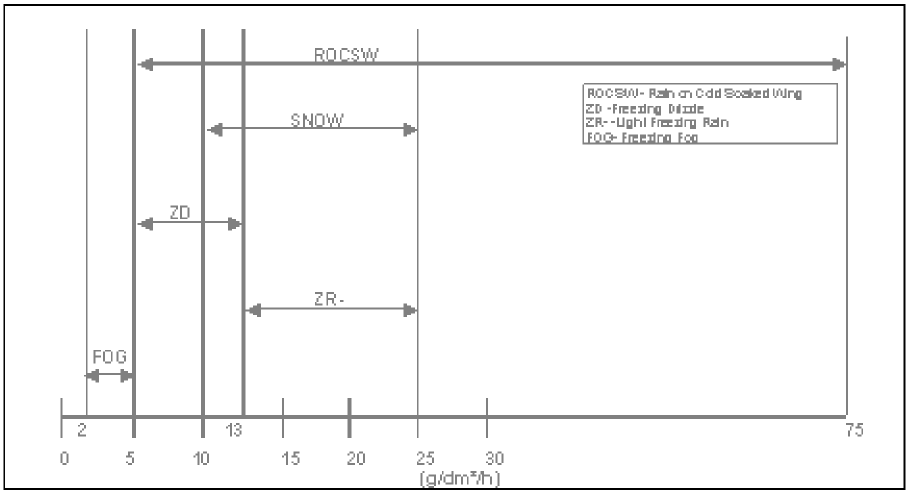


Figure 2.5: Precipitation Rate Breakdown

2.10 Video and Photo Equipment

Two Canon Digital Rebel XT digital still cameras were used to obtain high-speed, high-resolution photographs of the testing. The 8 mega-pixel resolution cameras are capable of taking up to three pictures per second in continuous shooting mode. As of 2009-10, the cameras were fitted with an intervalometer, and the frames were set at one per second; this reduced the storage size required for the photos while still providing sufficient detail of fluid flow-off. The cameras were fitted with 18-55 mm lenses.

To create a consistent and stable setup for the cameras, APS mounted the cameras in the observation window overlooking the wing section. The flashes, operated through radio-triggering sensors, were positioned in the opposing observation window; this created a shadow effect that could be used to measure and calculate the magnitude of the fluid waves and protruding contamination. An additional observation window was installed during the winter of 2009-10 directly overlooking the wing; the purpose was to allow observers to get a close look at the wing without interfering with the camera setup. Photos 2.9 and 2.10 demonstrate the camera setup used for the testing period.

The camera setup used during the winter of 2010-11 was similar to the setup used in 2009-10. The cameras were positioned to obtain a wide-angle view of the leading edge and close-up view of the trailing edge. In comparison to the 2006-07 and 2008-09 camera test setup, the positioning of the cameras was modified slightly due to the end plates installed on the wing and the wing geometry, both of which affected the camera view. During the 2006-07 tests, the cameras' primary focus was on the starboard section of the wing, whereas during the 2008-09 and 2009-10 tests, the primary focus point was on the center section of the wing; this was due to the restricted view points resulting from the changes in the wing setup. The trailing edge lens was also changed from a 105 mm macro lens (2006-07) to a 18-55 mm lens (2008-09 and 2009-10), as the primary focus point had been moved farther away from the camera. Additional information regarding the camera setup used can be found in Appendix F.

About midway through the 2010-11 testing, a requirement to shoot videos of the test runs became apparent during the wing stall runs. The still photos were not able to clearly demonstrate the wing buffeting and flow reversal effects. As a result, a hand-held camera with video recording capabilities was fitted onto the observation window overlooking the wing, and videos were taken of most of the test runs thereafter.

In addition, a professional photographer used a digital still camera to take pictures of the test setup and all phases of the test from both inside and outside the test section.

2.11 Additional Photos Taken During Precipitation Phase

In 2009-10, the cameras were fitted with an intervalometer to limit the number of frames taken during the high-speed run and to reduce the storage size of the photos. The same intervalometer was used for taking pictures during the precipitation phase. The cameras were set to trigger every minute and, during shorter tests, at shorter intervals as required. These photos proved to be useful for demonstrating the progression of contamination, as well as for reviewing and comparing tests. This protocol should be continued for future testing.

2.12 Type II/III/IV Fluid Application Equipment

The Type II/III/IV fluids were stored outside the wind tunnel and were kept at air temperature. The fluids were poured rather than sprayed so that application would not change the fluid viscosity. This methodology was appropriate, given the relatively small test area of the wing section and the goal of minimizing the amount of fluid flowing off the wing.

Type II/III/IV fluids were generally received in 20 L containers; however, during the 2010-11 testing, some select fluids were received in large 200 L barrels and larger 1000 L totes. The fluid was applied to the wing section by using smaller 2 L containers (see Photo 2.11). Approximately 16 L to 20 L of fluid were applied to the wing section for each test; less fluid was required for the less viscous Type II and III fluids. Due to the flat top surface of the supercritical wing, the thickened fluid did not easily settle and flow on the top surface. The wing was therefore tilted forward (by approximately 10 degrees) for 1 minute following the end of fluid application to allow for the fluid to spread out evenly over the top surface of the wing.

2.13 Waste Fluid Collection

Using a relatively small test area and applying the fluids by pouring minimized the amount of fluid falling off the wing. APS personnel used a vacuum to collect the fluid that would drip onto the tunnel floor prior to each test. The NRC also fitted the wind tunnel with appropriate drainage tubes to collect spent fluid during the takeoff test runs. At the end of the testing period, the services of Safety-Kleen were employed to safely dispose of the waste glycol fluid.

2.14 Personnel

NRC personnel operated the wind tunnel. Five APS staff members were required to conduct the tests, and four additional persons from Ottawa were hired to manufacture and dispense ice pellets as well as to help with general setup tasks. A professional photographer was retained to record digital images of the test setup and test runs. Representatives from the TDC and the FAA provided direction in testing and participated as observers. Photo 2.12 shows a portion of the 2010-11 research team (due to scheduling, not all participants were available for the photo).

2.15 Measurement of Test Parameters

2.15.1 Measurement Locations

For each test, the fluid thickness, skin temperature, and fluid Brix were measured at eight locations along the center chord. Measurements were taken during four stages of a typical test:

a) Before fluid application;
b) After fluid application;
c) After application of contamination; and
d) After the simulated takeoff test.

The locations designated for measurement, identified in Figure 2.6, were the following:

- Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
- Wing Position 2: Approximately 25 cm up from the leading edge stagnation point;
- Wing Position 3: Approximately 40 cm up from the leading edge stagnation point;
- Wing Position 4: Approximately 55 cm up from the leading edge stagnation point;
- Wing Position 5: Approximately 70 cm up from the leading edge stagnation point;
- Wing Position 6: Approximately 30 cm from the trailing edge;
- Wing Position 7: Approximately 15 cm from the trailing edge;
- Wing Position 8: Approximately 2.5 cm from the trailing edge;
- Wing Position 9: Midway up the flap; and
- Underside: Approximately 40 cm up from the leading edge stagnation point.

The wing positions were measured along the curvature of the wing.

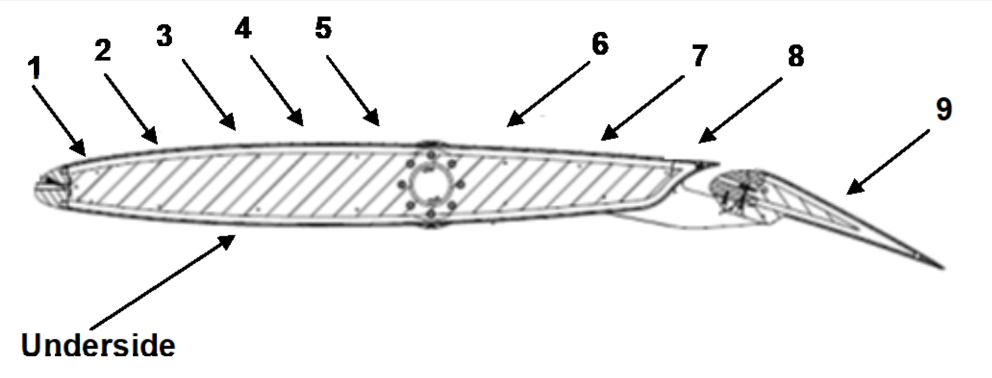


Figure 2.6: Measurement Locations Along Chord of Supercritical Wing Section

2.15.2 Fluid Thickness

Fluid thickness was measured using wet film thickness gauges at three stages of a typical test:

a) After fluid application;
b) After application of contamination; and
c) After the simulated takeoff test.

The locations designated for fluid thickness measurements, identified in Figure 2.6, were the following:

- Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
- Wing Position 2: Approximately 25 cm up from the leading edge stagnation point;
- Wing Position 3: Approximately 40 cm up from the leading edge stagnation point;
- Wing Position 4: Approximately 55 cm up from the leading edge stagnation point;
- Wing Position 5: Approximately 70 cm up from the leading edge stagnation point;
- Wing Position 6: Approximately 30 cm from the trailing edge;
- Wing Position 7: Approximately 15 cm from the trailing edge;
- Wing Position 8: Approximately 2.5 cm from the trailing edge;
- Wing Position 9: Midway up the flap; and
- Underside: Approximately 40 cm up from the leading edge stagnation point.

The wing positions were measured along the curvature of the wing. Photo 2.13 shows the fluid thickness gauges used for the testing.

2.15.3 Wing Skin Temperature

During the winter of 2009-10 and prior, wing temperatures were measured using a hand-held temperature probe at three locations during four stages of a typical test:

a) Before fluid application;
b) After fluid application;

c) After application of contamination; and

d) After the simulated takeoff test.

The locations designated for skin temperature measurements, identified in Figure 2.6, were the following:

• Wing Position 2:	Approximately 25 cm up from the leading edge stagnation point;
• Wing Position 5:	Approximately 70 cm up from the leading edge stagnation point; and
• Underside:	Approximately 40 cm up from the leading edge stagnation point.

The wing positions were measured along the curvature of the wing. Photo 2.14 shows the skin temperature probe used for the testing.

During the Winter 2009-10 testing, the hand-held measurements were compared to the NRC-monitored data from the RTDs located inside the wing (see Subsection 2.5.3). The average of the temperatures recorded by the pairs of RTDs denoted by RTD LE, RTD MID, and RTD UND were comparable to the manual measurements taken by APS using a hand-held temperature probe on positions 2, 5, and underside, respectively. Therefore, early on, the manual measurements were replaced by the data logged by the NRC (APS recorded an instantaneous average value from the NRC data at the required intervals for analysis purposes). The average instantaneous temperature indicated by the three pairs of RTDs (located to the left and right of the centreline) were recorded for each of the three locations where APS typically measured skin temperature. This methodology was continued for the winter of 2010-11, and the collection of manual skin temperature measurements was eliminated.

2.15.4 Fluid Brix

Fluid Brix was measured using hand-held refractometers at three stages of a typical test:

a) After fluid application;

b) After application of contamination; and

c) After the simulated takeoff test.

The locations designated for fluid Brix measurements, identified in Figure 2.6, were the following:

- Wing Position 2: Approximately 25 cm up from the leading edge stagnation point; and
- Wing Position 5: Approximately 70 cm up from the leading edge stagnation point.

The wing positions were measured along the curvature of the wing. Figure 2.7 and Photo 2.15 shows the hand-held Brixometer used for the testing.

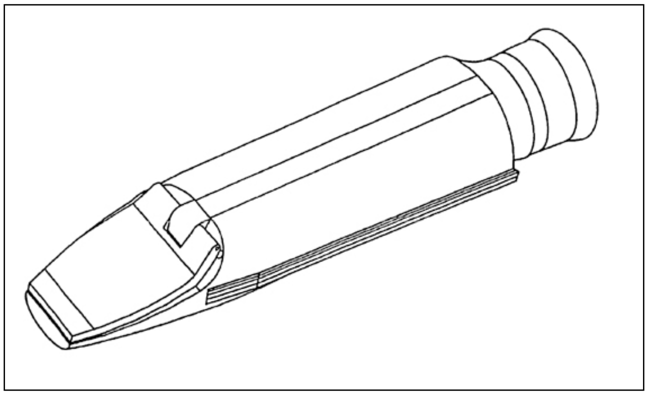


Figure 2.7: Hand-Held Brixometer

2.16 Data Forms

Several different forms were used to facilitate the documentation of the various data collected in the wind tunnel tests. These forms include:

a) General Form;
b) Wing Temperature, Fluid Thickness and Fluid Brix Form;
c) Ice Pellet and Snow Dispensing Forms;
d) Sprayer Calibration Form;
e) Visual Evaluation Rating Form
f) Condition of Wing and Plate Form;
g) Fluid Receipt Form; and
h) Log of Fluid Sample Bottles.

Copies of these forms are provided in the test procedure, which is included in Appendix B.

2.17 General Methodology

This section describes equipment and general information used for the wind tunnel tests. A considerable amount of test equipment was required to perform these tests. Key items are described in the following subsections; a full list of equipment is provided in the test procedure, which is included in Appendix B.

2.17.1 Refractometer

Fluid freezing points were measured using a hand-held Misco 10431VP refractometer with a Brix scale. The freezing points of the various fluid samples were determined using the conversion curve or table provided to APS by the fluid manufacturer. The following tables contain the fluid freezing points for the various fluids tested and the relevant conversion data.

- Table 2.2 - Kilfrost ABC-S Plus
- Table 2.3 - Clariant MPIII 2031 ECO
- Table 2.4 - Clariant MPIV Launch
- Table 2.5 - Brix to Refractive Index Conversion Table

Figure 2.8 illustrates the fluid freezing points for the Dow EG 106 fluid. It should be noted that conversion tables were not included for Dow AD-49 and Octagon Maxflight; however, the dilution curve would be very similar to Tables 2.2 to 2.5.

2.17.2 Temperature Sensor

When required, wing skin temperature and fluid temperature were measured using a Wahl digital heat-probe thermometer Model 392Vxc. A surface temperature probe was used for wing skin temperature measurements (generally, wing-mounted RTDs were used), and an immersion probe was used for measuring and monitoring fluid temperatures.

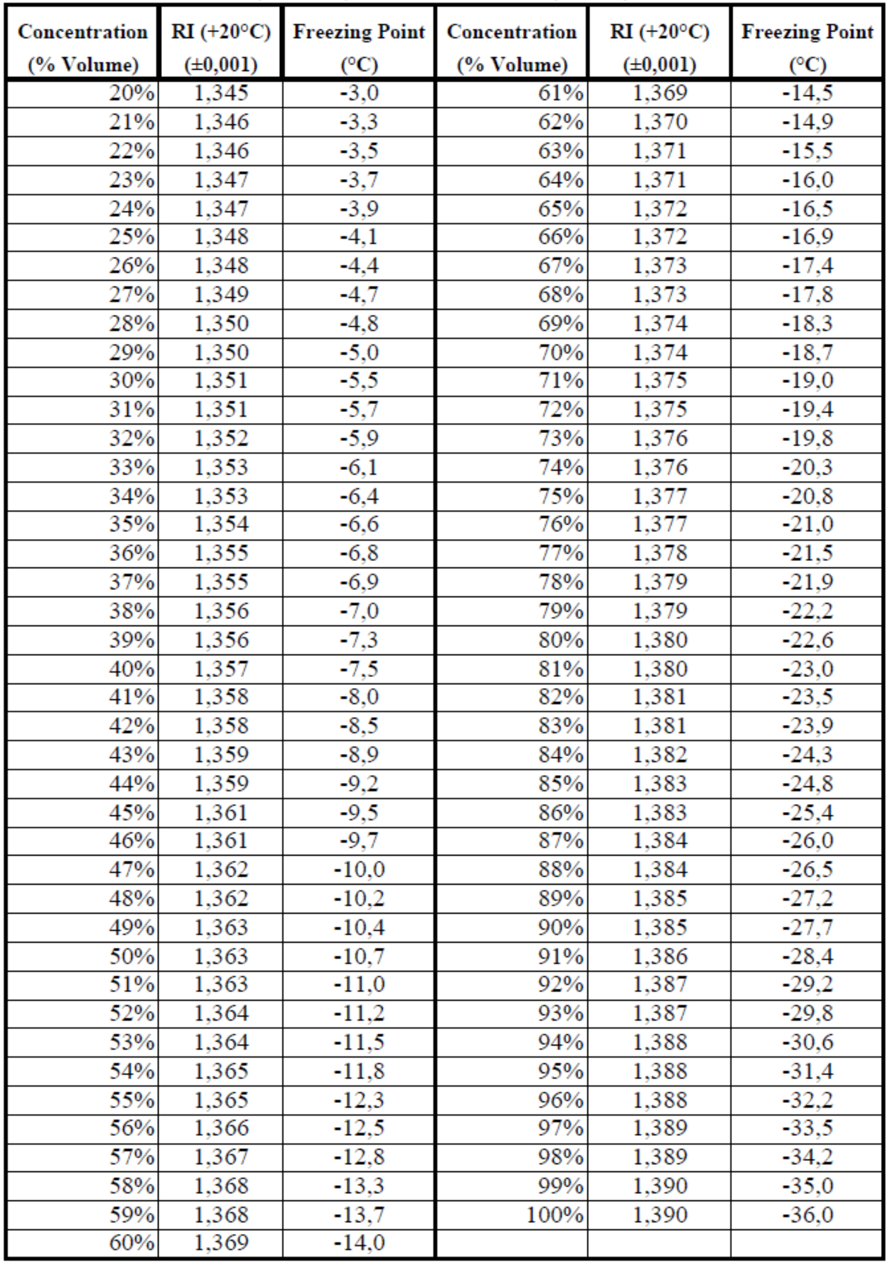
Table 2.2: Freezing Point vs. Brix of Aqueous Solutions of Kilfrost ABC-S Plus

Conc. (% Vol)	BRIX (20°C)	RI (20°C)	Freezing Point (20°C)		Conc. (% Vol)	BRIX (20°C)	RI (20°C)	Freezing Point (20°C)		Conc. (% Vol)	BRIX (20°C)	RI (20°C)	Freezing Point (20°C)
20%	8.20	1.345	-3.4		**50%**	**18.90**	**1.362**	**-10.6**		80%	29.40	1.380	-23.1
21%	8.59	1.345	-3.6		51%	19.26	1.363	-11.1		81%	29.73	1.380	-23.7
22%	8.98	1.346	-3.8		52%	19.62	1.364	-11.6		82%	30.06	1.381	-24.2
23%	9.37	1.346	-4.0		53%	19.98	1.364	-12.0		83%	30.36	1.382	-24.8
24%	9.76	1.347	-4.2		54%	20.34	1.365	-12.4		84%	30.72	1.382	-25.4
25%	10.15	1.348	-4.4		55%	20.70	1.365	-12.8		85%	31.05	1.383	-26.0
26%	10.54	1.348	-4.6		56%	21.06	1.366	-13.1		86%	31.38	1.383	-26.7
27%	10.93	1.349	-4.9		57%	21.42	1.366	-13.4		87%	31.71	1.384	-27.3
28%	11.32	1.349	-5.1		58%	21.78	1.367	-13.8		88%	32.04	1.384	-28.0
29%	11.71	1.350	-5.3		59%	22.14	1.368	-14.1		89%	32.37	1.385	-28.6
30%	12.10	1.351	-5.5		60%	22.50	1.368	-14.5		90%	32.70	1.386	-29.3
31%	12.43	1.351	-5.8		61%	22.85	1.369	-14.9		91%	33.02	1.386	-30.1
32%	12.76	1.352	-6.0		62%	23.20	1.369	-15.2		92%	33.34	1.387	-30.8
33%	13.09	1.352	-6.3		63%	23.55	1.370	-15.7		93%	33.66	1.387	-31.5
34%	13.42	1.353	-6.5		64%	23.90	1.371	-16.0		94%	33.98	1.388	-32.2
35%	13.75	1.354	-6.8		65%	24.25	1.371	-16.4		95%	34.30	1.389	-33.0
36%	14.08	1.354	-7.0		66%	24.60	1.372	-16.8		96%	34.62	1.389	-33.8
37%	14.41	1.355	-7.3		67%	24.95	1.372	-17.2		97%	34.94	1.390	-34.6
38%	14.74	1.355	-7.6		68%	25.30	1.373	-17.6		98%	35.26	1.391	-35.4
39%	15.07	1.356	-7.9		69%	25.65	1.373	-18.0		99%	35.58	1.391	-36.2
40%	15.40	1.356	-8.1		70%	26.00	1.374	-18.4		**100%**	**35.90**	**1.392**	**-37.0**
41%	15.75	1.357	-8.4		71%	26.34	1.375	-18.9					
42%	16.10	1.358	-8.7		72%	26.68	1.375	-19.3					
43%	16.45	1.358	-9.0		73%	27.02	1.376	-20.0					
44%	16.80	1.359	-9.3		74%	27.36	1.376	-20.7					
45%	17.15	1.359	-9.5		**75%**	**27.70**	**1.377**	**-21.4**					
46%	17.50	1.360	-9.8		76%	28.04	1.378	-21.7					
47%	17.85	1.361	-10.0		77%	28.38	1.379	-22.0					
48%	18.20	1.361	-10.2		78%	28.72	1.379	-22.3					
49%	18.55	1.362	-10.4		79%	29.06	1.379	-22.6					

Table 2.3: Dilution Chart for Clariant MPIII 2031 ECO

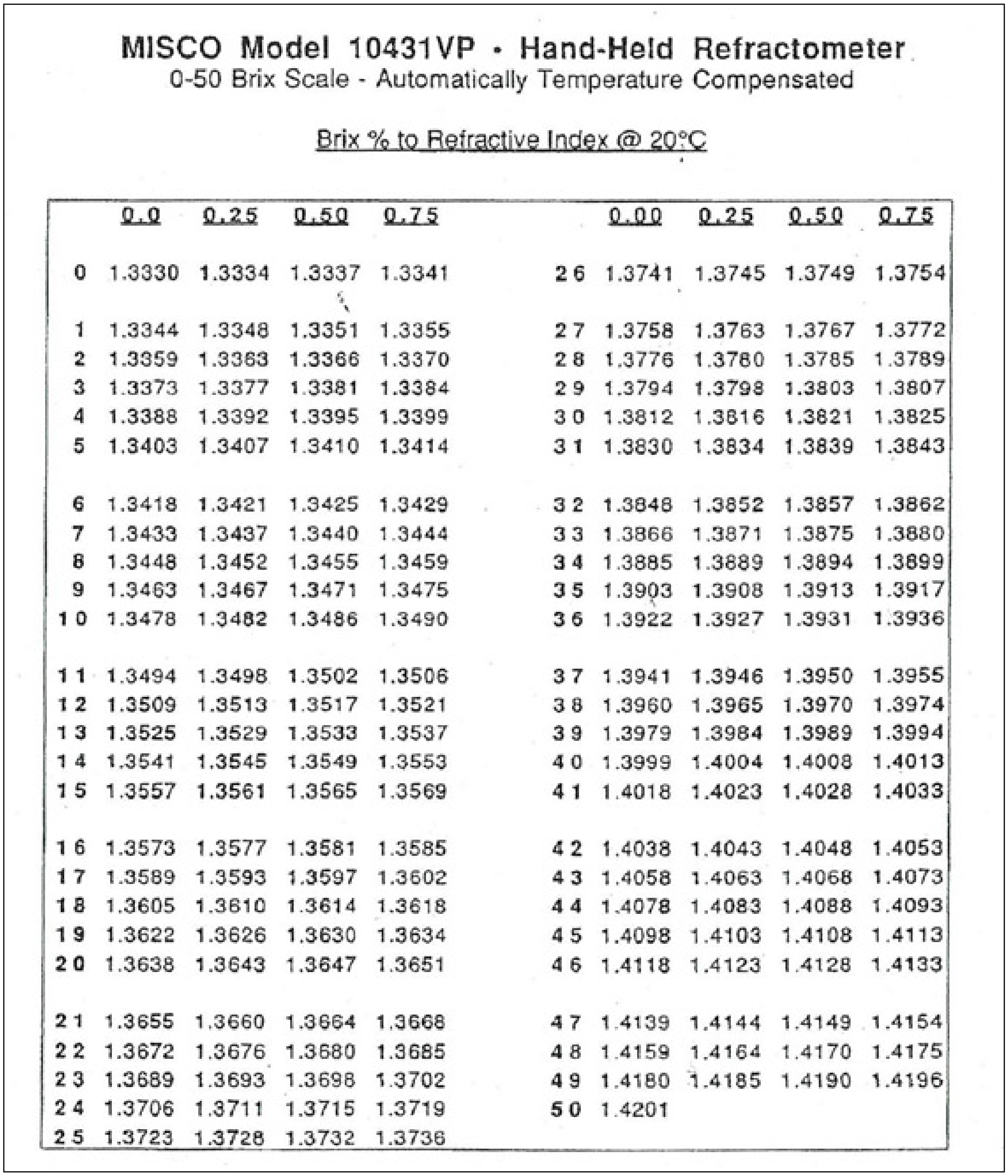
DILUTION (v/v) Safewing : Water	**BRIX (°)** MISCO 10431 VP	**FREEZING POINT (°C)**
100 : 0	34.3 to 36.0	-31 to -34
95 : 5	33.4	-29
90 : 10	31.8	-26
85 : 15	30.2	-23
80 : 20	28.8	-21
75 : 25	27.2	-18
70 : 30	25.4	-16
65 : 35	24.0	-14
60 : 40	22.2	-12
55 : 45	20.4	-11
50 : 50	18.8	-10

Table 2.4: Dilution Chart for Clariant MPIV Launch



Concentration (% Volume)	RI (+20°C) (±0,001)	Freezing Point (°C)	Concentration (% Volume)	RI (+20°C) (±0,001)	Freezing Point (°C)
20%	1,345	-3,0	61%	1,369	-14,5
21%	1,346	-3,3	62%	1,370	-14,9
22%	1,346	-3,5	63%	1,371	-15,5
23%	1,347	-3,7	64%	1,371	-16,0
24%	1,347	-3,9	65%	1,372	-16,5
25%	1,348	-4,1	66%	1,372	-16,9
26%	1,348	-4,4	67%	1,373	-17,4
27%	1,349	-4,7	68%	1,373	-17,8
28%	1,350	-4,8	69%	1,374	-18,3
29%	1,350	-5,0	70%	1,374	-18,7
30%	1,351	-5,5	71%	1,375	-19,0
31%	1,351	-5,7	72%	1,375	-19,4
32%	1,352	-5,9	73%	1,376	-19,8
33%	1,353	-6,1	74%	1,376	-20,3
34%	1,353	-6,4	75%	1,377	-20,8
35%	1,354	-6,6	76%	1,377	-21,0
36%	1,355	-6,8	77%	1,378	-21,5
37%	1,355	-6,9	78%	1,379	-21,9
38%	1,356	-7,0	79%	1,379	-22,2
39%	1,356	-7,3	80%	1,380	-22,6
40%	1,357	-7,5	81%	1,380	-23,0
41%	1,358	-8,0	82%	1,381	-23,5
42%	1,358	-8,5	83%	1,381	-23,9
43%	1,359	-8,9	84%	1,382	-24,3
44%	1,359	-9,2	85%	1,383	-24,8
45%	1,361	-9,5	86%	1,383	-25,4
46%	1,361	-9,7	87%	1,384	-26,0
47%	1,362	-10,0	88%	1,384	-26,5
48%	1,362	-10,2	89%	1,385	-27,2
49%	1,363	-10,4	90%	1,385	-27,7
50%	1,363	-10,7	91%	1,386	-28,4
51%	1,363	-11,0	92%	1,387	-29,2
52%	1,364	-11,2	93%	1,387	-29,8
53%	1,364	-11,5	94%	1,388	-30,6
54%	1,365	-11,8	95%	1,388	-31,4
55%	1,365	-12,3	96%	1,388	-32,2
56%	1,366	-12,5	97%	1,389	-33,5
57%	1,367	-12,8	98%	1,389	-34,2
58%	1,368	-13,3	99%	1,390	-35,0
59%	1,368	-13,7	100%	1,390	-36,0
60%	1,369	-14,0			

Table 2.5: Brix to Refractive Index Conversion Chart



MISCO Model 10431VP • Hand-Held Refractometer

0-50 Brix Scale - Automatically Temperature Compensated

Brix % to Refractive Index @ 20°C

	0.0	0.25	0.50	0.75		0.00	0.25	0.50	0.75
0	1.3330	1.3334	1.3337	1.3341	26	1.3741	1.3745	1.3749	1.3754
1	1.3344	1.3348	1.3351	1.3355	27	1.3758	1.3763	1.3767	1.3772
2	1.3359	1.3363	1.3366	1.3370	28	1.3776	1.3780	1.3785	1.3789
3	1.3373	1.3377	1.3381	1.3384	29	1.3794	1.3798	1.3803	1.3807
4	1.3388	1.3392	1.3395	1.3399	30	1.3812	1.3816	1.3821	1.3825
5	1.3403	1.3407	1.3410	1.3414	31	1.3830	1.3834	1.3839	1.3843
6	1.3418	1.3421	1.3425	1.3429	32	1.3848	1.3852	1.3857	1.3862
7	1.3433	1.3437	1.3440	1.3444	33	1.3866	1.3871	1.3875	1.3880
8	1.3448	1.3452	1.3455	1.3459	34	1.3885	1.3889	1.3894	1.3899
9	1.3463	1.3467	1.3471	1.3475	35	1.3903	1.3908	1.3913	1.3917
10	1.3478	1.3482	1.3486	1.3490	36	1.3922	1.3927	1.3931	1.3936
11	1.3494	1.3498	1.3502	1.3506	37	1.3941	1.3946	1.3950	1.3955
12	1.3509	1.3513	1.3517	1.3521	38	1.3960	1.3965	1.3970	1.3974
13	1.3525	1.3529	1.3533	1.3537	39	1.3979	1.3984	1.3989	1.3994
14	1.3541	1.3545	1.3549	1.3553	40	1.3999	1.4004	1.4008	1.4013
15	1.3557	1.3561	1.3565	1.3569	41	1.4018	1.4023	1.4028	1.4033
16	1.3573	1.3577	1.3581	1.3585	42	1.4038	1.4043	1.4048	1.4053
17	1.3589	1.3593	1.3597	1.3602	43	1.4058	1.4063	1.4068	1.4073
18	1.3605	1.3610	1.3614	1.3618	44	1.4078	1.4083	1.4088	1.4093
19	1.3622	1.3626	1.3630	1.3634	45	1.4098	1.4103	1.4108	1.4113
20	1.3638	1.3643	1.3647	1.3651	46	1.4118	1.4123	1.4128	1.4133
21	1.3655	1.3660	1.3664	1.3668	47	1.4139	1.4144	1.4149	1.4154
22	1.3672	1.3676	1.3680	1.3685	48	1.4159	1.4164	1.4170	1.4175
23	1.3689	1.3693	1.3698	1.3702	49	1.4180	1.4185	1.4190	1.4196
24	1.3706	1.3711	1.3715	1.3719	50	1.4201			
25	1.3723	1.3728	1.3732	1.3736					

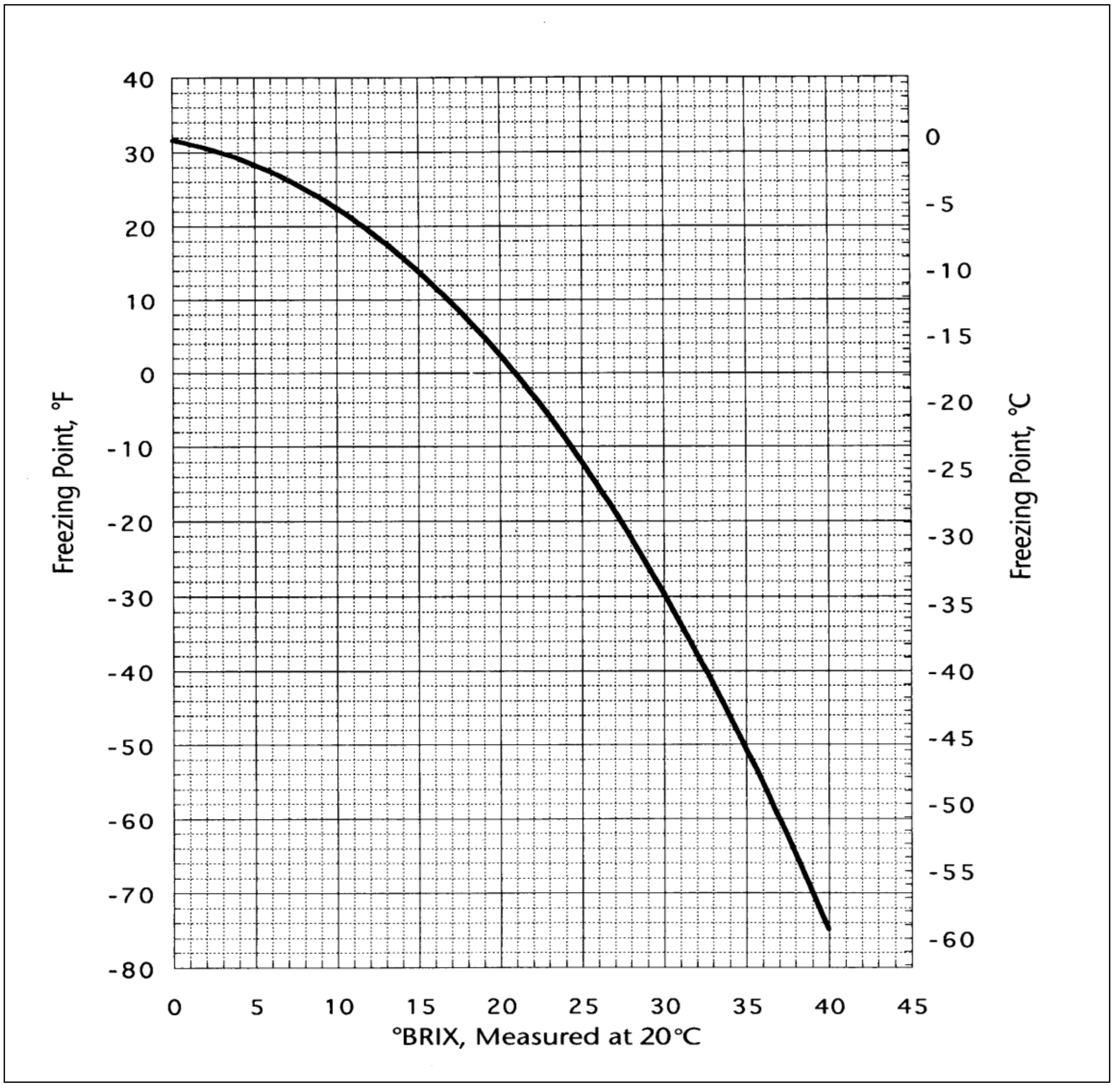


Figure 2.8: Freezing Point vs. Brix of Aqueous Solutions of Dow EG106

2.17.3 Thickness Gauges

Wet film thickness gauges, shown in Figure 2.9, were used to measure fluid film thickness. These gauges were selected because they provide an adequate range of thicknesses (0.1 mm to 10.2 mm) for Type I/II/III/IV fluids. The rectangular gauge shown in Figure 2.8 has a finer scale and was used in some cases when the fluid film was thinner (toward the end of a test). The observer recorded a thickness value (in mils), as read directly from the thickness gauge. The recorded value was the last wetted tooth of the thickness gauge; however, the true thickness lies between the last wetted tooth and the next un-wetted tooth. A thickness conversion table (shown in Table 2.6) was used to convert the recorded thickness values into the corrected thickness values.

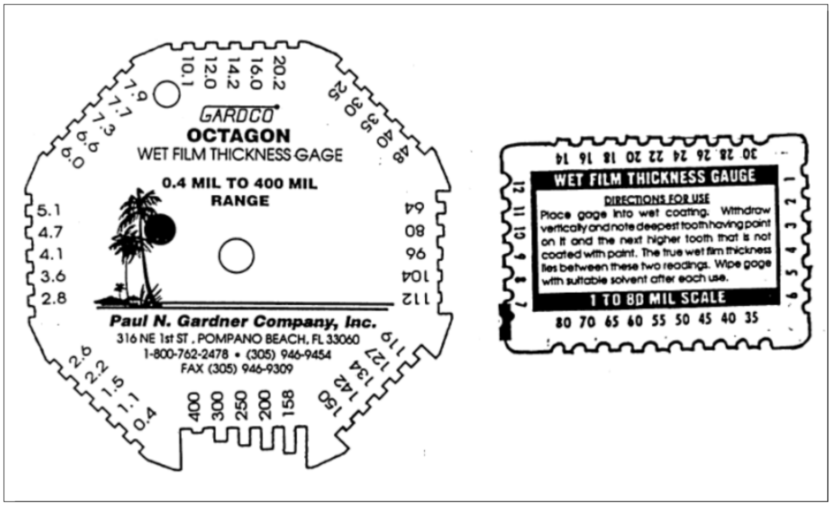


Figure 2.9: Thickness Gauges

2.17.4 Viscometer

Historically, viscosity measurements were carried out using a Brookfield viscometer (Model DV-1+, shown in Photo 2.16) fitted with a recirculating fluid bath and small sample adapter.

In recent years, on-site measurements are done with the Stony Brook PDVdi-120 Falling Ball Viscometer (Photo 2.17) to obtain a verification of the fluid integrity. Falling ball tests are much faster and convenient to perform compared to tests with the Brookfield viscometer.

2.17.5 Fluids

Six fluids were used during the wind tunnel tests conducted during the winter of 2010-11. The fluid used for testing was at mid-production viscosity. The viscosity of the fluids received was measured using the Stony Brook PDVdi-120 Falling Ball Viscometer to ensure the fluid was within the fluid manufacturer production specifications and comparable to previous samples received. The pertinent characteristics of these fluids are given in Table 2.7.

Table 2.6: Film Thickness Conversion Table

RECTANGULAR GAUGE			OCTAGON GAUGE		
Reading*	Calculated Thickness		Reading*	Calculated Thickness	
(mil)	(mil)	(mm)	(mil)	(mil)	(mm)
			0.4	0.8	0.0
1.0	1.5	0.0	1.1	1.3	0.0
			1.5	1.9	0.0
2.0	2.5	0.1	2.2	2.4	0.1
			2.6	2.7	0.1
3.0	3.5	0.1	2.8	3.2	0.1
			3.6	3.9	0.1
4.0	4.5	0.1	4.1	4.4	0.1
			4.7	4.9	0.1
5.0	5.5	0.1	5.1	5.6	0.1
6.0	6.4	0.2	6.0	6.4	0.2
			6.6	7.0	0.2
7.0	7.5	0.2	7.3	7.5	0.2
8.0	8.5	0.2	7.7	7.8	0.2
9.0	9.5	0.2	7.9	9.0	0.2
10	11	0.3	10	11	0.3
11	12	0.3			
12	13	0.3	12	13	0.3
14	15	0.4	14	15	0.4
16	18	0.4	16	18	0.4
18	19	0.5			
20	21	0.5	20	23	0.6
22	23	0.6			
24	25	0.6	25	28	0.7
26	27	0.7			
28	29	0.7			
30	33	0.8	30	33	0.8
35	38	1.0	35	38	1.0
40	43	1.1	40	43	1.1
45	48	1.2			
50	53	1.3	48	56	1.4
55	58	1.5			
60	63	1.6			
65	68	1.7	64	72	1.8
70	73	1.8			
75	78	2.0			
80	88	2.2	80	88	2.2
			96	100	2.5
			104	108	2.7
			112	116	2.9
			119	123	3.1
			127	131	3.3
			134	138	3.5
			142	146	3.7
			150	154	3.9
			158	179	4.5
			200	225	5.7
			250	275	7.0
			300	350	8.9
			400	400	10.2

* Reading of last wetted tooth.

Table 2.7: Test Fluids

	Wind Tunnel 2010-11			Wind Tunnel 2009-10			Wind Tunnel 2008-09		
Fluid Name	**Temp (°C)**	**Time (sec.)**	**Brix**	**Temp (°C)**	**Time (sec.)**	**Brix**	**Temp (°C)**	**Time (sec.)**	**Brix**
Dow Chemical Company EG106	23	53		22.7	48	31.6	22.5	47	33
	22	55					22.7	39	32.9
Kilfrost Limited ABC-S PLUS	22	33	36.25	22.3	26	35.8	22.9	26	36.5
	22	31							
	21.5	30	36.25						
	21.5	33							
Clariant Produkte Launch	21	31	35.75	22.6	31	35.7	23.6	30	35.1
	21	28					23.8	27	35.5
Clariant Produkte 2031	22	3	35.75	22.9	9	35.5	24.7	3	35.4
	22	4			<1		23.7	3	35.7
Dow Chemical Company AD-49	22.1	22	36.5						
	22.2	23							
Octagon Process Inc. MaxFlight	22.5	19	36						
	22.4	19							

Photo 2.1: Outside View of NRC Wind Tunnel Facility

Photo 2.2: Inside View of NRC Wind Tunnel Test Section

Photo 2.3: Supercritical Wing Section Used for Testing

Photo 2.4: Grid Markings on Supercritical Wing Section

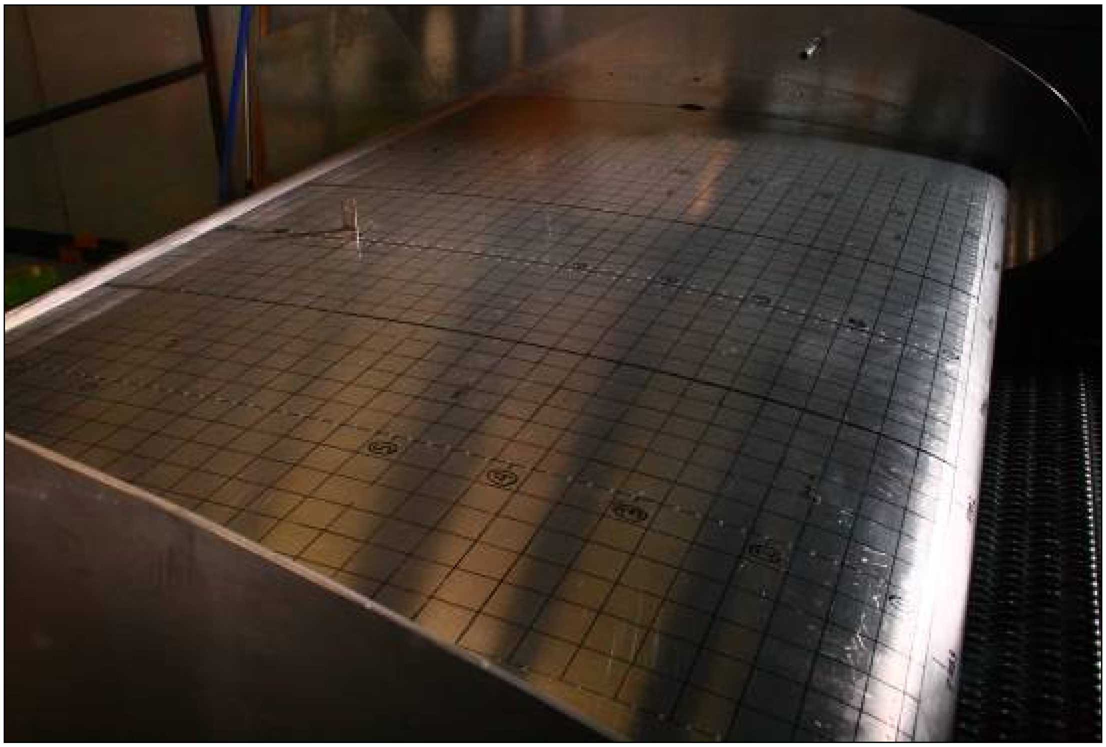


Photo 2.5: Refrigerated Truck Used for Manufacturing Ice Pellets

Photo 2.6: Calibrated Sieves Used to Obtain Desired Size Distribution

Photo 2.7: Ice Pellet Dispensers Operated by APS Personnel

Photo 2.8: Ceiling-Mounted Freezing Rain Sprayer

Photo 2.9: Wind Tunnel Setup for Flashes

Photo 2.10: Wind Tunnel Setup for Digital Cameras

Photo 2.11: Fluid Pour Containers

Photo 2.12: 2010-11 Research Team

Photo 2.13: Wet Film Thickness Gauges

Photo 2.14: Hand-Held Temperature Probe

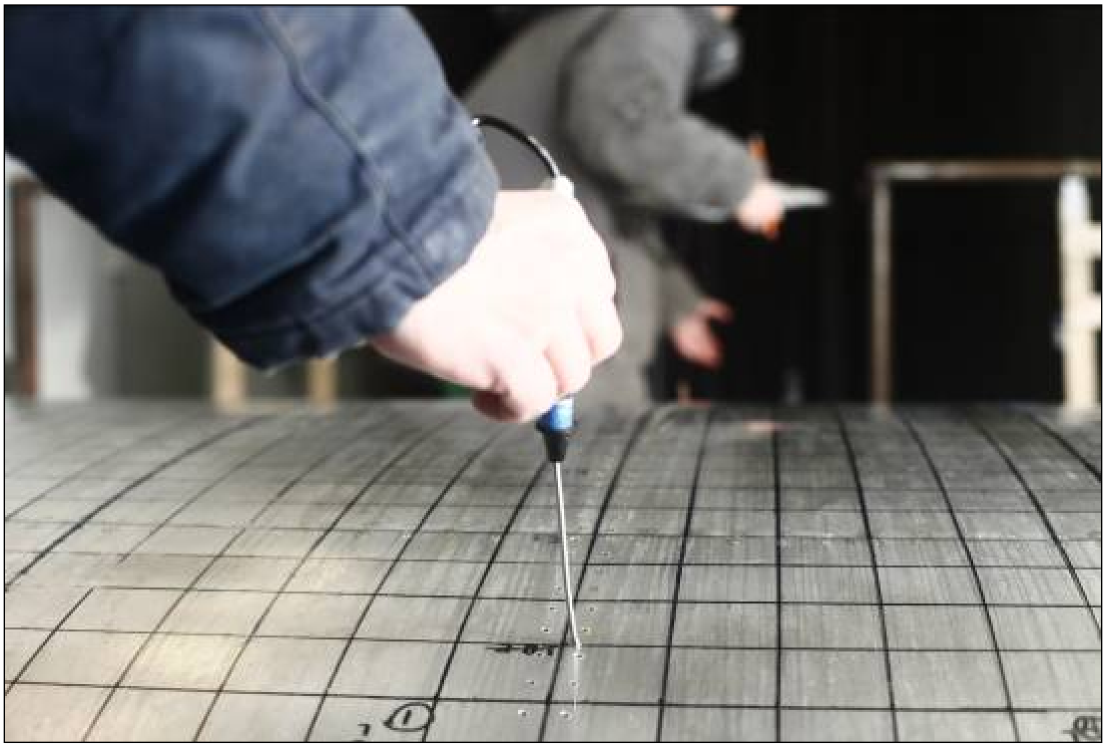


Photo 2.15: Hand-Held Brixometer (Misco 10431VP)

Photo 2.16: Brookfield Digital Viscometer Model DV-1+

Photo 2.17: Stony Brook PDVdi-120 Falling Ball Viscometer

This page intentionally left blank.

3. FULL-SCALE DATA COLLECTED

3.1 Test Log

A calendar of the tests conducted during the winters 2009-10 and 2010-11 can be found in Table 2.1. A detailed log of the tests conducted in the NRC PIWT is shown in Table 3.1; only data pertaining to the test objectives described in this report are included (see Table 1.2 for additional details). Table 3.1 provides relevant information for each of the tests, as well as final values used for the data analysis. Each column contains data specific to one test. The following is a brief description of the column headings for Table 3.1:

Run #:	Exclusive number identifying each test run.
Year:	The year in which the test was conducted.
Objective:	Main objective of the test.
Test Condition:	Description of the simulated conditions for the test.
Fluid:	Aircraft anti-icing fluid used during the test.
Rotation Angle:	Maximum angle of rotation obtained during simulated takeoff run; began testing with a max 8° rotation angle and increased to 20° as testing progressed.
Flap Angle:	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended). *Note: Flap was always extended at 20° during the takeoff run.*
Date:	Date when the test was conducted.
Precipitation End Time:	End time of the application of precipitation, recorded in local time.
Tunnel Start Time:	Start of the simulated takeoff run, recorded in local time.
OAT Before Test (°C):	Outside air temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius. *Note: Not an important parameter as "Tunnel Temp. Before Test" was used as actual test temperature for analysis.*

Tunnel Temp. Before Test (ºC):	Static tunnel air temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius. *Note: This parameter was used as the actual test temperature for analysis.*
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Precipitation Rate (Type: [g/dm^2/h]):	Simulated freezing precipitation rate (or combination of different precipitation rates). "N/A" indicates that no precipitation was applied.
Exposure Time:	Simulated precipitation period, recorded in minutes.

The visual contamination ratings are described below. Visual contamination ratings were typically reported as the average of the three observer ratings and rounded to the nearest decimal. The visual contamination ratings system is further described in Subsection 4.1.

Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present.

	3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating After Takeoff (LE, TE, Flap):	Visual contamination rating determined at the end of the test: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
CL at 0° Before Rotation:	Calculated lift coefficient at the 0° wing angle position just prior to the start of the rotation; data provided by the NRC.
CL at 8° During Rotation:	Calculated lift coefficient at the 8° wing rotation angle position; data provided by the NRC.
CL at 4° Following End of Rotation:	Calculated lift coefficient at the 4° wing rotation angle position attained at the end of the rotation cycle; data provided by the NRC.
% Lift Loss:	Percentage lift loss calculated based on the comparison of the 8° lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).

Table 3.1: Wind Tunnel Test Log 2010-11

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation Rate (g/dm^2/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
1	2010-11	**Dry Wing**	**None**	**None**	**8**	**20**	**18-Jan-11**	**N/A**	**N/A**	**-8.6**	**-6.9**	**N/A**	**-**	**-**	**-, -, -**	**-, -, -**	**-, -, -**	**-**	**1.274**	**1.442**	**-**	**-1.41**
2	2010-11	**Dry Wing**	**None**	**None**	**8**	**20**	**18-Jan-11**	**N/A**	**N/A**	**-8.6**	**-5.9**	**N/A**	**-**	**-**	**-, -, -**	**-, -, -**	**-, -, -**	**-**	**1.252**	**1.43**	**-**	**-0.56**
3	2010-11	**Dry Wing**	**None**	**None**	**16**	**20**	**18-Jan-11**	**N/A**	**N/A**	**-8.6**	**-4.6**	**N/A**	**-**	**-**	**-, -, -**	**-, -, -**	**-, -, -**	**-**	**1.262**	**1.438**	**-**	**-1.13**
5	2010-11	**Baseline (BLDT)**	**None**	**AD-49**	**8**	**20**	**19-Jan-11**	**N/A**	**8:53**	**-12.3**	**-10.3**	**-8.5**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**N/A**	**N/A**	**-**	**-**
5A	2010-11	**Baseline (BLDT)**	**None**	**AD-49**	**8**	**20**	**19-Jan-11**	**N/A**	**9:39**	**-12.4**	**-10.4**	**-8.2**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.167**	**1.367**	**-**	**3.87**
6	2010-11	**Type IV Fluid Val.**	**IP-**	**AD-49**	**8**	**20**	**19-Jan-11**	**10:40**	**10:47**	**-12.6**	**-10.9**	**-8.4**	**IP:25**	**30**	**2.4 , 2.5 , 3.3**	**1.1 , 2 , 2.3**	**1 , 1.2 , 1.25**	**-**	**1.163**	**1.321**	**-**	**7.10**
7	2010-11	**Type IV Fluid Val.**	**IP Mod**	**AD-49**	**8**	**20**	**19-Jan-11**	**11:30**	**11:37**	**-12.2**	**-10.4**	**-11.3**	**IP:75**	**10**	**2.7 , 2.7 , 3.4**	**1.3 , 2.2 , 2.4**	**1 , 1.3 , 1.4**	**-**	**1.171**	**1.321**	**-**	**7.10**
8	2010-11	**115 Knots Val.**	**IP-**	**AD-49**	**8**	**20**	**19-Jan-11**	**12:52**	**12:59**	**-11.4**	**-8.5**	**-10.5**	**IP:25**	**30**	**2.5 , 2.3 , 3.25**	**1 , 1.7 , 1.9**	**1 , 1.25 , 1.6**	**-**	**1.221**	**1.381**	**-**	**2.88**
9	2010-11	**Baseline (BLDT)**	**None**	**AD-49**	**8**	**20**	**19-Jan-11**	**N/A**	**14:00**	**-10**	**-6.7**	**-6.1**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.226**	**1.387**	**-**	**2.46**
10	2010-11	**Type IV Fluid Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**19-Jan-11**	**15:14**	**15:22**	**-9.7**	**-6.8**	**-10.3**	**IP:75**	**25**	**3.5 , 3.5 , 3.9**	**1 , 1.6 , 1.7**	**1 , 1 , 1**	**-**	**1.222**	**1.393**	**-**	**2.04**
12	2010-11	**Baseline (BLDT)**	**None**	**Max-Flight**	**8**	**20**	**20-Jan-11**	**N/A**	**9:19**	**-16**	**-14.2**	**-12.3**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.181**	**1.336**	**-**	**6.05**
13	2010-11	**Type IV Fluid Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**20-Jan-11**	**10:04**	**10:09**	**-15**	**-12.4**	**-13.9**	**IP:75**	**10**	**2.3 , 2.5 , 3.3**	**1 , 1.3 , 1.7**	**1 , 1 , 1.5**	**-**	**1.221**	**1.369**	**-**	**3.73**
14	2010-11	**Type IV Fluid Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**20-Jan-11**	**10:46**	**10:51**	**-14.2**	**-12.3**	**-13.8**	**IP:75**	**10**	**2.3 , 2.5 , 3.3**	**1.4 , 2.5 , 3**	**1 , 1 , 1.2**	**-**	**1.139**	**1.308**	**-**	**8.02**
15	2010-11	**115 Knots Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**20-Jan-11**	**11:32**	**11:38**	**-13.3**	**-10.8**	**-13.3**	**IP:75**	**10**	**2.3 , 2.3 , 3.2**	**1 , 1.3 , 1.4**	**1 , 1 , 1.1**	**-**	**1.188**	**1.355**	**-**	**4.71**
15A	2010-11	**115 Knots Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**20-Jan-11**	**12:18**	**12:23**	**-12.8**	**-10.4**	**-12.5**	**IP:75**	**10**	**2.3 , 2.3 , 2.9**	**1 , 1 , 1.3**	**1 , 1 , 1**	**-**	**1.216**	**1.378**	**-**	**3.09**
15B	2010-11	**115 Knots Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**20-Jan-11**	**13:06**	**13:10**	**-12.7**	**-10.8**	**-12.1**	**IP:75**	**10**	**2.4 , 2.3 , 2.9**	**1 , 1.4 , 1.5**	**1 , 1 , 1.1**	**-**	**1.167**	**1.347**	**-**	**5.27**
20	2010-11	**115 Knots Val.**	**IP-**	**ABC-S+**	**8**	**20**	**23-Jan-11**	**1:24**	**1:28**	**-20**	**-17.5**	**-15.9**	**IP:25**	**30**	**2.5 , 2.75 , 3.5**	**1.15 , 1.5 , 2**	**1 , 1 , 1.25**	**-**	**1.134**	**1.286**	**-**	**8.27**

Table 3.1: Wind Tunnel Test Log 2010-11 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation Rate ($g/dm^2/h$)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
21	2010-11	**Baseline (BLDT)**	**None**	**ABC-S+**	**8**	**20**	**23-Jan-11**	**N/A**	**2:07**	**-20.4**	**-18.2**	**-16.4**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.154**	**1.31**	**-**	**6.56**
22	2010-11	**IP Data Gap**	**IP-**	**ABC-S+**	**8**	**20**	**23-Jan-11**	**3:07**	**3:14**	**-21.3**	**-19.3**	**-17.7**	**IP:25**	**30**	**2.75 , 2.75 , 3.5**	**1.4 , 2 , 2.75**	**1 , 1.15 , 1.5**	**-**	**1.101**	**1.251**	**-**	**10.77**
23	2010-11	**115 Knots Val.**	**IP-**	**Launch**	**8**	**20**	**23-Jan-11**	**5:28**	**5:32**	**-23.6**	**-21.5**	**-20**	**IP:25**	**30**	**3 , 2.75 , 4**	**1.4 , 2 , 2.75**	**1 , 1.1 , 1.35**	**-**	**1.148**	**1.301**	**-**	**7.20**
24	2010-11	**IP Data Gap**	**IP-**	**Launch**	**8**	**20**	**23-Jan-11**	**6:34**	**6:38**	**-24.7**	**-22.5**	**-21.2**	**IP:25**	**30**	**3 , 2.75 , 4**	**1.2 , 2 , 2.5**	**1.05 , 1.15 , 1.5**	**-**	**1.137**	**1.299**	**-**	**7.35**
25	2010-11	**IP Data Gap**	**IP Mod**	**ABC-S+**	**8**	**20**	**23-Jan-11**	**22:34**	**22:37**	**-25.1**	**-22.3**	**-21.2**	**IP:75**	**10**	**2.75 , 2.75 , 4**	**1.6 , 2 , 2.75**	**1.1 , 1.2 , 2.35**	**-**	**1.085**	**1.251**	**-**	**10.77**
26	2010-11	**IP Data Gap**	**IP Mod**	**EG 106**	**8**	**20**	**23-Jan-11**	**23:19**	**23:24**	**-25.4**	**-21**	**-21**	**IP:75**	**10**	**2.35 , 2.35 , 3**	**1 , 1.2 , 1.5**	**1 , 1 , 1.1**	**-**	**1.197**	**1.359**	**-**	**3.07**
27	2010-11	**IP Data Gap**	**IP-**	**EG 106**	**8**	**20**	**23-Jan-11**	**0:22**	**0:24**	**-26.4**	**-22.6**	**-21.3**	**IP:25**	**30**	**2.35 , 2.35 , 3**	**1 , 1.2 , 1.5**	**1 , 1 , 1.1**	**-**	**1.208**	**1.357**	**-**	**3.21**
28	2010-11	**115 Knots Val.**	**IP Mod**	**Launch**	**8**	**20**	**24-Jan-11**	**0:59**	**1:01**	**-27.3**	**-24.5**	**-22.5**	**IP:75**	**10**	**3 , 3 , 4**	**1.25 , 1.75 , 2.25**	**1 , 1.1 , 1.35**	**-**	**1.151**	**1.296**	**-**	**7.56**
29	2010-11	**Baseline (BLDT)**	**None**	**Launch**	**8**	**20**	**24-Jan-11**	**N/A**	**1:26**	**-27.4**	**-23.9**	**-21.1**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.157**	**1.31**	**-**	**6.56**
30	2010-11	**Baseline (BLDT)**	**None**	**ABC-S+**	**8**	**20**	**24-Jan-11**	**N/A**	**1:54**	**-27.1**	**-23.5**	**-22.4**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.125**	**1.288**	**-**	**8.13**
31	2010-11	**115 Knots Val.**	**IP Mod**	**ABC-S+**	**8**	**20**	**24-Jan-11**	**2:30**	**2:33**	**-27.2**	**-22.8**	**-21.8**	**IP:75**	**10**	**3 , 2.75 , 3.75**	**1.35 , 2 , 2.75**	**1 , 1.15 , 1.45**	**-**	**1.101**	**1.256**	**-**	**10.41**
32	2010-11	**Baseline (BLDT)**	**None**	**AD-49**	**8**	**20**	**24-Jan-11**	**N/A**	**3:44**	**-27.1**	**-22.5**	**-22.4**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.208**	**1.347**	**-**	**3.92**
33	2010-11	**Baseline (BLDT)**	**None**	**Max-Flight**	**8**	**20**	**24-Jan-11**	**N/A**	**4:23**	**-27.4**	**-24.1**	**-22.6**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.138**	**1.286**	**-**	**8.27**
34	2010-11	**Baseline (BLDT)**	**None**	**EG 106**	**8**	**20**	**24-Jan-11**	**N/A**	**4:57**	**-27.4**	**-23.3**	**-22.7**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.185**	**1.342**	**-**	**4.28**
35	2010-11	**Type IV Fluid Val.**	**IP-**	**AD-49**	**8**	**20**	**24-Jan-11**	**5:55**	**5:59**	**-27.6**	**-23.2**	**-21.5**	**IP:25**	**30**	**3 , 3 , 4**	**1.35 , 2 , 2.5**	**1.1 , 1.25 , 1.6**	**-**	**1.154**	**1.313**	**-**	**6.35**
36	2010-11	**Baseline (BLDT)**	**None**	**2031**	**8**	**20**	**24-Jan-11**	**N/A**	**6:31**	**-27.7**	**-24.5**	**-22**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.184**	**1.323**	**-**	**5.63**
37	2010-11	**Type IV Fluid Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**24-Jan-11**	**7:09**	**7:12**	**-28.5**	**-24.5**	**-23.2**	**IP:75**	**10**	**3 , 3 , 4**	**1.35 , 1.75 , 2.25**	**1 , 1.1 , 1.35**	**-**	**1.124**	**1.266**	**-**	**9.70**

Table 3.1: Wind Tunnel Test Log 2010-11 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation Rate (g/dm^2/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
38	**2010-11**	**115 Knots Val.**	**IP Mod**	**ABC-S+**	**8**	**20**	**24-Jan-11**	**7:48**	**7:54**	**-28.3**	**-24.2**	**-23.2**	**IP:75**	**10**	**3 , 3 , 4**	**1.2 , 1.5 , 2**	**1 , 1.15 , 1.5**	**-**	**1.1**	**1.259**	**-**	**10.20**
39	**2010-11**	**Baseline (BLDT)**	**None**	**Max-Flight**	**8**	**20**	**24-Jan-11**	**N/A**	**22:41**	**-21.1**	**-16**	**-17.3**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.142**	**1.301**	**-**	**7.20**
40	**2010-11**	**Type IV Fluid Val.**	**IP-**	**Max-Flight**	**8**	**20**	**24-Jan-11**	**23:39**	**23:42**	**-21**	**-15.2**	**-15**	**IP:25**	**30**	**3 , 3 , 3.5**	**1.2 , 2 , 2.5**	**1 , 1.1 , 1.35**	**-**	**1.01**	**1.264**	**-**	**9.84**
41	**2010-11**	**Type IV Fluid Val.**	**IP Mod**	**AD-49**	**8**	**20**	**25-Jan-11**	**0:19**	**0:57**	**-20.6**	**-16.5**	**-16.1**	**IP:75**	**10**	**3.1 , 3 , 4**	**1.1 , 1.5 , 2**	**1 , 1.1 , 1.25**	**-**	**N/A**	**N/A**	**-**	**-**
41A	**2010-11**	**Type IV Fluid Val.**	**IP Mod**	**AD-49**	**8**	**20**	**25-Jan-11**	**0:54**	**0:57**	**-20.6**	**-15.4**	**-16.2**	**IP:75**	**10**	**3 , 3.1 , 4**	**1.1 , 2 , 2.75**	**1 , 1.2 , 1.35**	**-**	**1.159**	**1.323**	**-**	**5.63**
42	**2010-11**	**Baseline (BLDT)**	**None**	**AD-49**	**8**	**20**	**25-Jan-11**	**N/A**	**1:25**	**-20.5**	**-15.7**	**-16.3**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.186**	**1.352**	**-**	**3.57**
43	**2010-11**	**Baseline (BLDT)**	**None**	**EG 106**	**8**	**20**	**25-Jan-11**	**N/A**	**2:07**	**-20.2**	**-15**	**-16**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.204**	**1.359**	**-**	**3.07**
44	**2010-11**	**IP Expansion**	**IP- / SN**	**EG 106**	**8**	**20**	**25-Jan-11**	**2:50**	**3:00**	**-19.8**	**-13.2**	**-15.4**	**IP:25 , SN:25**	**10**	**2.25 , 2 , 3.5**	**1.15 , 1.35 , 1.1**	**1 , 1.1 , 1**	**-**	**1.214**	**1.362**	**-**	**2.85**
45	**2010-11**	**IP Expansion**	**IP- / SN-**	**EG 106**	**8**	**20**	**25-Jan-11**	**3:47**	**3:54**	**-19.4**	**-12.9**	**-15.7**	**IP:25 , SN:10**	**15**	**2.25 , 2 , 3**	**1 , 1.1 , 1.25**	**1 , 1 , 1**	**-**	**1.228**	**1.369**	**-**	**2.35**
46	**2010-11**	**IP Expansion**	**IP- / SN-**	**Launch**	**8**	**20**	**25-Jan-11**	**4:26**	**4:32**	**-19.1**	**-13.5**	**-13.8**	**IP:25 , SN:10**	**5**	**1.75 , 1.75 , 3**	**1.25 , 1.6 , 2.25**	**1 , 1 , 1.15**	**-**	**1.144**	**1.303**	**-**	**7.06**
47	**2010-11**	**IP Expansion / CL Max**	**IP- / SN**	**Launch**	**16**	**20**	**25-Jan-11**	**5:02**	**5:10**	**-19**	**-13.3**	**-14.9**	**IP:25 , SN:25**	**5**	**2.25 , 2 , 3.5**	**1.3 , 1.75 , 2.25**	**1 , 1.1 , 1.15**	**-**	**1.139**	**1.287**	**-**	**8.20**
48	**2010-11**	**Baseline (BLDT) / CL MAX**	**None**	**Launch**	**14**	**20**	**25-Jan-11**	**N/A**	**5:52**	**-18.7**	**-13.1**	**-14.4**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.206**	**1.345**	**-**	**4.07**
49	**2010-11**	**Baseline (BLDT)**	**None**	**2031**	**8**	**20**	**25-Jan-11**	**N/A**	**6:20**	**-18.7**	**-14.1**	**-16**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.186**	**1.352**	**-**	**3.57**
50	**2010-11**	**Baseline (BLDT)**	**None**	**2031**	**8**	**20**	**25-Jan-11**	**N/A**	**6:41**	**-18.5**	**-13.3**	**18.9**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.199**	**1.363**	**-**	**2.78**
51	**2010-11**	**Type IV Fluid Val.**	**IP-**	**EG 106**	**8**	**20**	**25-Jan-11**	**23:28**	**23:31**	**-16.2**	**-11.1**	**-12.9**	**IP:25**	**30**	**2.2 , 2 , 2.8**	**1 , 1.2 , 1.3**	**1 , 1 , 1.1**	**-**	**1.219**	**1.379**	**-**	**1.64**
52	**2010-11**	**Baseline (BLDT)**	**None**	**EG 106**	**8**	**20**	**25-Jan-11**	**N/A**	**0:01**	**-15.8**	**-13.4**	**-12.6**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.216**	**1.363**	**-**	**2.78**
53	**2010-11**	**Type IV Fluid Val.**	**IP-**	**ABC-S+**	**8**	**20**	**26-Jan-11**	**1:01**	**1:04**	**-15.6**	**-12.4**	**-12.8**	**IP:25**	**30**	**2.5 , 2.5 , 3.2**	**1.1 , 2 , 2.5**	**1 , 1.1 , 1.2**	**-**	**1.137**	**1.277**	**-**	**8.92**

Table 3.1: Wind Tunnel Test Log 2010-11 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation Rate ($g/dm^2/h$)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
54	**2010-11**	**Baseline (BLDT)**	**None**	**ABC-S+**	**8**	**20**	**26-Jan-11**	**N/A**	**1:33**	**-15.4**	**-12.1**	**-13.3**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.153**	**1.321**	**-**	**5.78**
55	**2010-11**	**Baseline (BLDT)**	**None**	**AD-49**	**8**	**20**	**26-Jan-11**	**N/A**	**2:04**	**-15**	**-11.4**	**-10.8**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.207**	**1.366**	**-**	**2.57**
56	**2010-11**	**Type IV Fluid Val.**	**IP- / SN-**	**AD-49**	**8**	**20**	**26-Jan-11**	**2:46**	**2:51**	**-14.6**	**-9.6**	**N/A**	**IP:25 , SN:10**	**15**	**3 , 2.8 , 4**	**1.5 , 2 , 2.5**	**1.1 , 1.7 , 1.9**	**-**	**1.149**	**1.307**	**-**	**6.78**
57	**2010-11**	**Baseline (BLDT)**	**None**	**Max-Flight**	**8**	**20**	**26-Jan-11**	**N/A**	**3:25**	**-14.5**	**-9.9**	**-11**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.152**	**1.306**	**-**	**6.85**
58	**2010-11**	**Type IV Fluid Val.**	**IP- / SN-**	**Max-Flight**	**8**	**20**	**26-Jan-11**	**4:10**	**4:14**	**-13.7**	**-11.2**	**-10.9**	**IP:25 , SN:10**	**15**	**2.3 , 2.3 , 3.2**	**1.3 , 1.7 , 2.2**	**1 , 1 , 1.2**	**-**	**1.148**	**1.295**	**-**	**7.63**
59	**2010-11**	**115 Knots Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**26-Jan-11**	**5:00**	**5:05**	**-13.7**	**-10.9**	**-12.5**	**IP:75**	**10**	**2.5 , 2.5 , 2.9**	**1.6 , 1.7 , 2.25**	**1 , 1 , 1**	**-**	**1.15**	**1.302**	**-**	**7.13**
59A	**2010-11**	**115 Knots Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**26-Jan-11**	**5:47**	**5:52**	**-13.9**	**-9.4**	**-12.4**	**IP:75**	**10**	**2.5 , 2.5 , 3**	**1.2 , 1.3 , 1.6**	**1 , 1 , 1.1**	**-**	**1.181**	**1.345**	**-**	**4.07**
60	**2010-11**	**Baseline (BLDT)**	**None**	**Launch**	**8**	**20**	**26-Jan-11**	**N/A**	**22:46**	**-7.4**	**-4.2**	**-4.2**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.168**	**1.336**	**-**	**4.71**
61	**2010-11**	**Baseline (BLDT)**	**None**	**Launch**	**8**	**20**	**26-Jan-11**	**N/A**	**23:24**	**-7.3**	**-3.5**	**-4.6**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.181**	**1.339**	**-**	**4.49**
62	**2010-11**	**Baseline (BLDT)**	**None**	**Launch**	**8**	**20**	**27-Jan-11**	**N/A**	**1:03**	**-7.4**	**-4.9**	**-4.3**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.191**	**1.35**	**-**	**5.06**
63	**2010-11**	**Baseline (BLDT)**	**None**	**Launch**	**8**	**20**	**27-Jan-11**	**N/A**	**1:32**	**-7.3**	**-4.5**	**-4.2**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.193**	**1.346**	**-**	**5.34**
65	**2010-11**	**Dry CL MAX**	**None**	**Dry**	**23**	**20**	**27-Jan-11**	**N/A**	**4:39**	**-6.1**	**-3.1**	**-2.8**	**-**	**-**	**-, -, -**	**-, -, -**	**-, -, -**	**-**	**1.27**	**1.418**	**-**	**0.28**
66	**2010-11**	**Baseline (BLDT)**	**None**	**Launch**	**23**	**23**	**27-Jan-11**	**N/A**	**5:10**	**-6.7**	**-4.3**	**-4.7**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.19**	**1.336**	**-**	**6.05**
67	**2010-11**	**Baseline (BLDT)**	**None**	**Launch**	**20**	**20**	**27-Jan-11**	**N/A**	**5:48**	**-6.9**	**-3.7**	**-5.1**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.182**	**1.346**	**-**	**5.34**
68	**2010-11**	**Baseline (BLDT)**	**None**	**AD-49**	**17**	**20**	**27-Jan-11**	**N/A**	**23:12**	**-5.7**	**-1.8**	**-1**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.219**	**1.37**	**-**	**3.66**
69	**2010-11**	**Type IV Fluid Val.**	**IP Mod**	**AD-49**	**18**	**20**	**27-Jan-11**	**0:20**	**0:25**	**-5.6**	**-3.6**	**-8.2**	**IP:75**	**25**	**3.3 , 2.8 , 3.7**	**1.2 , 1.6 , 1.6**	**1 , 1.4 , 1.2**	**-**	**1.195**	**1.362**	**-**	**4.22**
70	**2010-11**	**Type IV Fluid Val.**	**IP Mod**	**AD-49**	**18**	**20**	**28-Jan-11**	**1:13**	**1:17**	**-5.8**	**-4.2**	**-7.8**	**IP:75**	**15**	**2.3 , 2.5 , 3**	**1.2 , 1.6 , 1.6**	**1 , 1.1 , 1**	**-**	**1.208**	**1.366**	**-**	**3.94**

Table 3.1: Wind Tunnel Test Log 2010-11 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8 °CL vs. Dry CL)
71	**2010-11**	**Baseline (BLDT)**	**None**	**Max-Flight**	**18**	**20**	**28-Jan-11**	**N/A**	**1:57**	**-6**	**-3.7**	**-2.3**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.172**	**1.332**	**-**	**6.33**
72	**2010-11**	**Type IV Fluid Val.**	**IP Mod**	**Max-Flight**	**18**	**20**	**28-Jan-11**	**2:46**	**2:50**	**-6.9**	**-3.2**	**-6.5**	**IP:75**	**15**	**2.4 , 2.4 , 2.8**	**1 , 1.5 , 1.6**	**1 , 1 , 1**	**-**	**1.178**	**1.33**	**-**	**6.47**
73	**2010-11**	**Type IV Fluid Val.**	**IP- / SN**	**Max-Flight**	**18**	**20**	**28-Jan-11**	**3:38**	**3:44**	**-7.7**	**-4.2**	**N/A**	**IP:25 , SN:25**	**10**	**2.7 , 2.3 , 3.1**	**1 , 1.6 , 1.7**	**1 , 1 , 1**	**-**	**1.177**	**1.33**	**-**	**6.47**
74	**2010-11**	**Type IV Fluid Val.**	**IP- / SN-**	**Max-Flight**	**18**	**20**	**28-Jan-11**	**4:55**	**5:04**	**-8.4**	**-4.8**	**-6.8**	**IP:25 , SN:10**	**25**	**2.5 , 2.3 , 3**	**1 , 1.5 , 1.6**	**1 , 1 , 1**	**-**	**1.181**	**1.326**	**-**	**6.75**
75	**2010-11**	**Baseline (BLDT)**	**None**	**Max-Flight**	**8**	**20**	**28-Jan-11**	**N/A**	**5:42**	**-8.9**	**-5.8**	**-4.2**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.163**	**1.316**	**-**	**7.45**
76	**2010-11**	**Baseline (BLDT)**	**None**	**Max-Flight**	**18**	**20**	**28-Jan-11**	**N/A**	**6:12**	**-8.8**	**-5.5**	**-3.4**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.171**	**1.328**	**-**	**6.61**
77	**2010-11**	**Baseline (BLDT)**	**None**	**EG 106**	**16.5**	**20**	**30-Jan-11**	**N/A**	**22:48**	**-15.1**	**-11.8**	**-9.6**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.228**	**1.385**	**-**	**2.60**
78	**2010-11**	**IP Expansion**	**IP- / SN-**	**EG 106**	**8**	**20**	**30-Jan-11**	**23:35**	**23:45**	**-16.3**	**-13.8**	**-14.2**	**IP:25 , SN:10**	**25**	**2.7 , 2.2 , 4**	**1 , 1.6 , 1.8**	**1 , 1 , 1.2**	**-**	**1.247**	**1.384**	**-**	**2.67**
79	**2010-11**	**IP Expansion**	**IP- / SN**	**EG 106**	**8**	**20**	**31-Jan-11**	**0:32**	**0:40**	**-17.3**	**-15.1**	**-12.9**	**IP:25 , SN:25**	**15**	**2.8 , 2.6 , 4**	**1.1 , 1.4 , 1.8**	**1 , 1 , 1.2**	**-**	**1.223**	**1.379**	**-**	**3.02**
80	**2010-11**	**Baseline (BLDT)**	**None**	**ABC-S+**	**14.5**	**20**	**31-Jan-11**	**N/A**	**1:18**	**-18**	**-15.1**	**-12.3**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.167**	**1.323**	**-**	**6.96**
81	**2010-11**	**Baseline (BLDT)**	**None**	**ABC-S+**	**8**	**20**	**31-Jan-11**	**N/A**	**1:48**	**-18**	**-14.7**	**-12.4**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.171**	**1.321**	**-**	**7.10**
82	**2010-11**	**IP Expansion**	**IP- / SN-**	**ABC-S+**	**8**	**20**	**31-Jan-11**	**2:35**	**2:46**	**-18.7**	**-16**	**-13.8**	**IP:25 , SN:10**	**15**	**2.8 , 2.5 , 3.7**	**1.3 , 1.8 , 2.7**	**1 , 1.1 , 1.5**	**-**	**1.128**	**1.303**	**-**	**8.37**
83	**2010-11**	**IP Expansion**	**IP- / SN**	**ABC-S+**	**8**	**20**	**31-Jan-11**	**3:32**	**3:35**	**-19.6**	**-15.2**	**-13.3**	**IP:25 , SN:25**	**10**	**3 , 2.5 , 4**	**1.4 , 1.8 , 2.6**	**1.1 , 1.2 , 1.9**	**-**	**1.12**	**1.283**	**-**	**9.77**
84	**2010-11**	**IP Expansion**	**IP- / SN-**	**Launch**	**8**	**20**	**31-Jan-11**	**4:20**	**4:26**	**-20.3**	**-17.4**	**-15.1**	**IP:25 , SN:10**	**10**	**3 , 2.8 , 3.9**	**1.2 , 1.8 , 2.5**	**1 , 1.2 , 1.7**	**-**	**1.141**	**1.303**	**-**	**8.37**
85	**2010-11**	**IP Expansion**	**IP- / SN**	**Launch**	**8**	**20**	**31-Jan-11**	**5:07**	**5:15**	**-20.7**	**-17.4**	**-15.3**	**IP:25 , SN:25**	**5**	**2.6 , 2.5 , 3.5**	**1.1 , 1.7 , 2.3**	**1 , 1.1 , 1.6**	**-**	**1.145**	**1.307**	**-**	**8.09**
86	**2010-11**	**Baseline (BLDT)**	**None**	**2031**	**8**	**20**	**31-Jan-11**	**N/A**	**5:39**	**-20.7**	**-18**	**-14.7**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.169**	**1.335**	**-**	**6.12**
86A	**2010-11**	**Baseline (BLDT)**	**None**	**2031**	**8**	**20**	**31-Jan-11**	**N/A**	**6:03**	**-21.1**	**-17.9**	**-14.8**	**-**	**-**	**1 , 1 , 1**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.169**	**1.333**	**-**	**6.26**

Table 3.1: Wind Tunnel Test Log 2010-11 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation Rate ($g/dm^2/h$)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
92	2010-11	CL MAX/ IP VAL	IP Mod	ABC-S+		20	1-Feb-11	4:18	4:22	-17.3	-13.6	-13.1	IP:75	10	2.5 , 2.6 , 3.4	1.2 , 1.8 , 2.6	1 , 1 , 1	-	1.083	1.24	-	12.80
92A	2010-11	IP Val	IP Mod	ABC-S+	8	20	1-Feb-11	5:04	5:08	-17.1	-14.2	-14	IP:75	10	2.8 , 2.5 , 3.3	1.2 , 2 , 2.7	1 , 1.2 , 1.5	-	1.081	1.232	-	13.36
93	2010-11	CL MAX/ IP VAL	IP-	ABC-S+	18	20	1-Feb-11	6:10	6:13	-16.6	-12	-12.8	IP:25	30	2.6 , 1.8 , 3	1.2 , 1.8 , 1	1 , 1 , 1.1	-	1.11	1.282	-	9.85
94	2010-11	Baseline (BLDT)	None	Old 09-10	18	20	1-Feb-11	N/A	22:50	-14.4	-7.8	-7.2	-	-	1 , 1 , 1	1 , 1 , 1	1 , 1 , 1	-	1.227	1.395	-	1.90
95	2010-11	Baseline (BLDT)	None	EG 106	18	20	1-Feb-11	N/A	23:38	-14.4	-10.2	-7.4	-	-	1 , 1 , 1	1 , 1 , 1	1 , 1 , 1	-	1.22	1.37	-	3.66
95A	2010-11	Baseline (BLDT)	None	EG 106	18	20	2-Feb-11	N/A	0:24	-15.2	-10.4	-7.6	-	-	1 , 1 , 1	1 , 1 , 1	1 , 1 , 1	-	1.215	1.386	-	2.53
96	2010-11	Baseline (BLDT)	None	ABC-S+ Old 09-10	18	20	2-Feb-11	N/A	0:59	-14.6	-11.2	-9.1	-	-	1 , 1 , 1	1 , 1 , 1	1 , 1 , 1	-	1.198	1.346	-	5.34
97	2010-11	Baseline (BLDT)	None	ABC-S+	18	20	2-Feb-11	N/A	1:31	-14.7	-11.9	-10.4	-	-	1 , 1 , 1	1 , 1 , 1	1 , 1 , 1	-	1.184	1.338	-	5.91
100	2010-11	Dry Wing	None	Dry	23	20	2-Feb-11	N/A	3:14	-13.9	-10.1	N/A	-	-	-, -, -	-, -, -	-, -, -	-	1.284	1.416	-	0.42
102	2010-11	Type IV Fluid Val.	IP- / ZR-	AD-49	8	20	2-Feb-11	4:56	5:01	-13.4	-6.2	-7.1	IP:25 , ZR:25	10	3.2 , 2.1 , 2.8	1.1 , 1.6 , 1.6	1 , 1 , 1.1	-	1.163	1.326	-	6.75
103	2010-11	Type IV Fluid Val.	IP- / ZR-	Max-Flight	8	20	2-Feb-11	5:56	6:03	-14	-6.5	-8.6	IP:25 ,ZR:25	10	2.5 , 2.4 , 3.1	1.1 , 1.5 , 1.8	1 , 1 , 1	-	1.172	1.314	-	7.59
104	2010-11	IP Expansion	IP- / SN	Launch	8	20	2-Feb-11	22:52	22:59	-12	-7.5	-8.7	IP:25 , SN:25	7	2.8 , 2.5 , 3.1	1.1 , 1.6 , 1.9	1 , 1 , 1	-	1.181	1.33	-	6.47
105	2010-11	IP Expansion	IP- / SN	ABC-S+	18	20	3-Feb-11	0:50	0:57	-13.3	-9.3	-9.6	IP:25 , SN:25	7	2.3 , 2.2 , 2.8	1.1 , 1.6 , 2	1 , 1 , 1	-	1.146	1.301	-	8.51
106	2010-11	IP Expansion	IP- / SN	AD-49	8	20	3-Feb-11	1:43	1:48	-13.8	-9.4	-9.2	IP:25 , SN:25	7	1.4 , 2.2 , 3.1	1.2 , 1.8 , 2.3	1 , 1.1 , 1.2	-	1.16	1.319	-	7.24
107	2010-11	Baseline (BLDT)	None	2031	18	20	3-Feb-11	N/A	2:19	-14.1	-11.1	-8.3	-	-	1 , 1 , 1	1 , 1 , 1	1 , 1 , 1	-	1.201	1.368	-	3.80
112	2010-11	Dry Wing	None	None	23	20	7-Feb-11	N/A	12:55	0.9	2.3	N/A	-	-	-, -, -	-, -, -	-, -, -	-	1.262	1.44	-	-1.27
115	2010-11	IP Data Gap	IP- / R Mod	EG 106	8	20	7-Feb-11	15:42	15:48	0.7	1.4	1.5	IP:25 , R:75	25	2.3 , 1.3 , 1.6	1 , 1 , 1	1 , 1 , 1	-	1.252	1.416	-	0.42

Table 3.1: Wind Tunnel Test Log 2010-11 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation Rate (g/dm^2/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
116	**2010-11**	**IP Data Gap**	**IP- / R Mod**	**ABC-S+**	**8**	**20**	**7-Feb-11**	**16:52**	**16:59**	**-0.1**	**3**	**2.9**	**IP:25 , R:75**	**25**	**1.2 , 1.3 , 1.3**	**1 , 1 , 1.1**	**1 , 1 , 1**	**-**	**1.234**	**1.388**	**-**	**2.39**
117	**2010-11**	**IP Data Gap**	**IP- / R-**	**Launch**	**8**	**20**	**7-Feb-11**	**18:05**	**18:12**	**-0.6**	**2.3**	**0.2**	**IP:25 , R:25**	**25**	**1.3 , 1.3 , 1.3**	**1 , 1 , 1**	**1 , 1 , 1**	**-**	**1.227**	**1.381**	**-**	**2.88**
119	**2010-11**	**Dry Wing**	**None**	**None**	**23**	**20**	**7-Feb-11**	**N/A**	**19:52**	**-1.9**	**-0.1**	**N/A**	**-**	**-**	**-, -, -**	**-, -, -**	**-, -, -**	**-**	**1.278**	**1.44**	**-**	**-1.27**
120	**2010-11**	**Dry Wing**	**None**	**None**	**23**	**20**	**8-Feb-11**	**N/A**	**12:08**	**-15**	**-13.2**	**N/A**	**-**	**-**	**-, -, -**	**-, -, -**	**-, -, -**	**-**	**1.285**	**1.433**	**-**	**-0.77**
121	**2010-11**	**Type IV Fluid Val.**	**IP-**	**Max-Flight**	**18**	**20**	**8-Feb-11**	**13:14**	**13:19**	**-14.8**	**-12.9**	**-14.1**	**IP:25**	**30**	**2.5 , 2.5 , 3**	**1.2 , 1.8 , 2.3**	**1 , 1 , 1**	**-**	**1.135**	**1.301**	**-**	**8.51**
128	**2010-11**	**Type IV Fluid Val.**	**IP- / ZR-**	**AD-49**	**8**	**20**	**9-Feb-11**	**11:58**	**12:04**	**-6.2**	**-3.2**	**-3.8**	**IP:25 ,ZR:25**	**25**	**2.5 , 2.5 , 2.7**	**1.1 , 1.3 , 1.5**	**1 , 1 , 1**	**-**	**1.201**	**1.363**	**-**	**4.15**
129	**2010-11**	**Type IV Fluid Val.**	**IP-**	**AD-49**	**8**	**20**	**9-Feb-11**	**13:32**	**13:37**	**-5.7**	**-3.6**	**-5.2**	**IP:25**	**50**	**2.8 , 2.3 , 3**	**1 , 1.5 , 1.7**	**1 , 1 , 1**	**-**	**1.215**	**1.354**	**-**	**4.78**
131	**2010-11**	**Type IV Fluid Val.**	**IP Mod**	**Launch**	**8**	**20**	**9-Feb-11**	**12:51**	**15:55**	**-7.5**	**-4.5**	**-8.5**	**IP:75**	**25**	**2.8 , 3.3 , 3.9**	**1 , 1.5 , 2.2**	**1 , 1 , 1**	**-**	**1.199**	**1.35**	**-**	**5.06**
132	**2010-11**	**Type IV Fluid Val.**	**IP Mod**	**Max-Flight**	**8**	**20**	**9-Feb-11**	**17:09**	**17:13**	**-7.4**	**-5.9**	**-8.5**	**IP:75**	**25**	**2.8 , 3 , 3.9**	**1 , 1.6 , 2**	**1 , 1 , 1.1**	**-**	**1.157**	**1.324**	**-**	**6.89**

4. ANALYSIS METHODOLOGY

This section provides an overview of the analysis methodology used to evaluate the wind tunnel tests conducted. Due to the large amount of data collected during each test, a methodology was developed in order to facilitate the analysis process.

4.1 Visual Contamination Ratings

The wind tunnel was equipped with observation windows overlooking the wing section. During each of the tests conducted, visual contamination ratings were determined by three observers: one observer from the FAA and two observers from APS. The level of contamination present on the leading edge and trailing edge of the wing, as well as on the flap, was quantified using a scale of one-to-five with five being the worst case scenario; partial numbers were sometimes assigned when cases were also marginally above or below a specific rating. These observations were taken three times during each test: at the start of the test (just prior to the wind tunnel ramp-up), at the time of rotation, and at the end of the test. The values assigned by the three observers were then averaged and used for comparative analysis. The following is a description of the rating system used:

Visual Contamination Ratings (1 to 5):

1) Contamination not very visible, fluid still clean;
2) Contamination visible, but lots of fluid still present;
3) Contamination visible, spots of bridging contamination;
4) Contamination visible, lots of dry bridging present; and
5) Contamination visible, adherence of contamination.

It should be noted that the visual contamination ratings were subjective due to the various conditions tested; it was not feasible to develop rating descriptions that were applicable to all conditions. The descriptions were primarily used as an aid for determining the numerical visual contamination rating. Having the same three observers for all the tests provided a level of consistency in the rating system, which allowed for a more accurate comparison system.

The visual contamination ratings were evaluated based on pre-determined criteria; less than or equal to 3 on the leading and trailing edge, less than or equal to 4 on the flap at the start of the test, and equal to 1 on the leading edge at the time of rotation were considered acceptable. Ratings higher than these indicated potential fluid contamination or fluid flow-off issues; these results were supported by the lift coefficient data collected.

4.2 Lift Coefficient Data

The NRC collected various parameters during each of the wind tunnel test runs. The data was collected at a rate of 250 samples per second. Parameters such as lift force, normal force, drag force, wind speed, and pitch angle were collected and used to calculate the lift, normal, and drag coefficients. For the purpose of the tests conducted, the lift coefficient was primarily used as the evaluation criteria when analysing the fluid flow-off performance during the tests. Typically, the lift coefficient typically varied from 0.6 and 1.7 depending on the wing angle of attack, which ranged from -2° to 8°. The calculated lift coefficient at the 6 and 8 degree rotation angles was typically evaluated against the dry wing average data. Lift losses below 5.4 percent compared to the dry wing were considered acceptable, lift losses between 5.4 percent and 9.2 percent were considered marginal, and lift losses greater than 9.2 percent were considered severe. Further information on how these ranges were developed is provided in Section 5. The lift coefficient data collected as part of the ice pellet allowance time research has been included in Appendix D.

The lift coefficient is a non-dimensional measure of lift and is not a function of airspeed. As a result, the lift generated during a dry wing scenario for low-speed and high-speed test runs should generate similar lift coefficient profiles. During the fluid tests, variations in airspeed could potentially cause variations in the lift data collected; the fluid shearing is a function of the airspeed, and this would be demonstrated in the data. Therefore, when comparing lift coefficient data under similar conditions, differences as a result of airspeed variations would only be apparent during the fluid cases and not the dry wing cases.

4.2.1 Sequence of When Test Parameters Were Recorded

Figure 4.1 demonstrates the lift coefficient data collected during an example test run. The x-axis shows the time in seconds as of the start of the test; rotation begins at approximately 28 seconds, the wing rotates to a maximum angle of 8 degrees in approximately 3.7 seconds, and then it is rotated back to 4 degrees over a period of approximately 16 seconds. The y-axis indicates the calculated lift coefficient. The visual observations of the condition of the wing were recorded at the start of the test (time = 0), just before the start of rotation (time = 28 seconds), at the end of the rotation (time = 32 seconds), and at the end of the test (time = 60 seconds). The lift coefficient data used to calculate lift losses compared to the baseline test (typically the dry wing case) was measured at the 8° angle of rotation.

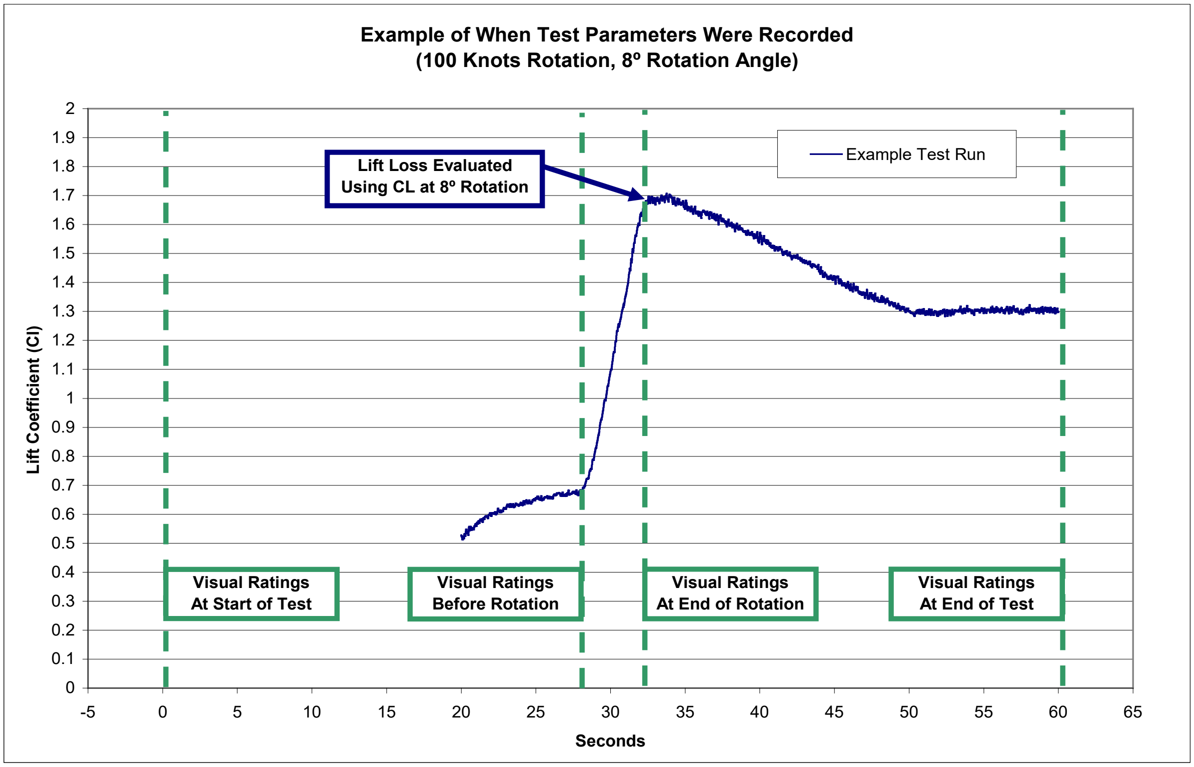
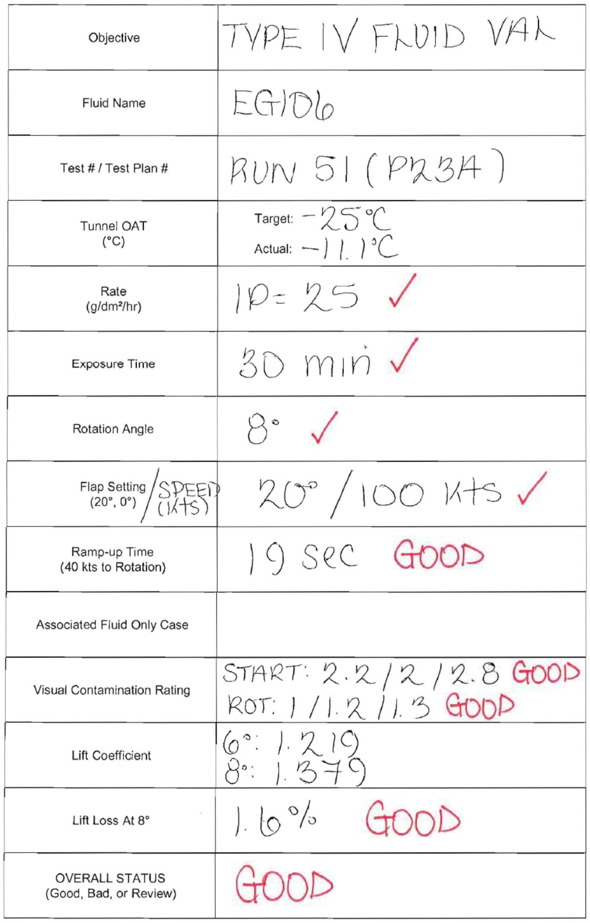


Figure 4.1: Example of When Test Parameters Were Recorded

4.3 Analysis Summary Worksheets

Due to the large amount of data to be processed for each of the tests conducted, analysis worksheets were developed and completed for each of the tests to provide a summary regarding the status of each test. Figure 4.2 demonstrates a typical worksheet. Each worksheet comprised eleven rows: the first three rows indicated the test objective, fluid, and test number, and the next eight rows evaluated the status of the tunnel temperature before the start of the test, rate of precipitation, exposure time of precipitation, associated fluid only case, visual contamination ratings at the start of the test and time of rotation, calculated lift coefficient at 6 and 8 degree rotation, the calculated lift loss at 8 degree rotation, and finally provided an overall status summarizing the test. The evaluation grades included "very good," "good," "good/review," "fair," and "bad," and they were determined based on whether the criteria satisfied the test objective requirements or not. In the case of the tunnel temperature before the start of the test, Precipiation Rate, and Exposure Time, these parameters were compared against the target parameters determined from the test plan (i.e., a colder temperature than the target would constitute a more conservative test and was therefore "good," whereas a warmer temperature would be "fair" or "bad"). The visual contamination ratings were evaluated based on pre-determined criteria; less than or equal to 3 on the leading and trailing edge and less than or equal to 4 on the flap at the start of the test were considered “good” or “very good,” and equal to 1 on the leading edge at the time of rotation was also considered “good” or “very good” (less than 1.5 on the leading edge was considered “review”). The calculated lift coefficient at the 8-degree rotation angle was evaluated against the corresponding lift loss cut-off of <5.4%, 5.4% to 9.2%, and >9.2% (as described in Subsection 5.5.4). The overall status provided a summary of the test and indicated whether or not the test objective was met with successful results. A complete set of the analysis summary sheets for the ice pellet allowance time objectives has been included in Appendix F and separated according to test objective.



Objective	TYPE IV FLUID VAL
Fluid Name	EG106
Test # / Test Plan #	RUN 51 (P23A)
Tunnel OAT (°C)	Target: −25°C Actual: −11.1°C
Rate (g/dm²/hr)	IP= 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 kts ✓
Ramp-up Time (40 kts to Rotation)	19 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.2 / 2 / 2.8 GOOD ROT: 1 / 1.2 / 1.3 GOOD
Lift Coefficient	6°: 1.219 8°: 1.379
Lift Loss At 8°	1.6% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

NOTE: For the purpose of the worksheets, OAT refers to the Tunnel Temperature Before the start of the test.
This applies for all analysis worksheets included in Appendix E.

Figure 4.2: Typical Worksheet Used for Analysis

4.4 Comparison of Test Methodologies

4.4.1 Methodology Used for 2006-07 vs. 2008-09

During the 2008-09 testing, lift data collected from the NRC was monitored in real-time and was provided to APS at the end of each test run. This allowed TC, the FAA, and APS personnel to better assess and modify the test plan according to the results obtained. During the 2006-07 testing, data was only made available at the very end of the testing period; therefore, lift data was only used to confirm the visual observations and was not efficiently used as a decision-making tool for planning during the testing.

As a result of the availability of real-time lift data, a more structured approach was employed during the 2008-09 testing that encompassed the critical aspects of the data collected. Marginal tests were more easily identified and were dealt with accordingly following the end of the test (in some cases, marginal tests were re-run or modified in order to be able to satisfy test objectives). As compared to the 2006-07 testing, the analysis was ultimately based on the same type of evaluation criteria (visual and lift data); however, the 2008-09 methodology was a more conservative analysis approach as a result of the real-time data provided by the NRC.

4.4.2 Methodology Used for 2009-10 vs. 2008-09

During the 2009-10 testing, the lift data collected by the NRC was provided to APS at the end of each test run, and as in 2008-09, testing was monitored in real-time. Due to some software upgrades, preliminary analysis was done following each test run during the winter of 2009-10, which provided guidance when modifying the test plan on site. The analysis methodology and criteria used to evaluate each test during the winter of 2009-10 were essentially the same as those used during the winter of 2008-09.

4.4.3 Methodology Used for 2010-11 vs. 2009-10

During the 2010-11 testing, the test methodology was the same as that used during the 2009-10; however, some upgrades in measurement equipment and software were made by the NRC. The result was aerodynamic data that was corrected for 2D and 3D effects and various tunnel effects. An effort was also made to reprocess the previous year’s databased on the new software upgrades to have a consistent 2-year data set. The analysis methodology and criteria used to evaluate each test during the winter of 2010-11 was essentially the same as those used during the winter of 2009-10; however, the lift coefficient evaluation criteria were further refined.

This page intentionally left blank.

5. ADDITIONAL ANALYSIS OF TEST PARAMETERS AND TESTING METHODOLOGIES USED

This section describes the additional analysis performed in order to support and substantiate the analysis methodologies used to evaluate the tests conducted (as described in Section 4).

5.1 Ice Pellet Summary Worksheet Analysis Criteria

As described in Subsection 4.3, analysis worksheets were developed and completed for all ice pellet tests conducted.

Each ice pellet test was analysed in detail using the following objectives:

a) Test parameters;
b) Visual ratings at the start of the test;
c) Visual ratings at rotation;
d) 8° lift loss; and
e) Overall test status.

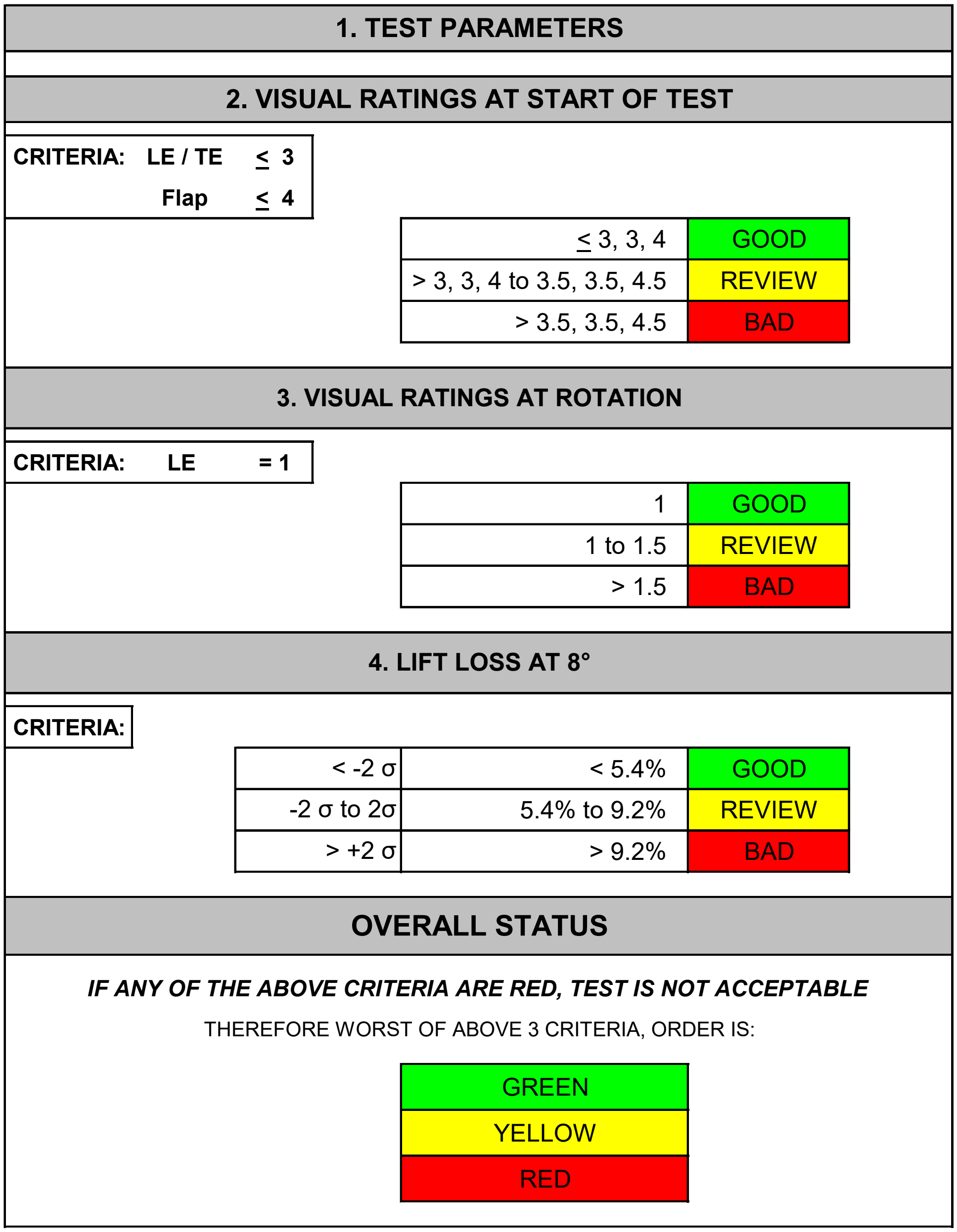
The evaluation grades for each criterion were “good,” “review,” or “bad.” These grades were determined based on whether the criteria satisfied each test objective requirement. Figure 5.1 shows a summary of each test objective and criteria.

5.1.1 Test Parameters

Several test parameters were evaluated, such as tunnel temperature before the start of the test, rate of precipitation, and exposure time of precipitation. These parameters were compared against the target parameters described in the test plan. The ramp-up time was also evaluated and compared to the target ramp-up time (as described in Subsection 5.8).

5.1.2 Visual Ratings at the Start of the Test

The visual contamination rating criteria at the start of the test on both the leading and trailing edge must be equal to or less than 3 in order to pass. The flap must have a rating of 4 or less. For a review grade to be given, the leading and trailing edge must have a rating between 3 and 3.5, and the flap must have a rating between 4 and 4.5. Any rating greater than 3.5 on the leading and trailing edge is considered a fail, while anything greater than 4.5 on the flap is considered a fail.



1. TEST PARAMETERS

2. VISUAL RATINGS AT START OF TEST

CRITERIA: LE / TE ≤ 3
Flap ≤ 4

≤ 3, 3, 4	GOOD
> 3, 3, 4 to 3.5, 3.5, 4.5	REVIEW
> 3.5, 3.5, 4.5	BAD

3. VISUAL RATINGS AT ROTATION

CRITERIA: LE = 1

1	GOOD
1 to 1.5	REVIEW
> 1.5	BAD

4. LIFT LOSS AT 8°

CRITERIA:

< -2 σ	< 5.4%	GOOD
-2 σ to 2σ	5.4% to 9.2%	REVIEW
> +2 σ	> 9.2%	BAD

OVERALL STATUS

IF ANY OF THE ABOVE CRITERIA ARE RED, TEST IS NOT ACCEPTABLE

THEREFORE WORST OF ABOVE 3 CRITERIA, ORDER IS:

GREEN
YELLOW
RED

Figure 5.1: Ice Pellet Test Analysis Criteria

5.1.3 Visual Ratings at Rotation

The visual contamination rating criteria at the time of rotation on the leading edge must be equal to 1 or less in order to pass. For a review grade to be given, the leading edge must have a rating between 1 and 1.5. Any rating on the leading edge greater than 1.5 is considered a fail.

5.1.4 8° Lift Loss

Subsection 4.2 outlines how the 8° lift loss criteria was determined. For a pass, the lift loss must be less than 5.4 percent. A review grade was given should the lift loss be between 5.4 percent and 9.2 percent. Any lift loss greater than 9.2 percent is considered a fail.

5.1.5 Overall Test Status

After all objectives were analysed, an overall status was given a grade of “good,” “review,” or “bad.” This provided an overall summary for each test. The overall status was determined by the worst case scenario from any of the test objectives; if any of the criteria were given a “bad” grade, the overall status would be bad and the test is considered a fail.

5.2 Tunnel Measurement Repeatability

5.2.1 2009-10 Data

Testing methodology in the wind tunnel was based on comparative test runs; therefore, it was necessary to evaluate the repeatability of the tests to validate the comparative test methodology. A comparison of similar test runs conducted in the wind tunnel during the winter of 2009-10 with contaminated and uncontaminated fluid was conducted. The lift coefficient data collected by the NRC was superimposed to identify any potential differences in the results obtained. Figure 5.2 demonstrates a comparison of two light ice pellet allowance time tests conducted in comparable conditions. The x-axis shows the time in seconds as of the start of the test; rotation begins at approximately 33 seconds, the wing rotates to a maximum angle of 8 degrees in approximately 3 seconds, and then it is rotated back to 4 degrees over a period of approximately 16 seconds. The y-axis indicates the calculated lift coefficient. Similar graphs were compiled for uncontaminated fluid only cases. Figures 5.3 and 5.4 demonstrate the comparison of the data collected for Type IV PG (two test runs) and Type IV ethylene glycol (EG) fluids (three test runs), respectively.

In all three figures (Figures 5.2 to 5.4), the data demonstrates that there was very little difference in the results obtained during the individual comparative tests. Each set of tests demonstrates a similar aerodynamic improvement as the fluid sheds prior to rotation and an almost identical lift coefficient profile following the time of rotation. During sets of tests with varying air conditions (i.e., OAT and humidity), differences were observed and are primarily due to the differences in fluid dynamics and the resulting effects on aerodynamic performance. In general, the uncontaminated and the contaminated fluid test runs demonstrated good repeatability, which adds confidence to the results obtained during the testing.

In addition, a dry wing test run was conducted at the start of each test day to ensure that the recorded baseline dry wing data had not changed; the integrity of the measurement capabilities was monitored by the NRC. Figure 5.5 demonstrates the CL data collected during five dry wing runs conducted with similar test parameters (i.e., rotation speed and max rotation angle). As is demonstrated, all five lift profiles are superimposed with little variation, indicating minimal scatter in the data collected.

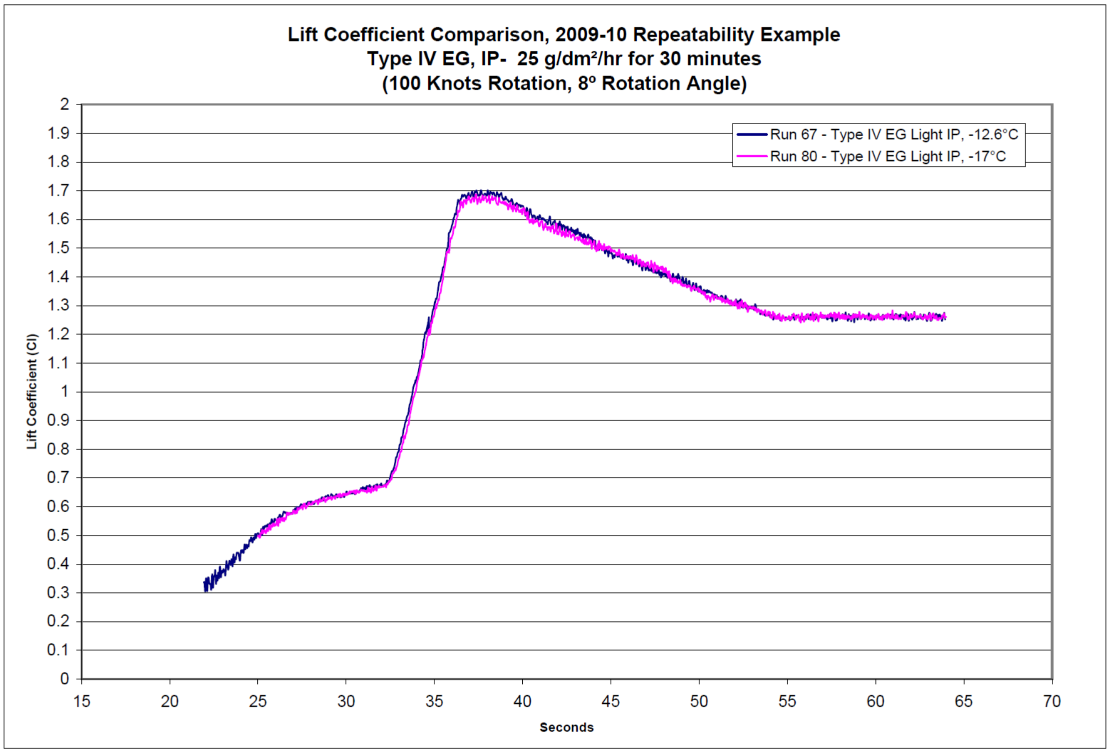


Figure 5.2: Lift Coefficient Repeatability Example for IP-

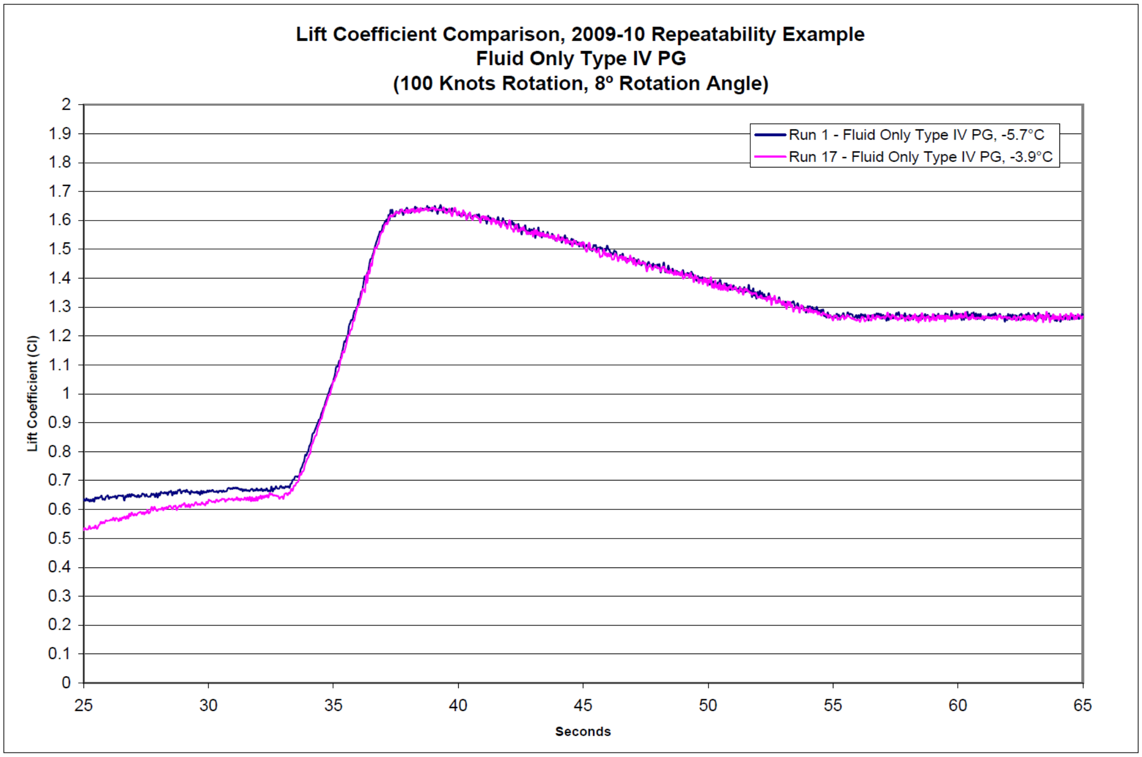


Figure 5.3: Lift Coefficient Repeatability Example for Type IV PG Fluid Only

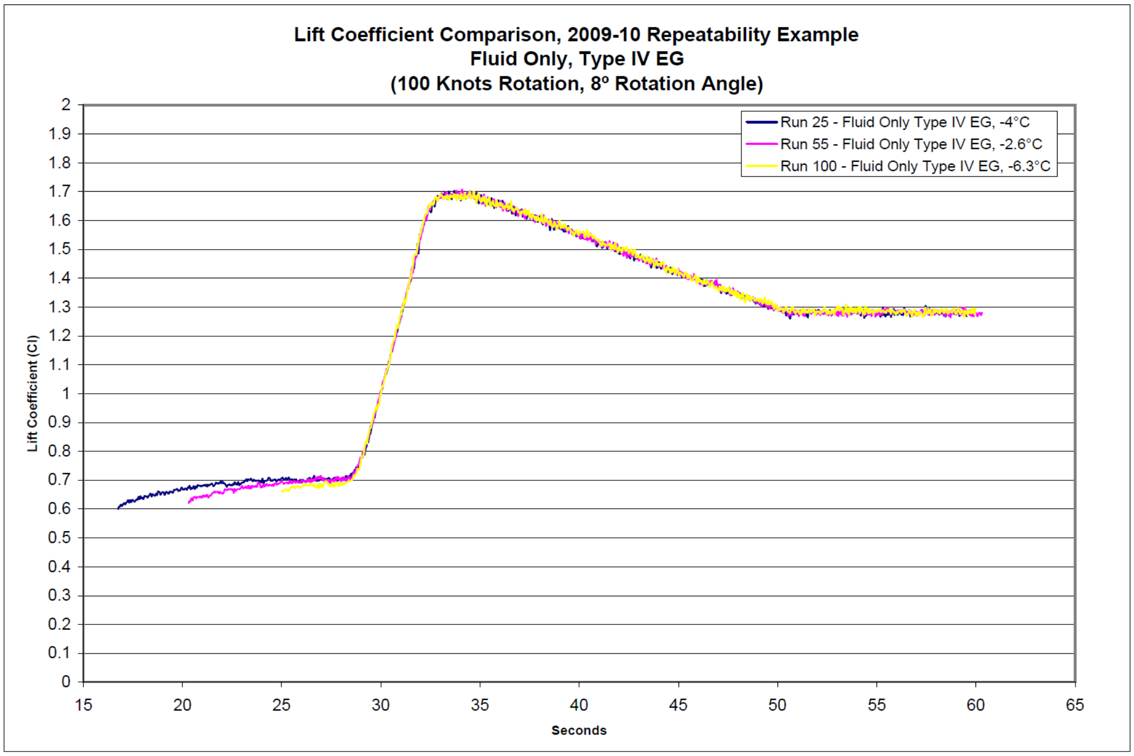


Figure 5.4: Lift Coefficient Repeatability Example for Type IV EG Fluid Only

Figure 5.5: Dry Wing Lift Coefficient Repeatability Example

5.2.2 2010-11 Data

Similar results to the 2009-10 tests were obtained during the winter of 2010-11. In Figure 5.6, the data demonstrates that there was very little difference in the results obtained during the four individual comparative tests. In these cases, two tests (#60 and #61) were conducted with a sandpaper type abrasive installed on the leading edge as a trip, and two tests (#62 and #63) were conducted without. The performance was as expected: the effect of the sandpaper did not cause a degradation in lift coefficient below stall, and all four tests were comparable. It also demonstrated that the uncontaminated fluid test runs demonstrated good repeatability, which adds confidence to the results obtained during the testing.

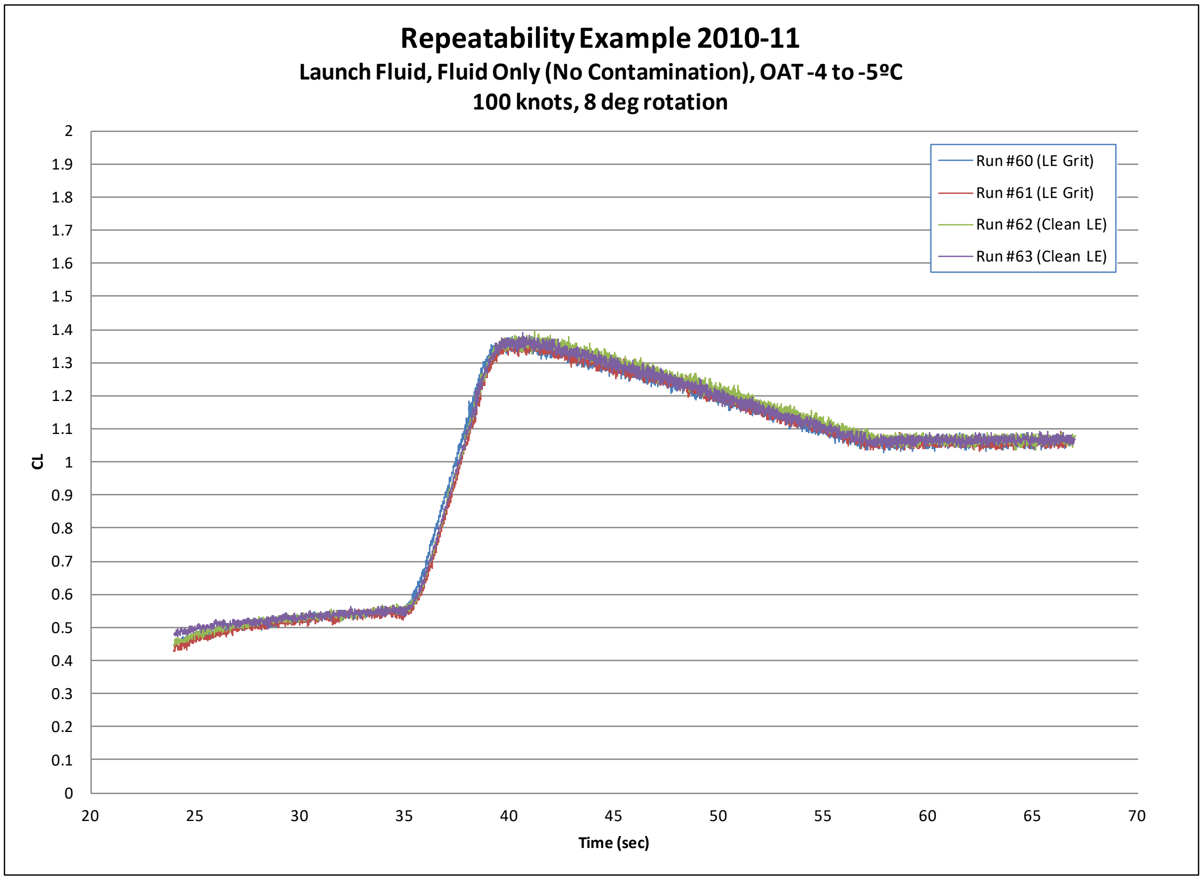


Figure 5.6: Lift Coefficient Repeatability Example for Type IV PG Fluid Only

5.2.3 Historical Data

Historical data from 1996-97 and 1997-98 shows very good repeatability of the wind tunnel results with the LS-0417 wing model. Figure 5.7 demonstrates the dry wing performance during three different years of testing. Some changes in the lift coefficient curve were observed from 1996 to 1997 when the tunnel underwent some modifications; however, the 1997 and 1998 data sets correlate very well and are almost identical.

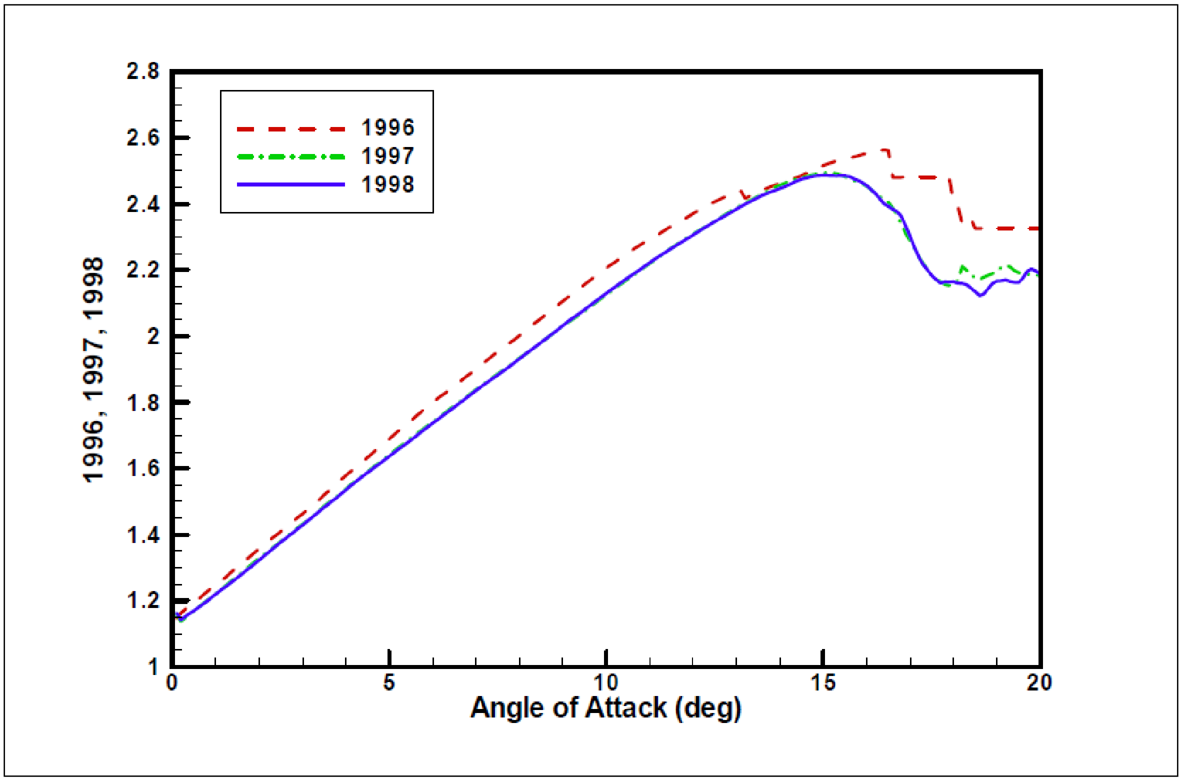


Figure 5.7: Historical Dry Wing Lift Coefficient Repeatability Example with LS-0417 Wing Section

5.3 Comparison of Experimental vs. Simulated Lift Profile

Prior to the start of testing, the NRC conducted extensive testing to calibrate the wind tunnel. One task was to compare the actual experimental lift profile curve to the theoretical curve developed analytically by the airframe manufacturer through simulation. Figure 5.8 demonstrates the comparison of the lift coefficient curves obtained by the NRC calibration (NRC Tests) and by the simulation analysis (2D BA). The results indicated that the wing performance in the wind tunnel was as expected and the slope of the curve closely matched the simulation results. Based on the opinions of the aerodynamicists at the NRC and from the airframe manufacturer, the discrepancies in the simulated versus actual results are associated with 2D versus 3D effects. It was determined that these differences would not affect the testing results, as the allowance time testing was comparative and based on the delta differences when comparing dry wing versus fluid only versus fluid and contamination lift performance and not based on the absolute value of the lift coefficient.

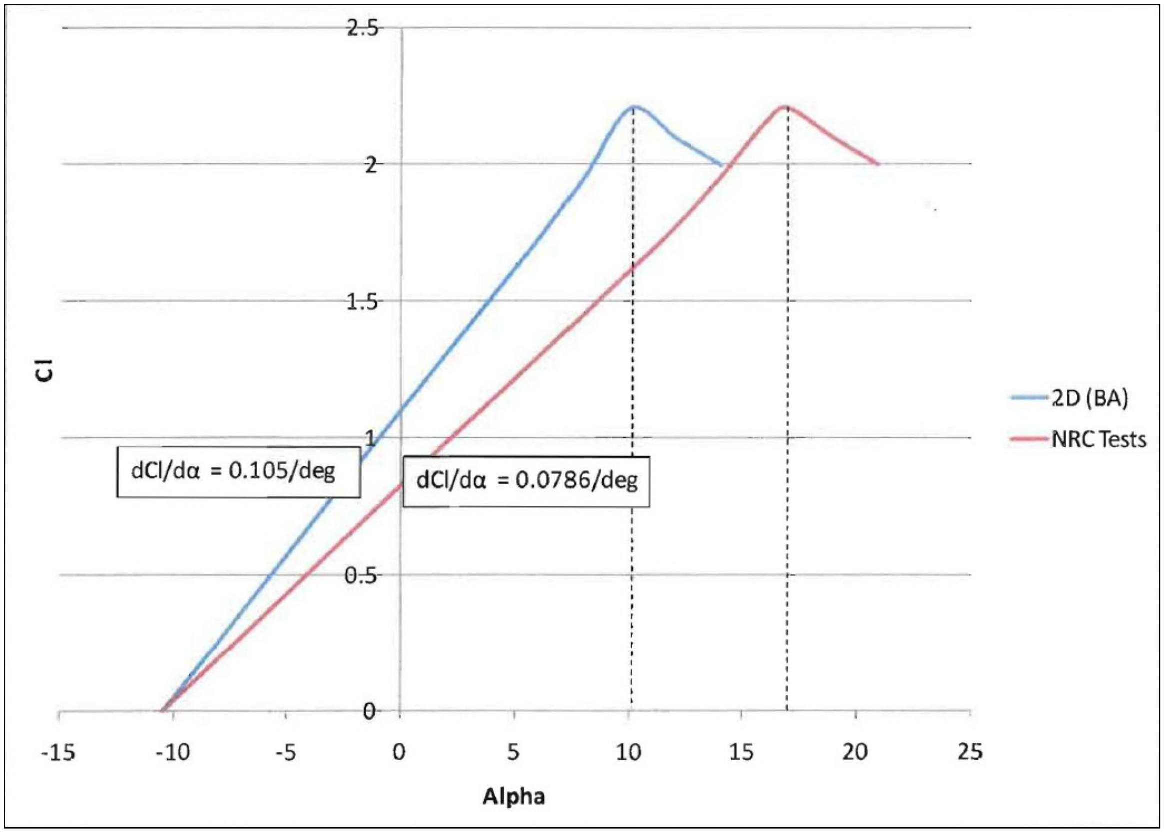


Figure 5.8: Comparison of Experimental vs. Simulated CL Data

5.4 Associated Fluid Only Cases

For each ice pellet test conducted at the wind tunnel, an associated fluid only test was selected. The associated fluid only runs were chosen based on temperature and other run factors (speed, rotation angle, lift loss), matching with their corresponding ice pellet test.

A list of the associated fluid only cases can be found in the summary tables located at the beginning of each test condition section of this report. Photos are also available of the ice pellet tests with their corresponding fluid baseline tests and can be found at the end of each test condition section of this report. It is important to note that certain ice pellet cases do not have an associated fluid only test.

Table 5.1 presents all ice pellets tests conducted, along with their associated baseline tests. The table includes all ice pellet cases performed at the wind tunnel in 2009-10 and 2010-11.

Table 5.1: Ice Pellet Associated Fluid Only Cases

Light IP	Associated Fluid Only Test
9	1
22	25
28	29
28A	29
65	64
66	64
67	100
68	70
69	70
80	75
96	64
6	5A
22	21
24	29
27	34
40	12
51	52
53	54
129	5A
8*	9*
20*	N/A
23*	N/A
35*	N/A
93**	97**
121**	76**

Mod. IP	Associated Fluid Only Test
10	1
10A	1
10B	1
21	55
47	29
48	54
49	60
71	75
72	76
73	76
74	70
95	64
7	5A
13***	N/A
14	12
25	30
26	34
59	57
92A	81
131	63
132	75
10*	N/A
15*	N/A
~~15A*~~	~~N/A~~
15B*	N/A
28*	N/A
31*	N/A
37*	N/A
38*	N/A
~~41*~~	~~N/A~~
41A*	9*
59A*	N/A
69**	68**
70**	68**
72**	71**
92**	80**

Light IP & Light ZR	Associated Fluid Only Test
0	1
26	55
26A	25
59	60
63	64
98	100
102	5A
103	75
128	5A

Light IP & Light R	Associated Fluid Only Test
117	54 (09-10)

Light IP & Mod R	Associated Fluid Only Test
20	53
44	55
56	55
56A	55
115	52
116	54

Light IP & Light SN	Associated Fluid Only Test
5	4
11	1
23	25
57	29
57A	29
77	64
78	76
79	75
94	1
45	52
46	70 (09-10)
56	5A
58	57
78	52
82*	N/A
84*	N/A
74**	76**

Light IP & Mod SN	Associated Fluid Only Test
13	17
14	17
15	17
16	17
24	25
58	60
81	75
82	76
97	64
44	52
79	43
104	101 (09-10)
106	5A
83*	N/A
85*	N/A
47**	N/A
73**	71**
105**	97**

*	115 Kts
**	C_L Max
***	Special Test
🟥	Temp. Much Colder
🟨	Temp. Much Warmer

5.5 Development of PIWT Lift Loss Evaluation Criteria

A separate report has been developed and published by Andy P. Broeren and James T. Riley entitled *Review of the Aerodynamic Acceptance Test and Application to Anti-Icing Fluids Testing in the NRC Propulsion and Icing Wind Tunnel* (15). This section briefly describes the general methodology used and end results; however, the details can be found in the abovementioned report.

5.5.1 Background and General Concept

During the 2009-10 wind tunnel testing, larger lift losses were observed compared to the previous testing conducted in 2006-07 and 2008-09; this was especially true for Type IV PG fluids. During earlier testing, a 5 percent lift loss was used as the cut-off for the acceptable lift loss due to fluid; the 5 percent lift loss was loosely linked to the historical development of the fluid certification BLDT requirements.

During the 2009-10 testing, some fluid only cases were generating lift losses greater than 5 percent, indicating that the 5 percent cutoff may be too restrictive as even fluid only cases (with fluids that are certified and approved for use) would not meet the pass criteria. It was therefore recommended that the data from the fluid only cases tested in the NRC wind tunnel be compared to the fluid certification BLDT results; the intent was to develop a correlation between the two tests. The assumption used was that the point at which the fluid fails during the BLDT test is the limit of acceptable lift loss, and by evaluating the same fluid in the PIWT under similar conditions, we could determine the respective lift loss limit in the PIWT.

This concept and a preliminary analysis were presented by APS to the SAE Aerodynamics working group. The group agreed that this methodology seemed feasible and appropriate. The concept was further refined, and it was that APS could proceed with developing a correlation during the winter of 2010-11.

5.5.2 Data Used for the Analysis

PIWT testing that was conducted during the winters of 2009-10 and 2010-11 with fluid only (no contamination) was used as the basis of this analysis. During the Winter 2010-11 tests, an effort was made to collect data as close as possible to the fluid lowest operational use temperature (LOUT) to obtain the most conservative data. A total of 44 test points were deemed applicable for this analysis.

Samples from the 2009-10 and 2010-11 testing were retained and submitted for BLDT testing. A smaller subset of BLDT tests were conducted compared to the PIWT tests; one BLDT test was often used as a baseline comparison for several PIWT tests.

The temperature for the BLDT tests were selected based on the conditions from the PIWT tests.

5.5.3 Analysis Methodology

The data indicated that the results were highly dependent on temperature: the lower the temperature, the higher the lift losses in the PIWT and the respective BLDT. A separate preliminary analysis was conducted by APS to verify if the results were fluid dependant. It was determined that although some fluids performed better compared to others and generated less lift losses, all the data should be processed as one data set. For example, if a fluid performed better in the PIWT, it generally performed better in the BLDT test; therefore, because the PIWT and BLDT tests evaluated lift degradation, and the two tests demonstrated similar data trends, grouping all fluids together provided a broader, more robust data set.

The following steps briefly describe the final analysis methodology that was developed and used by NASA and APS in order to develop the lift loss evaluation criteria described in Subsection 5.5.4:

- The PIWT data was plotted with lift loss measured at 8 degrees of rotation as a function of test temperature.
- The BLDT data was plotted with boundary layer displacement thickness as a function of test temperature.
  - Only a subset of BLDT tests were conducted. The results were extrapolated linearly to provide a comparative data point for each single PIWT test.
- Based on a known relationship between the maximum lift loss on the B737-200ADV airplane and the AAT BLDT, the 2010-11 BLDT test results were converted to a maximum lift loss value for the B737-200ADV.
  - Note: 5.24 percent lift loss was determined as the highest acceptable lift loss during the historical work.
- The BLDT data maximum lift loss value for the B737-200ADV was plotted against the PIWT lift loss calculated at 8 degrees of rotation. A linear regression of the data was performed on the one-to-one data set.
- The point at which the linear regression equation was equal to 5.24 percent lift loss on the B737-200ADV was 7.29 percent lift loss in the PIWT. The standard error of estimate determined a range based on the scatter of the data set, which was 5.41 percent to 9.17 percent.

5.5.4 Lift Loss Evaluation Criteria

Based on the work that was conducted by NASA and APS, it was determined that a maximum lift loss of 5.24 percent on the B737-200ADV airplane is equivalent to a lift loss of 7.29 percent on the PIWT model. Due to the scatter in the data, the standard error of the estimate determined an upper limit of lift loss on the PIWT model of 9.17 percent and a lower limit of 5.41 percent.

For the purpose of the ice pellet allowance time testing, the following ranges were applied for evaluating each test:

- Less than 5.41 percent lift loss;
    - Good Test.
- 5.41 percent to 9.17 percent lift loss; and
    - Review. Generally acceptable, but needs support of visual data and more rigorous evaluation.
- Greater than 9.17 percent lift loss.
    - Bad test. Unacceptable lift loss.

Currently, the scatter in the “review” range is still large and causes complications when analysing the data collected. It is anticipated that as future testing progresses and as more data is collected, a single-value pass/fail cut-off will be developed similar to the AAT and B737-200ADV airplane tests.

5.6 Maximum Allowable Lift Loss

Another methodology was examined apart from the method described in Subsection 5.5: maximum allowable lift loss. This method demonstrated the acceptable lift loss limits for each fluid only test conducted. A total of 44 fluid baseline tests were analysed comprising seven fluids. These tests were performed in 2009-10 and 2010-11.

The results from both methods demonstrated similar lift loss acceptance ranges (approximately 4 percent variance).

Figure 5.9 illustrates an example of how the maximum allowable lift loss was calculated (which is represented by “X”). The NRC lift loss data was provided following each of the 44 tests conducted. The limit, dry, and BLDT data were provided from the 23 Anti-Icing Materials International Laboratory (AMIL) tests conducted.

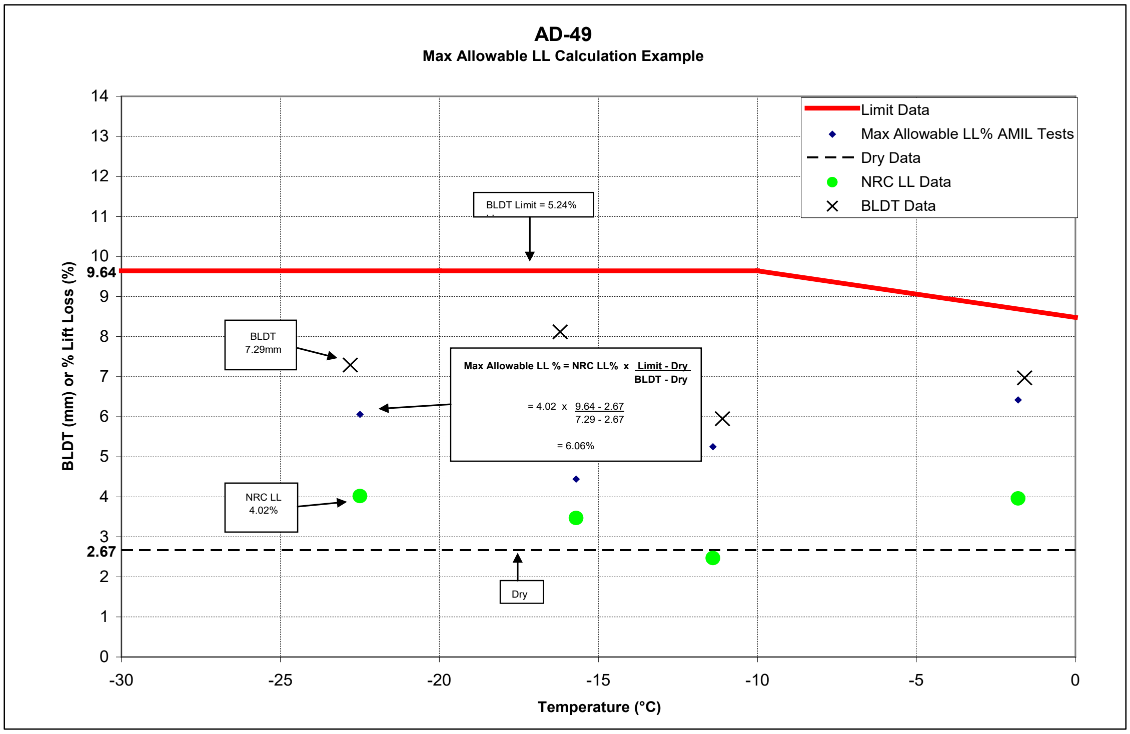


Figure 5.9: Maximum Allowable Lift Loss

An evaluation of the fluids and other parameters was undertaken to determine the impacts they have on lift loss criteria using the maximum allowable lift loss method. They are:

a) Tunnel temperature vs. wing temperature;
b) Aero reports vs. actual fluid results;
c) 44 data points vs. 23 data points; and
d) 44 data points vs. individual fluids.

5.6.1 Tunnel Temperature vs. Wing Temperature

An analysis was conducted to see if there was a significant difference between the tunnel and wing temperatures and whether it had an impact on the acceptance limits. The tunnel temperature is what is used during analysis, and it is the temperature in the tunnel directly before the start of the test. The wing temperature is the temperature of the wing directly before the start of the test.

Results indicate that the tunnel temperature is generally colder than the wing temperature. In terms of the acceptance limits, results indicate the wing temperature offers a slightly larger range in lift loss criteria (approximately 3 percent).

5.6.2 Aerodynamic Reports vs. Actual Fluid Results

Aerodynamic reports for the five fluids used during testing were examined and compared to the test results conducted by AMIL. This information was analysed, and it was determined that each method did not have a significant impact on the acceptance limits. The aerodynamic reports provided a slightly higher range in lift loss criteria (approximately 4 percent variance), but overall not much of a difference.

5.6.3 Forty-four (44) Data Points vs. 23 Data Points

In total, there were 44 fluid only tests conducted at the wind tunnel between 2009-10 and 2010-11. From these 44 tests, 23 were chosen to be tested at AMIL. It is important to note that all tests conducted at AMIL, with the exception of 1 test, were conducted at a temperature close to the tunnel test temperature. This single test was conducted at a temperature closer to the wing temperature and results demonstrated no difference between the lift loss data.

A small analysis was also conducted to determine what the results would look like should that single test have been conducted using the tunnel temperature. Results indicate no difference between the data conducted at the wing and tunnel temperature.

5.6.4 Forty-four (44) Data Points vs. Individual Fluids

Finally, a look into all fluid tests conducted and the five individual fluids were examined. Results show some variance within the acceptance limits, but this could be attributed to the characteristics of each of the individual fluids.

In conclusion, there was not a significant difference in lift loss criteria based on the four parameters described above.

Figure 5.10 demonstrates the maximum allowable lift loss results from the 44 fluid only tests conducted. The results are categorized based on a lift loss range and the number of tests that fall into these ranges.

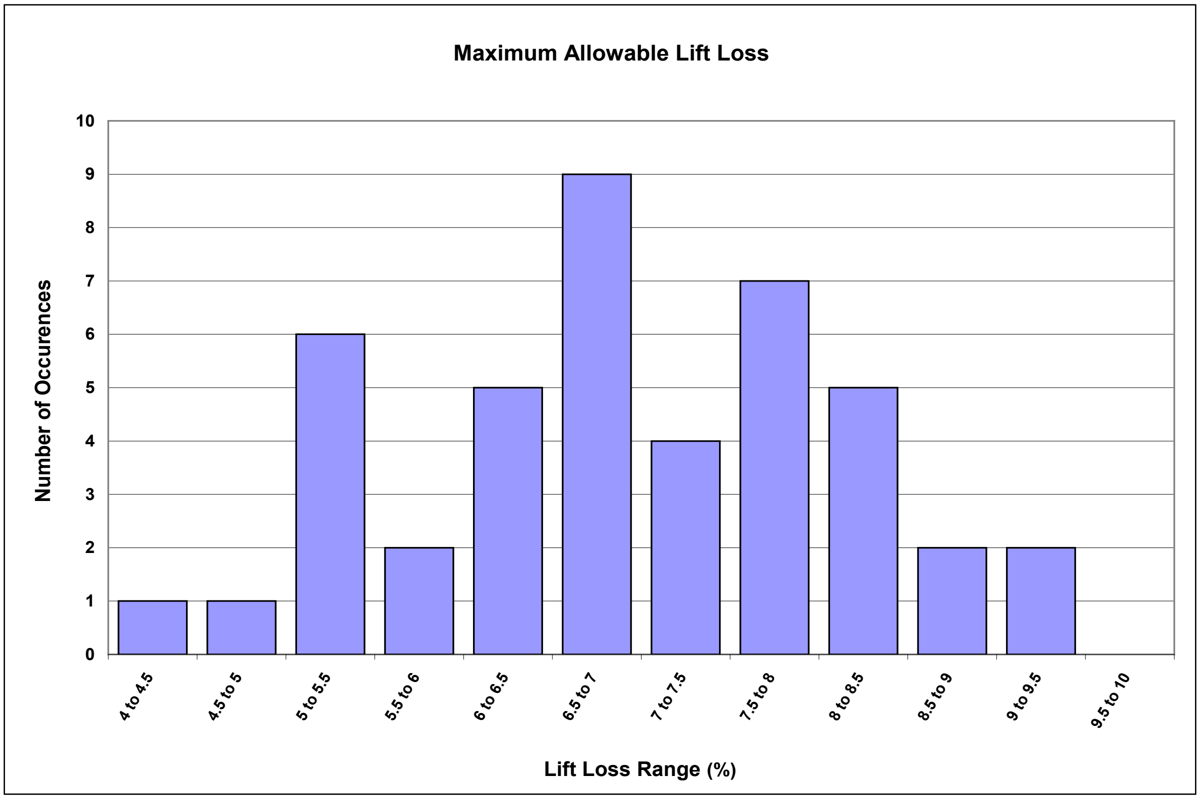


Figure 5.10: Distribution of Maximum Allowable Lift Loss Range by Occurrence

6. LIGHT ICE PELLET ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Previous testing in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive supercritical wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Light Freezing Rain;
- Section 9: Light Ice Pellets and Moderate Rain;
- Section 10: Light Ice Pellets and Light Snow;
- Section 11: Light Ice Pellets and Moderate Snow; and
- Section 12: Light Ice Pellets and Light Rain.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellet conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

6.1 Overview of Tests

A summary of the Light Ice Pellet tests conducted in the wind tunnel is shown in Table 6.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1. The following is a brief description of the column headings for Table 6.1:

Test #:	Exclusive number identifying each test.
Date:	Date when the test was conducted.

Fluid:	Aircraft deicing fluid specified by product name; all fluids were in the "neat" 100/0 dilution.
Associated Baseline Run:	The associated fluid only baseline run based on fluid selection.
Condition:	Simulated precipitation condition.
Precipitation Rate (g/dm²/h):	Simulated freezing precipitation rate (or combination of different precipitation rates). "N/A" indicates that no precipitation was applied.
Precip. Time (min.):	Total time of exposure to simulated precipitation.
Tunnel Temp. at Start of Test (ºC):	The tunnel air temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Flap Angle (º):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended).
Speed (kts):	Maximum speed attained at time of rotation.
Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation:

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

CL at 8° During Rotation: Calculated lift coefficient at the 8° wing rotation angle position; data provided by the NRC.

% Lift Loss: % Lift Loss calculated based on the comparison of the 8° lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).

Table 6.1: Summary of 2010-11 Light Ice Pellet Testing

Test No.	Date	Fluid	Associated Fluid Only Test	Condition	Precip. Rate (g/dm^2/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
6	19-Jan-11	AD-49	5A	IP-	IP:25	30	-10.9	-8.4	20	100	2.4 , 2.5 , 3.3	1.1 , 2 , 2.3	1.321	7.10
8	19-Jan-11	AD-49	9	IP-	IP:25	30	-8.5	-10.5	20	115	2.5 , 2.3 , 3.25	1 , 1.7 , 1.9	1.381	2.88
20	23-Jan-11	ABC-S+	N/A	IP-	IP:25	30	-17.5	-15.9	20	115	2.5 , 2.75 , 3.5	1.15 , 1.5 , 2	1.286	8.27
22	23-Jan-11	ABC-S+	21	IP-	IP:25	30	-19.3	-17.7	20	100	2.75 , 2.75 , 3.5	1.4 , 2 , 2.75	1.251	10.77
23	23-Jan-11	Launch	N/A	IP-	IP:25	30	-21.5	-20	20	115	3 , 2.75 , 4	1.4 , 2 , 2.75	1.301	7.20
24	23-Jan-11	Launch	29	IP-	IP:25	30	-22.5	-21.2	20	100	3 , 2.75 , 4	1.2 , 2 , 2.5	1.299	7.35
27	23-Jan-11	EG 106	34	IP-	IP:25	30	-22.6	-21.3	20	100	2.35 , 2.35 , 3	1 , 1.2 , 1.5	1.357	3.21
35	24-Jan-11	AD-49	N/A	IP-	IP:25	30	-23.2	-21.5	20	115	3 , 3 , 4	1.35 , 2 , 2.5	1.313	6.35
40	24-Jan-11	Max-Flight	12	IP-	IP:25	30	-15.2	-15	20	100	3 , 3 , 3.5	1.2 , 2 , 2.5	1.264	9.84
51	25-Jan-11	EG 106	52	IP-	IP:25	30	-11.1	-12.9	20	100	2.2 , 2 , 2.8	1 , 1.2 , 1.3	1.379	1.64
53	26-Jan-11	ABC-S+	54	IP-	IP:25	30	-12.4	-12.8	20	100	2.5 , 2.5 , 3.2	1.1 , 2 , 2.5	1.277	8.92
93	1-Feb-11	ABC-S+	97*	IP-	IP:25	30	-12	-12.8	20	100	2.6 , 1.8 , 3	1.2 , 1.8 , 1	1.282	9.85
121	8-Feb-11	Max-Flight	76*	IP-	IP:25	30	-12.9	-14.1	20	100	2.5 , 2.5 , 3	1.2 , 1.8 , 2.3	1.301	8.51
129	9-Feb-11	AD-49	5A	IP-	IP:25	50	-3.6	-5.2	20	100	2.8 , 2.3 , 3	1 , 1.5 , 1.7	1.354	4.78
5A	19-Jan-11	AD-49	-	Fluid Only	-	-	-10.4	-8.2	20	100	1 , 1 , 1	1 , 1 , 1	1.367	3.87
9	19-Jan-11	AD-49	-	Fluid Only	-	-	-6.7	-6.1	20	115	1 , 1 , 1	1 , 1 , 1	1.387	2.46
12	20-Jan-11	Max-Flight	-	Fluid Only	-	-	*-14.2*	*-12.3*	20	100	1 , 1 , 1	1 , 1 , 1	1.336	6.05
21	23-Jan-11	ABC-S+	-	Fluid Only	-	-	*-18.2*	*-16.4*	20	100	1 , 1 , 1	1 , 1 , 1	1.31	6.56
29	23-Jan-11	ABC-S+	-	Fluid Only	-	-	*-23.9*	*-21.1*	20	100	1 , 1 , 1	1 , 1 , 1	1.31	6.56
34	24-Jan-11	Launch	-	Fluid Only	-	-	*-23.3*	*-22.7*	20	100	1 , 1 , 1	1 , 1 , 1	1.342	4.28
52	25-Jan-11	EG 106	-	Fluid Only	-	-	-13.4	-12.6	20	100	1 , 1 , 1	1 , 1 , 1	1.363	2.78
54	26-Jan-11	ABC-S+	-	Fluid Only	-	-	-12.1	-13.3	20	100	1 , 1 , 1	1 , 1 , 1	1.321	5.78
76*	28-Jan-11	Max-Flight	-	Fluid Only	-	-	-5.5	-3.4	20	100	1 , 1 , 1	1 , 1 , 1	1.328	6.61
97*	2-Feb-11	ABC-S+	-	Fluid Only	-	-	-11.9	-10.4	20	100	1 , 1 , 1	1 , 1 , 1	1.338	5.91

**** CL Max Test***

6.2 Data Collected

6.2.1 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.2. Fluid thickness measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix G shows the fluid thickness measurements collected during the contaminated fluid tests.

6.2.2 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.3. Skin temperature measurements were recorded at the following intervals:

- Before fluid application;
- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix H shows the wing temperature measurements recorded during the contaminated fluid tests.

6.2.3 Fluid Brix Data

Fluid Brix measurements were recorded at the following intervals by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.4.

- After fluid application
- After application of contamination
- After the simulated takeoff test

Appendix I shows the fluid Brix measurements collected during the contaminated fluid tests.

6.3 Photos

High-speed digital photographs of each test were taken; wide-angle photos were taken of the leading edge, and close-up photos were taken of the trailing edge. For each test, photo summaries have been compiled comprising four stages:

- Start of test;
- Before Rotation (just before the wing began to pitch);
- End of Rotation (end of the rotation cycle when the wing position is returned to 4 degrees); and
- End of test.

The photos taken during the light ice pellet testing have been presented along with the fluid only (baseline) tests for comparison purposes. Photos 6.1 to 6.96 show the photo summaries of the tests conducted in accordance with the order presented in Table 6.1. A complete set of photos will be provided to the TDC in electronic format.

6.4 Summary of Results

6.4.1 OAT -5°C and Above

One test (#129) was conducted with exposure times of 50 minutes in this cell (see Table 6.2).

Test #129, conducted with PG fluid, demonstrated very good results. The temperature during this test run was -3.6°C. The lift loss and the visual rating results were deemed good. The 8° lift loss was 4.8 percent, below the 5.4 percent safety criteria. The ramp-up time from 40 knots to rotation was 23 seconds in this run. See Table 6.3 for a summary of the light ice pellet tests.

In conclusion, this test demonstrated positive results, indicating that the current allowance time of 50 minutes for this cell is acceptable and validated.

Table 6.2: Light Ice Pellets Allowance Time Tests Winter 2010-11

Light Ice Pellets	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts Runs	50 minutes **Test # 129**	30 minutes **Test # (6), (51), (53), (93), (121),**	30 minutes **Test # 6, 22, 24, 27, 40, 51, 53, 93, 121**
115 kts Runs	50 minutes	30 minutes **Test # 8**	30 minutes **Test # 20, 23, 35**

Table 6.3: Summary of Light Ice Pellets Allowance Time Test Results

OAT -5°C AND ABOVE (50 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
129	AD-49	-3.6	IP:25	50	2.8 , 2.3 , 3	GOOD	1 , 1.5 , 1.7	GOOD	4.78	GOOD	GOOD

Notes: No Notes

CONCLUSION: ALLOWANCE TIME AT 50 MINUTES IS GOOD

OAT LESS THAN -5°C TO -10°C (30 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
115 kts											
8	AD-49	-8.5	IP:25	30	2.5 , 2.3 , 3.25	GOOD	1 , 1.7 , 1.9	GOOD	2.88	GOOD	GOOD

Notes: Run # 8 not valid due to long ramp-up time.

CONCLUSION: ALLOWANCE TIME AT 30 MINUTES IS OK

Table 6.3: Summary of LIGHT ICE PELLETS Allowance Time Test Results (cont'd)

OAT LESS THAN -10°C (30 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
6	AD-49	-10.9	IP:25	30	2.4 , 2.5 , 3.3	GOOD	1.1 , 2 , 2.3	GOOD	7.10	REVIEW	REVIEW
22	ABC-S+	-19.3	IP:25	30	2.75 , 2.75 , 3.5	GOOD	1.4 , 2 , 2.75	REVIEW	10.77	BAD	BAD
24	Launch	-22.5	IP:25	30	3 , 2.75 , 4	GOOD	1.2 , 2 , 2.5	REVIEW	7.35	REVIEW	REVIEW
27	EG 106	-22.6	IP:25	30	2.35 , 2.35 , 3	GOOD	1 , 1.2 , 1.5	GOOD	3.21	GOOD	GOOD
40	Max-Flight	-15.2	IP:25	30	3 , 3 , 3.5	GOOD	1.2 , 2 , 2.5	REVIEW	9.84	BAD	BAD
51	EG 106	-11.1	IP:25	30	2.2 , 2 , 2.8	GOOD	1 , 1.2 , 1.3	GOOD	1.64	GOOD	GOOD
53	ABC-S+	-12.4	IP:25	30	2.5 , 2.5 , 3.2	GOOD	1.1 , 2 , 2.5	REVIEW	8.92	REVIEW	REVIEW
93	ABC-S+	-12	IP:25	30	2.6 , 1.8 , 3	GOOD	1.2 , 1.8 , 1	REVIEW	9.85	BAD	BAD
121	Max-Flight	-12.9	IP:25	30	2.5 , 2.5 , 3	GOOD	1.2 , 1.8 , 2.3	REVIEW	8.51	REVIEW	REVIEW
115 kts											
20	ABC-S+	-17.5	IP:25	30	2.5 , 2.75 , 3.5	GOOD	1.15 , 1.5 , 2	REVIEW	8.27	REVIEW	REVIEW
23	Launch	-21.5	IP:25	30	3 , 2.75 , 4	GOOD	1.4 , 2 , 2.75	REVIEW	7.20	REVIEW	REVIEW
35	AD-49	-23.2	IP:25	30	3 , 3 , 4	GOOD	1.35 , 2 , 2.5	REVIEW	6.35	REVIEW	REVIEW
Notes: Run #24 not a valid test											
CONCLUSION: ALLOWANCE TIME AT 30 MINUTES IS BAD for PG FLUIDS. CANNOT GO BACK TO 100 KTS FOR PROPYLENE											

6.4.2 OAT Less than -5°C to -10°C

One test (Test #8) was conducted with exposure times of 30 minutes in this cell. This test was conducted at a speed of 115 knots (see Table 6.2). Additional tests were conducted at 100 knots with the appropriate allowance time, but at colder temperatures; these can be referenced for informational purposes and are indicated by the test number in brackets. Test #8 was deemed an invalid test due to a long ramp-up time of 40 seconds (it was conducted as part of other objectives, however, and still serves as a point of reference). The temperature during this test run was -8.5°C. The lift coefficient and the visual rating results were deemed good. The 8° lift loss was 2.9 percent, well below the 5 percent safety criteria; the low lift loss was likely due to the long ramp-up time. See Table 6.3 for a summary of the light ice pellet tests.

In conclusion, the current allowance time of 30 minutes for this cell is satisfactory at this time based on the limited results obtained.

6.4.3 OAT Less than -10°C

Nine tests were conducted in this cell with an exposure time of 30 minutes: Tests #6, #22, #24, #27, #40, #51, #53, #93, and #121. Three other tests, #20, #23, and #35, were also used for analysis based on a test run of 115 knots (see Table 6.2).

Test #6, conducted at a temperature of -10.9°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 7.1 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a strong need to change the current allowance time of 30 minutes. See Table 6.3 for a summary of the light ice pellet tests.

Test #22, conducted at a temperature of -19.3°C with a PG fluid, demonstrated poor results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 10.8 percent, which is well above the 9.2 percent upper limit. This test was deemed bad due to the poor flow-off and resulting large lift loss. See Table 6.3 for a summary of the light ice pellet tests.

Test #24, conducted at a temperature of -22.5°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 7.4 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. Test #24 was deemed an invalid test due to a long ramp-up time of 31 seconds; however, it still serves as a point of reference. See Table 6.3 for a summary of the light ice pellet tests.

Test #27, conducted with EG fluid, demonstrated very good results. The temperature during this test run was -22.6°C. The visual rating at the start of test was good, and the results at rotation were deemed good. The 8° lift loss was 3.2 percent, below the 5.4 percent lower limit. The ramp-up time from 40 knots to rotation was 17 seconds in this run. Due to the positive results that were displayed, there may be potential to further expand the current allowance time for EG fluids. See Table 6.3 for a summary of the light ice pellet tests.

Test #40, conducted at a temperature of -15.2°C with a PG fluid, demonstrated poor results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 9.8 percent, which is well above the 9.2 percent upper limit.. This test was deemed bad due to the poor flow-off and resulting large lift loss; higher rotation speeds would have likely improved flow-off during this test. See Table 6.3 for a summary of the light ice pellet tests.

Test #51, conducted with EG fluid, demonstrated very good results. The temperature during this test run was -11.1°C. The lift coefficient and the visual rating results were deemed good. The 8° lift loss was 1.6 percent, well below the 5 percent lower limit. The ramp-up time from 40 knots to rotation was 19 seconds in this run. Due to the positive results that were displayed, there is potential to further expand the current allowance time for EG fluids. See Table 6.3 for a summary of the light ice pellet tests.

Test #53, conducted at a temperature of -12.4°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 8.9 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a strong need to change the current allowance time of 30 minutes. See Table 6.3 for a summary of the light ice pellet tests.

Test #93, conducted at a temperature of -12.0°C with a PG fluid, demonstrated satisfactory results. This test was conducted at a higher rotation angle of 18°. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 9.9 percent, which is well above the 9.2 percent upper limit. This test was deemed bad due to the poor flow-off and resulting large lift loss. See Table 6.3 for a summary of the light ice pellet tests.

Test #121, conducted at a temperature of -12.9°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 8.5 percent, which is above the 5.4 percent lower limit, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a strong need to change the current allowance time of 30 minutes. See Table 6.3 for a summary of the light ice pellet tests.

Test #20, conducted at a temperature of -17.5°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 8.3 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. This test was deemed satisfactory. See Table 6.3 for a summary of the light ice pellet tests.

Test #23, conducted at a temperature of -21.5°C with a PG fluid, demonstrated satisfactory results. The lift coefficient and the visual rating results at rotation were deemed satisfactory. The lift loss at 8° was 7.2 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. This test was deemed satisfactory. See Table 6.3 for a summary of the light ice pellet tests.

Test #35, conducted at a temperature of -23.2°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 6.4 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. This test was deemed satisfactory. See Table 6.3 for a summary of the light ice pellet tests.

In conclusion, the current allowance time of 30 minutes is acceptable for EG fluids, and a potential to expand this time for EG fluids may be possible. With PG fluids, a speed of 115 knots or more is required to drive lift losses below 8 percent for the flatter and newer generation airfoils. At this time, the current allowance time of 30 minutes for PG fluids is still acceptable with speeds of 115 knots or more, but further research and testing are required.

This page intentionally left blank.

Photo 6.1: Test #5A – Start of Test

Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

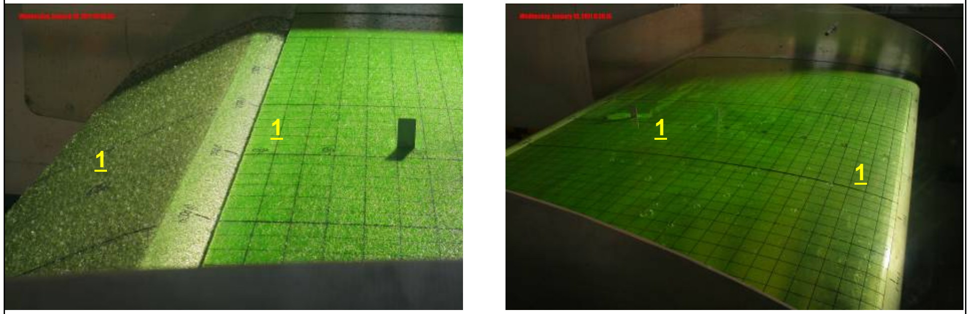


Photo 6.2: Test #5A – Before Rotation

Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8° Lift Loss = 3.87%
Before Rotation

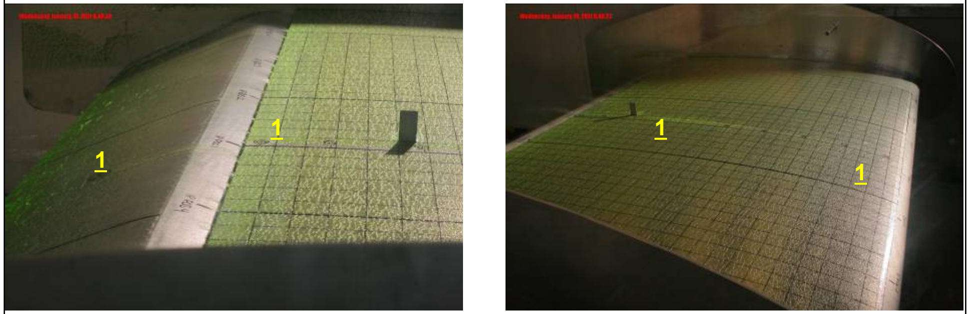


Photo 6.3: Test #5A – End of Rotation

Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8° Lift Loss = 3.87%
End of Rotation

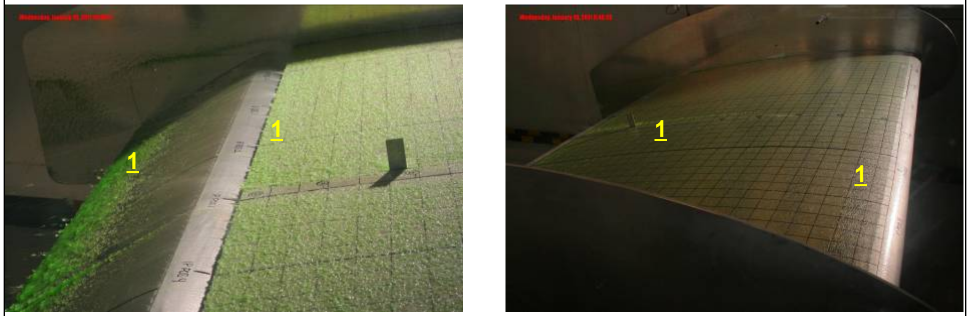


Photo 6.4: Test #5A – End of Test

Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

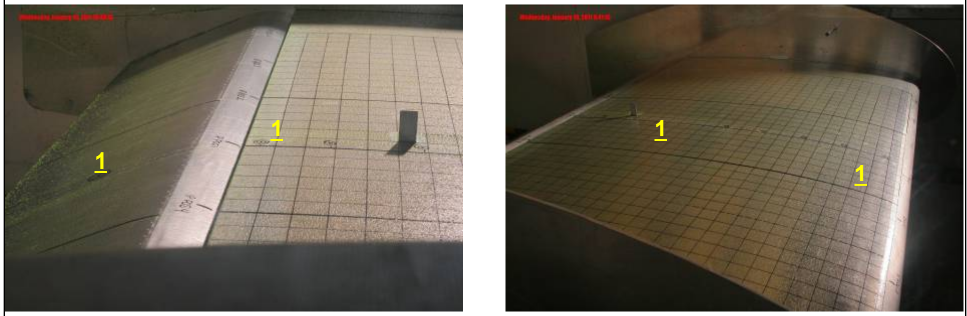


Photo 6.5: Test #6 – Start of Test

Test #6

AD-49, IP- 25 g/dm²/h, 30 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.4, 2.5, 3.3)

Start of Test

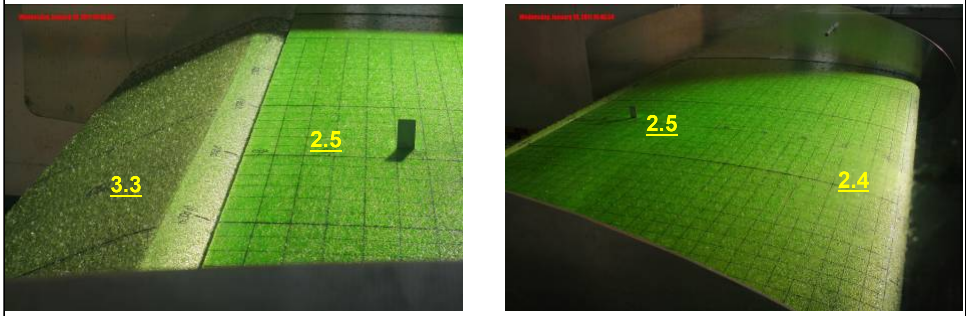


Photo 6.6: Test #6 – Before Rotation

Test #6

AD-49, IP- 25 g/dm²/h, 30 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 2, 2.3), 8° Lift Loss = 7.10%

Before Rotation

Photo 6.7: Test #6 – End of Rotation

Test #6

AD-49, IP- 25 g/dm²/h, 30 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 2, 2.3), 8° Lift Loss = 7.10%

End of Rotation

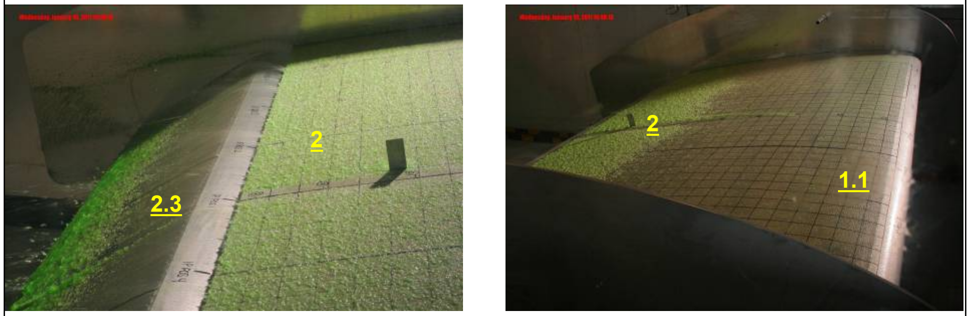


Photo 6.8: Test #6 – End of Test

Test #6

AD-49, IP- 25 g/dm²/h, 30 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.25)

End of Test

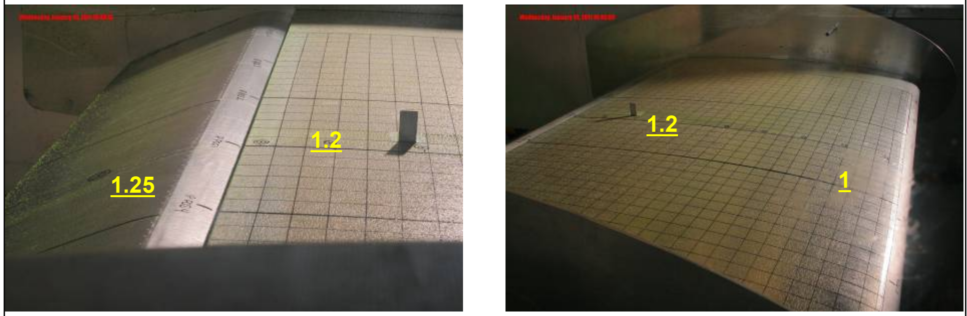
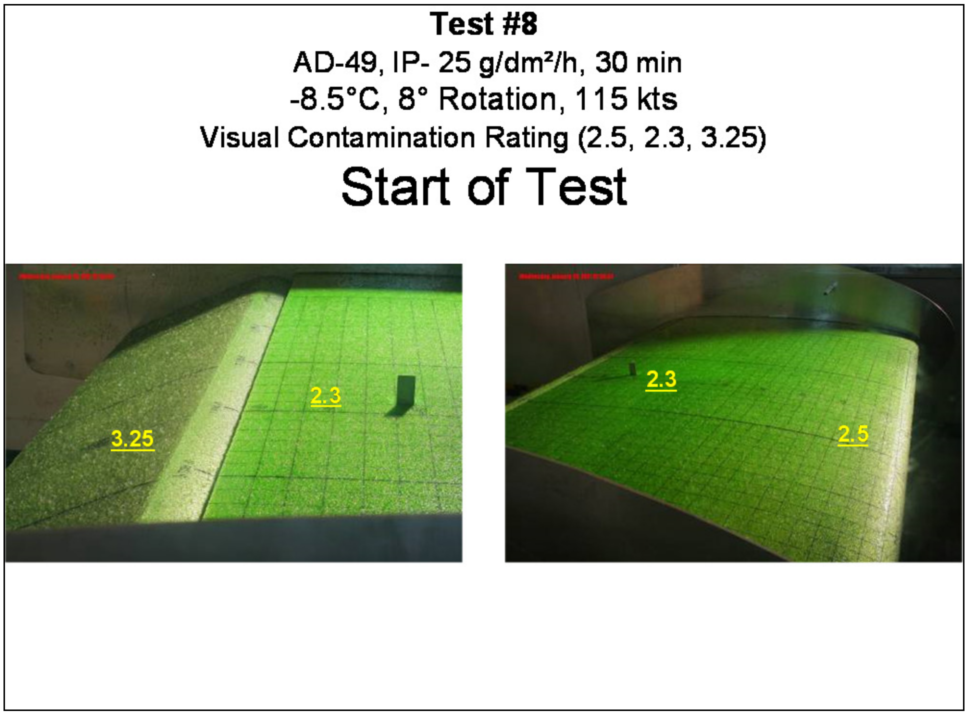


Photo 6.9: Test #8 – Start of Test



Test #8

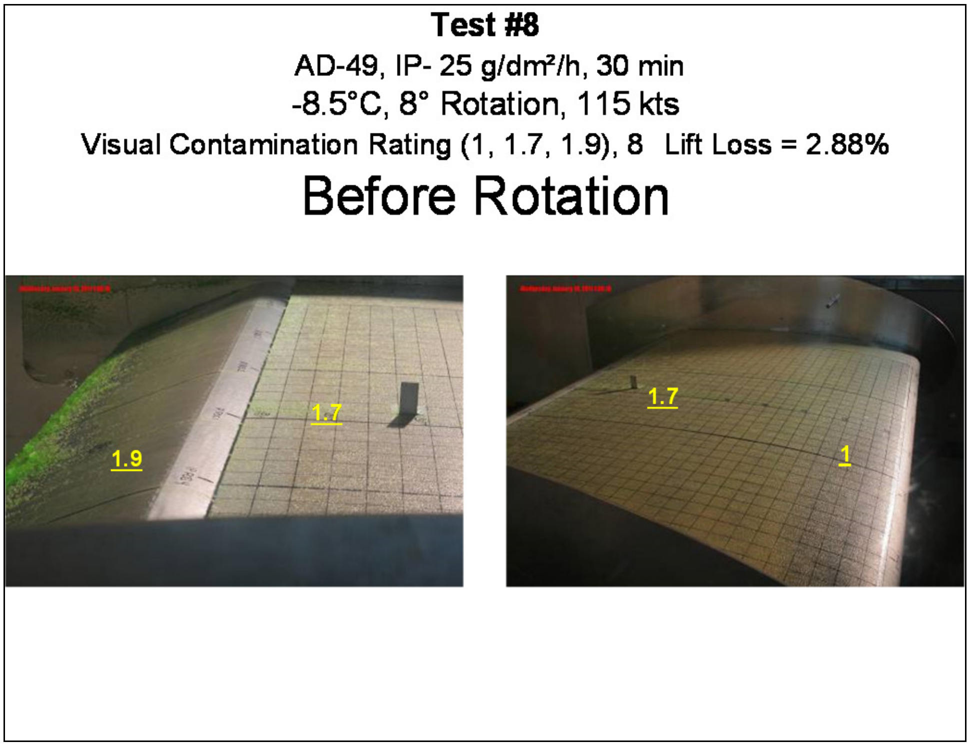
AD-49, IP- 25 g/dm²/h, 30 min

-8.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (2.5, 2.3, 3.25)

Start of Test

Photo 6.10: Test #8 – Before Rotation



Test #8

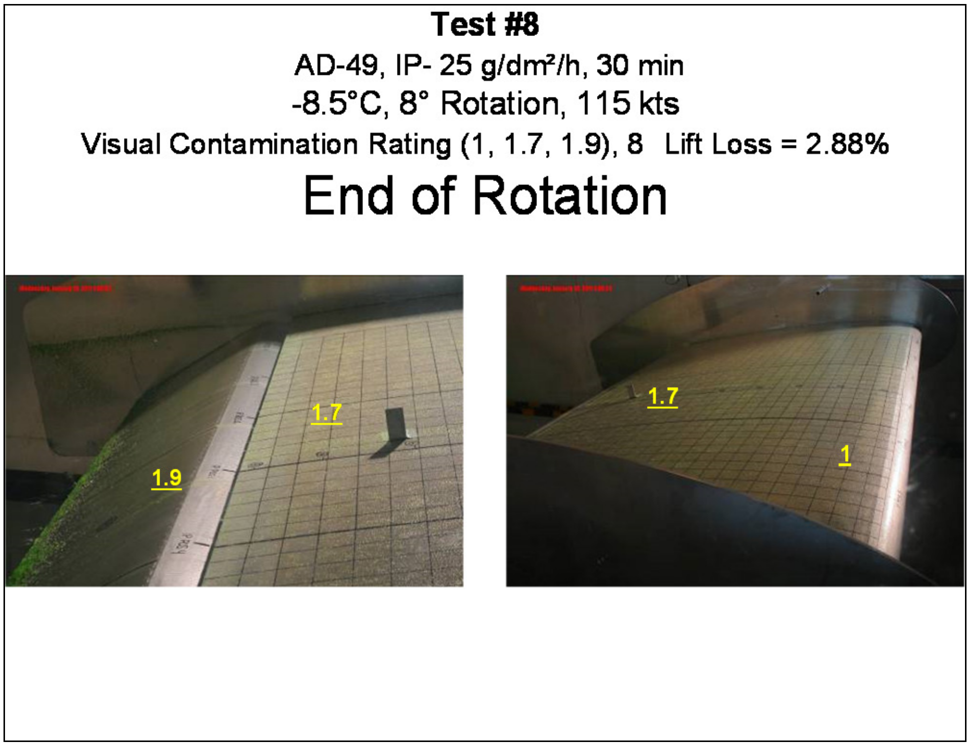
AD-49, IP- 25 g/dm²/h, 30 min

-8.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.7, 1.9), 8 Lift Loss = 2.88%

Before Rotation

Photo 6.11: Test #8 – End of Rotation



Test #8

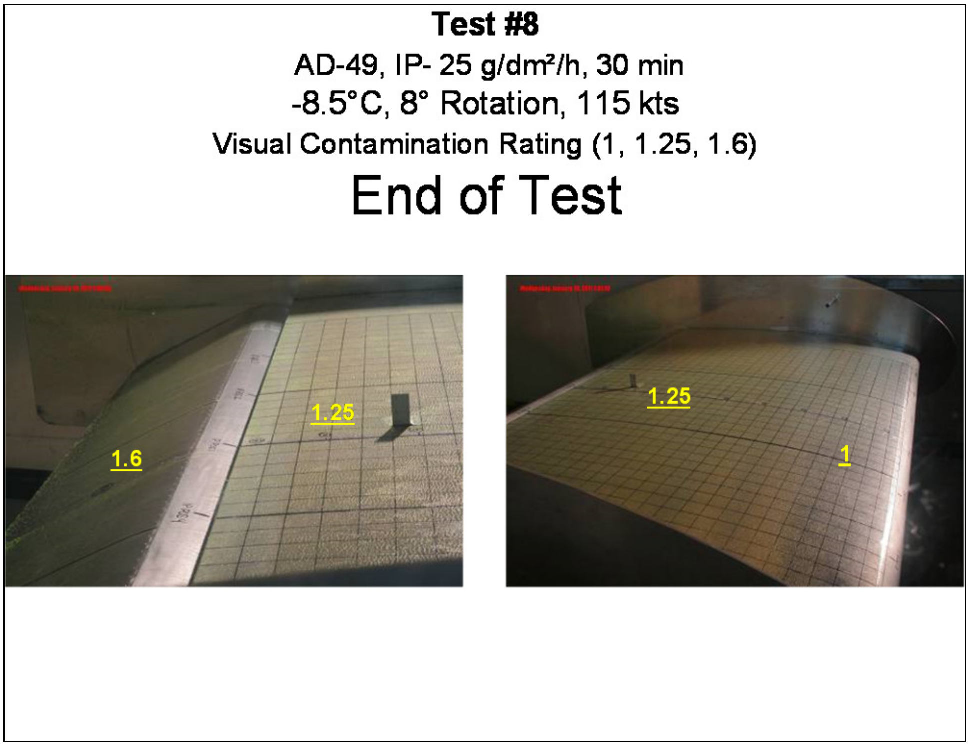
AD-49, IP- 25 g/dm²/h, 30 min

-8.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.7, 1.9), 8 Lift Loss = 2.88%

End of Rotation

Photo 6.12: Test #8 – End of Test



Test #8

AD-49, IP- 25 g/dm²/h, 30 min

-8.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.25, 1.6)

End of Test

Photo 6.13: Test #9 – Start of Test

Test #9

AD-49, Fluid Only

-6.7°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

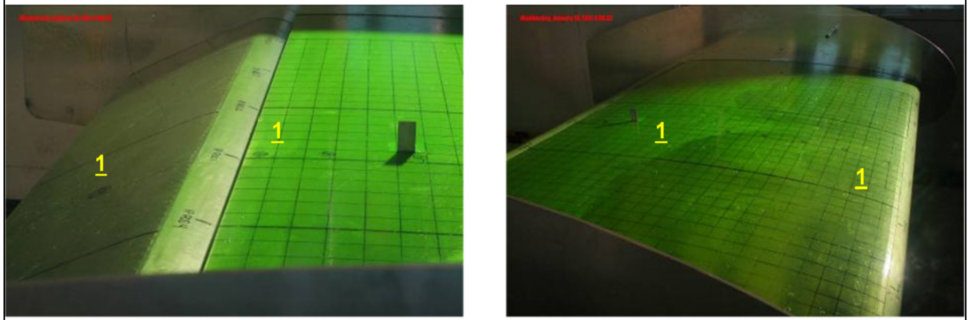


Photo 6.14: Test #9 – Before Rotation

Test #9

AD-49, Fluid Only

-6.7°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.46%

Before Rotation

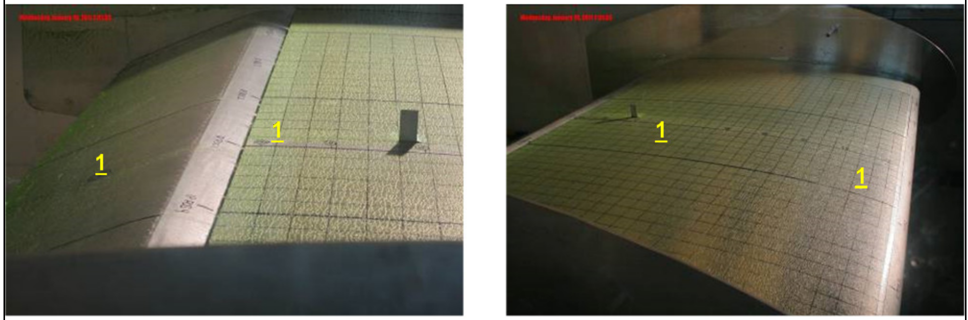
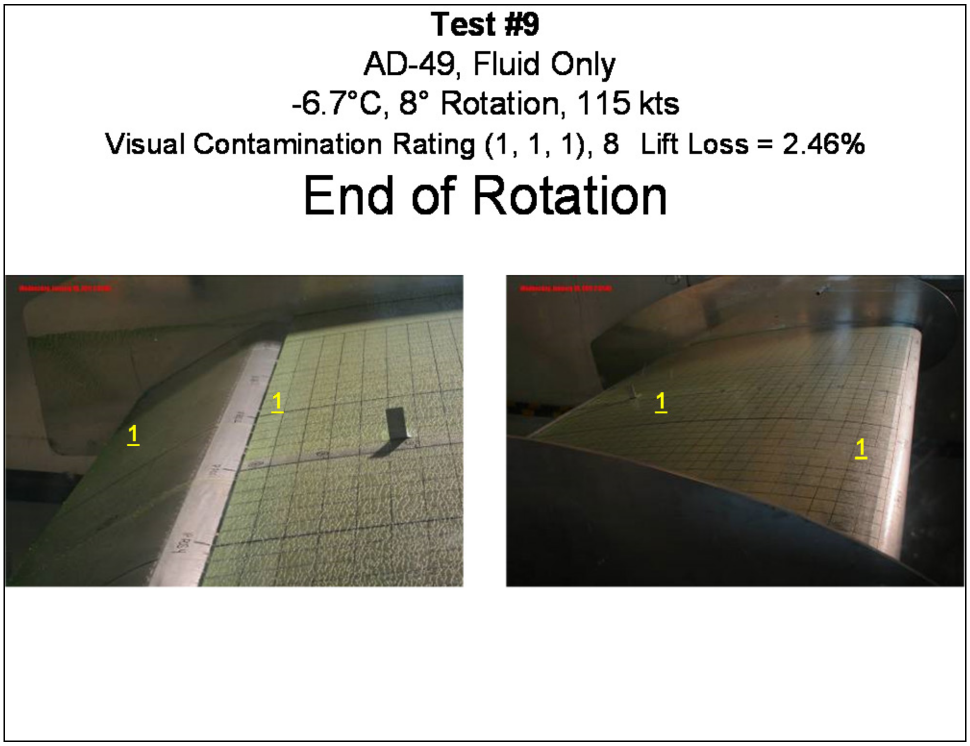


Photo 6.15: Test #9 – End of Rotation



Test #9

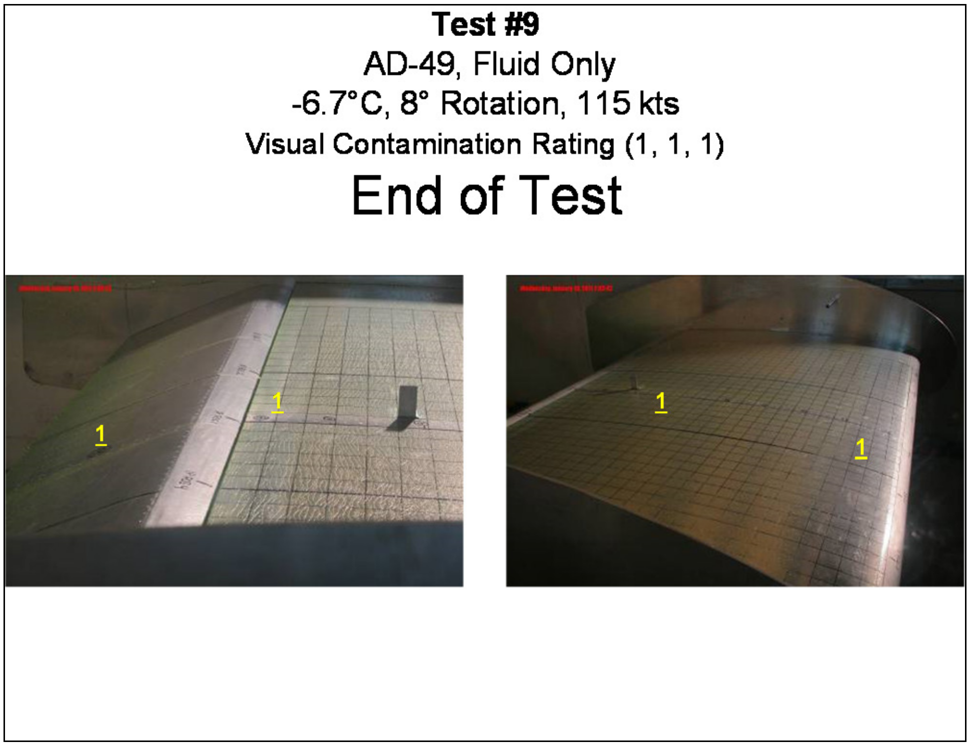
AD-49, Fluid Only

-6.7°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.46%

End of Rotation

Photo 6.16: Test #9 – End of Test



Test #9

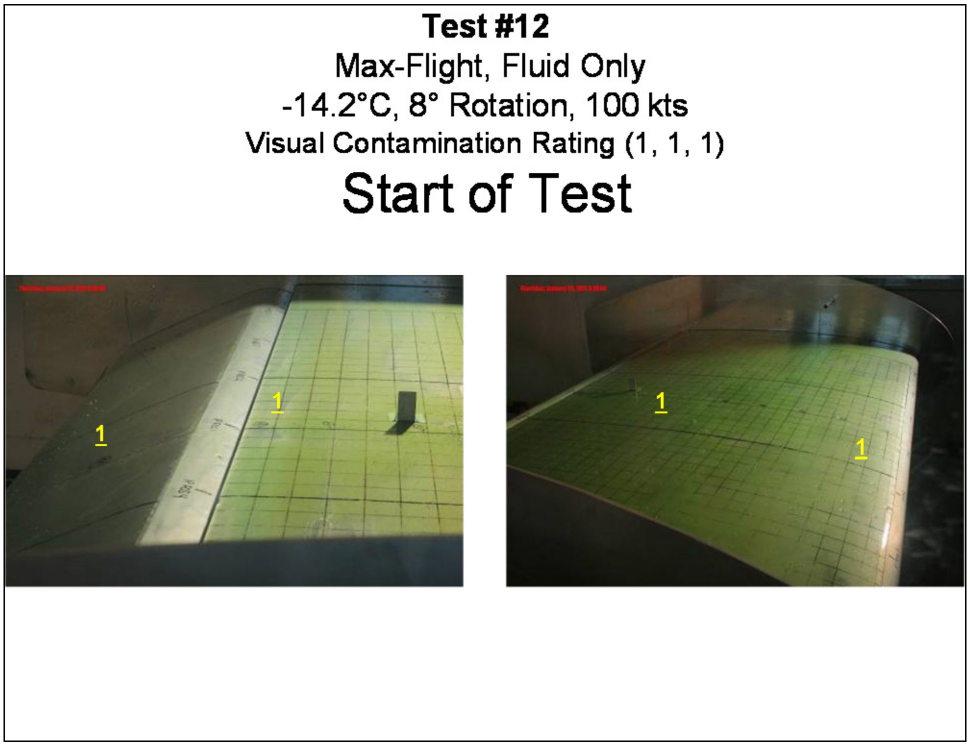
AD-49, Fluid Only

-6.7°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 6.17: Test #12 – Start of Test



Test #12

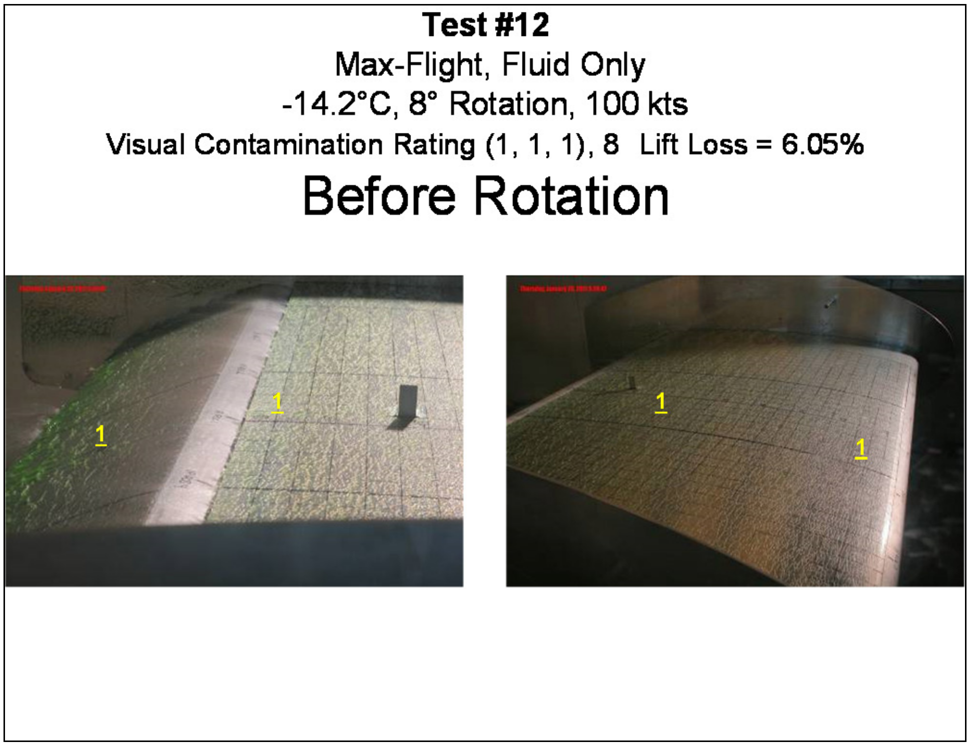
Max-Flight, Fluid Only

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 6.18: Test #12 – Before Rotation



Test #12

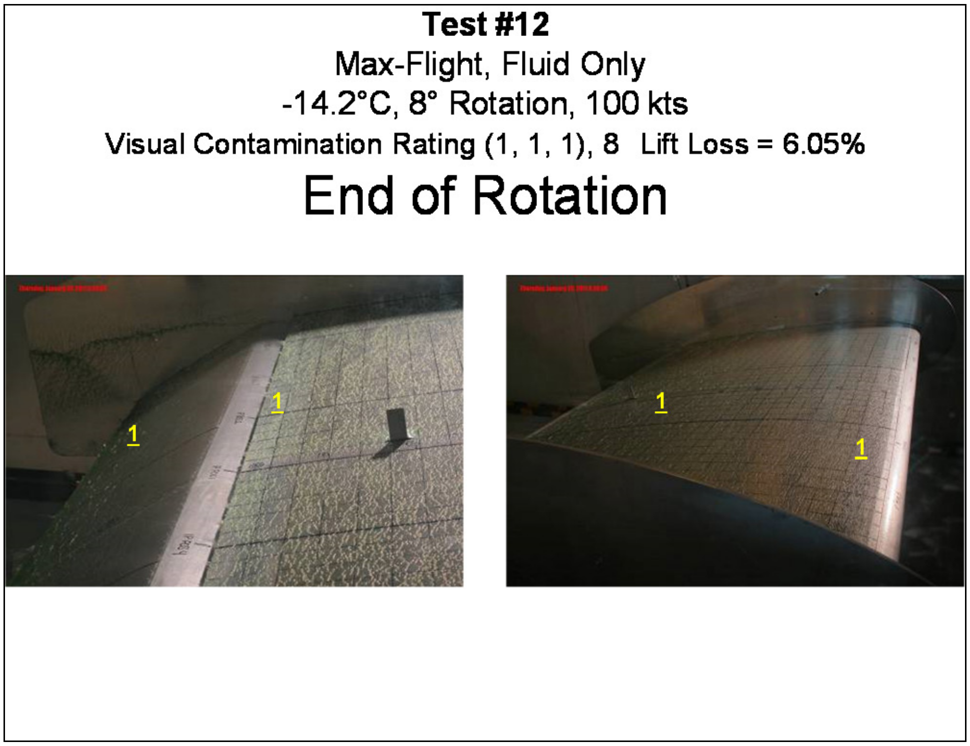
Max-Flight, Fluid Only

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.05%

Before Rotation

Photo 6.19: Test #12 – End of Rotation



Test #12

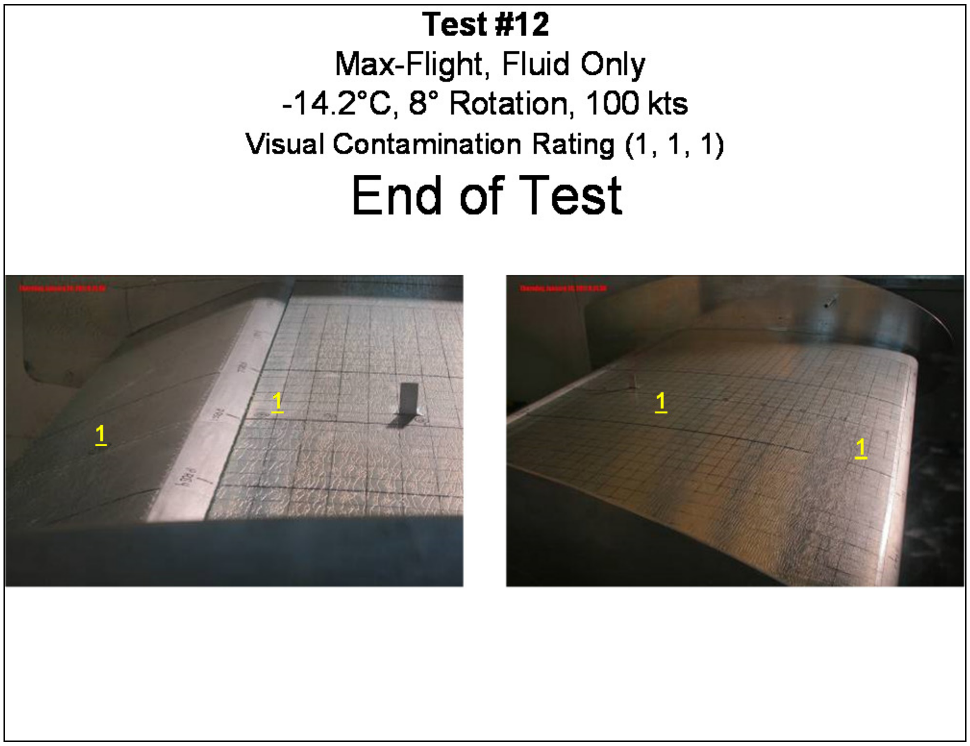
Max-Flight, Fluid Only

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.05%

End of Rotation

Photo 6.20: Test #12 – End of Test



Test #12

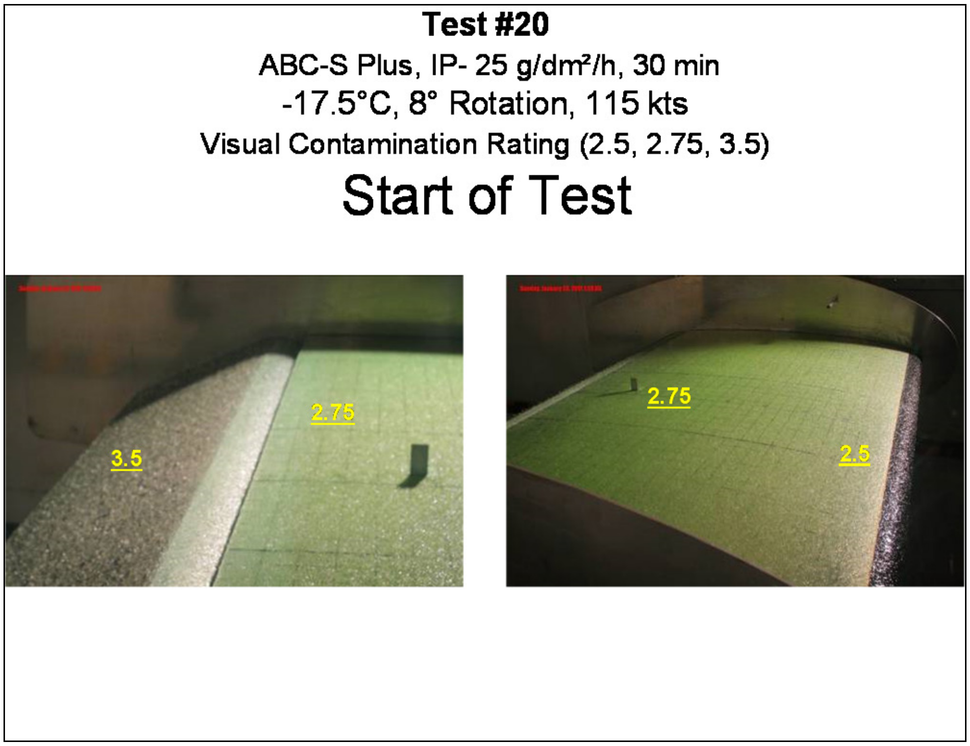
Max-Flight, Fluid Only

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 6.21: Test #20 – Start of Test



Test #20

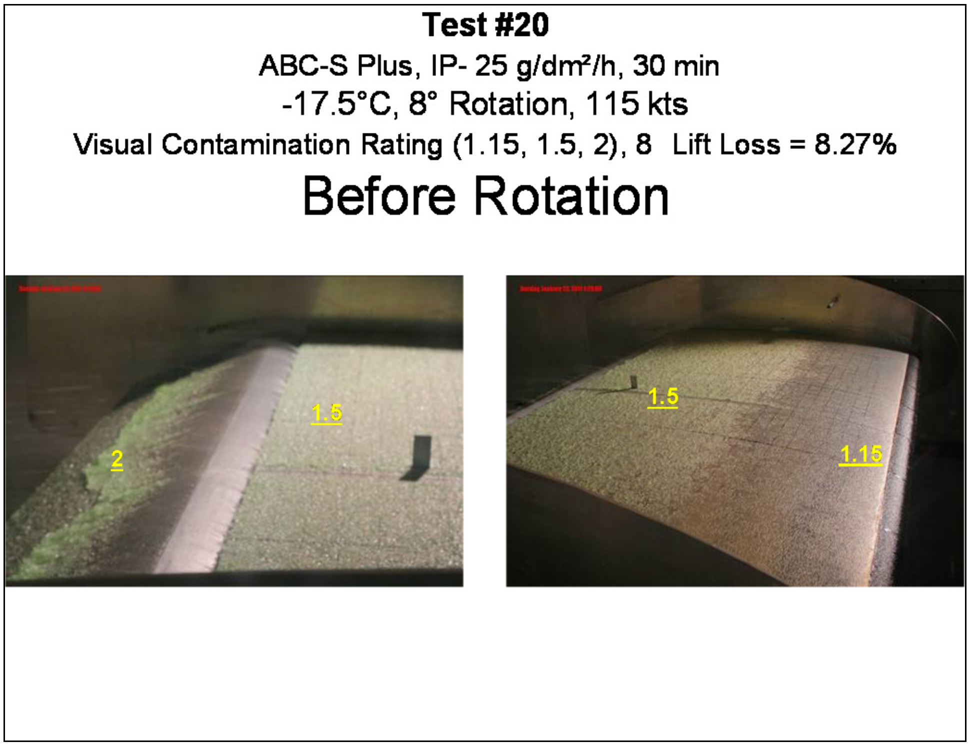
ABC-S Plus, IP- 25 g/dm²/h, 30 min

-17.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (2.5, 2.75, 3.5)

Start of Test

Photo 6.22: Test #20 – Before Rotation



Test #20

ABC-S Plus, IP- 25 g/dm²/h, 30 min

-17.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.15, 1.5, 2), 8 Lift Loss = 8.27%

Before Rotation

Photo 6.23: Test #20 – End of Rotation

Test #20

ABC-S Plus, IP- 25 g/dm²/h, 30 min

-17.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.15, 1.5, 2), 8 Lift Loss = 8.27%

End of Rotation

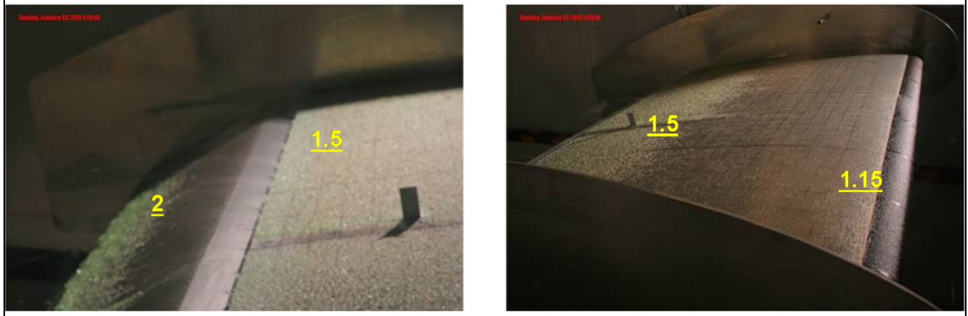


Photo 6.24: Test #20 – End of Test

Test #20

ABC-S Plus, IP- 25 g/dm²/h, 30 min

-17.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.2, 1.6, 2)

End of Test

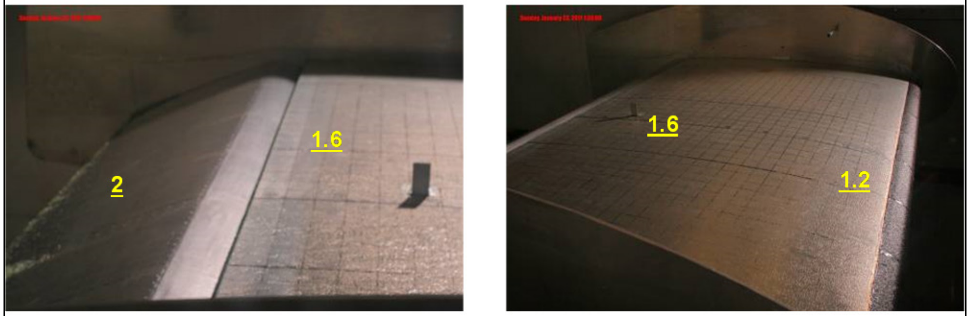


Photo 6.25: Test #21 – Start of Test

Test #21
ABC-S Plus, Fluid Only
-18.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

Start of Test

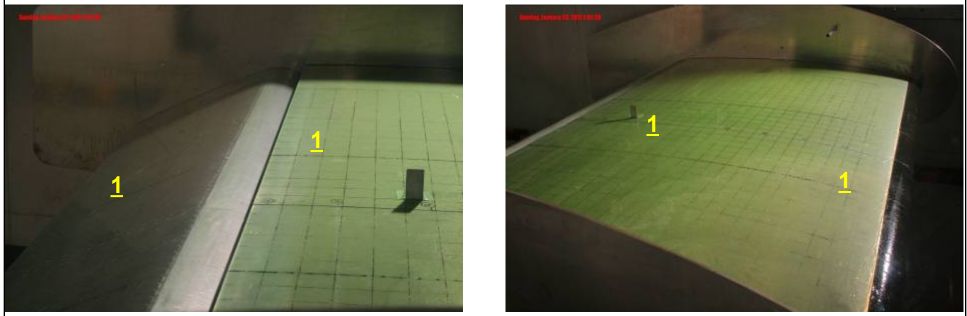


Photo 6.26: Test #21 – Before Rotation

Test #21
ABC-S Plus, Fluid Only
-18.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8° Lift Loss = 6.56%

Before Rotation

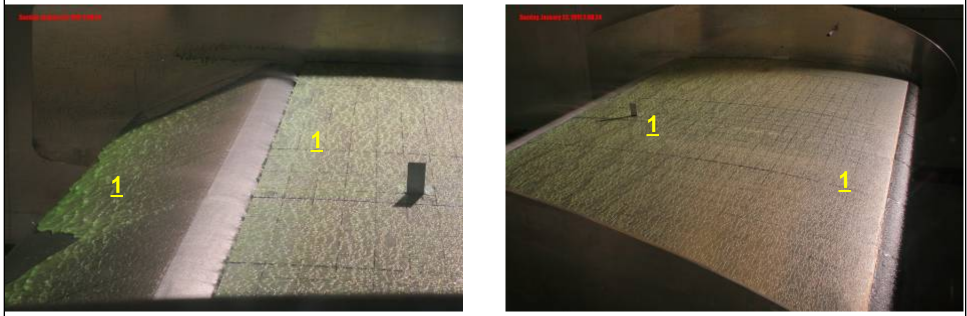
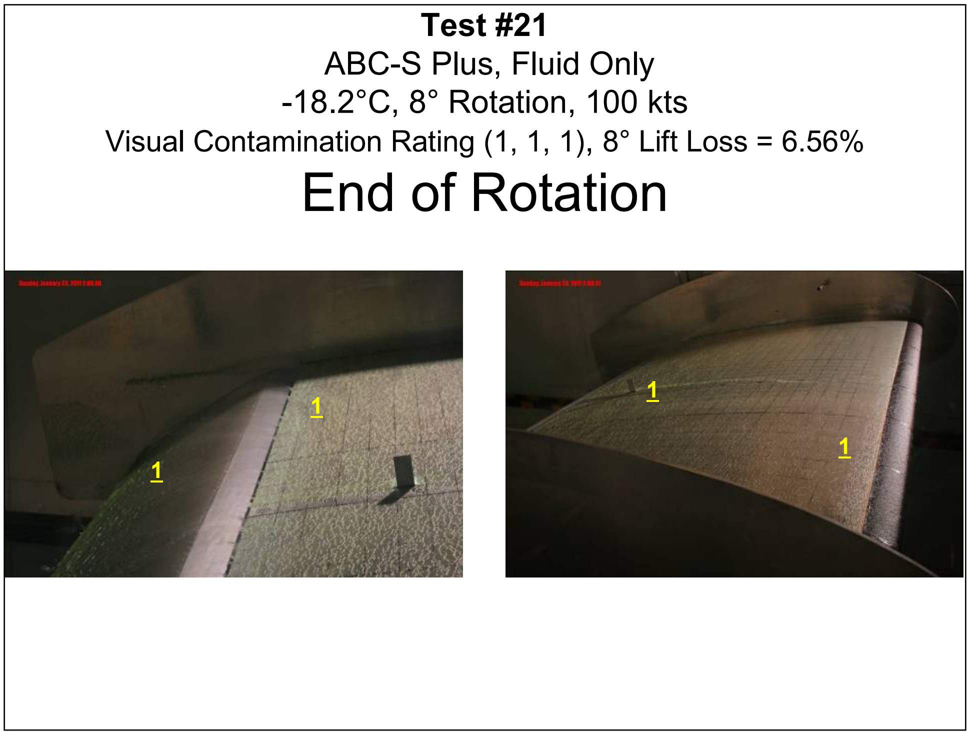
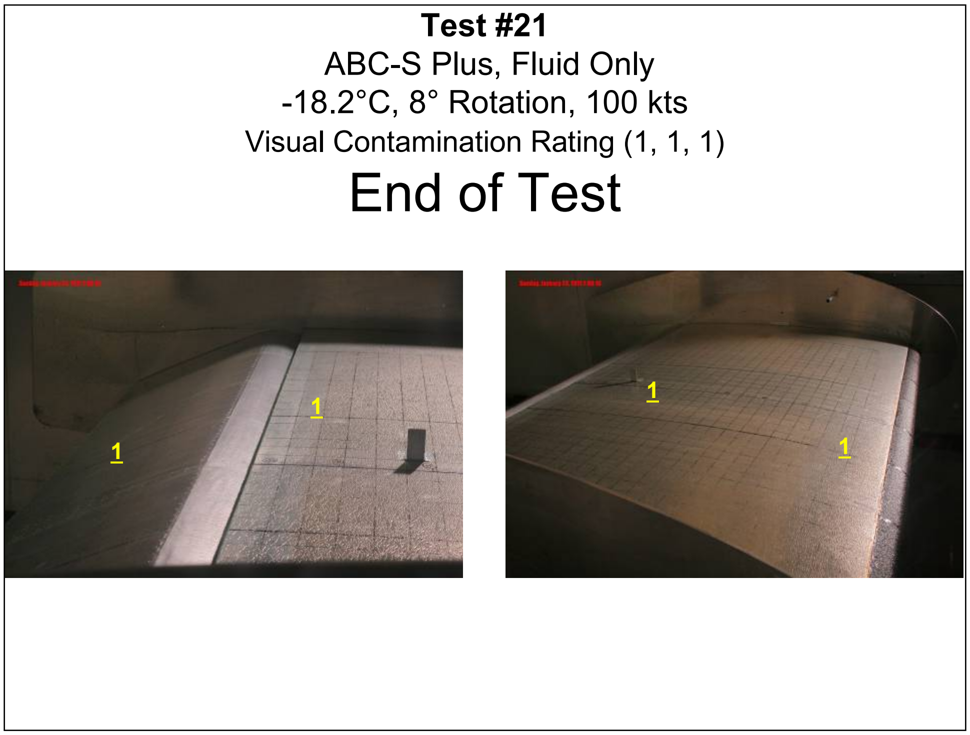


Photo 6.27: Test #21 – End of Rotation



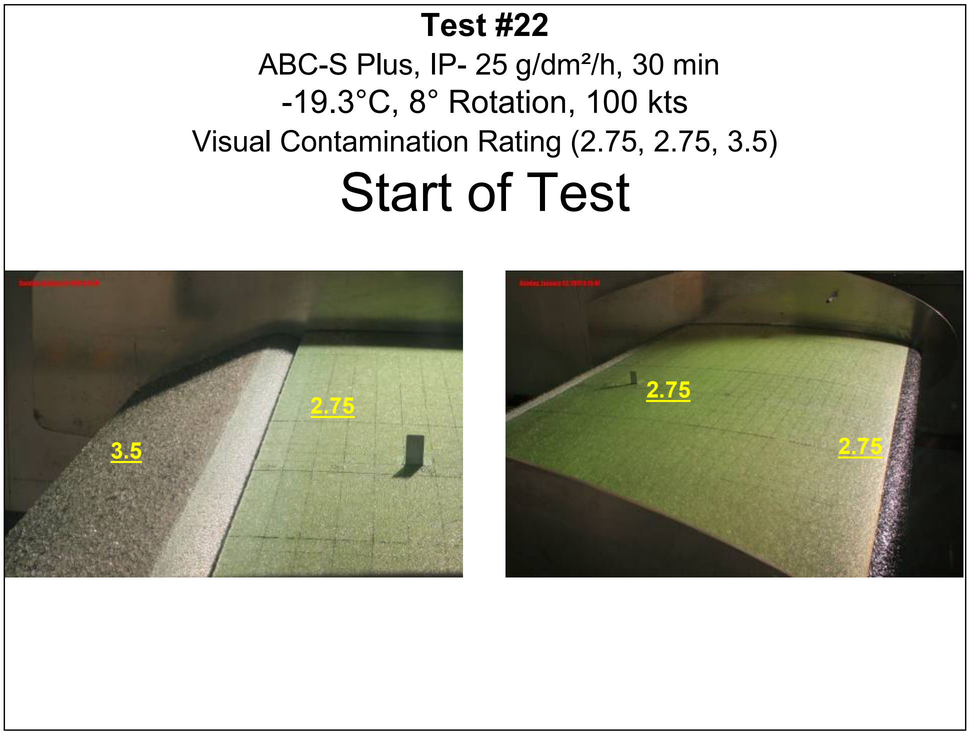
Test #21
ABC-S Plus, Fluid Only
-18.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8° Lift Loss = 6.56%
End of Rotation

Photo 6.28: Test #21 – End of Test



Test #21
ABC-S Plus, Fluid Only
-18.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 6.29: Test #22 – Start of Test



Test #22

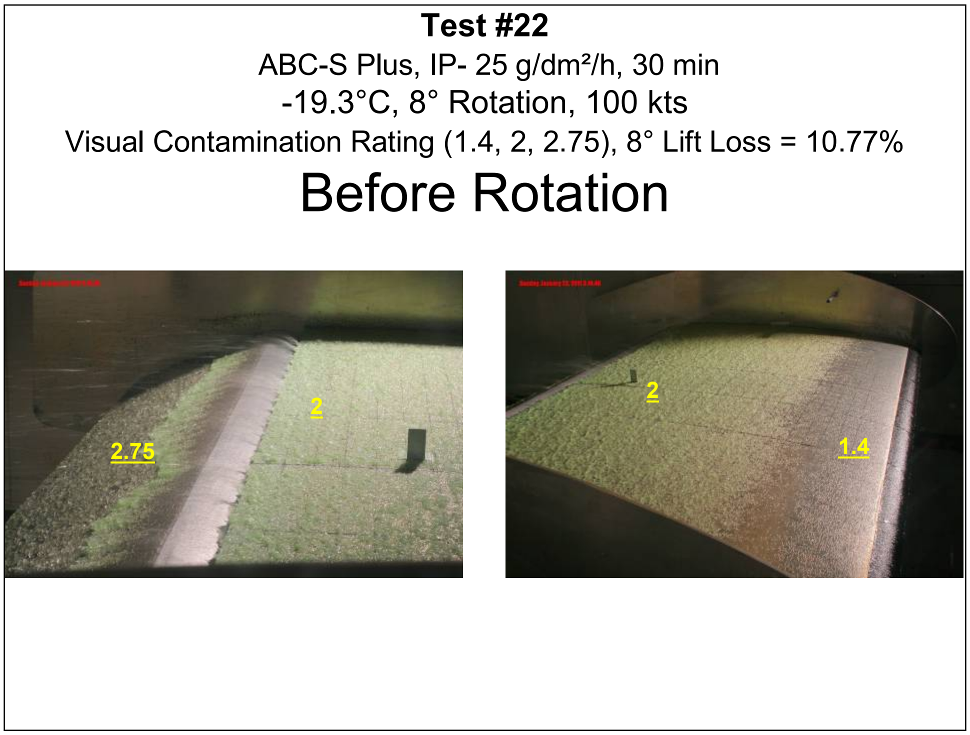
ABC-S Plus, IP- 25 g/dm²/h, 30 min

-19.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.75, 2.75, 3.5)

Start of Test

Photo 6.30: Test #22 – Before Rotation



Test #22

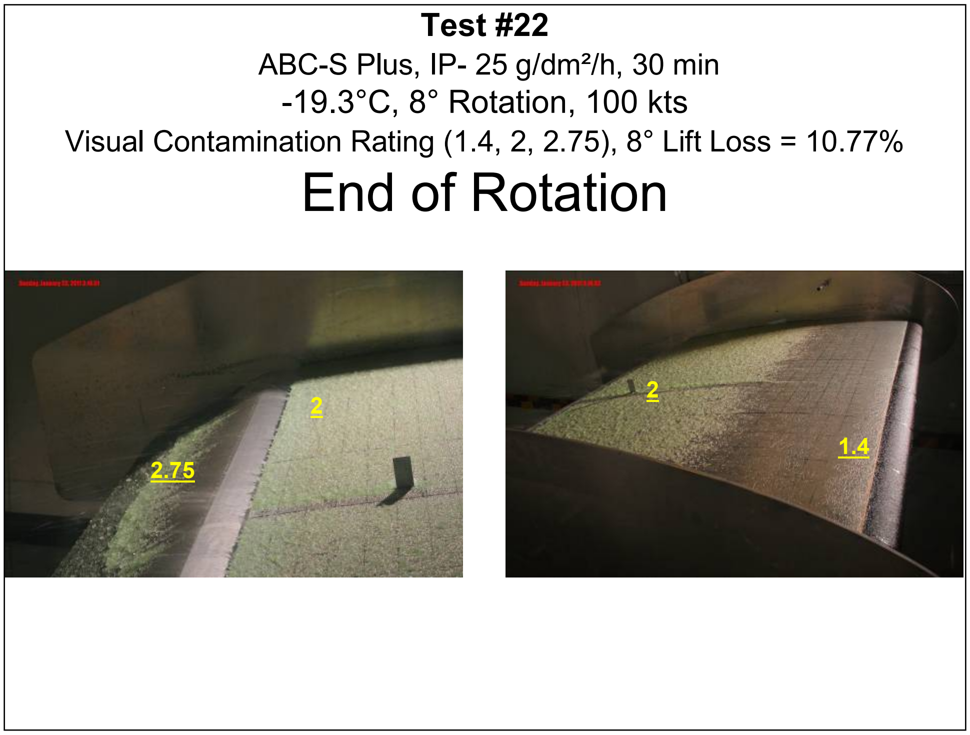
ABC-S Plus, IP- 25 g/dm²/h, 30 min

-19.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.4, 2, 2.75), 8° Lift Loss = 10.77%

Before Rotation

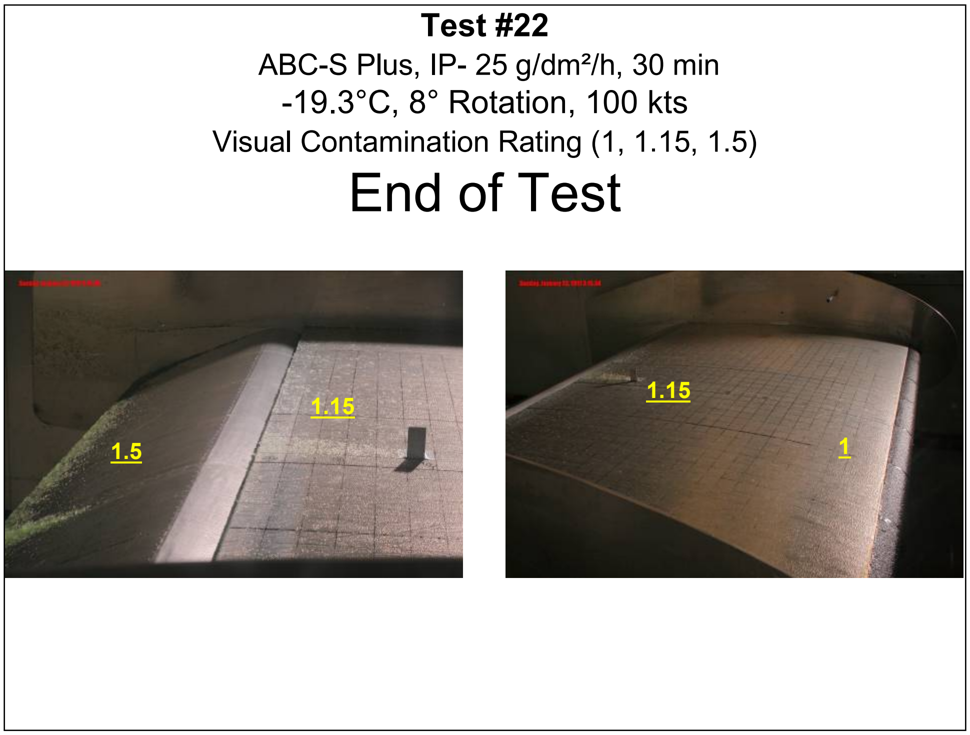
Photo 6.31: Test #22 – End of Rotation



Test #22
ABC-S Plus, IP- 25 g/dm²/h, 30 min
-19.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1.4, 2, 2.75), 8° Lift Loss = 10.77%

End of Rotation

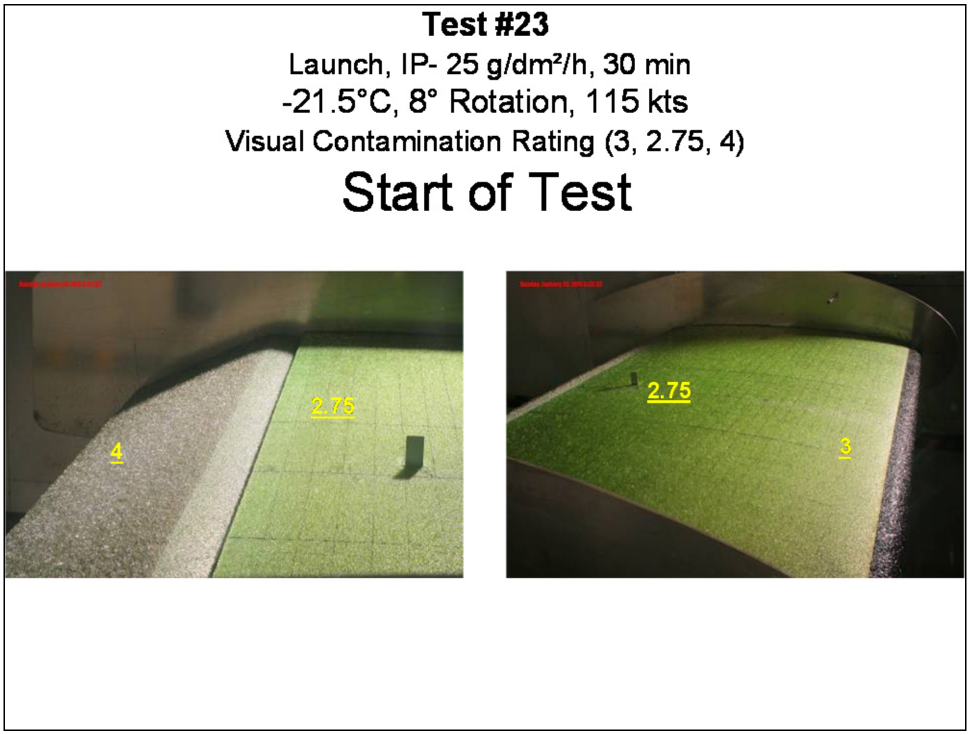
Photo 6.32: Test #22 – End of Test



Test #22
ABC-S Plus, IP- 25 g/dm²/h, 30 min
-19.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1.15, 1.5)

End of Test

Photo 6.33: Test #23 – Start of Test



Test #23

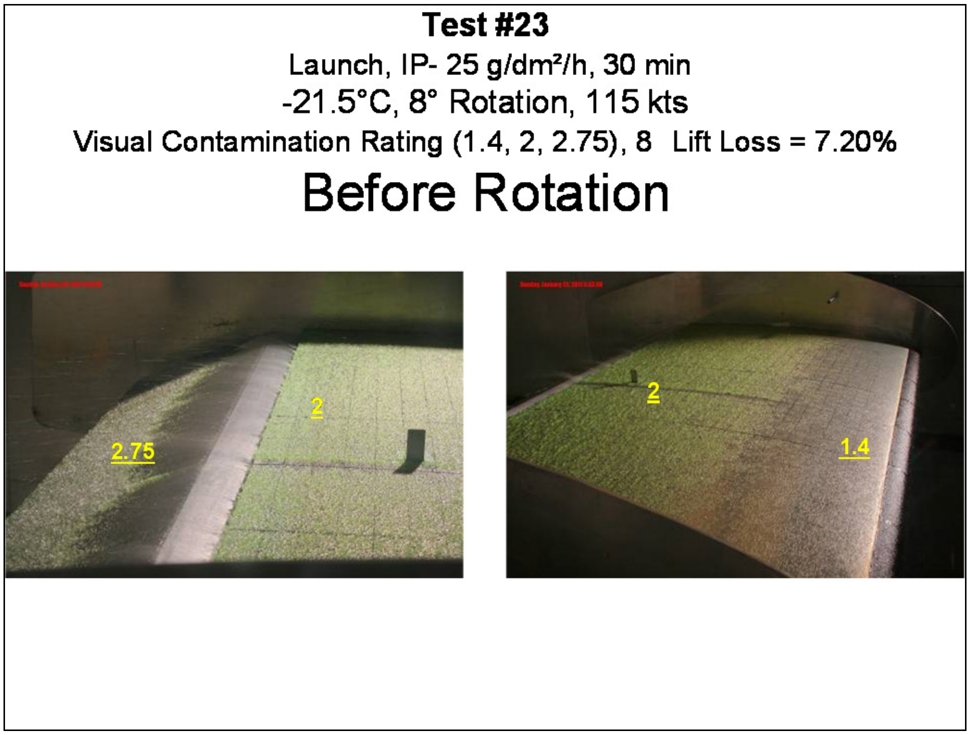
Launch, IP- 25 g/dm²/h, 30 min

-21.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (3, 2.75, 4)

Start of Test

Photo 6.34: Test #23 – Before Rotation



Test #23

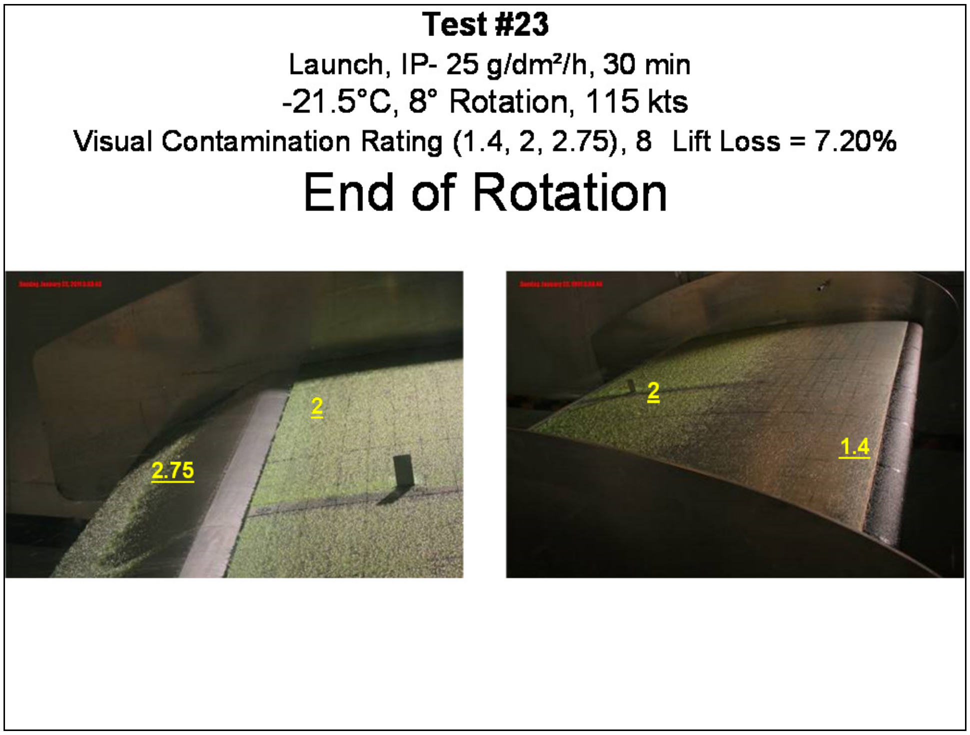
Launch, IP- 25 g/dm²/h, 30 min

-21.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.4, 2, 2.75), 8 Lift Loss = 7.20%

Before Rotation

Photo 6.35: Test #23 – End of Rotation



Test #23

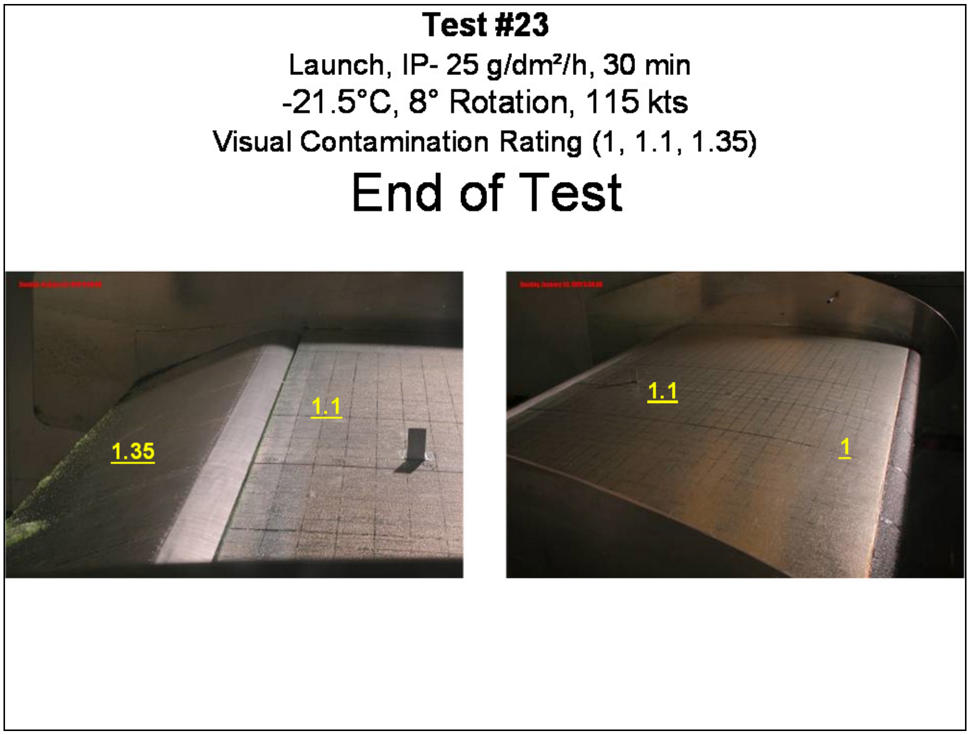
Launch, IP- 25 g/dm²/h, 30 min

-21.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.4, 2, 2.75), 8 Lift Loss = 7.20%

End of Rotation

Photo 6.36: Test #23 – End of Test



Test #23

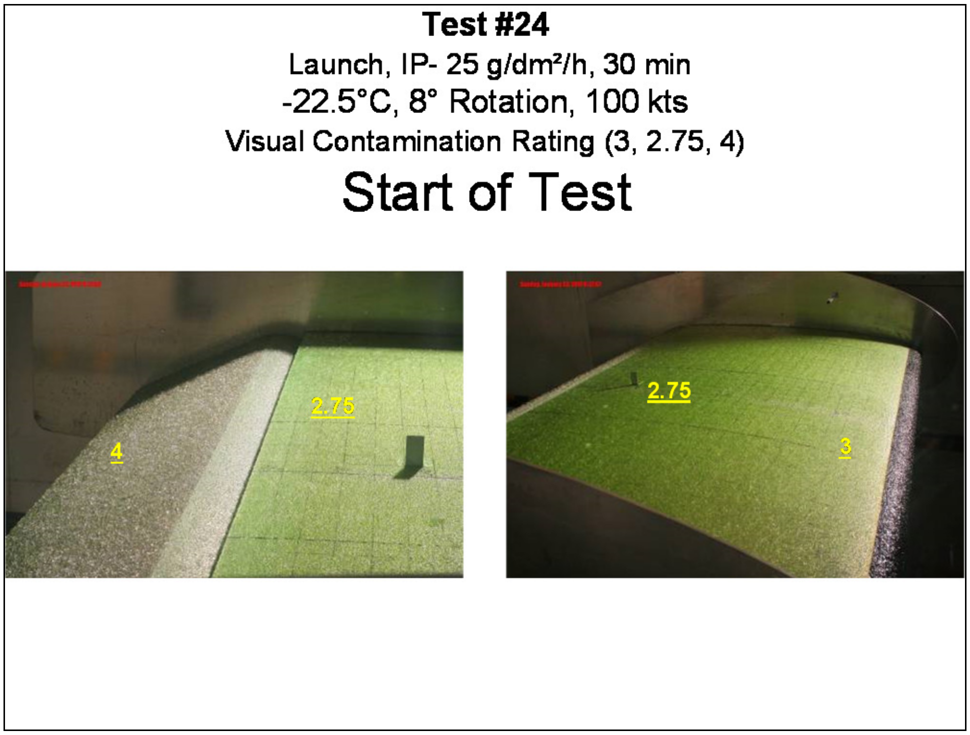
Launch, IP- 25 g/dm²/h, 30 min

-21.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.1, 1.35)

End of Test

Photo 6.37: Test #24 – Start of Test



Test #24

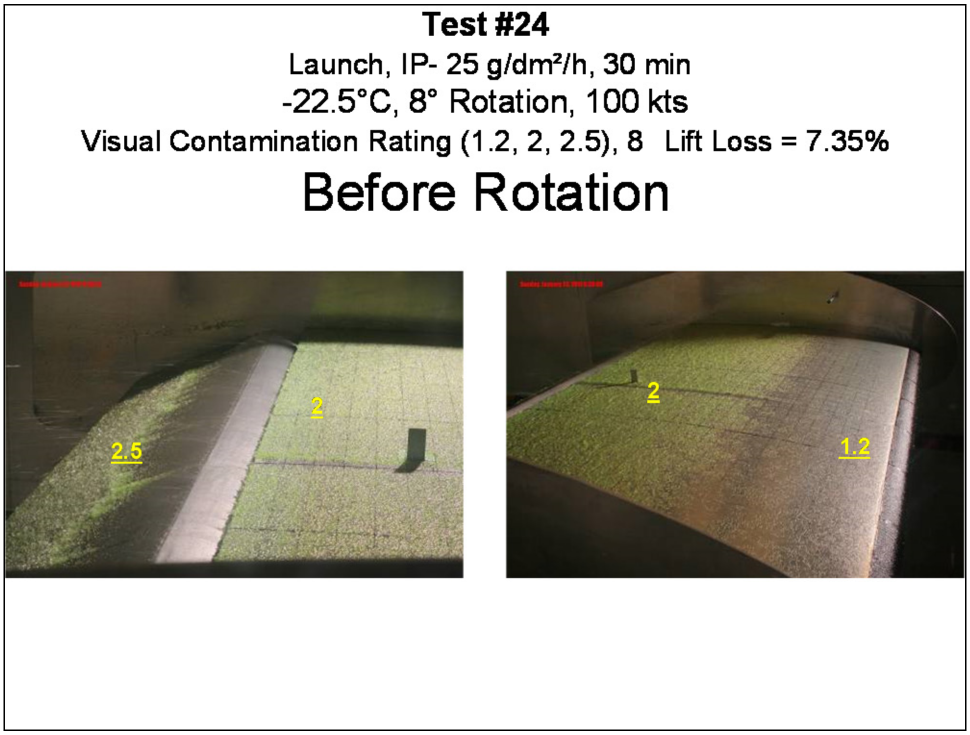
Launch, IP- 25 g/dm²/h, 30 min

-22.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (3, 2.75, 4)

Start of Test

Photo 6.38: Test #24 – Before Rotation



Test #24

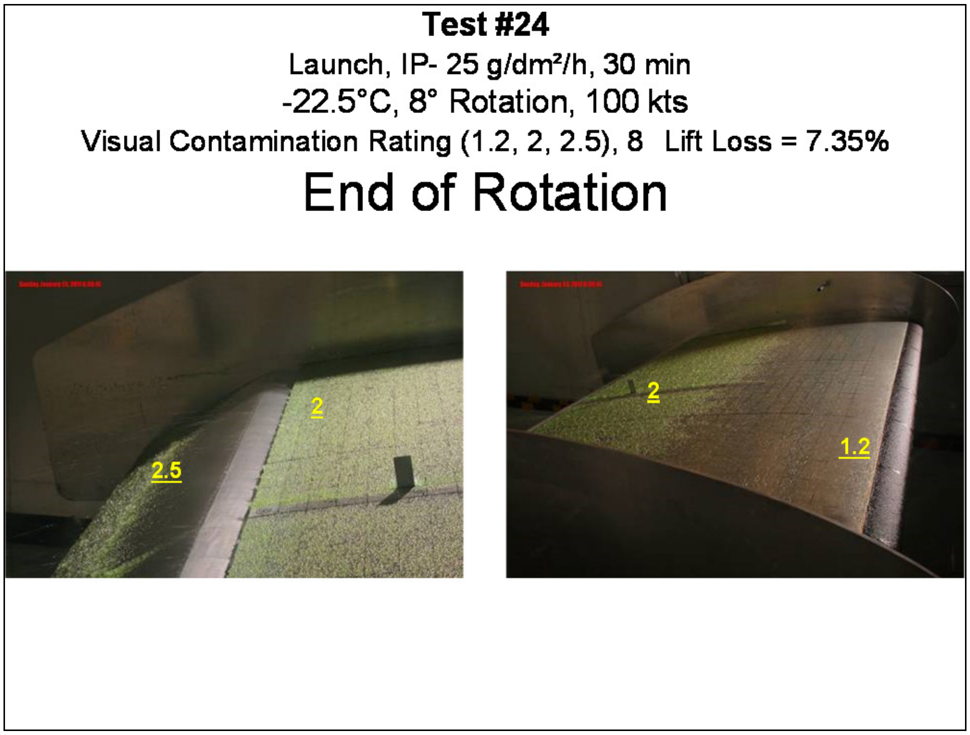
Launch, IP- 25 g/dm²/h, 30 min

-22.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 2, 2.5), 8 Lift Loss = 7.35%

Before Rotation

Photo 6.39: Test #24 – End of Rotation



Test #24

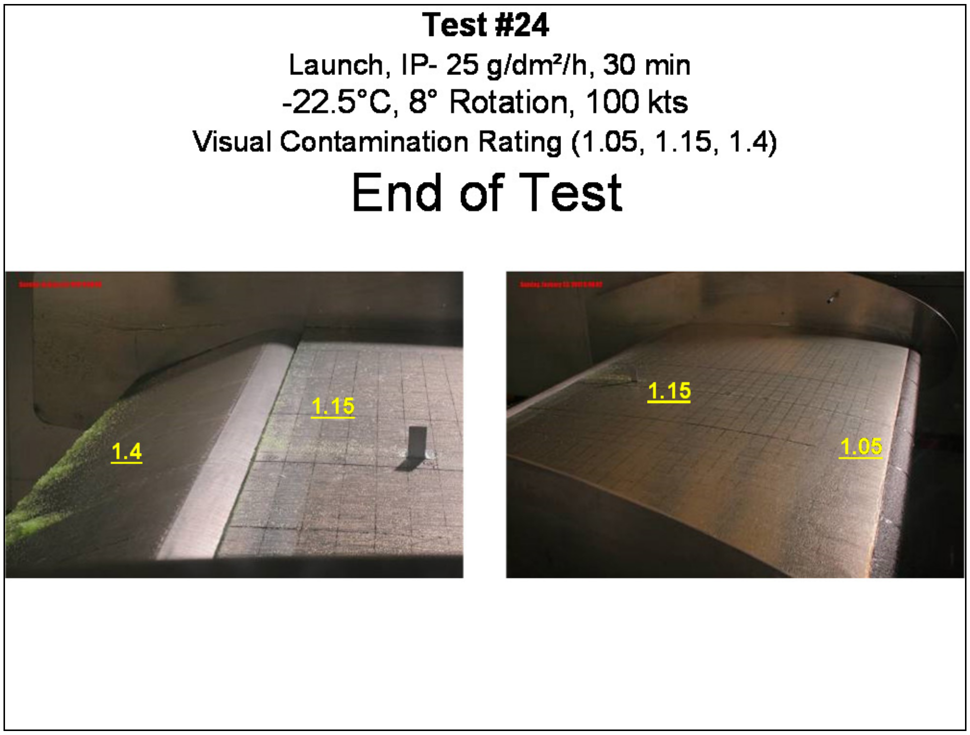
Launch, IP- 25 g/dm²/h, 30 min

-22.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 2, 2.5), 8 Lift Loss = 7.35%

End of Rotation

Photo 6.40: Test #24 – End of Test



Test #24

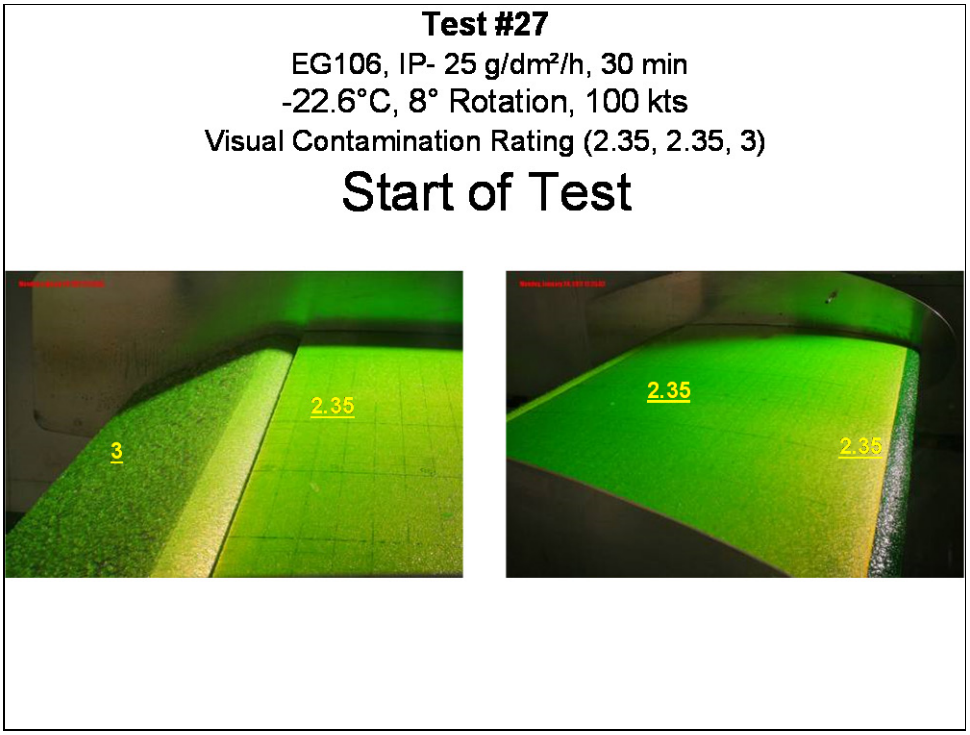
Launch, IP- 25 g/dm²/h, 30 min

-22.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.05, 1.15, 1.4)

End of Test

Photo 6.41: Test #27 – Start of Test



Test #27

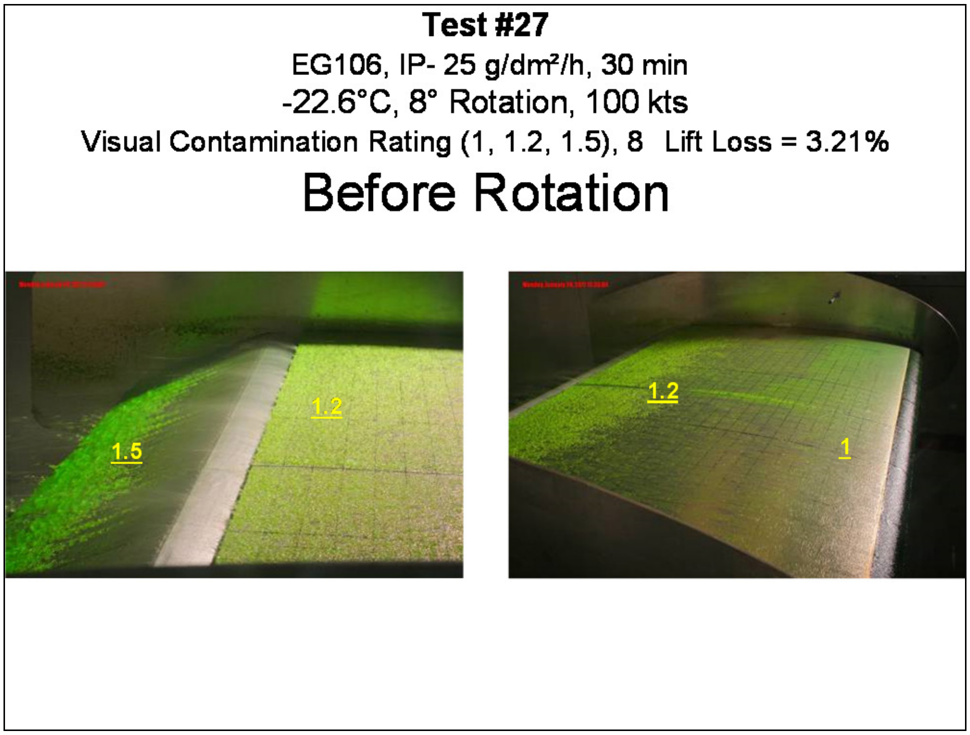
EG106, IP- 25 $g/dm^2/h$, 30 min

-22.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.35, 2.35, 3)

Start of Test

Photo 6.42: Test #27 – Before Rotation



Test #27

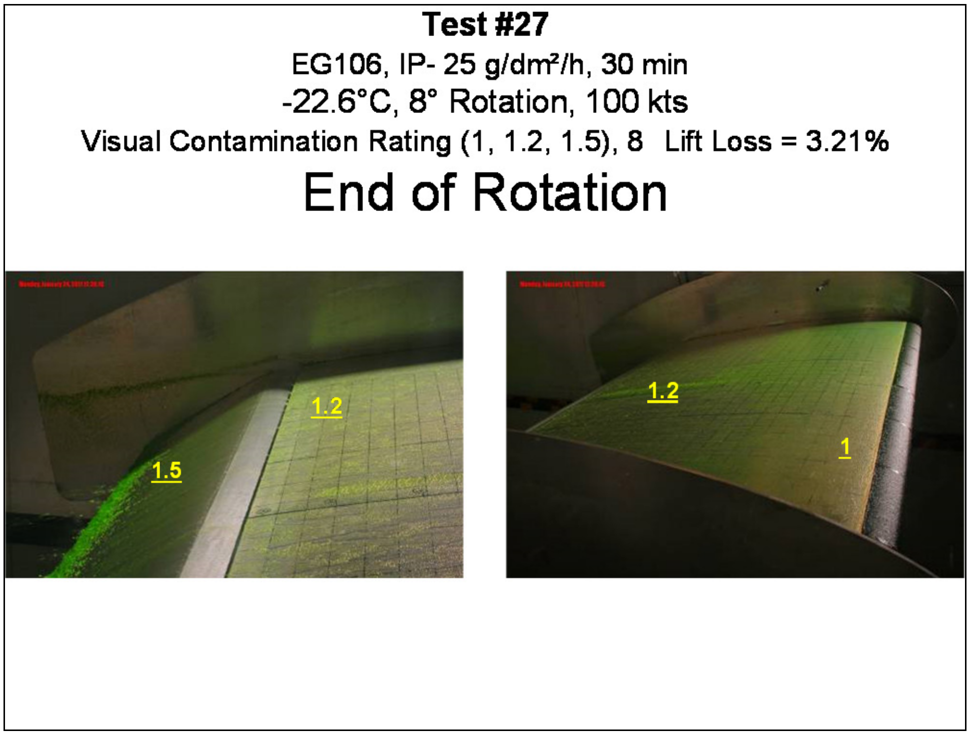
EG106, IP- 25 $g/dm^2/h$, 30 min

-22.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.5), 8 Lift Loss = 3.21%

Before Rotation

Photo 6.43: Test #27 – End of Rotation



Test #27

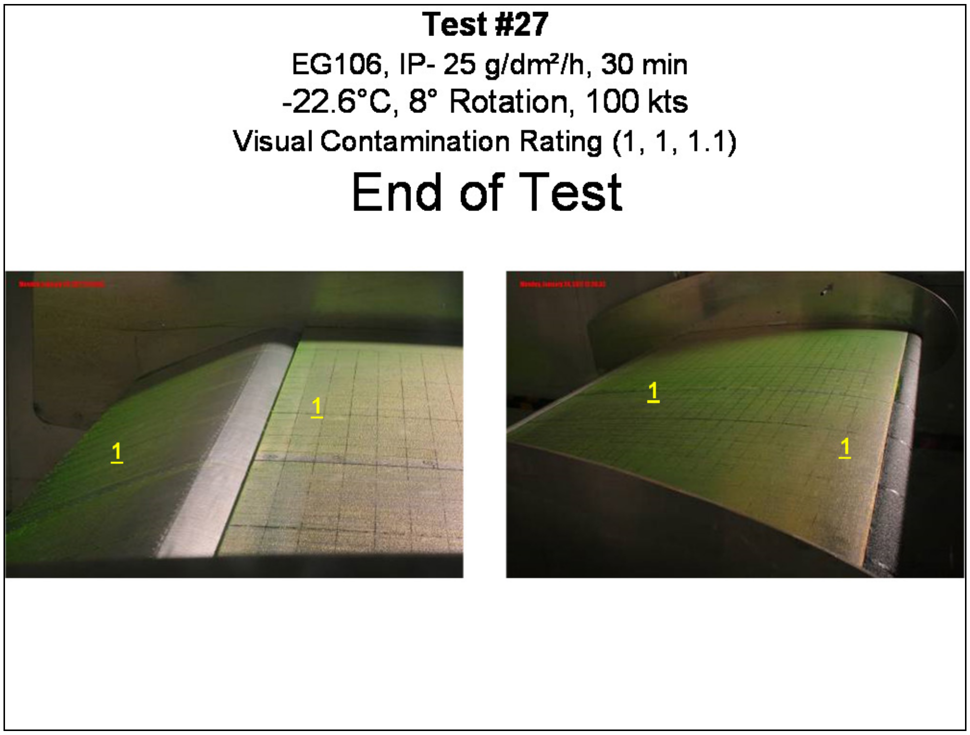
EG106, IP- 25 g/dm²/h, 30 min

-22.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.5), 8 Lift Loss = 3.21%

End of Rotation

Photo 6.44: Test #27 – End of Test



Test #27

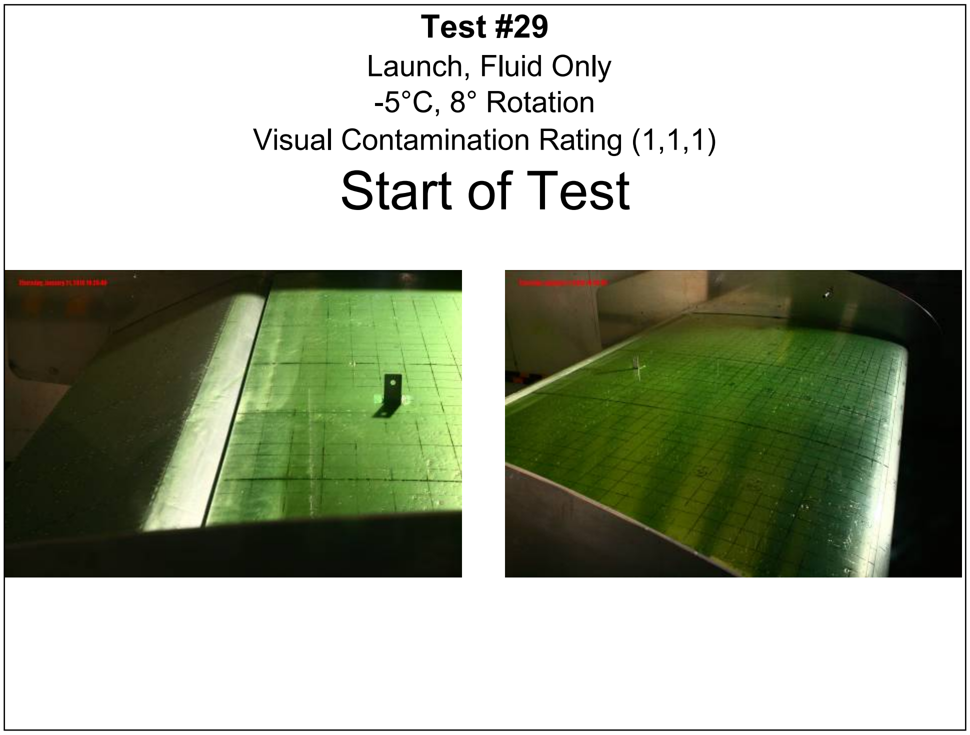
EG106, IP- 25 g/dm²/h, 30 min

-22.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.1)

End of Test

Photo 6.45: Test #29 – Start of Test



Test #29

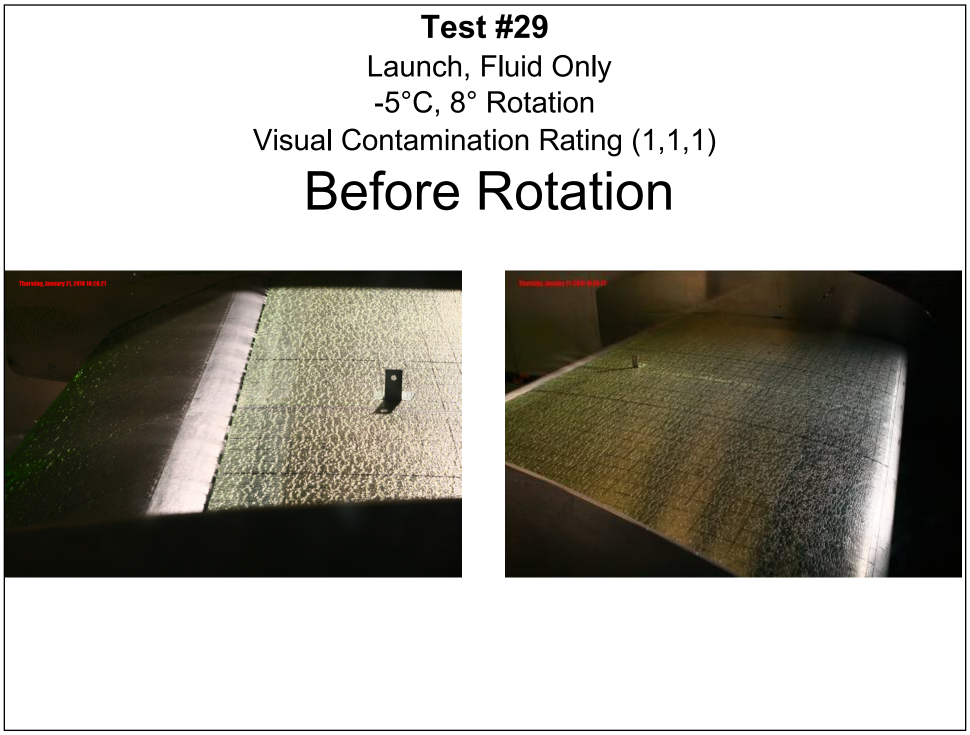
Launch, Fluid Only

-5°C, 8° Rotation

Visual Contamination Rating (1,1,1)

Start of Test

Photo 6.46: Test #29 – Before Rotation



Test #29

Launch, Fluid Only

-5°C, 8° Rotation

Visual Contamination Rating (1,1,1)

Before Rotation

Photo 6.47: Test #29 – End of Rotation

Test #29
Launch, Fluid Only
-5°C, 8° Rotation
Visual Contamination Rating (1,1,1), 8° Lift Loss = 4.96%
End of Rotation

Photo 6.48: Test #29 – End of Test

Test #29
Launch, Fluid Only
-5°C, 8° Rotation
Visual Contamination Rating (1,1,1)
End of Test

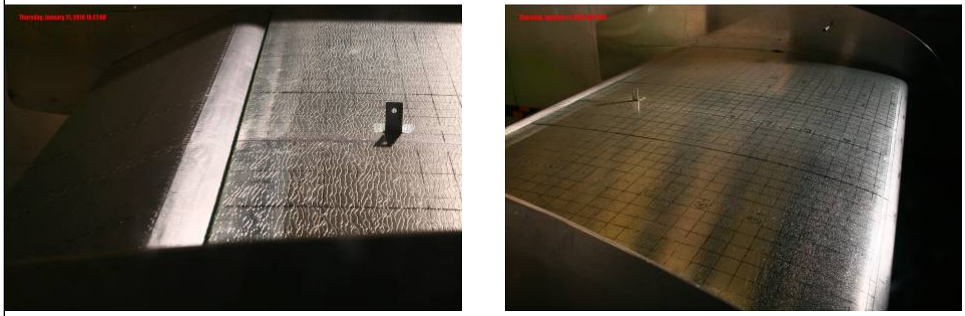
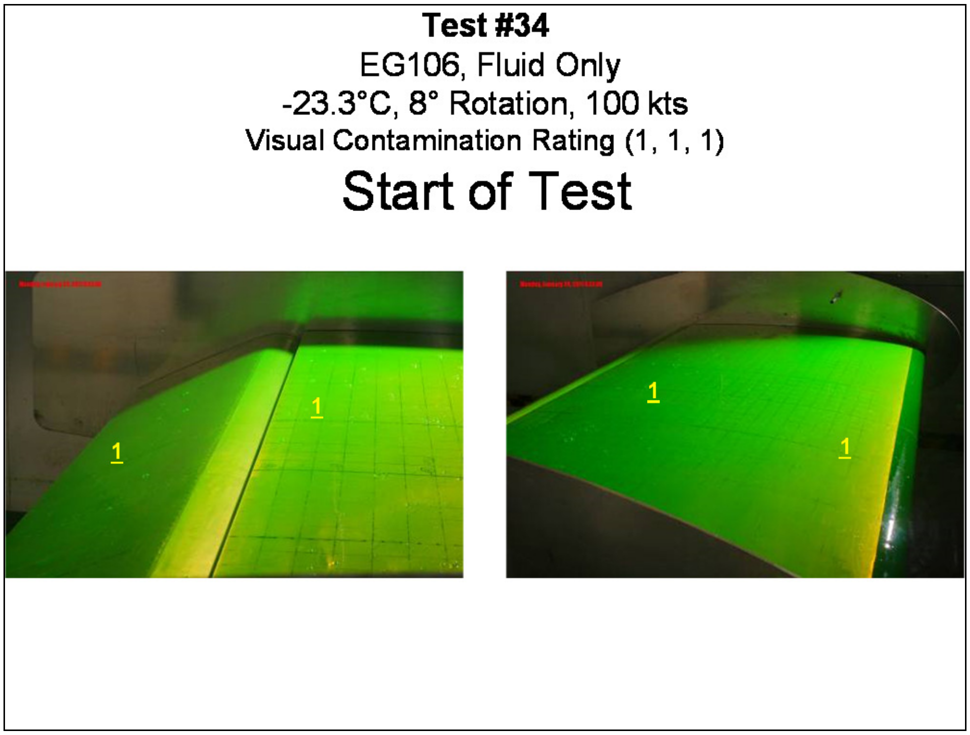
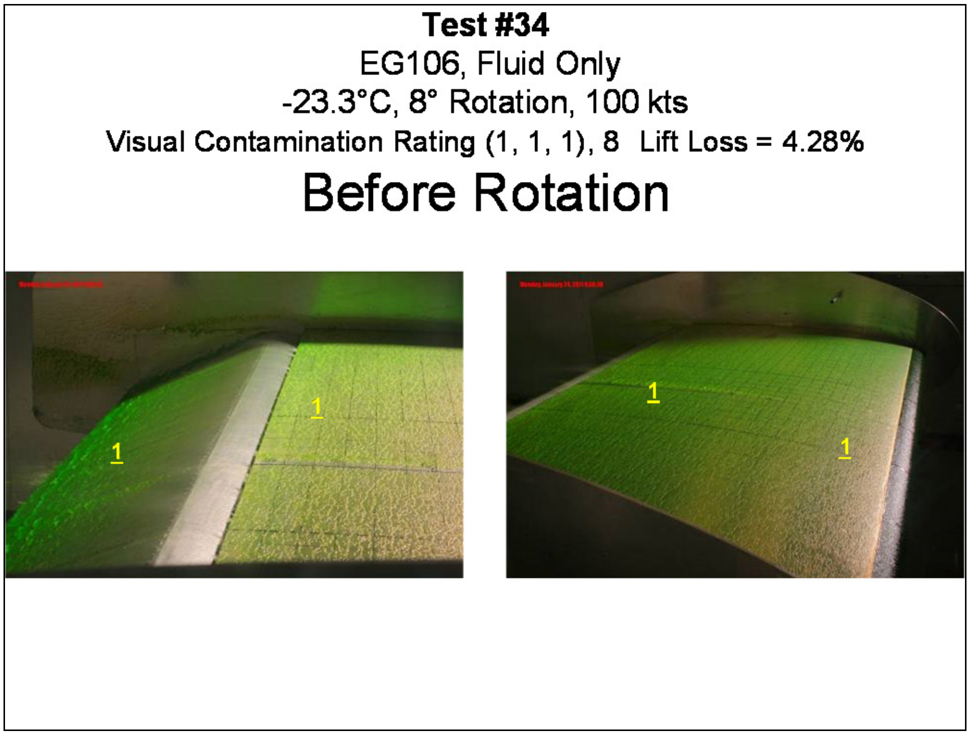


Photo 6.49: Test #34 – Start of Test



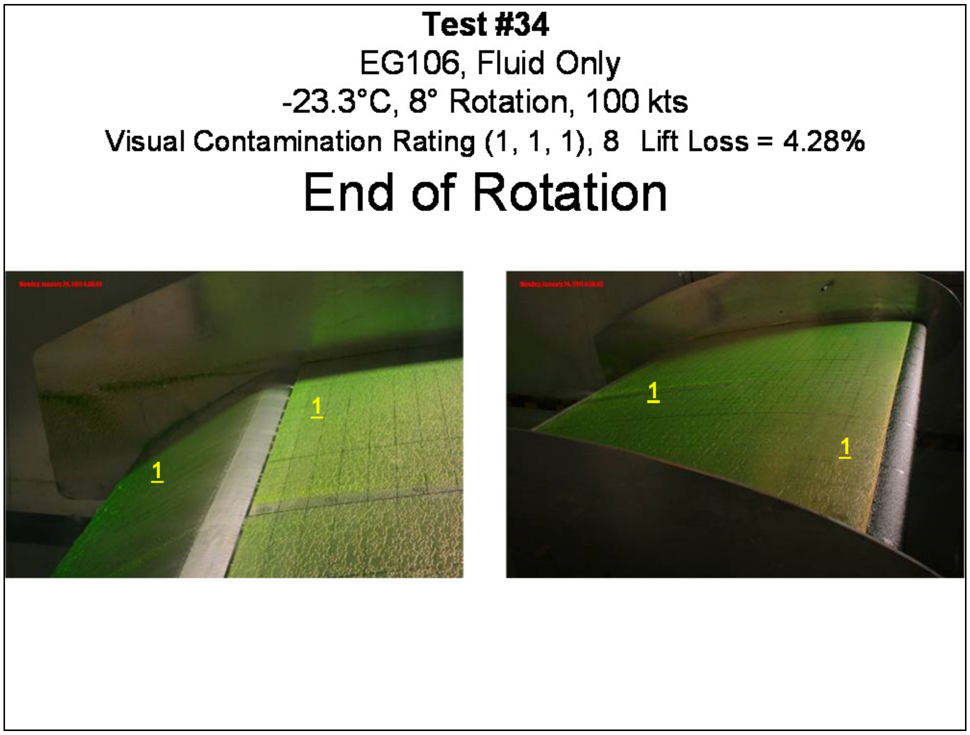
Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 6.50: Test #34 – Before Rotation



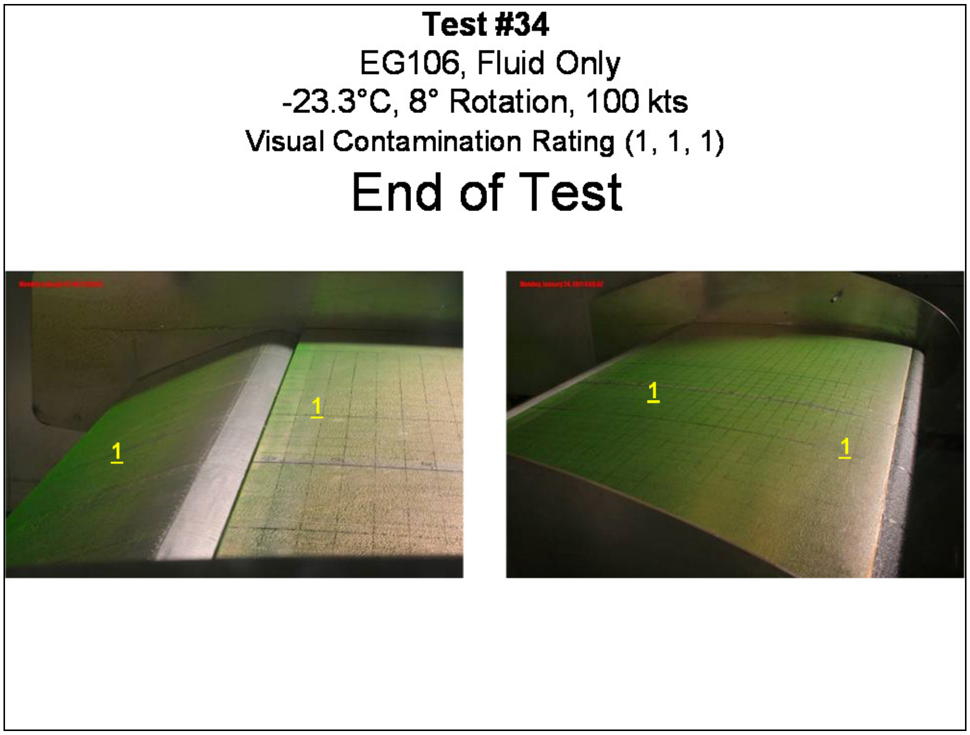
Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 4.28%
Before Rotation

Photo 6.51: Test #34 – End of Rotation



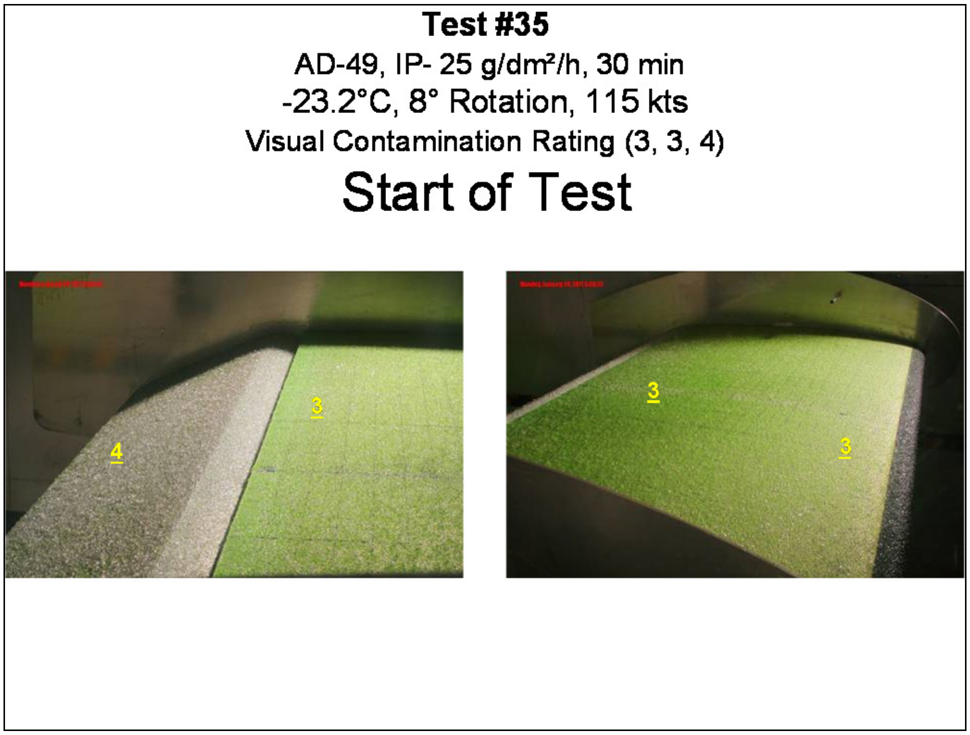
Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 4.28%
End of Rotation

Photo 6.52: Test #34 – End of Test



Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 6.53: Test #35 – Start of Test



Test #35

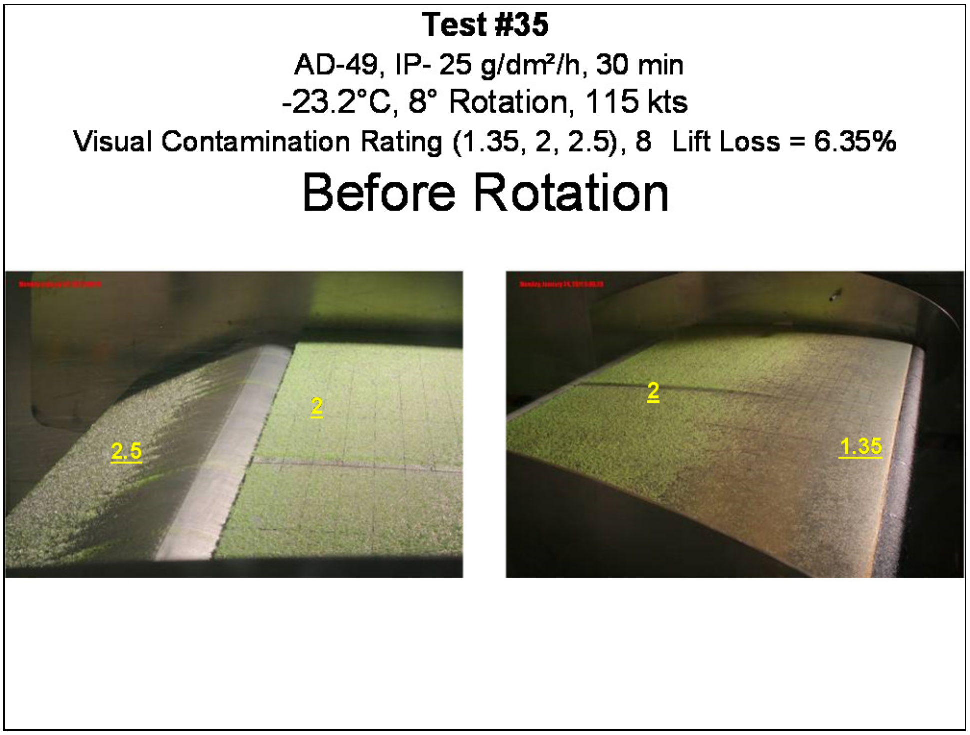
AD-49, IP- 25 g/dm²/h, 30 min

-23.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (3, 3, 4)

Start of Test

Photo 6.54: Test #35 – Before Rotation



Test #35

AD-49, IP- 25 g/dm²/h, 30 min

-23.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.35, 2, 2.5), 8 Lift Loss = 6.35%

Before Rotation

Photo 6.55: Test #35 – End of Rotation

Test #35
AD-49, IP- 25 g/dm²/h, 30 min
-23.2°C, 8° Rotation, 115 kts
Visual Contamination Rating (1.35, 2, 2.5), 8 Lift Loss = 6.35%

End of Rotation

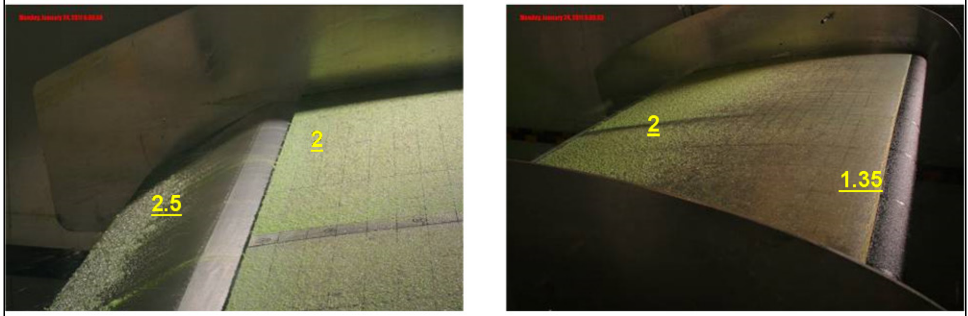


Photo 6.56: Test #35 – End of Test

Test #35
AD-49, IP- 25 g/dm²/h, 30 min
-23.2°C, 8° Rotation, 115 kts
Visual Contamination Rating (1.1, 1.25, 1.6)

End of Test

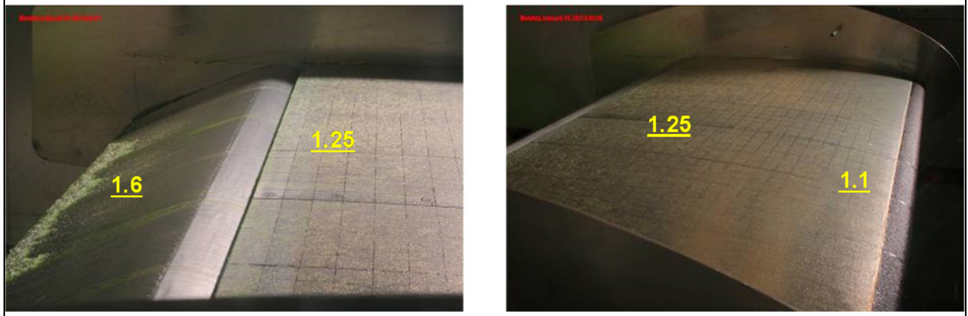
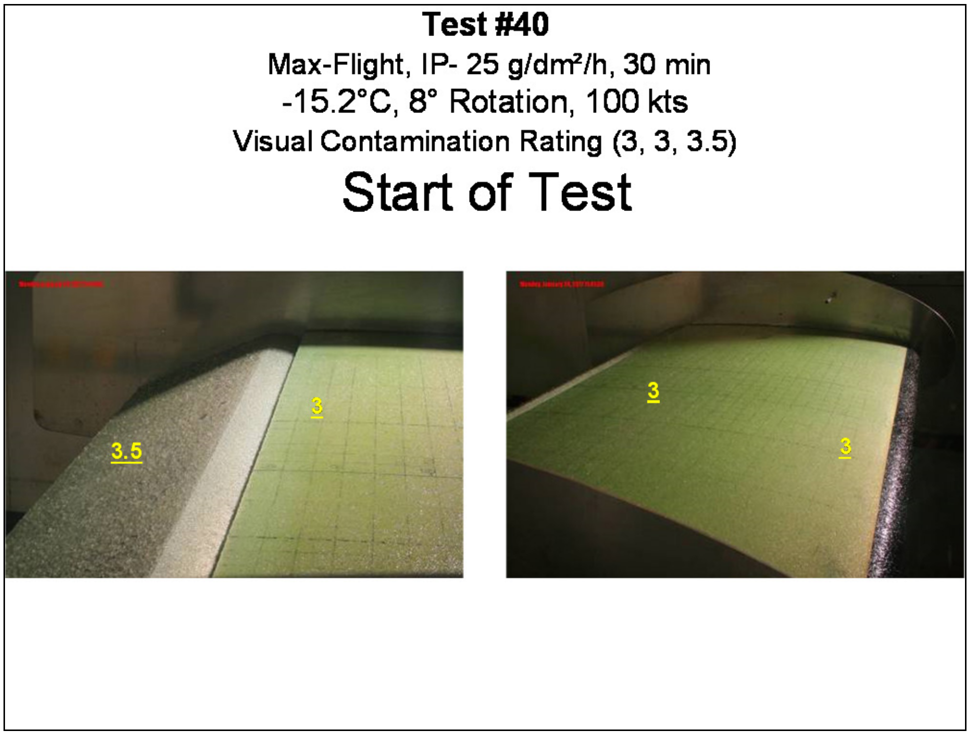


Photo 6.57: Test #40 – Start of Test



Test #40

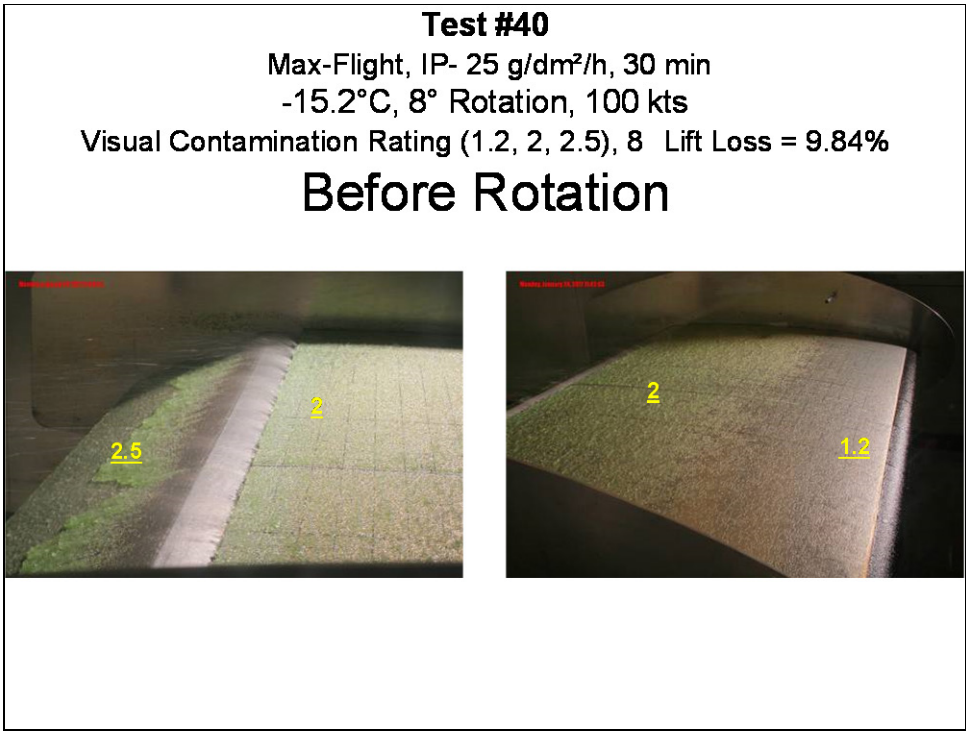
Max-Flight, IP- 25 g/dm²/h, 30 min

-15.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (3, 3, 3.5)

Start of Test

Photo 6.58: Test #40 – Before Rotation



Test #40

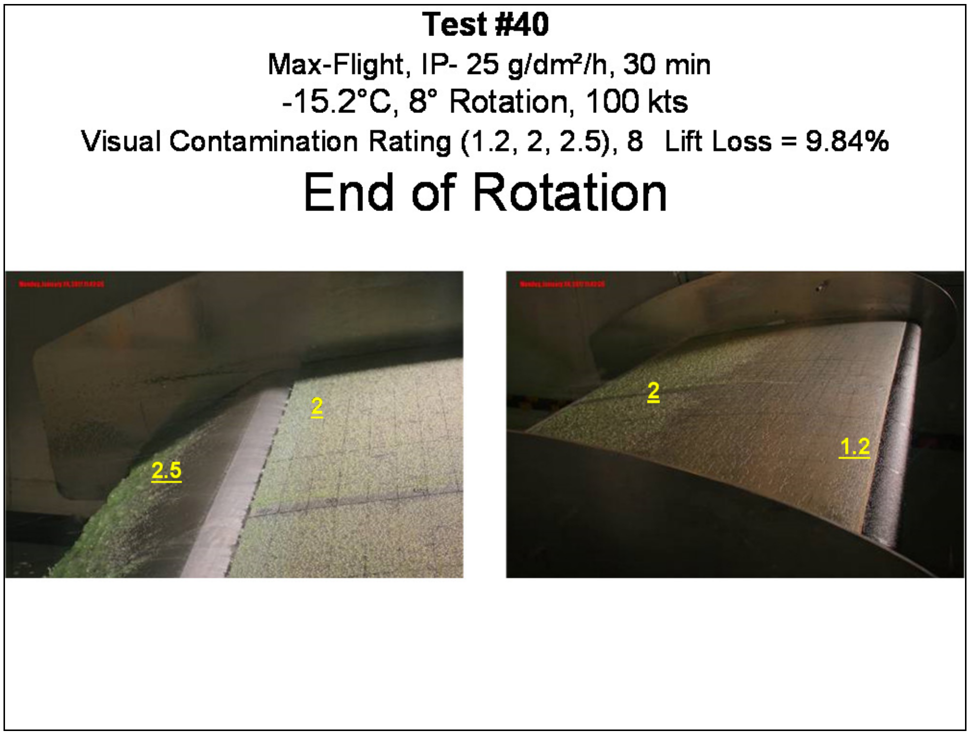
Max-Flight, IP- 25 g/dm²/h, 30 min

-15.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 2, 2.5), 8 Lift Loss = 9.84%

Before Rotation

Photo 6.59: Test #40 – End of Rotation



Test #40

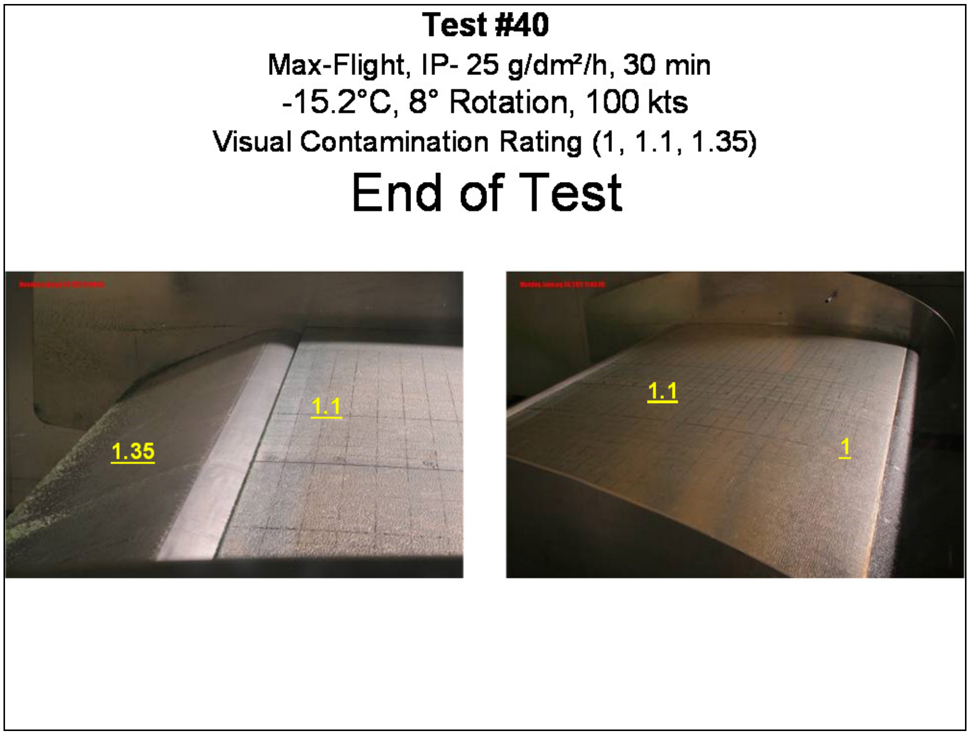
Max-Flight, IP- 25 g/dm²/h, 30 min

-15.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 2, 2.5), 8 Lift Loss = 9.84%

End of Rotation

Photo 6.60: Test #40 – End of Test



Test #40

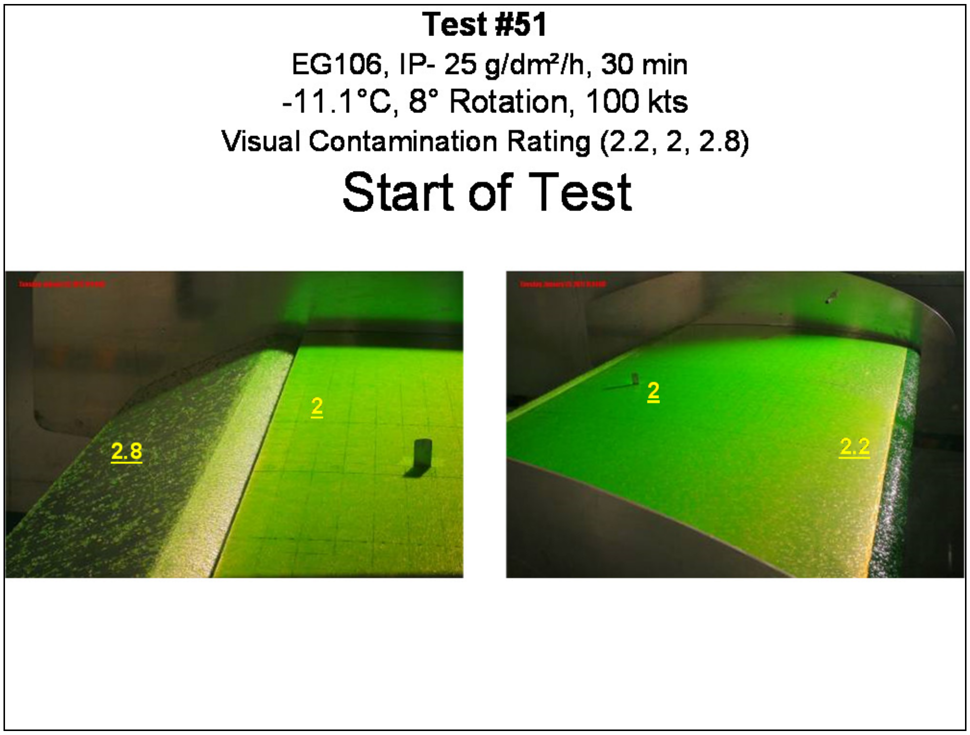
Max-Flight, IP- 25 g/dm²/h, 30 min

-15.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.1, 1.35)

End of Test

Photo 6.61: Test #51 – Start of Test



Test #51

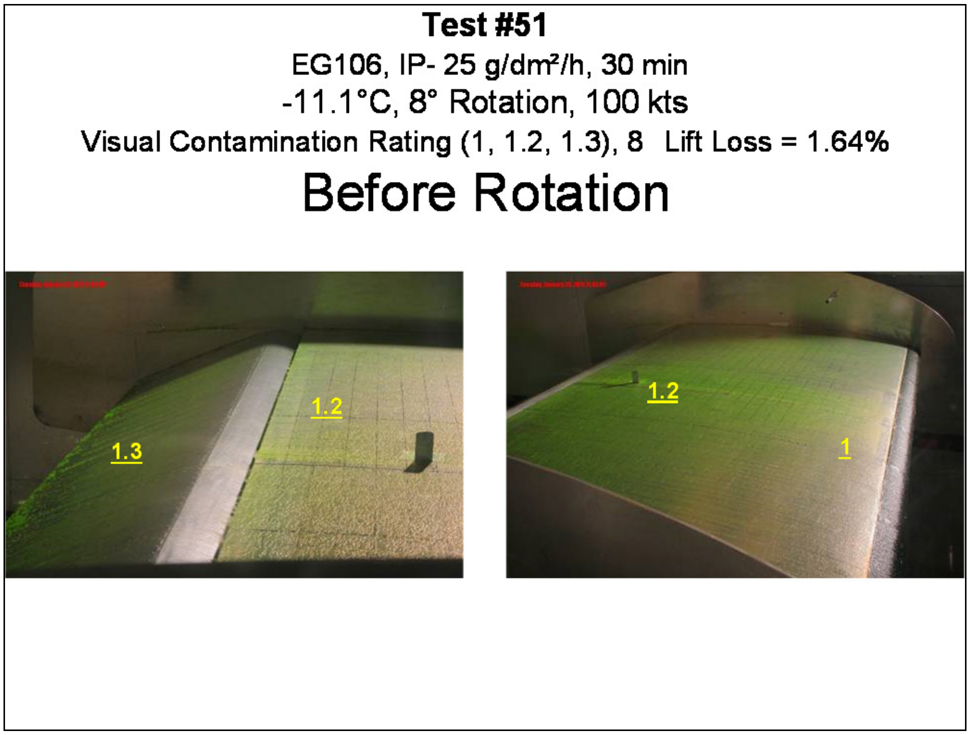
EG106, IP- 25 g/dm²/h, 30 min

-11.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.2, 2, 2.8)

Start of Test

Photo 6.62: Test #51 – Before Rotation



Test #51

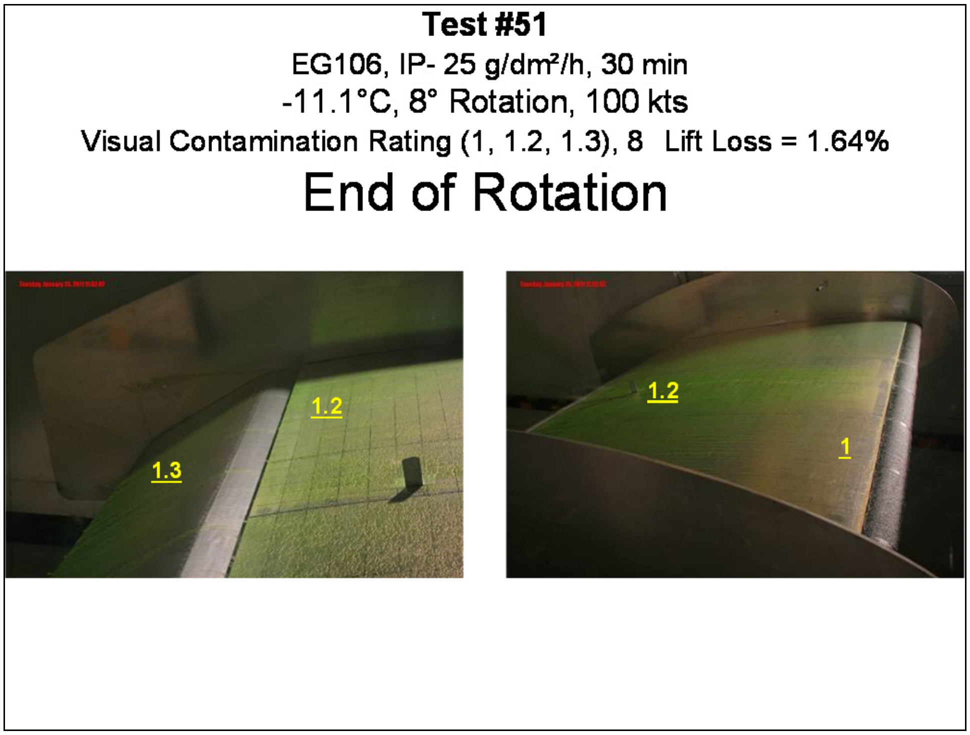
EG106, IP- 25 g/dm²/h, 30 min

-11.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.3), 8 Lift Loss = 1.64%

Before Rotation

Photo 6.63: Test #51 – End of Rotation



Test #51

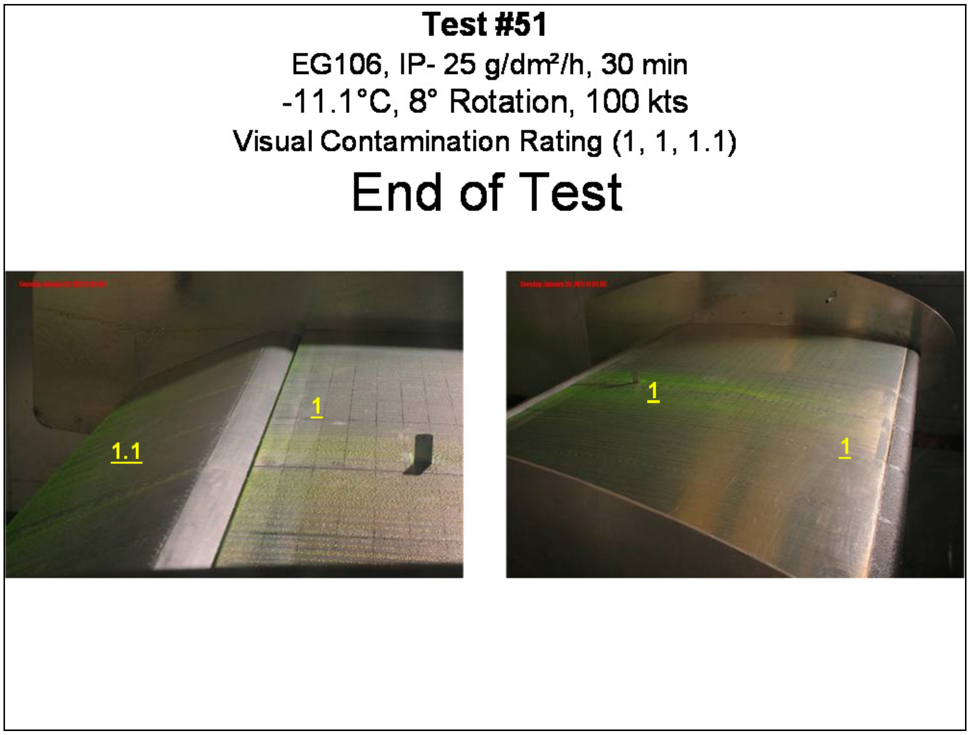
EG106, IP- 25 g/dm²/h, 30 min

-11.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.3), 8 Lift Loss = 1.64%

End of Rotation

Photo 6.64: Test #51 – End of Test



Test #51

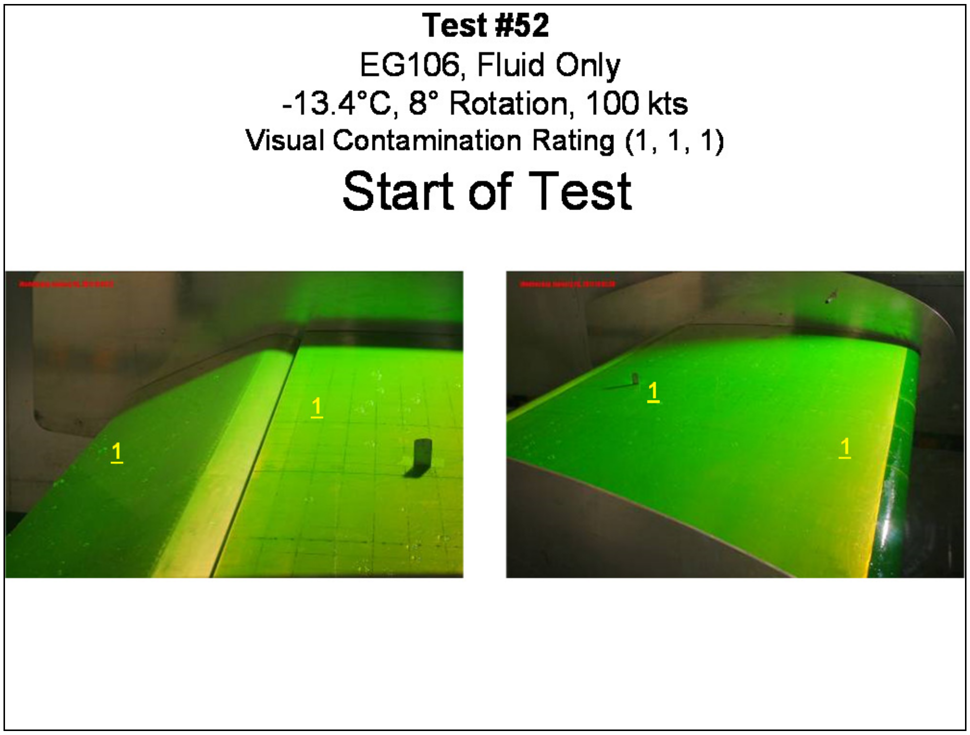
EG106, IP- 25 g/dm²/h, 30 min

-11.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.1)

End of Test

Photo 6.65: Test #52 – Start of Test



Test #52

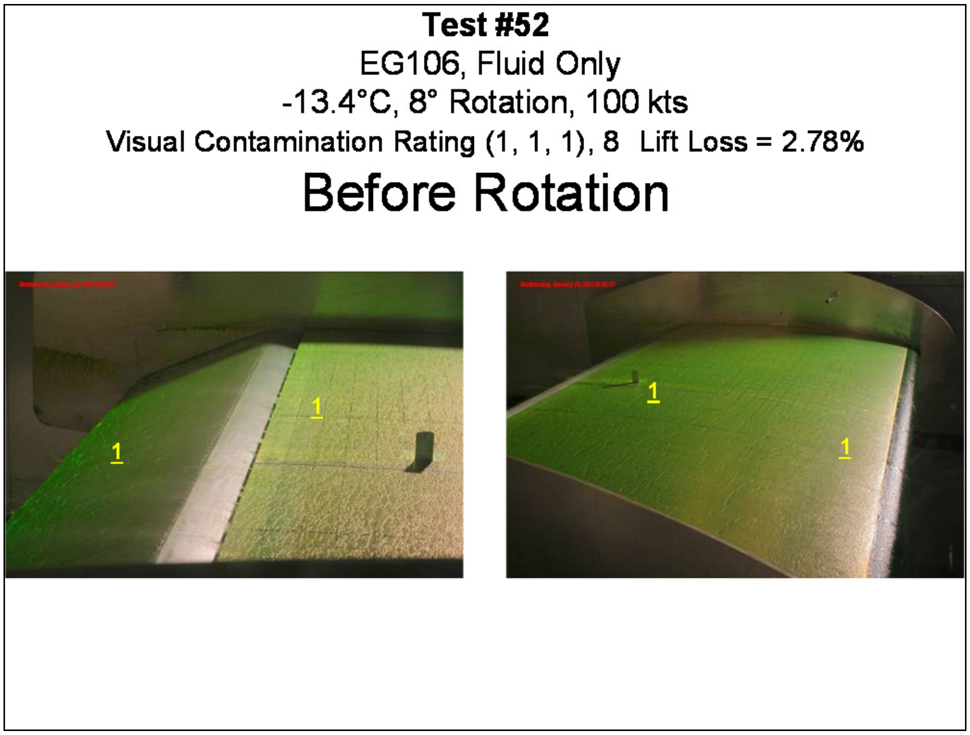
EG106, Fluid Only

-13.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 6.66: Test #52 – Before Rotation



Test #52

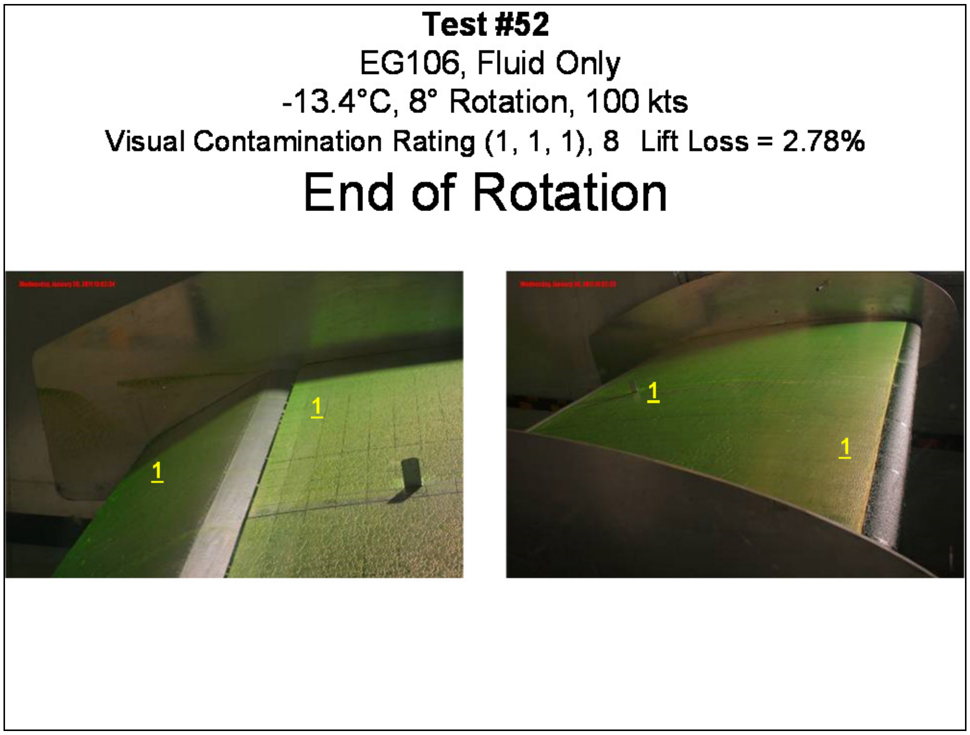
EG106, Fluid Only

-13.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%

Before Rotation

Photo 6.67: Test #52 – End of Rotation



Test #52

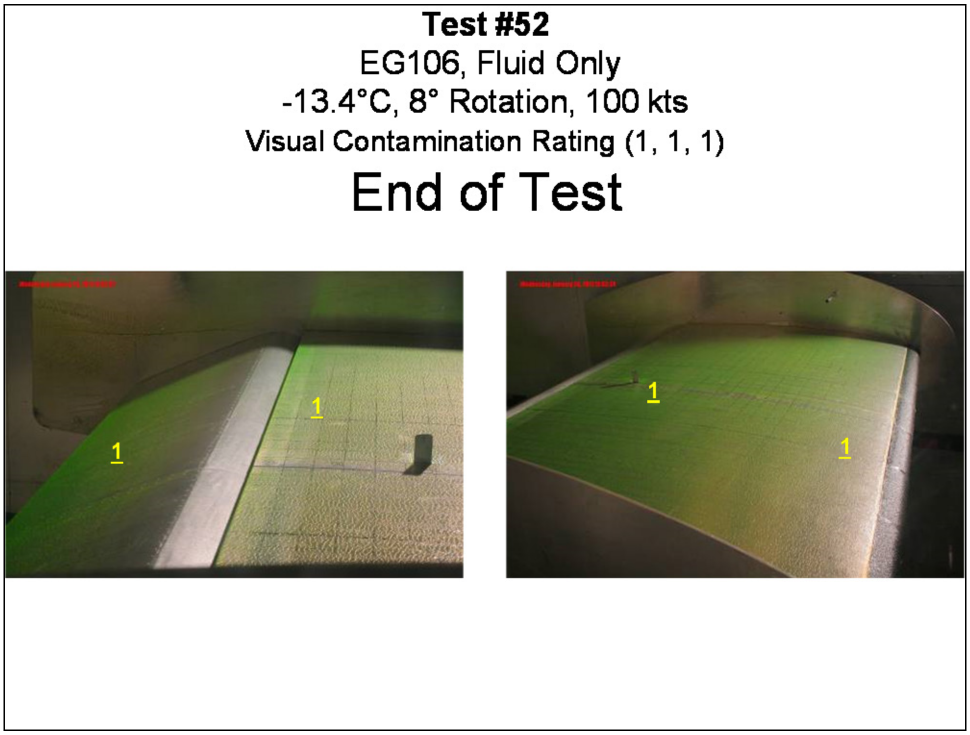
EG106, Fluid Only

-13.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%

End of Rotation

Photo 6.68: Test #52 – End of Test



Test #52

EG106, Fluid Only

-13.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 6.69: Test #53 – Start of Test

Test #53

ABC-S Plus, IP- 25 g/dm²/h, 30 min

-12.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.5, 2.5, 3.2)

Start of Test

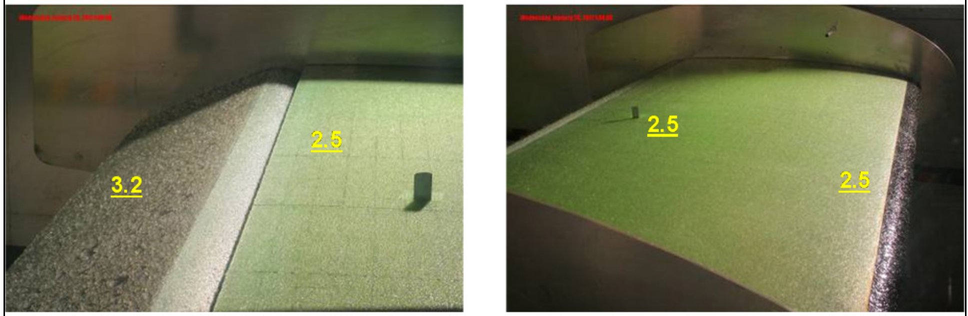


Photo 6.70: Test #53 – Before Rotation

Test #53

ABC-S Plus, IP- 25 g/dm²/h, 30 min

-12.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 2, 2.5), 8 Lift Loss = 8.92%

Before Rotation

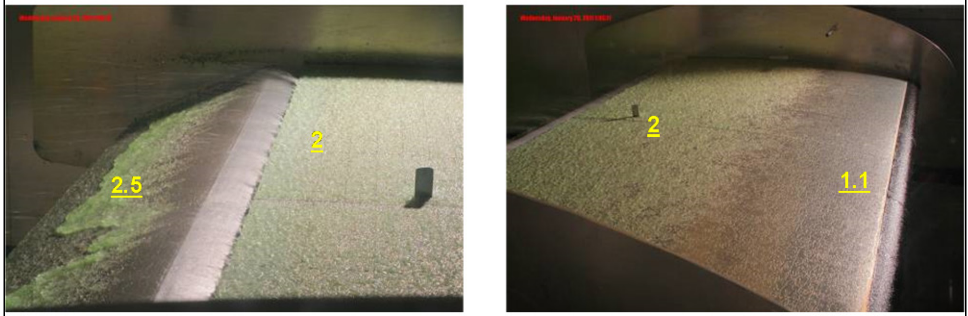
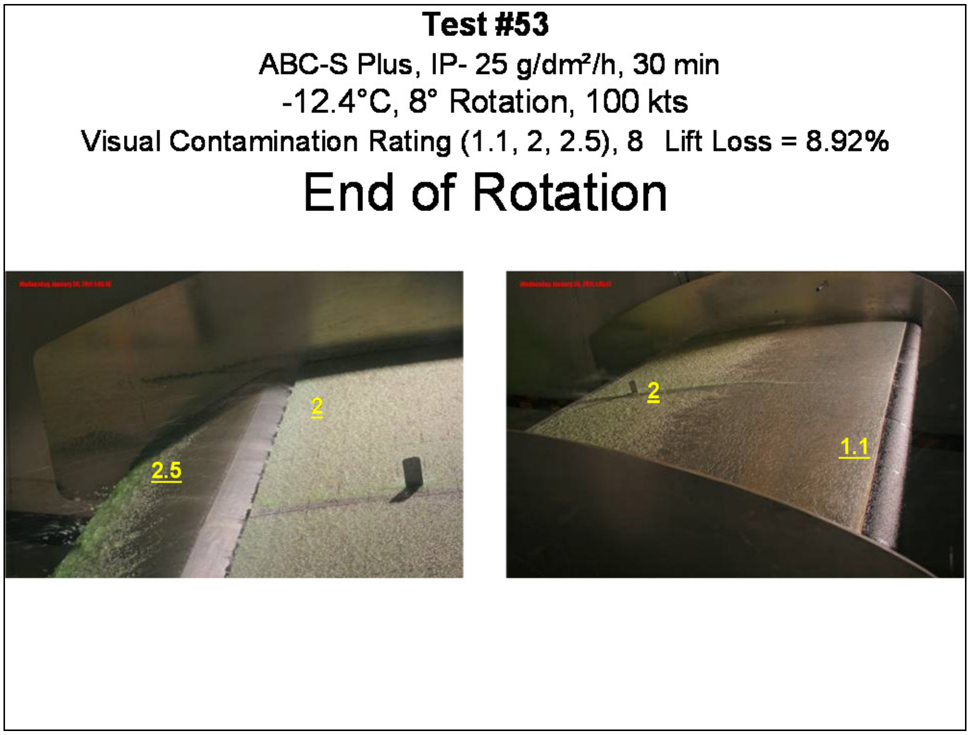


Photo 6.71: Test #53 – End of Rotation



Test #53

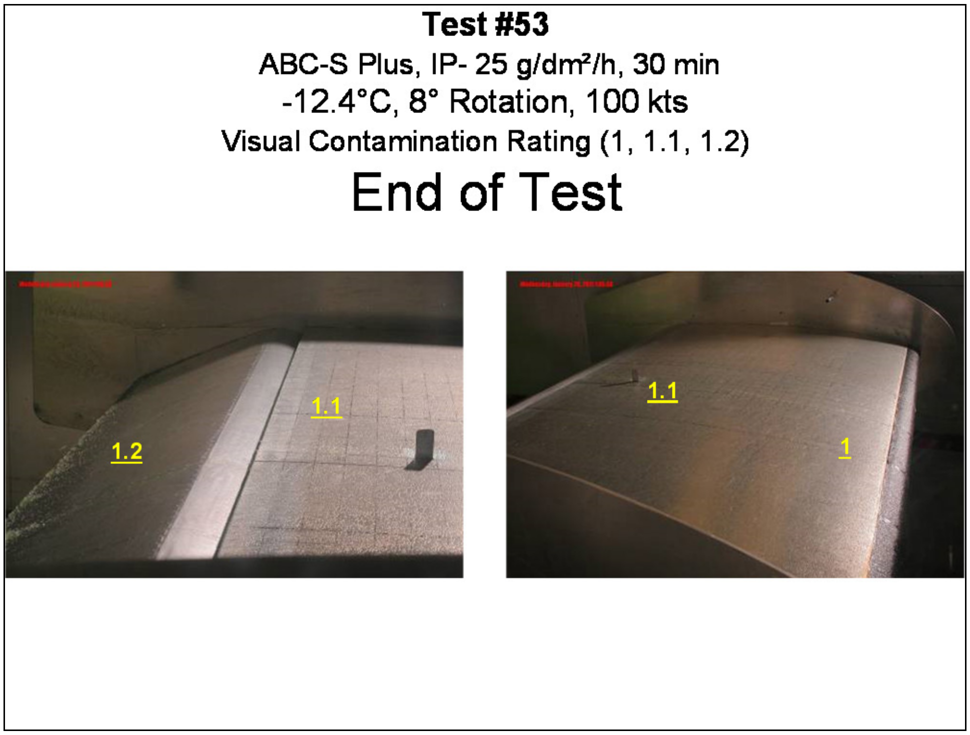
ABC-S Plus, IP- 25 g/dm²/h, 30 min

-12.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 2, 2.5), 8 Lift Loss = 8.92%

End of Rotation

Photo 6.72: Test #53 – End of Test



Test #53

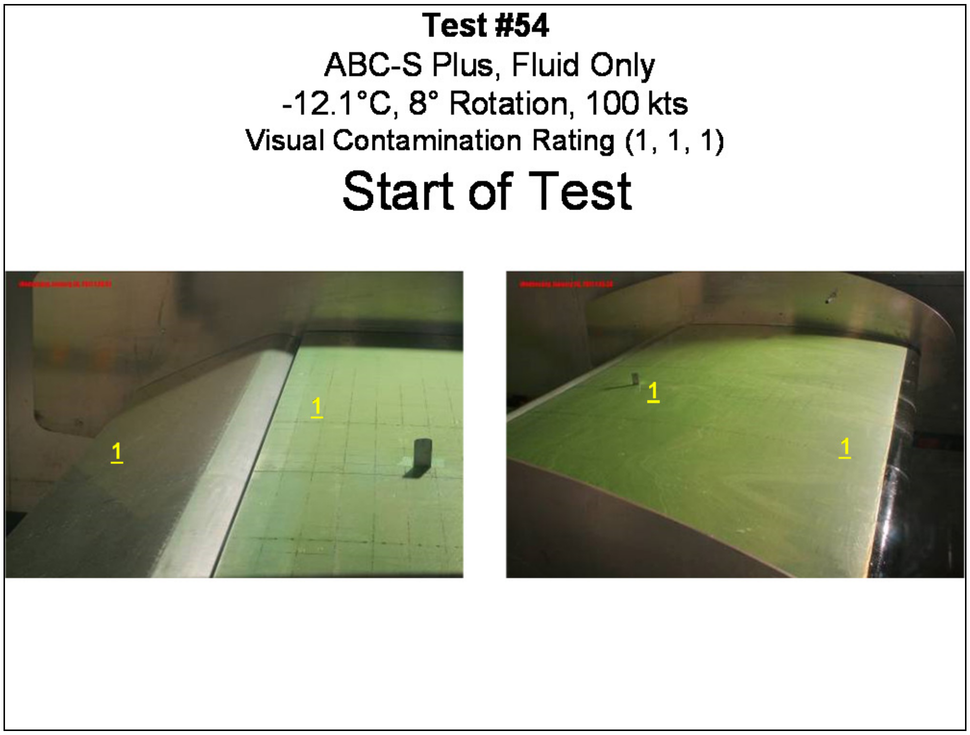
ABC-S Plus, IP- 25 g/dm²/h, 30 min

-12.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.1, 1.2)

End of Test

Photo 6.73: Test #54 – Start of Test



Test #54

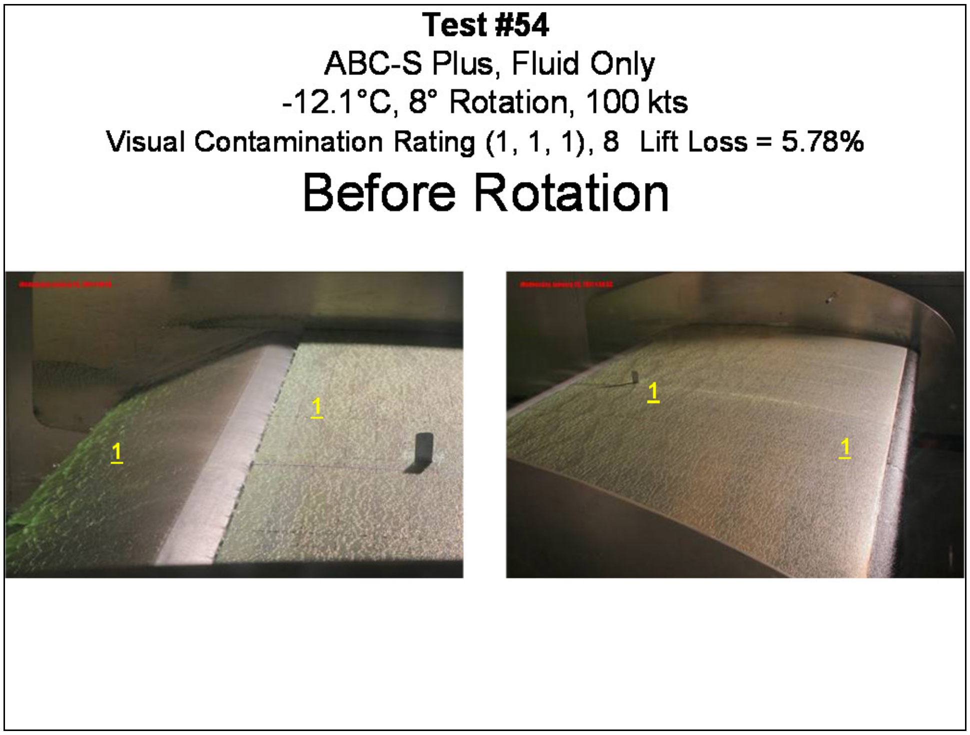
ABC-S Plus, Fluid Only

-12.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 6.74: Test #54 – Before Rotation



Test #54

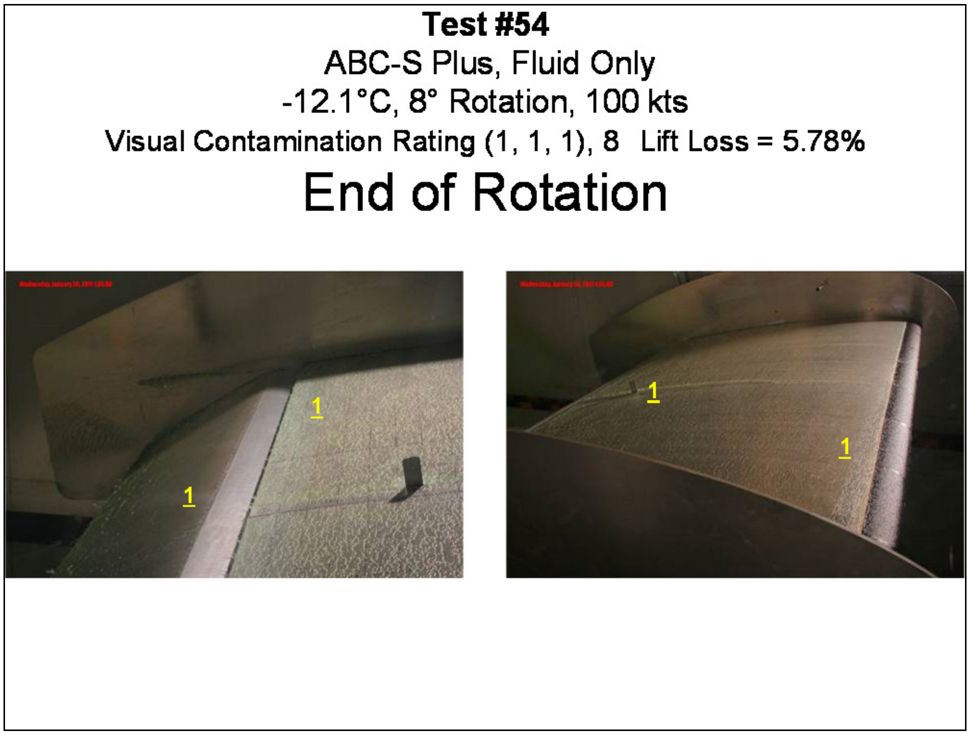
ABC-S Plus, Fluid Only

-12.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.78%

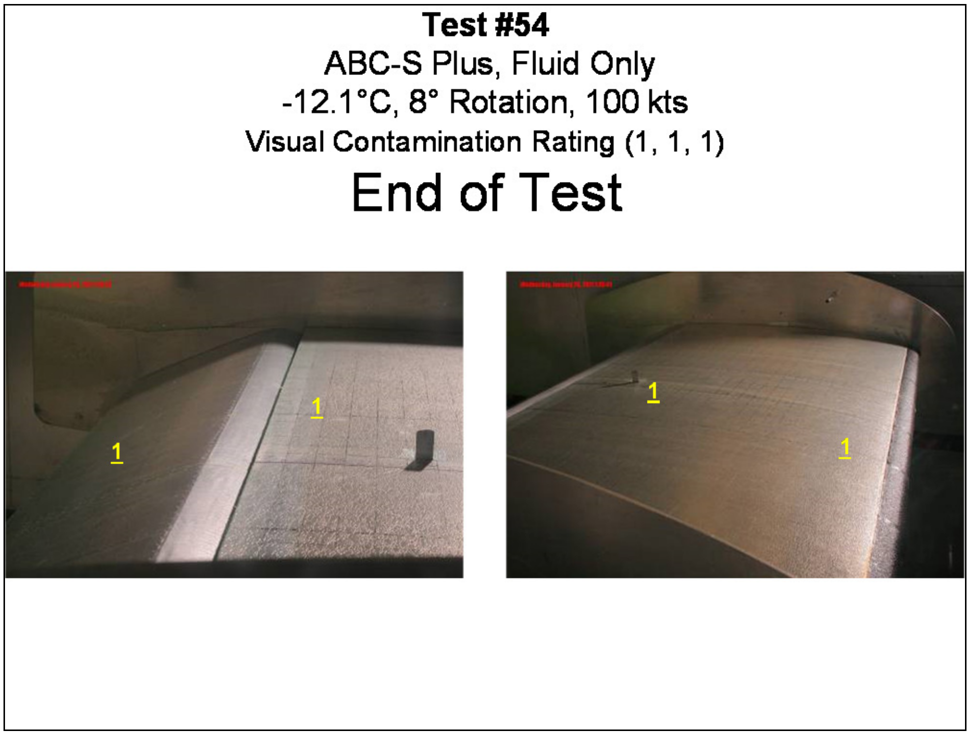
Before Rotation

Photo 6.75: Test #54 – End of Rotation



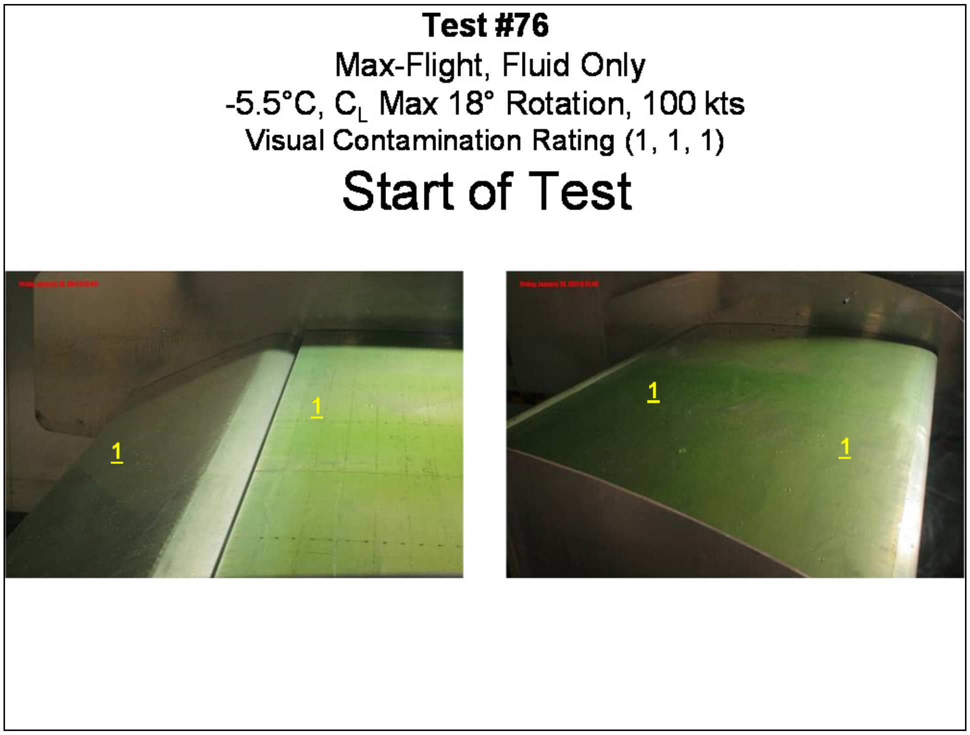
Test #54
ABC-S Plus, Fluid Only
-12.1°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.78%
End of Rotation

Photo 6.76: Test #54 – End of Test



Test #54
ABC-S Plus, Fluid Only
-12.1°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 6.77: Test #76 – Start of Test



Test #76

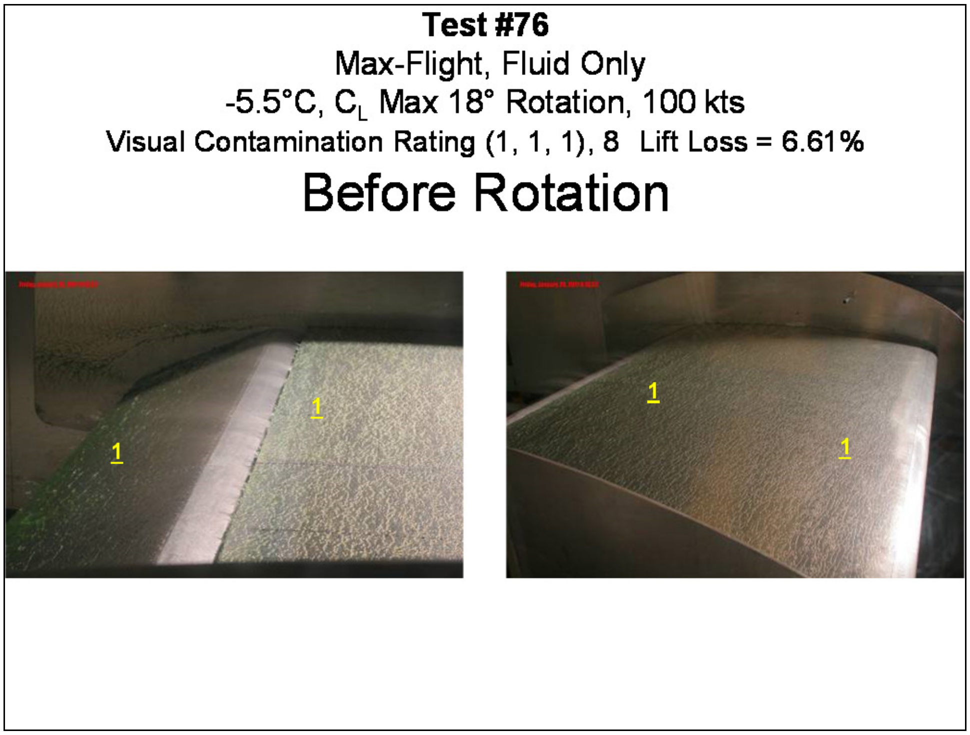
Max-Flight, Fluid Only

-5.5°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 6.78: Test #76 – Before Rotation



Test #76

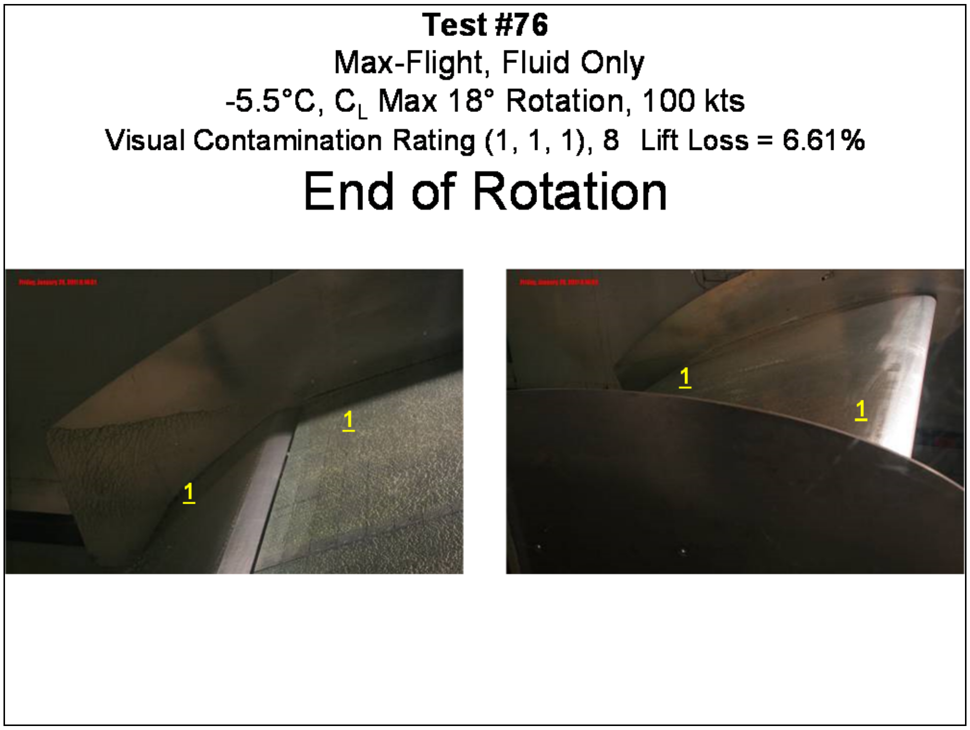
Max-Flight, Fluid Only

-5.5°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.61%

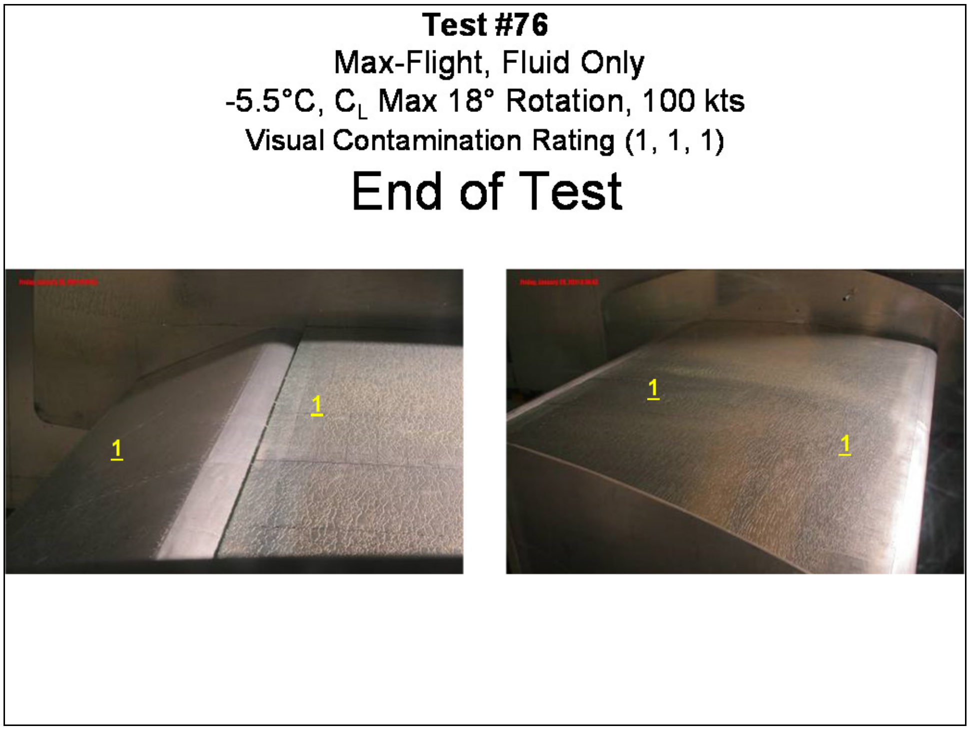
Before Rotation

Photo 6.79: Test #76 – End of Rotation



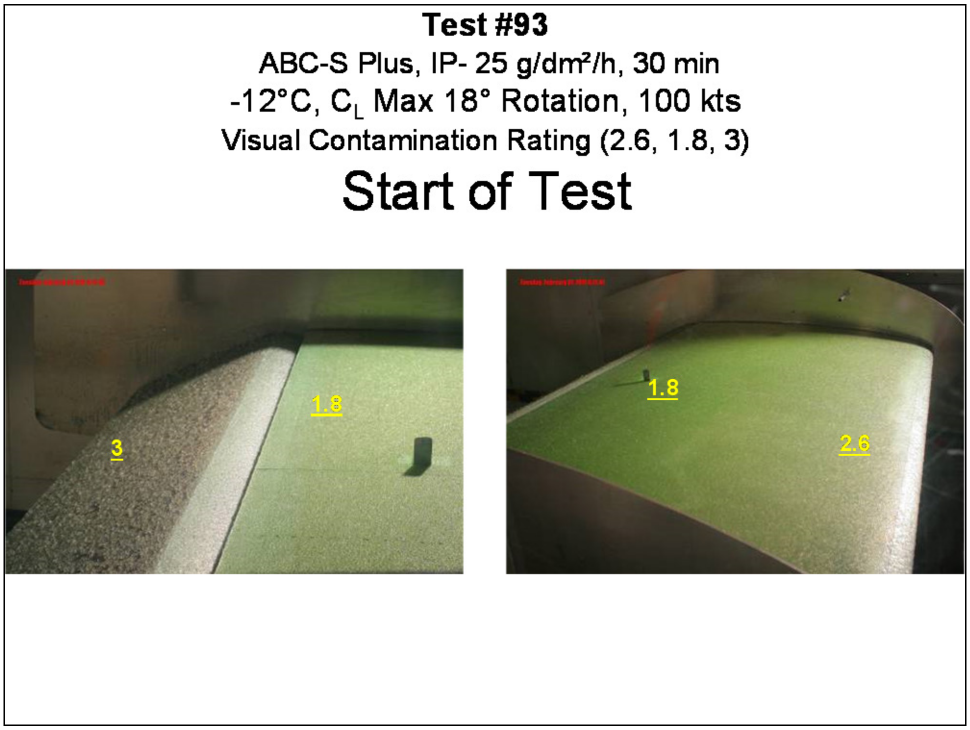
Test #76
Max-Flight, Fluid Only
-5.5°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.61%
End of Rotation

Photo 6.80: Test #76 – End of Test



Test #76
Max-Flight, Fluid Only
-5.5°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

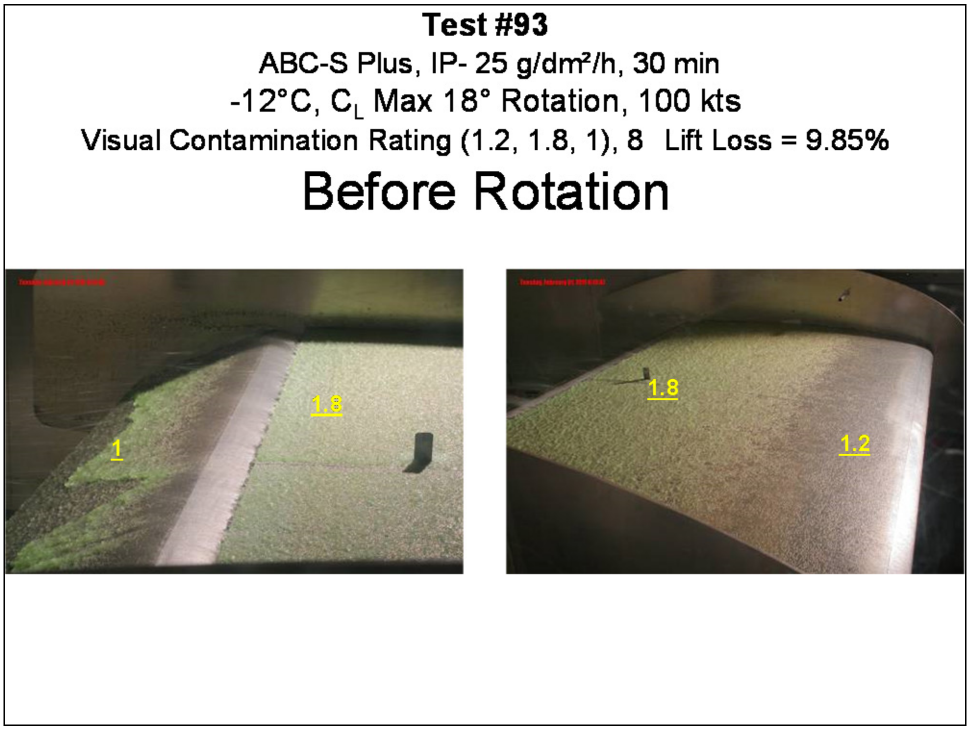
Photo 6.81: Test #93 – Start of Test



Test #93
ABC-S Plus, IP- 25 g/dm²/h, 30 min
-12°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (2.6, 1.8, 3)

Start of Test

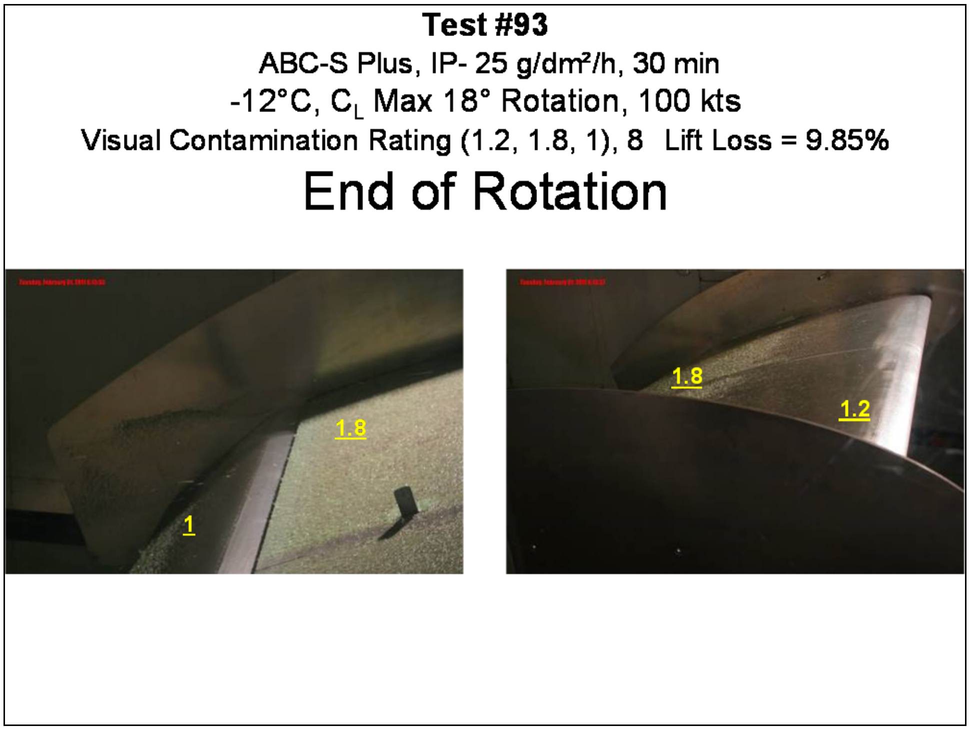
Photo 6.82: Test #93 – Before Rotation



Test #93
ABC-S Plus, IP- 25 g/dm²/h, 30 min
-12°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1.2, 1.8, 1), 8 Lift Loss = 9.85%

Before Rotation

Photo 6.83: Test #93 – End of Rotation



Test #93

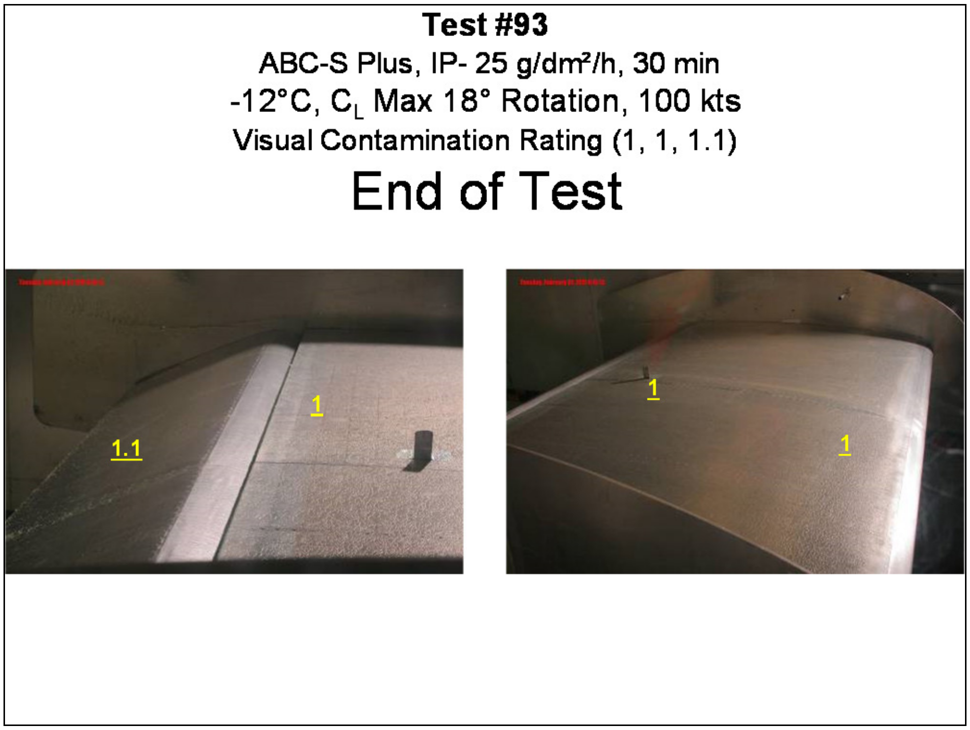
ABC-S Plus, IP- 25 $g/dm^2/h$, 30 min

-12°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.8, 1), 8 Lift Loss = 9.85%

End of Rotation

Photo 6.84: Test #93 – End of Test



Test #93

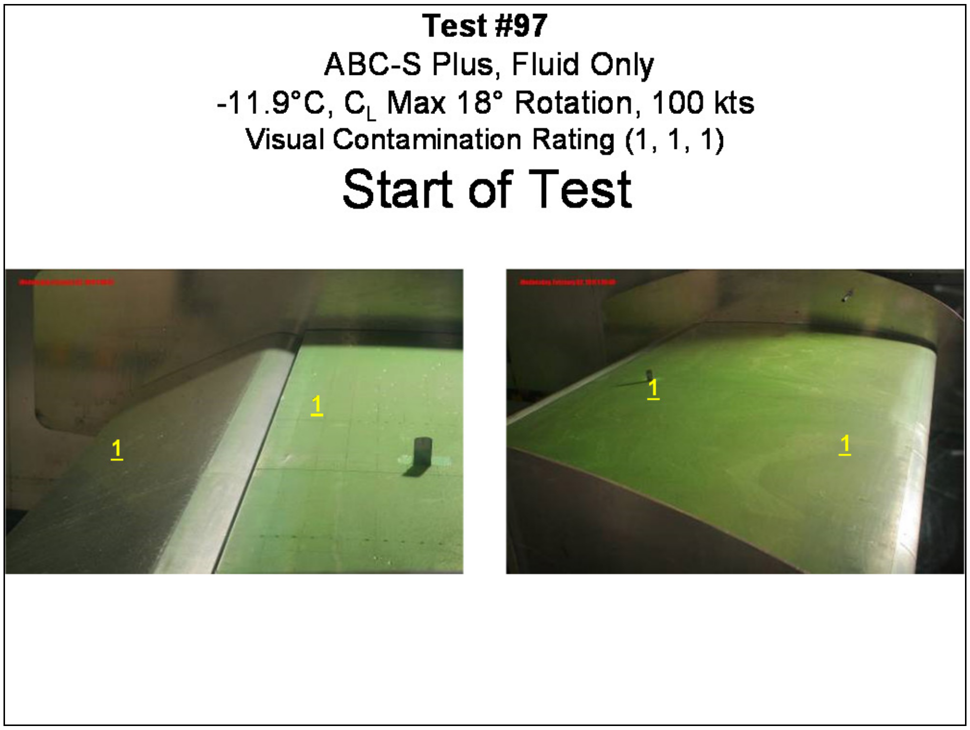
ABC-S Plus, IP- 25 $g/dm^2/h$, 30 min

-12°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.1)

End of Test

Photo 6.85: Test #76 – Start of Test



Test #97

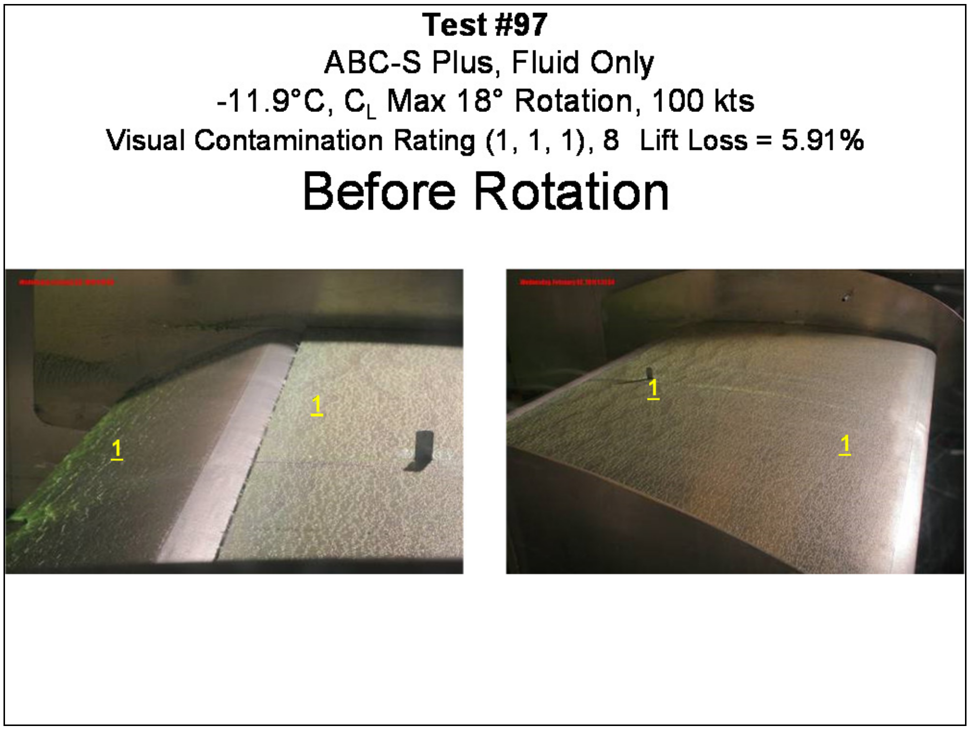
ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 6.86: Test #97 – Before Rotation



Test #97

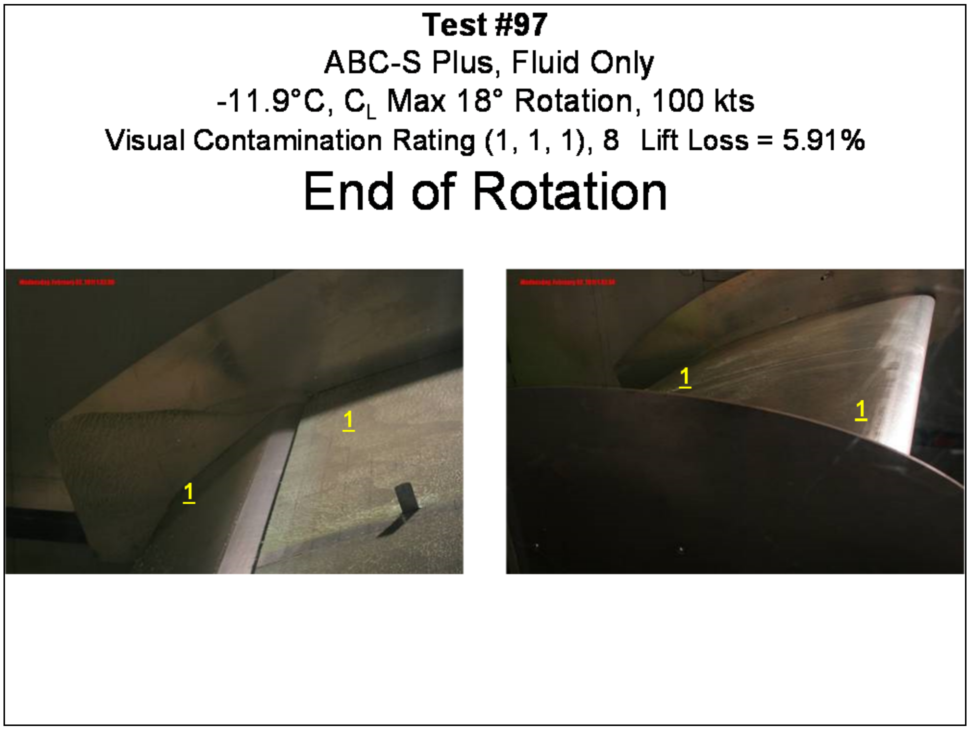
ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.91%

Before Rotation

Photo 6.87: Test #97 – End of Rotation



Test #97

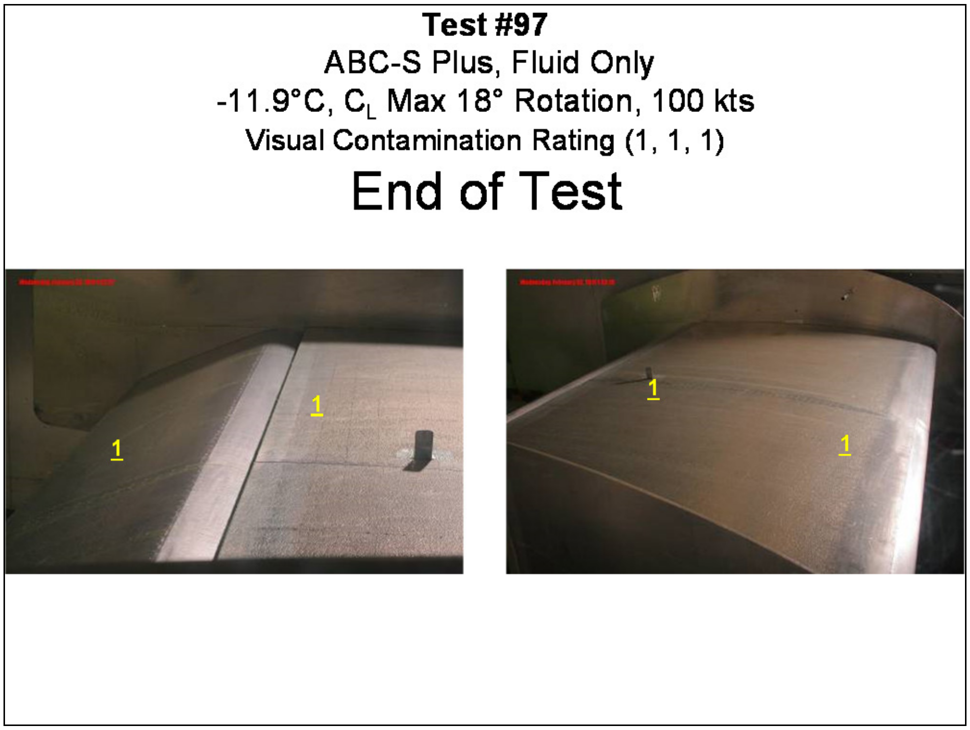
ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.91%

End of Rotation

Photo 6.88: Test #97 – End of Test



Test #97

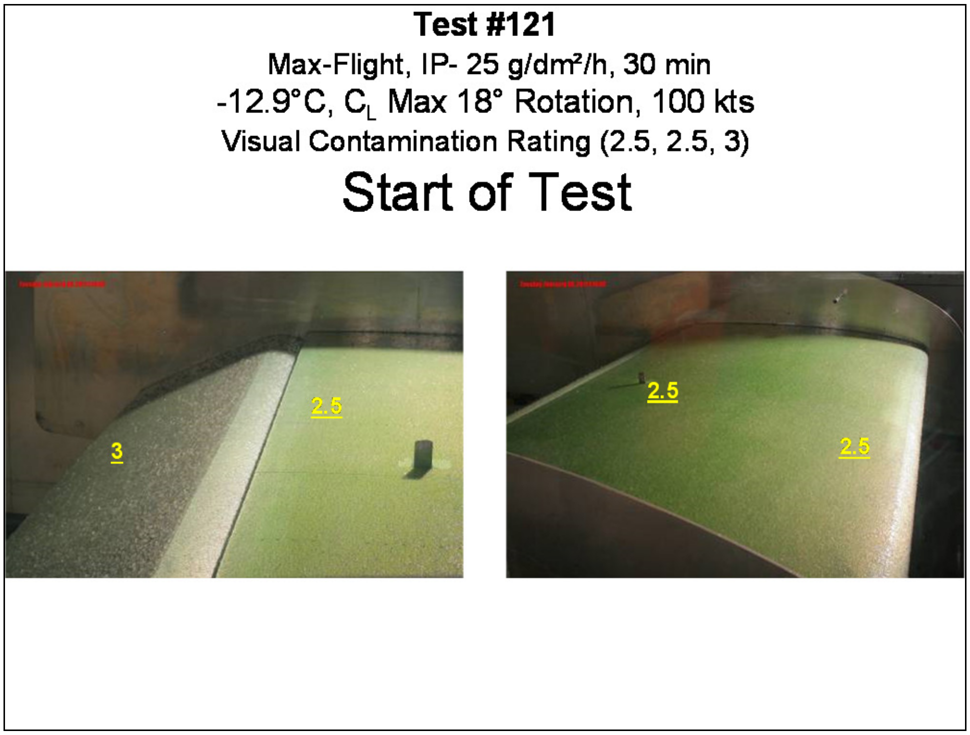
ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 6.89: Test #121 – Start of Test



Test #121

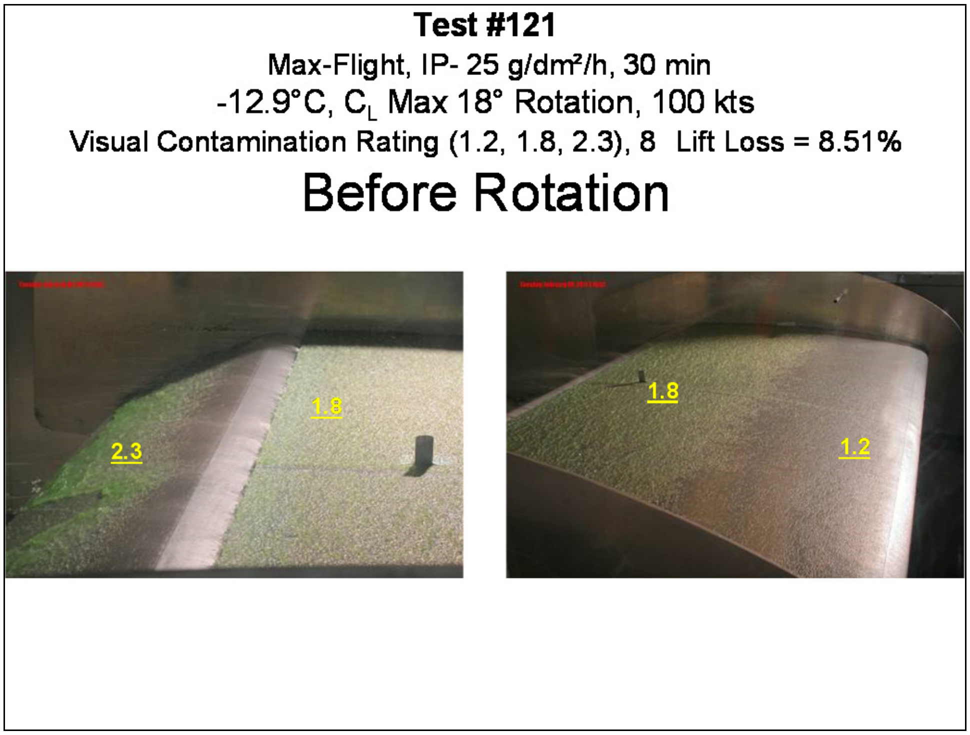
Max-Flight, IP- 25 $g/dm^2/h$, 30 min

-12.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (2.5, 2.5, 3)

Start of Test

Photo 6.90: Test #121 – Before Rotation



Test #121

Max-Flight, IP- 25 $g/dm^2/h$, 30 min

-12.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.8, 2.3), 8 Lift Loss = 8.51%

Before Rotation

Photo 6.91: Test #121 – End of Rotation

Test #121
Max-Flight, IP- 25 g/dm²/h, 30 min
-12.9°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1.2, 1.8, 2.3), 8 Lift Loss = 8.51%

End of Rotation

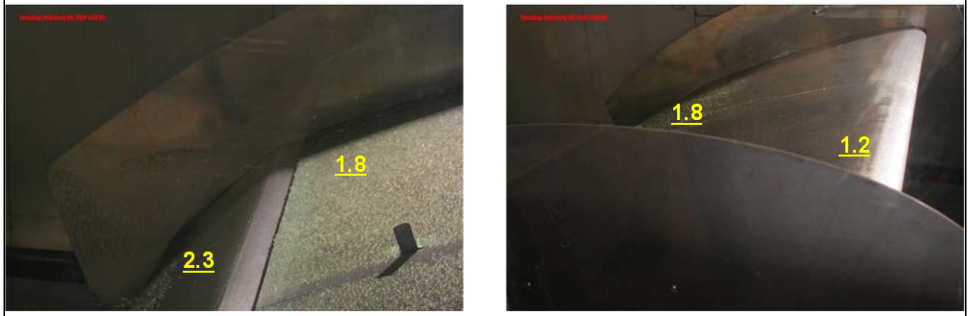
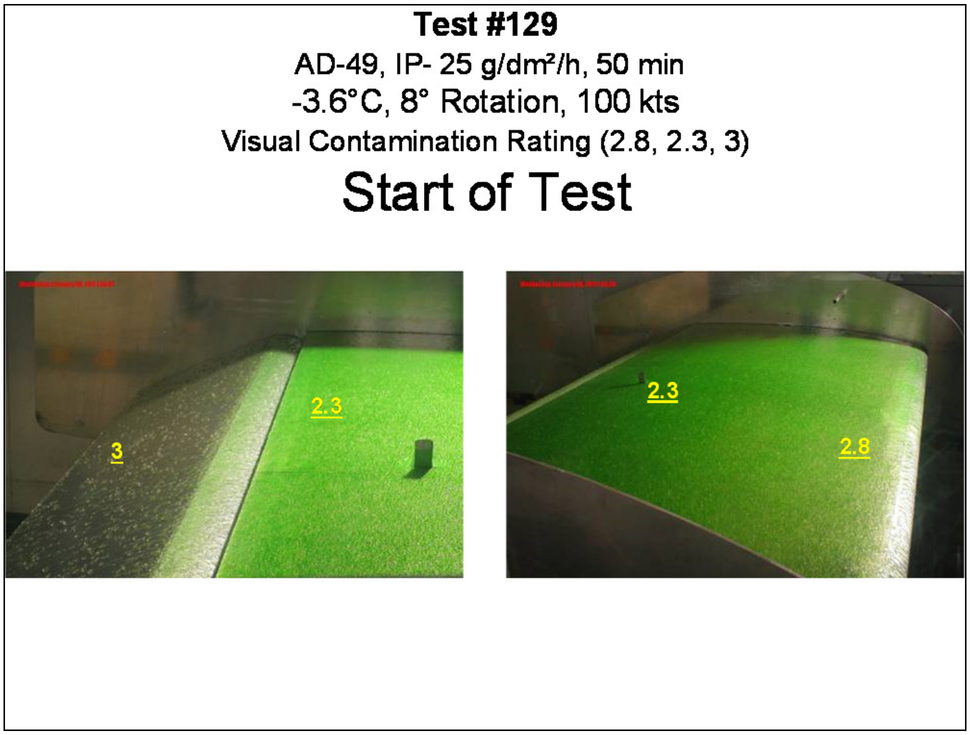


Photo 6.92: Test #121 – End of Test

Test #121
Max-Flight, IP- 25 g/dm²/h, 30 min
-12.9°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

Photo 6.93: Test #129 – Start of Test



Test #129

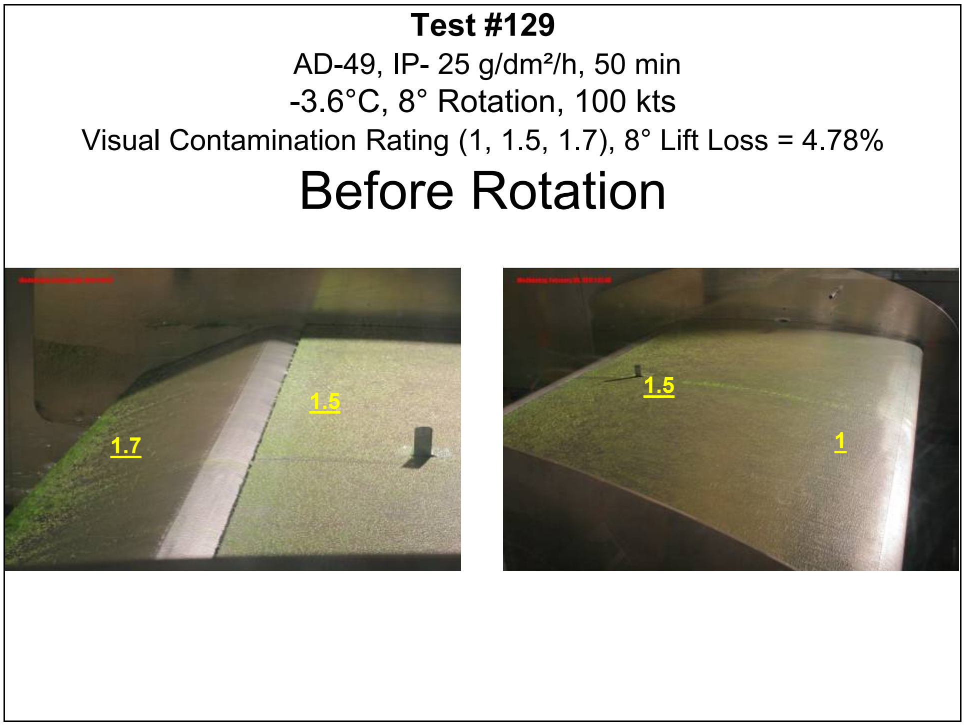
AD-49, IP- 25 g/dm²/h, 50 min

-3.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.8, 2.3, 3)

Start of Test

Photo 6.94: Test #129 – Before Rotation



Test #129

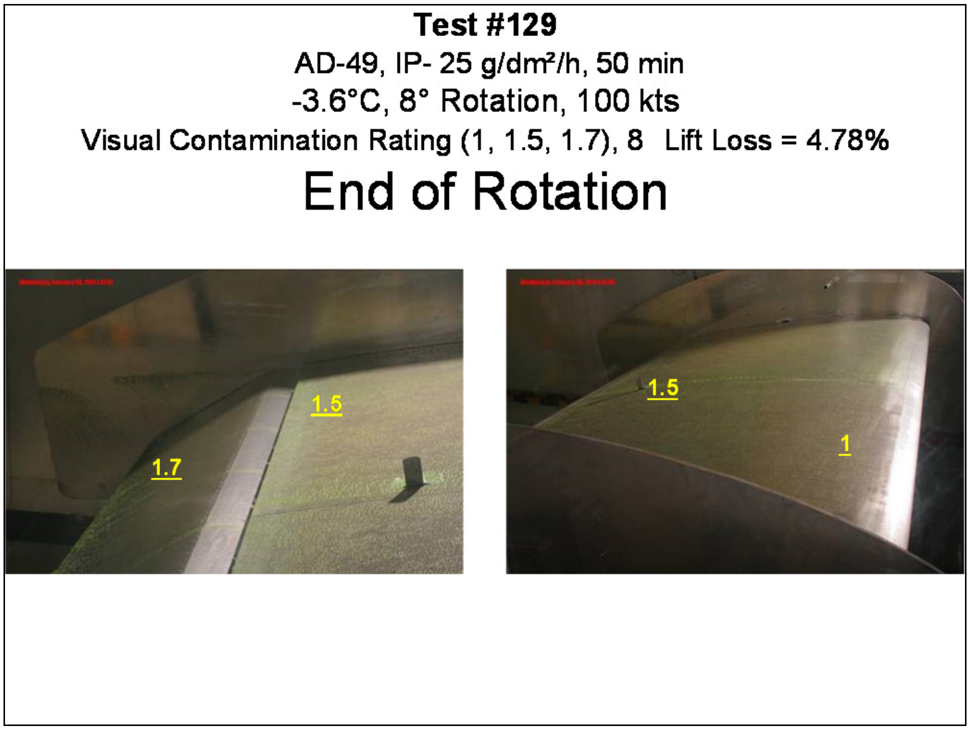
AD-49, IP- 25 g/dm²/h, 50 min

-3.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.5, 1.7), 8° Lift Loss = 4.78%

Before Rotation

Photo 6.95: Test #129 – End of Rotation



Test #129

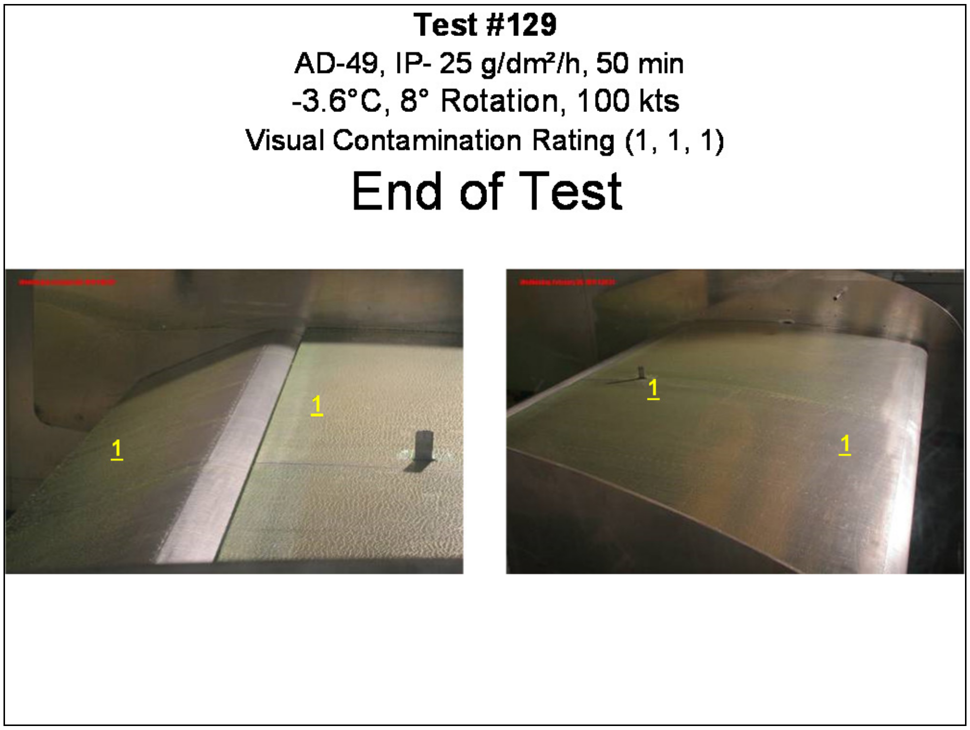
AD-49, IP- 25 g/dm²/h, 50 min

-3.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.5, 1.7), 8 Lift Loss = 4.78%

End of Rotation

Photo 6.96: Test #129 – End of Test



Test #129

AD-49, IP- 25 g/dm²/h, 50 min

-3.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

7. MODERATE ICE PELLETS

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Previous testing in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Light Freezing Rain;
- Section 9: Light Ice Pellets and Moderate Rain;
- Section 10: Light Ice Pellets and Light Snow;
- Section 11: Light Ice Pellets and Moderate Snow; and
- Section 12: Light Ice Pellets and Light Rain.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Moderate Ice Pellet conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

7.1 Overview of Tests

A summary of the Moderate Ice Pellet tests conducted in the wind tunnel is shown in Table 7.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1. The following is a brief description of the column headings for Table 7.1:

Test #:	Exclusive number identifying each test.
Date:	Date when the test was conducted.
Fluid:	Aircraft deicing fluid specified by product name; all fluids were in the “neat” 100/0 dilution.

Condition:	Simulated precipitation condition.
Precipitation Rate (g/dm²/h):	Simulated freezing precipitation rate (or combination of different precipitation rates). "N/A" indicates that no precipitation was applied.
Precip. Time (min.):	Total time of exposure to simulated precipitation.
Tunnel Temp. at Start of Test (ºC):	The tunnel air temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Flap Angle (º):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended).
Speed (kts):	Maximum speed attained at time of rotation.
Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination.

	4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
CL at 8º During Rotation:	Calculated lift coefficient at the 8º wing rotation angle position; data provided by the NRC.
% Lift Loss:	% Lift Loss calculated based on the comparison of the 8º lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).
Associated Baseline Run:	The associated fluid only baseline run based on fluid selection.

Table 7.1: Summary of 2010-11 Moderate Ice Pellet Testing

Test No.	Date	Fluid	Associated Fluid Only Test	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
7	19-Jan-11	AD-49	5A	IP Mod	IP:75	10	-10.4	-11.3	20	100	2.7 , 2.7 , 3.4	1.3 , 2.2 , 2.4	1.321	7.10
10	19-Jan-11	Max-Flight	N/A	IP Mod	IP:75	25	-6.8	-10.3	20	115	3.5 , 3.5 , 3.9	1 , 1.6 , 1.7	1.393	2.04
13	20-Jan-11	Max-Flight	N/A	IP Mod	IP:75	10	-12.4	-13.9	20	100	2.3 , 2.5 , 3.3	1 , 1.3 , 1.7	1.369	3.73
14	20-Jan-11	Max-Flight	12	IP Mod	IP:75	10	-12.3	-13.8	20	100	2.3 , 2.5 , 3.3	1.4 , 2.5 , 3	1.308	8.02
15	20-Jan-11	Max-Flight	N/A	IP Mod	IP:75	10	-10.8	-13.3	20	115	2.3 , 2.3 , 3.2	1 , 1.3 , 1.4	1.355	4.71
15A	20-Jan-11	Max-Flight	N/A	IP Mod	IP:75	10	-10.4	-12.5	20	115	2.3 , 2.3 , 2.9	1 , 1 , 1.3	1.378	3.09
15B	20-Jan-11	Max-Flight	N/A	IP Mod	IP:75	10	-10.8	-12.1	20	115	2.4 , 2.3 , 2.9	1 , 1.4 , 1.5	1.347	5.27
25	23-Jan-11	ABC-S+	30	IP Mod	IP:75	10	-22.3	-21.2	20	100	2.75 , 2.75 , 4	1.6 , 2 , 2.75	1.251	10.77
26	23-Jan-11	EG 106	34	IP Mod	IP:75	10	-21	-21	20	100	2.35 , 2.35 , 3	1 , 1.2 , 1.5	1.359	3.07
28	24-Jan-11	Launch	N/A	IP Mod	IP:75	10	-24.5	-22.5	20	115	3 , 3 , 4	1.25 , 1.75 , 2.25	1.296	7.56
31	24-Jan-11	ABC-S+	N/A	IP Mod	IP:75	10	-22.8	-21.8	20	115	3 , 2.75 , 3.75	1.35 , 2 , 2.75	1.256	10.41
37	24-Jan-11	Max-Flight	N/A	IP Mod	IP:75	10	-24.5	-23.2	20	115	3 , 3 , 4	1.35 , 1.75 , 2.25	1.266	9.70
38	24-Jan-11	ABC-S+	N/A	IP Mod	IP:75	10	-24.2	-23.2	20	115	3 , 3 , 4	1.2 , 1.5 , 2	1.259	10.20
41	25-Jan-11	AD-49	N/A	IP Mod	IP:75	10	-16.5	-16.1	20	115	3.1 , 3 , 4	1.1 , 1.5 , 2	N/A	-
41A	25-Jan-11	AD-49	9	IP Mod	IP:75	10	-15.4	-16.2	20	115	3 , 3.1 , 4	1.1 , 2 , 2.75	1.323	5.63
59	26-Jan-11	Max-Flight	57	IP Mod	IP:75	10	-10.9	-12.5	20	100	2.5 , 2.5 , 2.9	1.6 , 1.7 , 2.25	1.302	7.13
59A	26-Jan-11	Max-Flight	N/A	IP Mod	IP:75	10	-9.4	-12.4	20	115	2.5 , 2.5 , 3	1.2 , 1.3 , 1.6	1.345	4.07
69*	27-Jan-11	AD-49	68*	IP Mod	IP:75	25	-3.6	-8.2	20	100	3.3 , 2.8 , 3.7	1.2 , 1.6 , 1.6	1.362	4.22
70*	28-Jan-11	AD-49	68*	IP Mod	IP:75	15	-4.2	-7.8	20	100	2.3 , 2.5 , 3	1.2 , 1.6 , 1.6	1.366	3.94
72*	28-Jan-11	Max-Flight	71*	IP Mod	IP:75	15	-3.2	-6.5	20	100	2.4 , 2.4 , 2.8	1 , 1.5 , 1.6	1.33	6.47
92*	1-Feb-11	ABC-S+	80*	IP Mod	IP:75	10	-13.6	-13.1	20	100	2.5 , 2.6 , 3.4	1.2 , 1.8 , 2.6	1.24	12.80
92A	1-Feb-11	ABC-S+	81	IP Mod	IP:75	10	-14.2	-14	20	100	2.8 , 2.5 , 3.3	1.2 , 2 , 2.7	1.232	13.36
131	9-Feb-11	Launch	63	IP Mod	IP:75	25	-4.5	-8.5	20	100	2.8 , 3.3 , 3.9	1 , 1.5 , 2.2	1.35	5.06
132	9-Feb-11	Max-Flight	75	IP Mod	IP:75	25	-5.9	-8.5	20	100	2.8 , 3 , 3.9	1 , 1.6 , 2	1.324	6.89

Table 7.1: Summary of 2010-11 Moderate Ice Pellet Testing (cont'd)

Test No.	Date	Fluid	Associated Fluid Only Test	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
5A	19-Jan-11	AD-49	N/A	Fluid Only			-10.4	-8.2	20	100	1 , 1 , 1	1 , 1 , 1	1.367	3.87
9	19-Jan-11	AD-49	N/A	Fluid Only			-6.7	-6.1	20	115	1 , 1 , 1	1 , 1 , 1	1.387	2.46
12	20-Jan-11	Max-Flight	N/A	Fluid Only			-14.2	-12.3	20	100	1 , 1 , 1	1 , 1 , 1	1.336	6.05
30	24-Jan-11	ABC-S+	N/A	Fluid Only			-23.5	-22.4	20	100	1 , 1 , 1	1 , 1 , 1	1.288	8.13
34	24-Jan-11	EG 106	N/A	Fluid Only			-23.3	-22.7	20	100	1 , 1 , 1	1 , 1 , 1	1.342	4.28
57	26-Jan-11	Max-Flight	N/A	Fluid Only			-9.9	-11	20	100	1 , 1 , 1	1 , 1 , 1	1.306	6.85
63	27-Jan-11	Launch	N/A	Fluid Only			-4.5	-4.2	20	100	1 , 1 , 1	1 , 1 , 1	1.346	5.34
68	27-Jan-11	AD-49	N/A	Fluid Only			-1.8	-1	20	100	1 , 1 , 1	1 , 1 , 1	1.37	3.66
71	28-Jan-11	Max-Flight	N/A	Fluid Only			-3.7	-2.3	20	100	1 , 1 , 1	1 , 1 , 1	1.332	6.33
75	28-Jan-11	Max-Flight	N/A	Fluid Only			-5.8	-4.2	20	100	1 , 1 , 1	1 , 1 , 1	1.316	7.45
80	31-Jan-11	ABC-S+	N/A	Fluid Only			-15.1	-12.3	20	100	1 , 1 , 1	1 , 1 , 1	1.323	6.96
81	31-Jan-11	ABC-S+	N/A	Fluid Only			-14.7	-12.4	20	100	1 , 1 , 1	1 , 1 , 1	1.321	7.10

***** CL Max Test***

7.2 Data Collected

7.2.1 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.2. Fluid thickness measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix G shows the fluid thickness measurements collected during the contaminated fluid tests.

7.2.2 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.3. Skin temperature measurements were recorded at the following intervals:

- Before fluid application;
- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix H shows the wing temperature measurements recorded during the contaminated fluid tests.

7.2.3 Fluid Brix Data

Fluid Brix measurements were recorded at the following intervals by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.4. Fluid Brix measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and

- After the simulated takeoff test.

Appendix I shows the fluid Brix measurements collected during the contaminated fluid tests.

7.3 Photos

High-speed digital photographs of each test were taken; wide-angle photos were taken of the leading edge, and close-up photos were taken of the trailing edge. For each test, photo summaries have been compiled comprising four stages:

- Start of test;
- Before Rotation (just before the wing began to pitch);
- End of Rotation (end of the rotation cycle when the wing position is returned to 4 degrees); and
- End of test.

The photos taken during the moderate ice pellet testing have been presented along with the fluid only (baseline) tests for comparison purposes. Photos 7.1 to 7.144 show the photo summaries of the tests conducted in accordance with the order presented in Table 7.1. A complete set of photos will be provided to the TDC in electronic format.

7.4 Summary of Results

7.4.1 OAT -5°C and Above

Three tests were conducted with exposure times of 25 minutes in this cell: Tests #69, #131, and #132. Two tests were conducted with exposure times of 15 minutes in this cell: Tests #70, and #72. An additional test, Test #10, was also used for analysis based on a test run of 115 knots. The exposure time for this run was also 25 minutes. See Table 7.2 for a summary of the tests.

Test #69, conducted at a temperature of -3.6°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test and at rotation were at the upper limit and marginally above the acceptable limit. The lift loss at 8° was 4.22 percent, which is below the 5.4 percent lower limit. A lengthy ramp-up time of 23 seconds indicated a further need to review this test; the extra ramp-up time may have reduced the lift loss. The results of this test indicate that 25 minutes may not be appropriate for PG fluids. See Table 7.3 for the details of this test.

Test #131, conducted at a temperature of -4.5°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was marginally above the acceptable limit on the trailing edge; however, the results at rotation were deemed good. The lift loss at 8° was 5.06 percent, which is below the 5.4 percent lower limit. A lengthy ramp-up time of 24 seconds indicated a further need to review this test; the extra ramp-up time may have reduced the lift loss. The results of this test indicate that 25 minutes may not be appropriate for PG fluids. See Table 7.3 for the details of this test.

Test #132, conducted at a temperature of -5.9°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test and the results at rotation were deemed good. The lift loss at 8° was 6.9 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test indicate that 25 minutes may not be appropriate for PG fluids. See Table 7.3 for the details of this test.

Test #70, conducted at an exposure time of 15 minutes and at a temperature of -4.5°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory, as they were on the upper end of the acceptable limit. The lift loss at 8° was 3.94 percent, which is below the 5.4 percent lower limit. A lengthy ramp-up time of 25 seconds indicated a further need to review this test; the extra ramp-up time may have reduced the lift loss. The results of this test support the 2009-10 change, which reduced the moderate ice pellet allowance time for PG fluids from 25 minutes to 15 minutes. See Table 7.3 for the details of this test.

Test #72, conducted at an exposure time of 15 minutes and at a temperature of -3.2°C with a PG fluid, demonstrated good results. The visual ratings at the start of test and at rotation were deemed good. The lift loss at 8° was 6.43 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test support the 2009-10 change, which reduced the moderate ice pellet allowance time from 25 minutes to 15 minutes. See Table 7.3 for the details of this test.

One test (Test #10) was conducted with exposure times of 25 minutes in this cell. This test was conducted at a speed of 115 knots (see Table 6.56). Test #10 was deemed an invalid test due to a long ramp-up time of 30 seconds; however, it still serves as a point of reference. The temperature during this test run was -6.8°C. The visual rating at the start of test was marginally above the limit; however, the results at rotation were deemed good. The 8° lift loss was 2.04 percent, well below the 5.4 percent lower limit. See Table 7.3 for the details of this test.

In conclusion, the current allowance time of 25 minutes is acceptable for EG fluids. An allowance time of 15 minutes is acceptable for PG fluids primarily as a result of unsatisfactory visual contamination on certain tests.

7.4.2 OAT Less than -5°C to -10°C

One test (Test #7) was conducted in this cell with an exposure time of 10 minutes. One other test (Test #59A) was used for analysis based on a test run of 115 knots. See Table 7.2 for a summary of the tests.

Test #7, conducted at a temperature of -10.4°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 7.10 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a need to change the current allowance time of 10 minutes. See Table 7.3 for the details of this test.

Test #59A, conducted at a temperature of -9.4°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 4.07 percent, which is below the 5.4 percent lower limit; the extra ramp-up time may have reduced the lift loss. The results of this test do not suggest a need to change the current allowance time of 10 minutes. See Table 7.3 for the details of this test.

In conclusion, the current allowance time of 10 minutes is acceptable for EG and PG fluids.

7.4.3 OAT Less than -10°C

Seven tests were conducted with exposure times of 10 minutes in this cell: Tests #13, #14, #25, #26, #59, #92, and #92A. An additional nine tests were also used for analysis based on a test run of 115 knots and exposure time of 10 minutes: Tests #15, #15A, #15B, #28, #31, #37, #38, #41, and #41A. See Table 7.2 for a summary of the tests.

Test #13 was a research test in which the typical ramp-up time of 20 seconds was achieved but held for an additional 20 seconds before rotation. This test was determined invalid for aerodynamic evaluation, but it could be referenced for visual observation before the start of the test. Test #13 was conducted with a PG fluid and demonstrated good results before takeoff. The temperature during this test run was -2.4°C. The lift coefficient and the visual rating results were deemed good. The 8° lift loss was 3.73 percent, below the 5.4 percent lower limit; the extra ramp-up time most likely helped reduce the lift loss. See Table 7.2 for the details of this test.

Test #14, conducted at a temperature of -12.3°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed high but satisfactory. The lift loss at 8° was 8.02 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a need to change the current allowance time of 10 minutes. See Table 7.3 for the details of this test.

Test #25, conducted at a temperature of -22.3°C with a PG fluid, demonstrated poor results. The visual rating at the start of test was good; however, the results at rotation were deemed poor due to the contamination present on the leading edge. The lift loss at 8° was 10.77 percent, which is well above the 9.2 percent upper limit. The results of this test indicate potential flow-off issues with PG fluids at colder temperatures. See Table 7.3 for the details of this test.

Test #26, conducted at a temperature of -21.0°C with EG fluid, demonstrated good results. The visual ratings at the start of test and at rotation were deemed good. The lift loss at 8° was 3.07 percent, which is below the 5.4 percent lower limit. Due to positive results that were displayed, there may be a potential to further expand the current allowance time for EG fluid. See Table 7.3 for the details of this test.

Test #59, conducted at a temperature of -10.9°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 7.13 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a need to change the current allowance time of 10 minutes. See Table 7.3 for the details of this test.

Test #92, conducted at a temperature of -13.6°C with a PG fluid, demonstrated poor results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 12.8 percent, which is well above the 9.2 percent upper limit. The results of this test indicate potential flow-off issues with PG fluids at colder temperatures. See Table 7.3 for the details of this test.

Test #92A, conducted at a temperature of -14.2°C with a PG fluid, demonstrated poor results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 13.36 percent, which is well above the 9.2 percent upper limit. The results of this test indicate potential flow-off issues with PG fluids at colder temperatures. See Table 7.3 for the details of this test.

Test #15, conducted at a temperature of -10.8°C with PG fluid, demonstrated good results. This test was conducted at 115 knots; however, it was deemed not representative due to a lengthy ramp-up time of 33 seconds. The visual ratings at the start of test and at rotation were deemed good. The lift loss at 8° was 4.71 percent, which is below the 5.4 percent lower limit. This test cannot be used to support an increase in allowance time at 115 knots due to the issue with the ramp-up time. See Table 7.3 for the details of this test.

Test #15A, conducted at a temperature of -10.4°C with PG fluid, demonstrated good results. This test was conducted at 115 knots; however, it was deemed not representative due to a lengthy ramp-up time of 38 seconds. The visual ratings at the start of test and at rotation were deemed good. The lift loss at 8° was 3.09 percent, which is below the 5.4 percent lower limit. This test cannot be used to support an increase in allowance time at 115 knots due to the issue with the ramp-up time. See Table 7.3 for the details of this test.

Test #15B, conducted at a temperature of -10.8°C with PG fluid, demonstrated good results. This test was conducted at 115 knots; however, it was deemed satisfactory due to a slightly longer ramp-up time of 24 seconds. The visual ratings at the start of test and at rotation were deemed good. The lift loss at 8° was 5.27 percent, which is slightly below the 5.4 percent lower limit. The results of this test do not support an increase in allowance time. See Table 7.3 for the details of this test.

Test #28, conducted at a temperature of -24.5°C with a PG fluid, demonstrated satisfactory results. The test was conducted at 115 knots. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 7.56 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test indicate that the extra speed at 115 knots provides better flow-off and aerodynamic performance. See Table 7.3 for the details of this test.

Test #31, conducted at a temperature of -22.8°C with a PG fluid, demonstrated poor results. This test was conducted at 115 knots. The ramp-up time of 19 seconds was determined to be a little fast but still valid. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 10.41 percent, which is well above the 9.2 percent upper limit. The results of this test indicate flow-off issues with PG fluids at colder temperatures, even at higher speeds of 115 knots. See Table 7.3 for the details of this test.

Test #37, conducted at a temperature of -24.5°C with a PG fluid, demonstrated poor results. This test was conducted at 115 knots. The ramp-up time of 20 seconds was determined to be a little fast but still valid. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 9.7 percent, which is above the 9.2 percent upper limit. The results of this test indicate flow-off issues with PG fluids at colder temperatures, even at higher speeds of 115 knots. See Table 7.3 for the details of this test.

Test #38, conducted at a temperature of -24.2°C with a PG fluid, demonstrated poor results. This test was conducted at 115 knots. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 10.2 percent, which is well above the 9.2 percent upper limit. The results of this test indicate flow-off issues with PG fluids at colder temperatures, even at higher speeds of 115 knots. See Table 7.3 for the details of this test.

Test #41, conducted at a temperature of -15.4°C with a PG fluid, was not used as part of the analyses, and it was re-run as Test #41A. Lift coefficient and lift loss data were not retained due to a procedural error. See Table 7.3 for the details of this test.

Test #41A, conducted at a temperature of -15.4°C with PG fluid, demonstrated satisfactory results. This test was conducted at 115 knots. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 5.63 percent, which is slightly above the 5.4 percent lower limit. The results of this test indicate that the extra speed at 115 knots provides better flow-off and aerodynamic performance. See Table 7.3 for the details of this test.

In conclusion, the current allowance time of 10 minutes is acceptable for EG fluids. With PG fluids, a speed of 115 knots or more is required to drive lift losses below 9.2 percent, particularly in the -14°C to -25°C range. It should be noted that three tests conducted at 115 knots, #31, #37, and #38, demonstrated lift loss results that were marginally above the upper acceptable limit of 9.2 percent; however, the visual observations demonstrated satisfactory results. It was agreed that changes would not be made until some additional testing could be conducted to support this work and until the lift loss limits were further investigated. At this time, the current allowance time of 10 minutes for PG fluids is acceptable with speeds of 115 knots or more, but further research and testing are required to better understand these lift losses.

Table 7.2: Moderate Ice Pellets Allowance Time Tests Winter 2010-11

Moderate Ice Pellets	**OAT -5°C and Above**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	25 minutes **Test # 69, 131 , 132**	10 minutes **Test # 7, (13), (14), (59), (92)**	10 minutes **Test # (7), 13, 14, 25, 26, 59, 92, 92A**
	15 Minutes **Test # 70, 72**		
115 kts	25 minutes **Test # 10**	10 minutes **Test # (15), (15A), (15B), 59A**	10 minutes **Test # 15, 15A, 15B, 28, 31, 37, 38, 41, 41A, (59A)**

Table 7.3: Summary of Moderate Ice Pellets Allowance Time Test Results

OAT -5°C AND ABOVE (25 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (ºC)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
100 kts											
69	AD-49	-3.6	IP:75	25	3.3 , 2.8 , 3.7	REVIEW	1.2 , 1.6 , 1.6	REVIEW	4.22	GOOD	REVIEW
70	AD-49	-4.2	IP:75	15	2.3 , 2.5 , 3	GOOD	1.2 , 1.6 , 1.6	REVIEW	3.94	GOOD	REVIEW
72	Max-Flight	-3.2	IP:75	15	2.4 , 2.4 , 2.8	GOOD	1 , 1.5 , 1.6	GOOD	6.47	REVIEW	REVIEW
131	Launch	-4.5	IP:75	25	2.8 , 3.3 , 3.9	REVIEW	1 , 1.5 , 2.2	GOOD	5.06	GOOD	REVIEW
132	Max-Flight	-5.9	IP:75	25	2.8 , 3 , 3.9	GOOD	1 , 1.6 , 2	GOOD	6.89	REVIEW	REVIEW
115 kts											
10	Max-Flight	-6.8	IP:75	25	3.5 , 3.5 , 3.9	REVIEW	1 , 1.6 , 1.7	GOOD	2.04	GOOD	REVIEW

Notes: Run 10 – Not a valid test due to lengthy ramp-up time

CONCLUSION: ALLOWANCE TIME AT 25 MINUTES IS <u>GOOD</u>

OAT LESS THAN -5°C TO -10°C (10 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (ºC)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
100 kts											
7	AD-49	-10.4	IP:75	10	2.7 , 2.7 , 3.4	GOOD	1.3 , 2.2 , 2.4	REVIEW	7.10	REVIEW	REVIEW
115 kts											
59A	Max-Flight	-9.4	IP:75	10	2.5 , 2.5 , 3	GOOD	1.2 , 1.3 , 1.6	REVIEW	4.07	GOOD	REVIEW

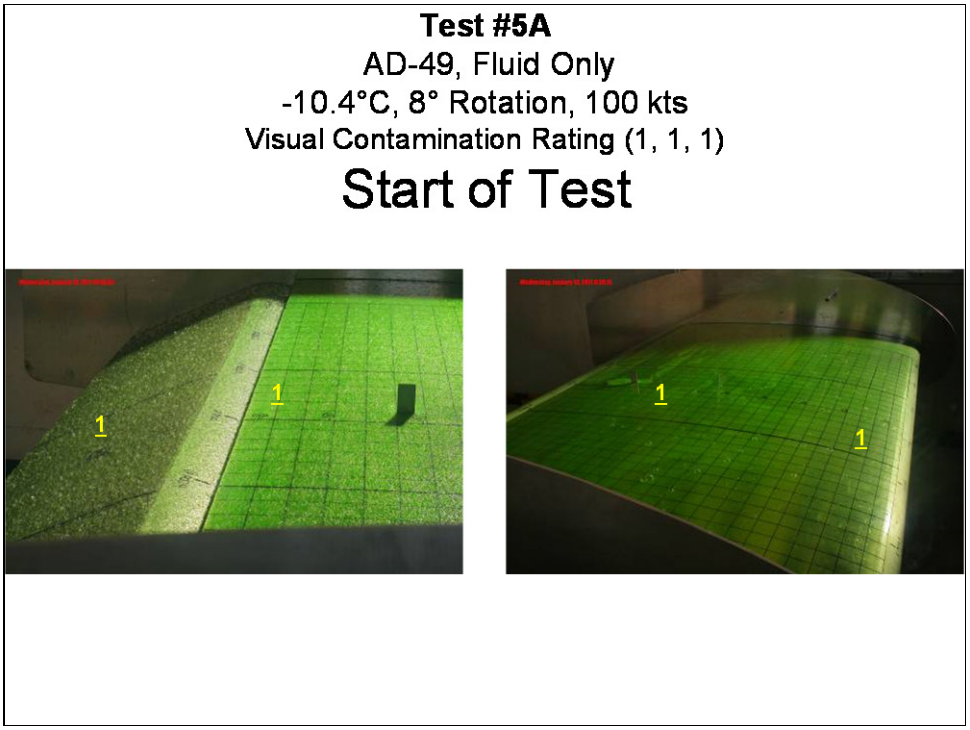
Notes:

CONCLUSION: ALLOWANCE TIME AT 10 MINUTES IS <u>OK</u>

Table 7.3: Summary of Moderate Ice Pellets Allowance Time Test Results (cont'd)

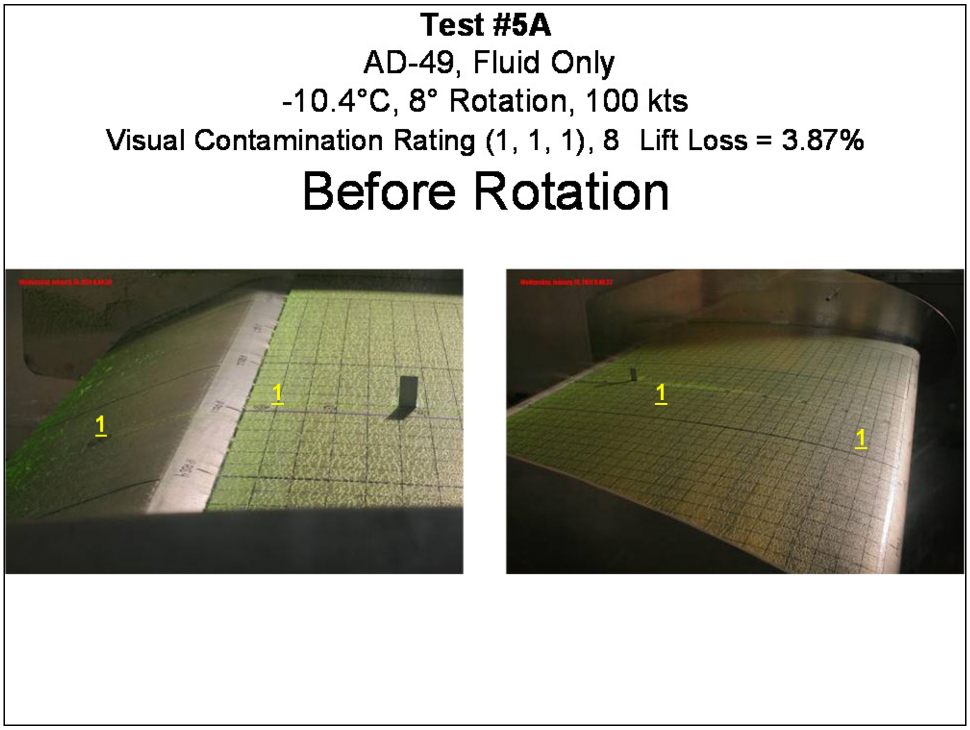
OAT LESS THAN -10°C (10 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (ºC)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
13	*Max-Flight*	*-12.4*	IP:75	*10*	2.3 , 2.5 , 3.3	GOOD	1 , 1.3 , 1.7	GOOD	*3.73*	GOOD	GOOD
14	*Max-Flight*	*-12.3*	IP:75	*10*	2.3 , 2.5 , 3.3	GOOD	1.4 , 2.5 , 3	REVIEW	*8.02*	REVIEW	REVIEW
25	*ABC-S+*	*-22.3*	IP:75	*10*	2.75 , 2.75 , 4	GOOD	1.6 , 2 , 2.75	BAD	*10.77*	BAD	BAD
26	*EG 106*	*-21*	IP:75	*10*	2.35 , 2.35 , 3	GOOD	1 , 1.2 , 1.5	GOOD	*3.07*	GOOD	GOOD
59	*Max-Flight*	*-10.9*	IP:75	*10*	2.5 , 2.5 , 2.9	GOOD	1.6 , 1.7 , 2.25	REVIEW	*7.13*	REVIEW	REVIEW
92	*ABC-S+*	*-13.6*	IP:75	*10*	2.5 , 2.6 , 3.4	GOOD	1.2 , 1.8 , 2.6	REVIEW	*12.80*	BAD	BAD
92A	*ABC-S+*	*-14.2*	IP:75	*10*	2.8 , 2.5 , 3.3	GOOD	1.2 , 2 , 2.7	REVIEW	*13.36*	BAD	BAD
115 kts											
15	*Max-Flight*	*-10.8*	IP:75	*10*	2.3 , 2.3 , 3.2	GOOD	1 , 1.3 , 1.4	GOOD	*4.71*	GOOD	GOOD
15A	*Max-Flight*	*-10.4*	IP:75	*10*	2.3 , 2.3 , 2.9	GOOD	1 , 1 , 1.3	GOOD	*3.09*	GOOD	GOOD
15B	*Max-Flight*	*-10.8*	IP:75	*10*	2.4 , 2.3 , 2.9	GOOD	1 , 1.4 , 1.5	GOOD	*5.27*	GOOD	REVIEW
28	*Launch*	*-24.5*	IP:75	*10*	3 , 3 , 4	GOOD	1.25 , 1.75 , 2.25	REVIEW	*7.56*	REVIEW	REVIEW
31	*ABC-S+*	*-22.8*	IP:75	*10*	3 , 2.75 , 3.75	GOOD	1.35 , 2 , 2.75	REVIEW	*10.41*	BAD	BAD
37	*Max-Flight*	*-24.5*	IP:75	*10*	3 , 3 , 4	GOOD	1.35 , 1.75 , 2.25	REVIEW	*9.70*	BAD	BAD
38	*ABC-S+*	*-24.2*	IP:75	*10*	3 , 3 , 4	GOOD	1.2 , 1.5 , 2	REVIEW	*10.20*	BAD	BAD
41	*AD-49*	*-16.5*	IP:75	*10*	3.1 , 3 , 4	REVIEW	1.1 , 1.5 , 2	REVIEW	*N/A*	*N/A*	*N/A*
41A	*AD-49*	*-15.4*	IP:75	*10*	3 , 3.1 , 4	REVIEW	1.1 , 2 , 2.75	REVIEW	*5.63*	REVIEW	REVIEW
Notes: Runs 13, 15, 15A, 41 – Not a valid tests due to lengthy ramp-up time											
CONCLUSION: ALLOWANCE TIME AT 10 MINUTES IS OK BELOW -10 ºC FOR EG FLUIDS. ALLOWANCE TIME AT 10 MINUTES IS OK FROM -14 TO -25 ºC FOR PG FLUIDS WITH ROTATION SPEEDS ABOVE 115 KTS ONLY											

Photo 7.1: Test #5A – Start of Test



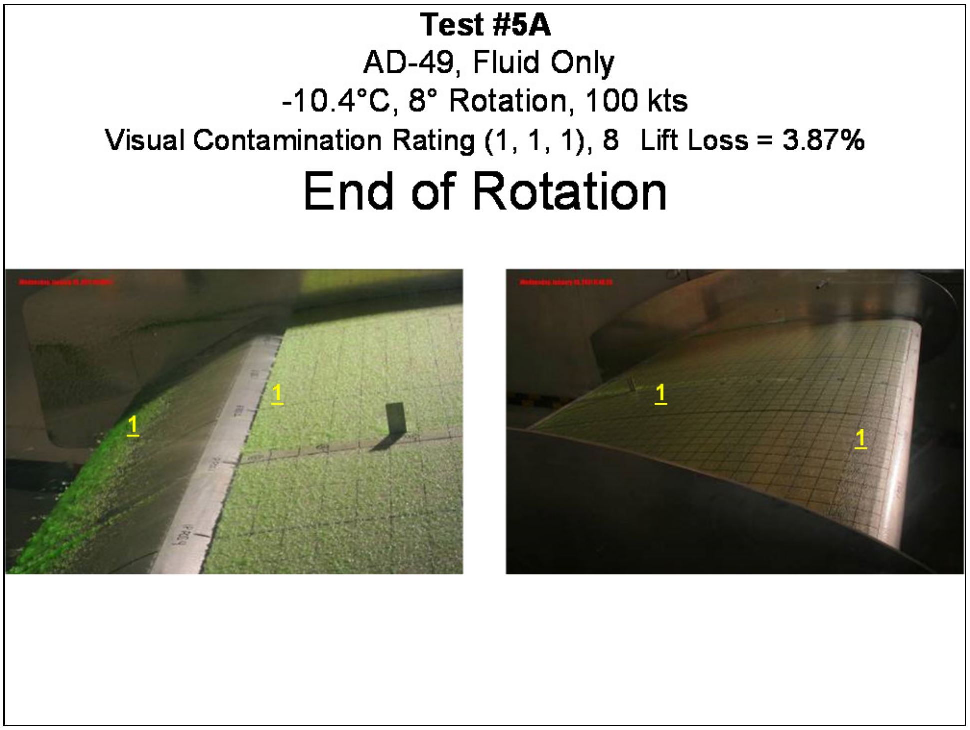
Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 7.2: Test #5A – Before Rotation



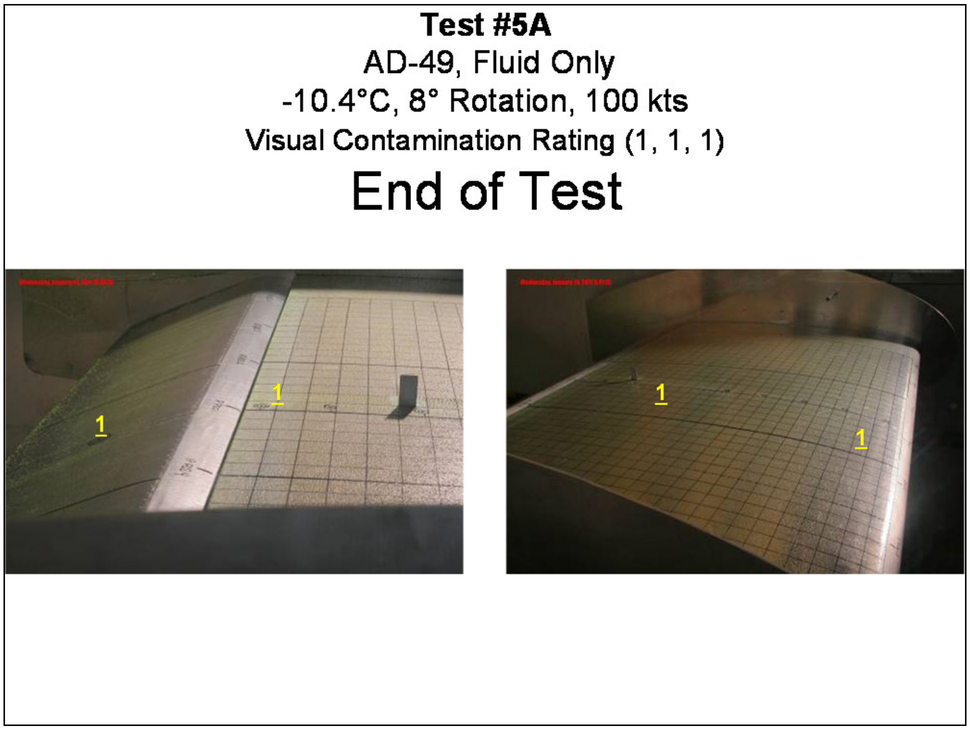
Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.87%
Before Rotation

Photo 7.3: Test #5A – End of Rotation



Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.87%
End of Rotation

Photo 7.4: Test #5A – End of Test



Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 7.5: Test #7 – Start of Test

Test #7

AD-49, IP Mod 75 g/dm²/h, 10 min

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.7, 2.7, 3.4)

Start of Test

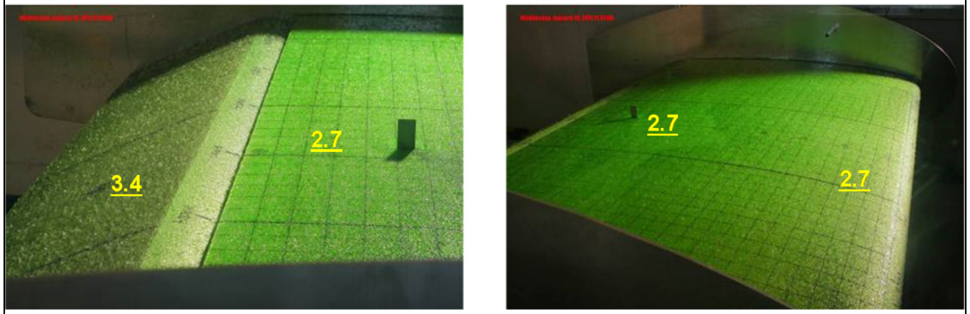


Photo 7.6: Test #7 – Before Rotation

Test #7

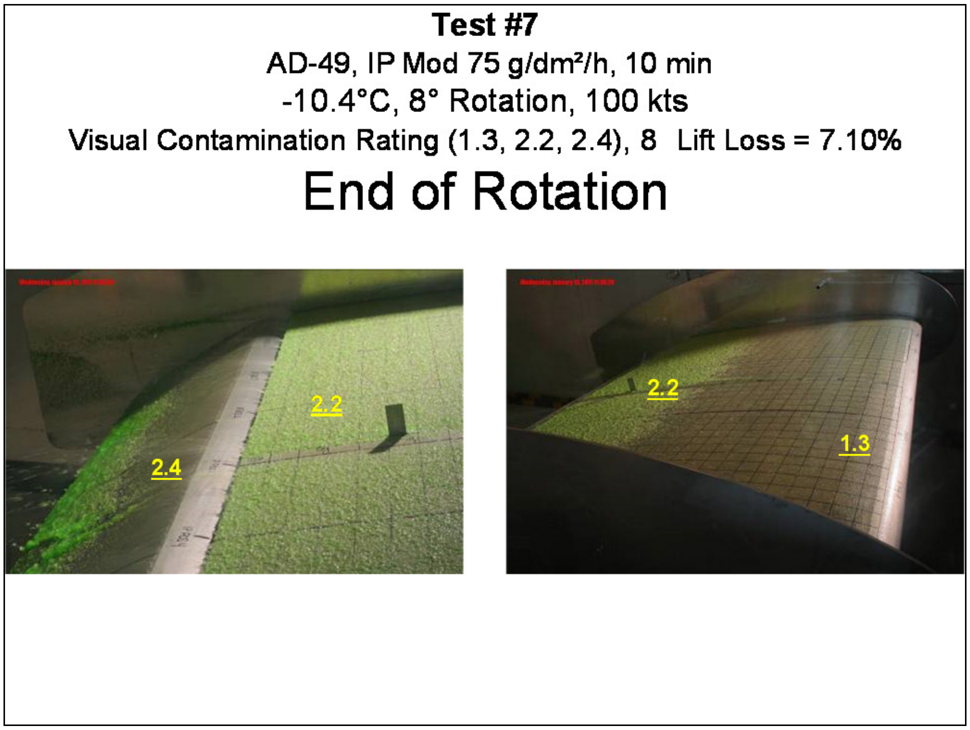
AD-49, IP Mod 75 g/dm²/h, 10 min

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.3, 2.2, 2.4), 8 Lift Loss = 7.10%

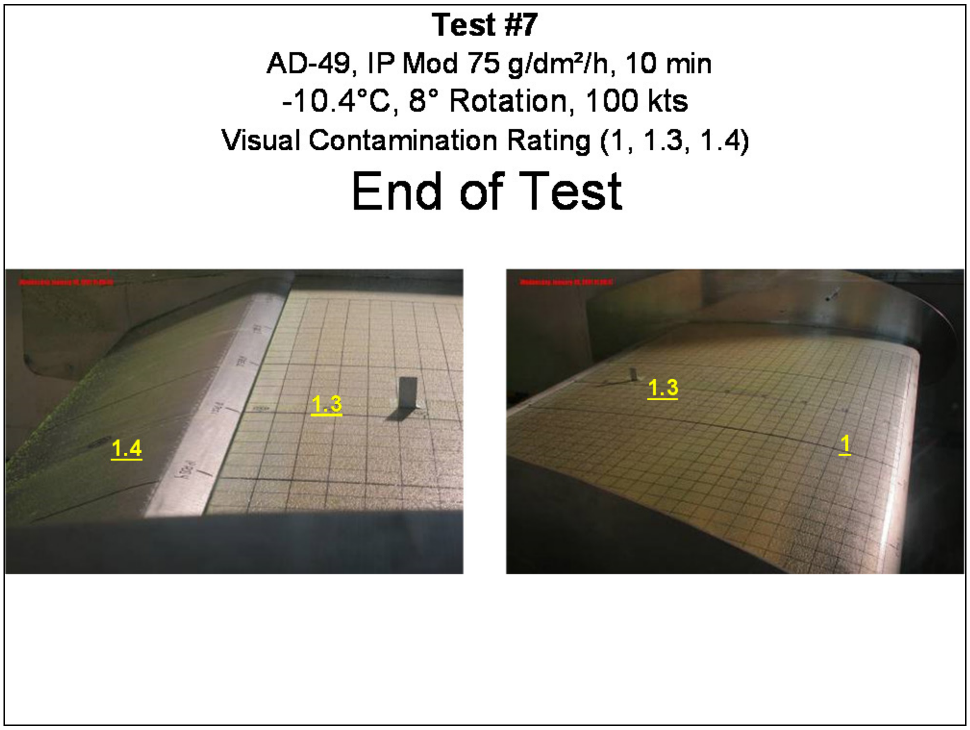
Before Rotation

Photo 7.7: Test #7 – End of Rotation


Test #7
AD-49, IP Mod 75 g/dm²/h, 10 min
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1.3, 2.2, 2.4), 8 Lift Loss = 7.10%

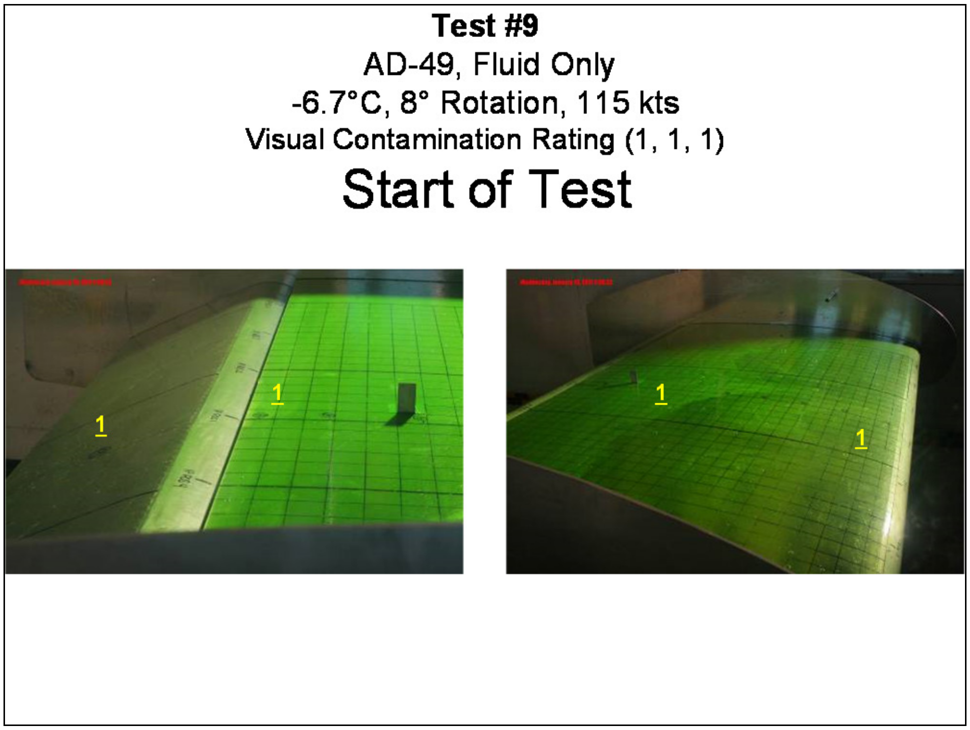
End of Rotation

Photo 7.8: Test #7 – End of Test


Test #7
AD-49, IP Mod 75 g/dm²/h, 10 min
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1.3, 1.4)

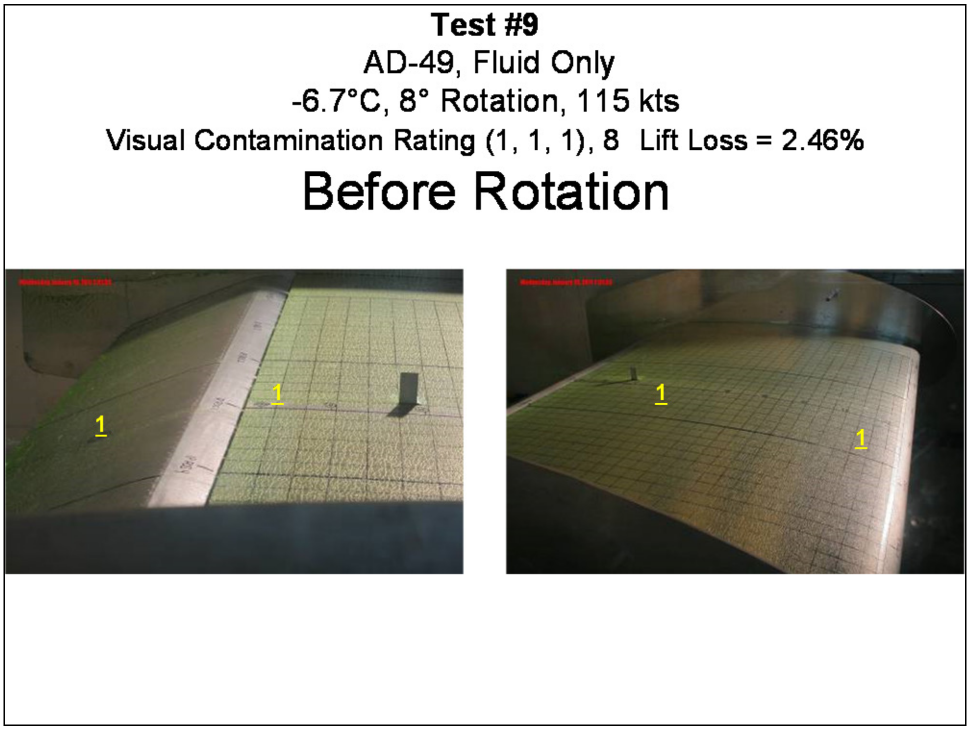
End of Test

Photo 7.9: Test #9 – Start of Test



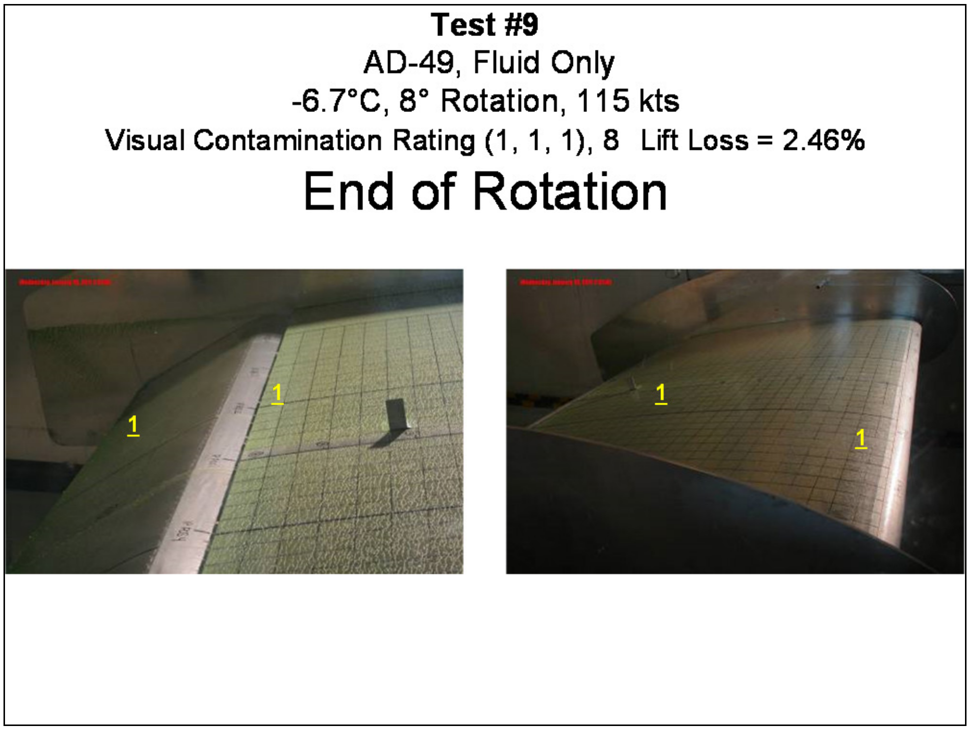
Test #9
AD-49, Fluid Only
-6.7°C, 8° Rotation, 115 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 7.10: Test #9 – Before Rotation



Test #9
AD-49, Fluid Only
-6.7°C, 8° Rotation, 115 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.46%
Before Rotation

Photo 7.11: Test #9 – End of Rotation



Test #9

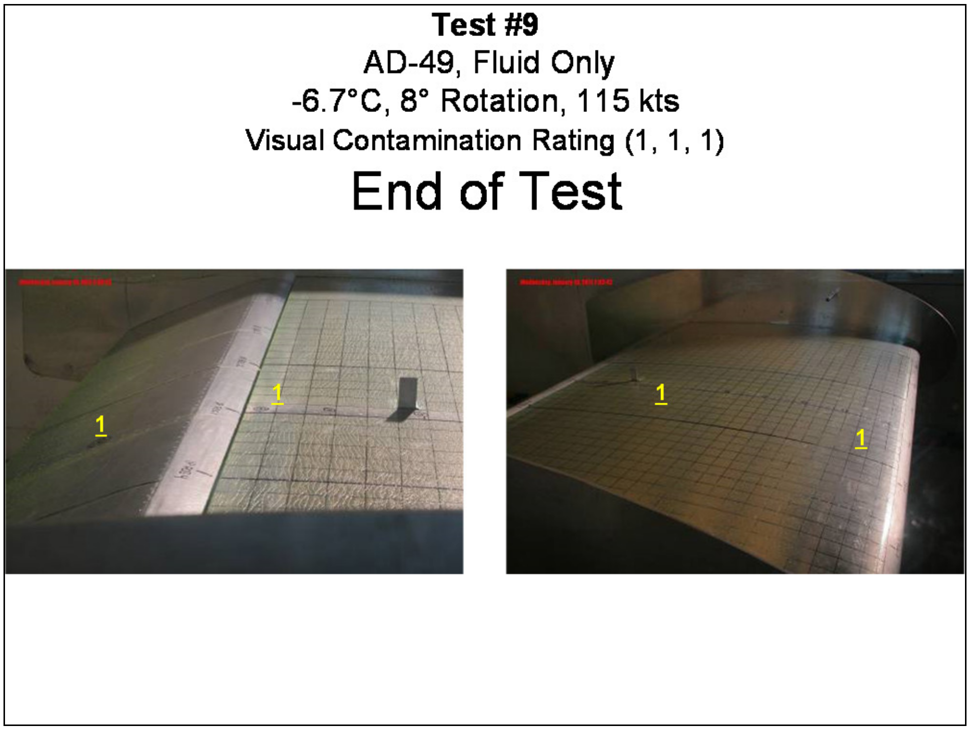
AD-49, Fluid Only

-6.7°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.46%

End of Rotation

Photo 7.12: Test #9 – End of Test



Test #9

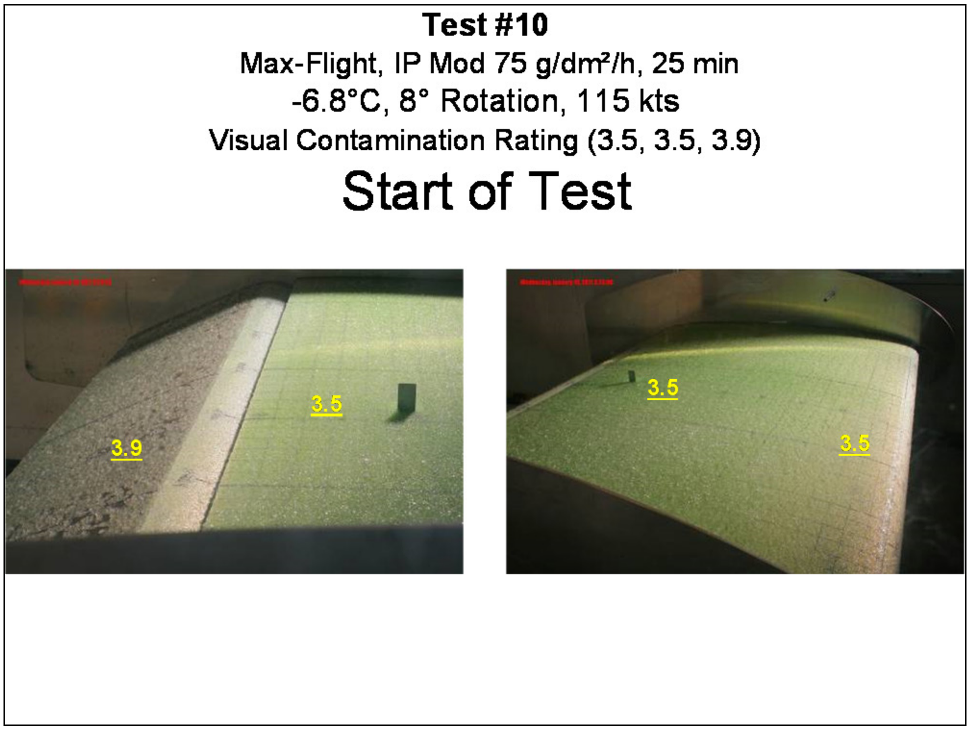
AD-49, Fluid Only

-6.7°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.13: Test #10 – Start of Test



Test #10

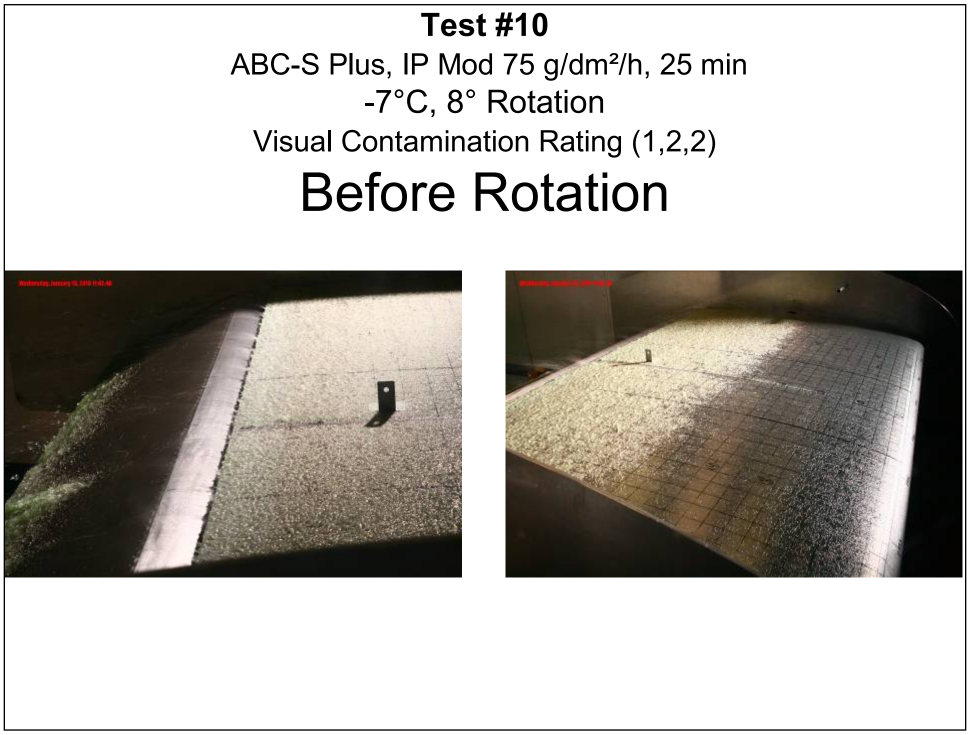
Max-Flight, IP Mod 75 g/dm²/h, 25 min

-6.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (3.5, 3.5, 3.9)

Start of Test

Photo 7.14: Test #10 – Before Rotation



Test #10

ABC-S Plus, IP Mod 75 g/dm²/h, 25 min

-7°C, 8° Rotation

Visual Contamination Rating (1,2,2)

Before Rotation

Photo 7.15: Test #10 – End of Rotation

Test #10
ABC-S Plus, IP Mod 75 g/dm²/h, 25 min
-7°C, 8° Rotation
Visual Contamination Rating (1,2,2), 8° Lift Loss = 6.12%
End of Rotation

Photo 7.16: Test #10 – End of Test

Test #10
ABC-S Plus, IP Mod 75 g/dm²/h, 25 min
-7°C, 8° Rotation
Visual Contamination Rating (1,1,1)
End of Test

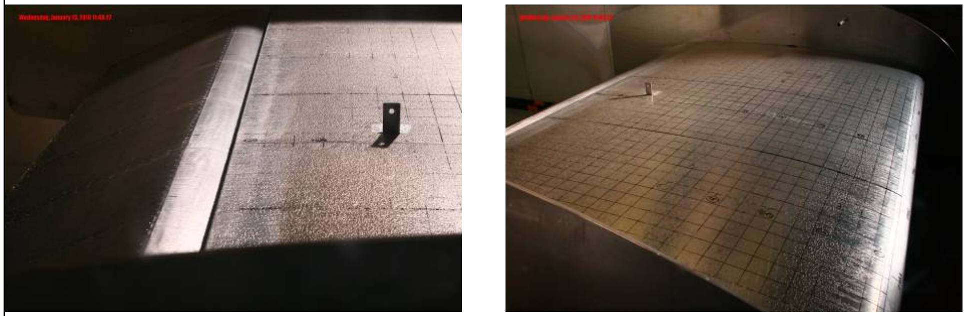
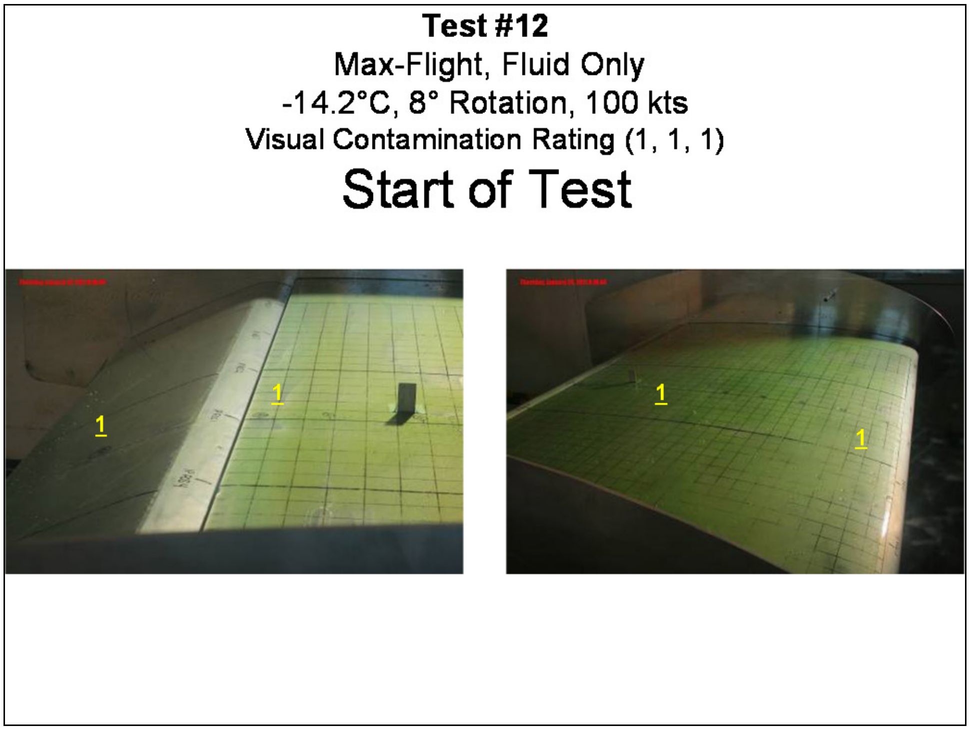


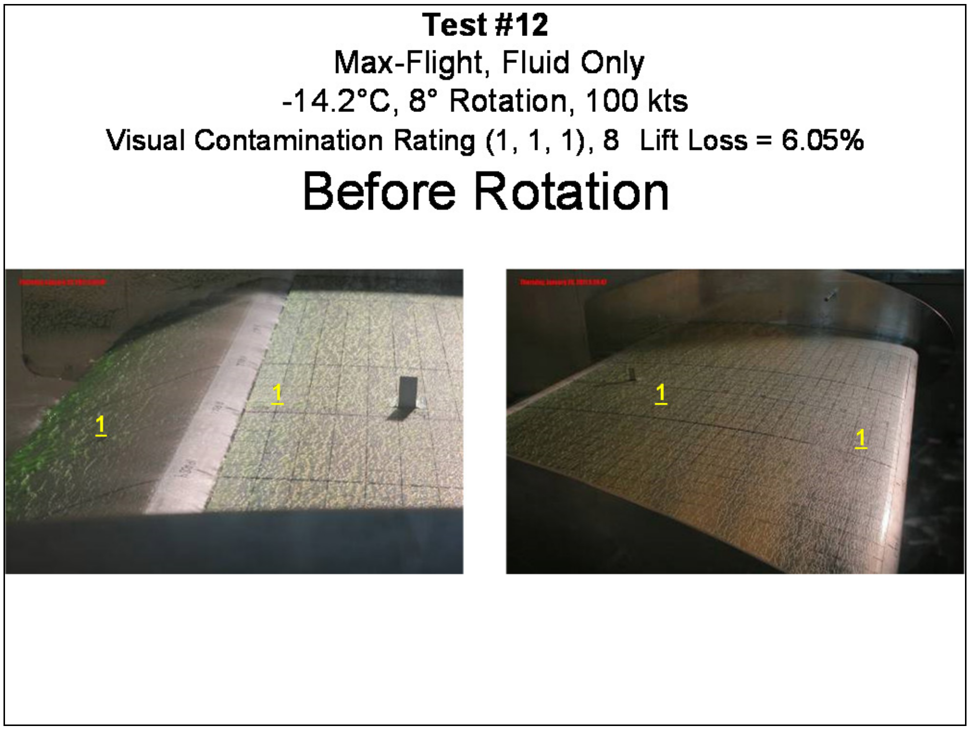
Photo 7.17: Test #12 – Start of Test



Test #12
Max-Flight, Fluid Only
-14.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

Start of Test

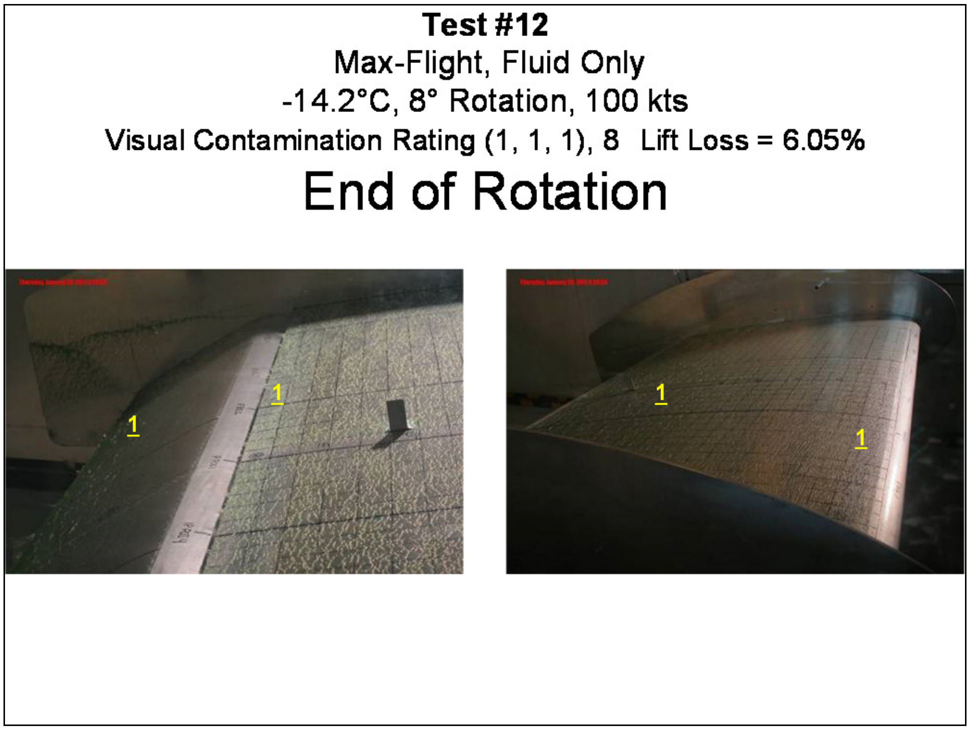
Photo 7.18: Test #12 – Before Rotation



Test #12
Max-Flight, Fluid Only
-14.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.05%

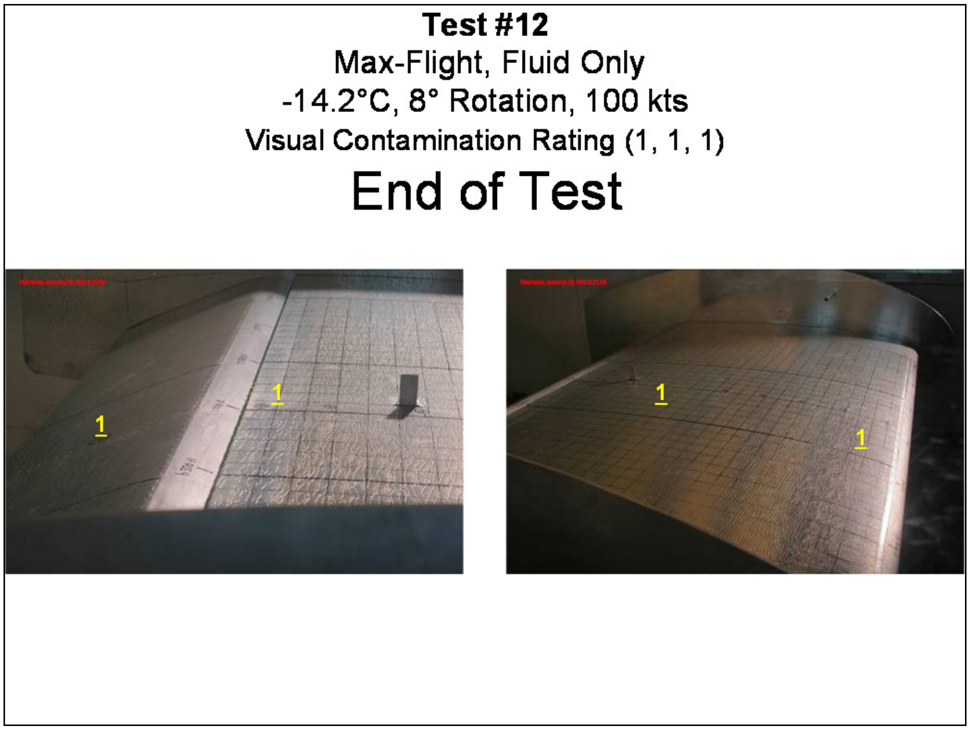
Before Rotation

Photo 7.19: Test #12 – End of Rotation



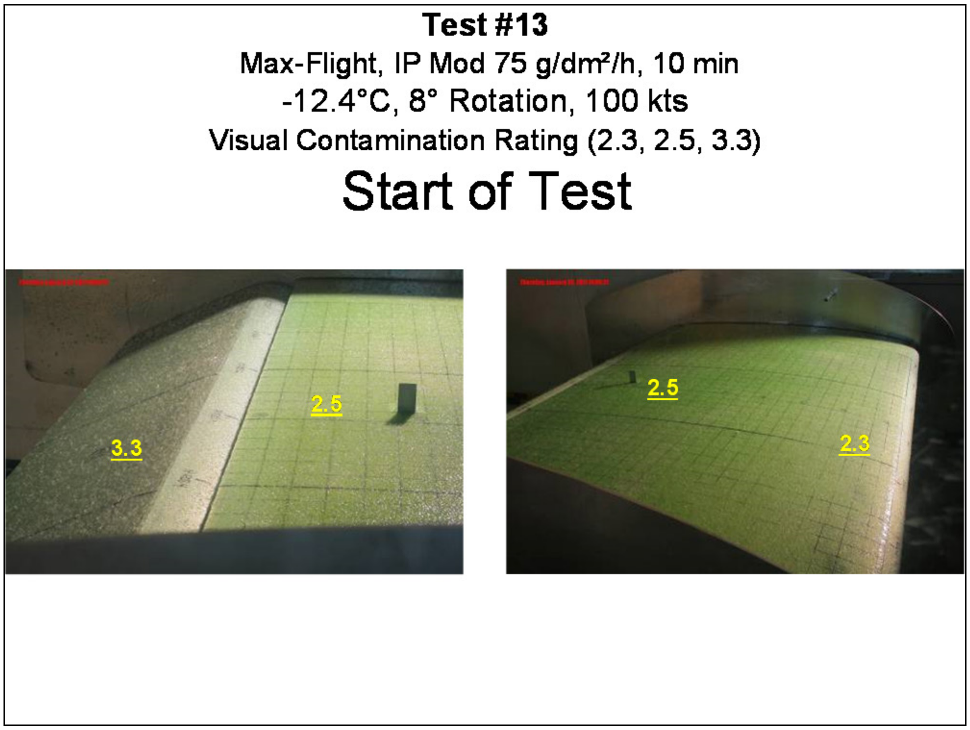
Test #12
Max-Flight, Fluid Only
-14.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.05%
End of Rotation

Photo 7.20: Test #12 – End of Test



Test #12
Max-Flight, Fluid Only
-14.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 7.21: Test #13 – Start of Test



Test #13

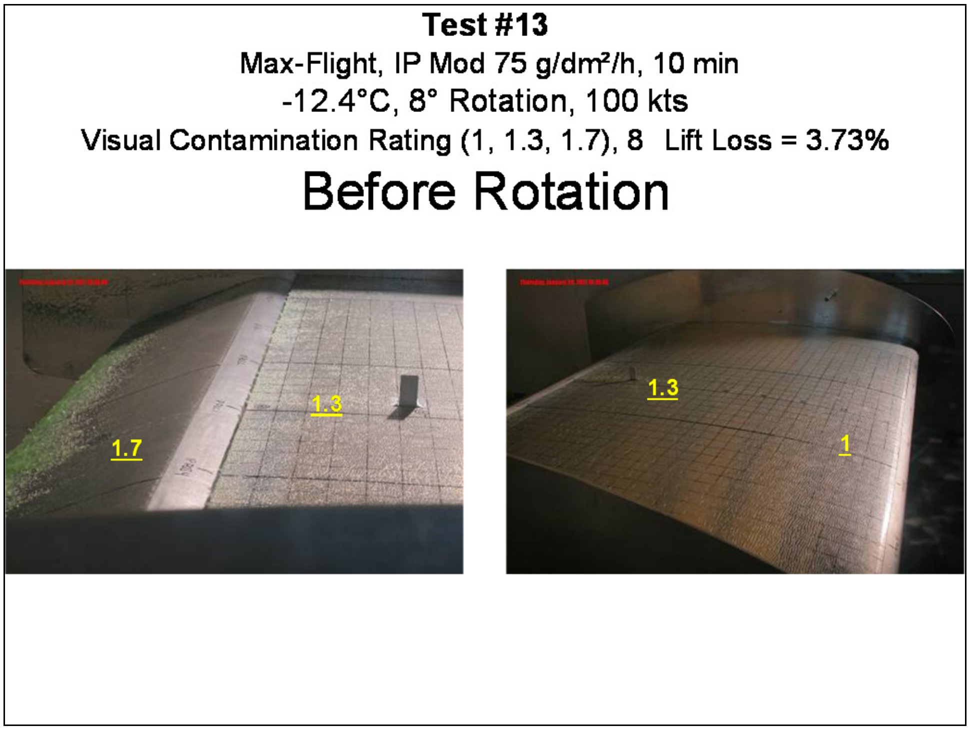
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-12.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.3, 2.5, 3.3)

Start of Test

Photo 7.22: Test #13 – Before Rotation



Test #13

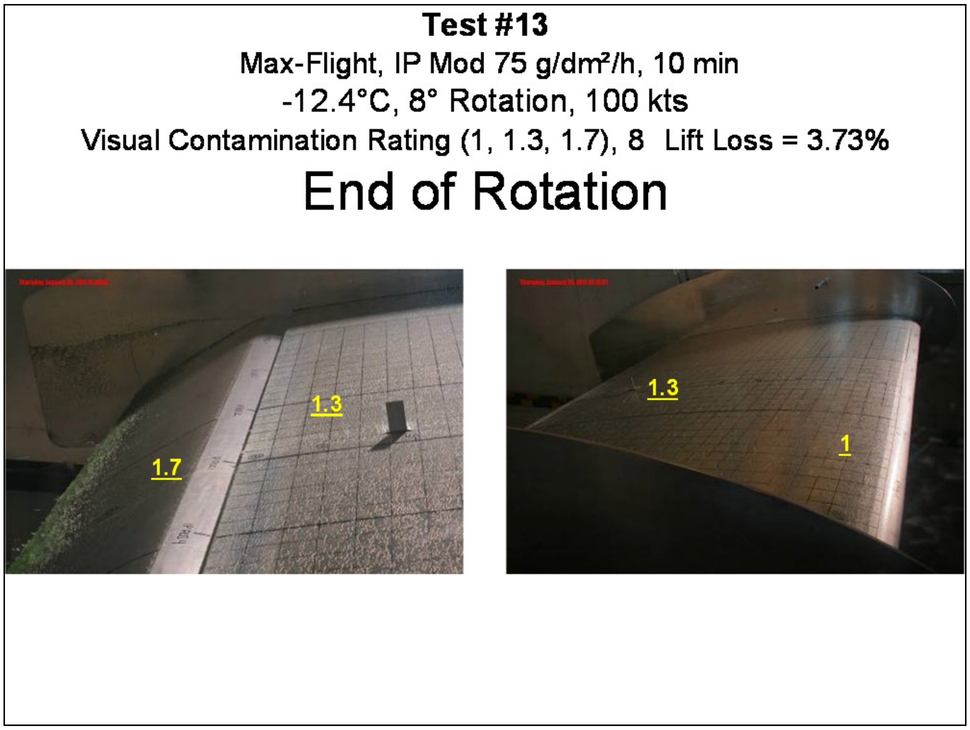
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-12.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.3, 1.7), 8 Lift Loss = 3.73%

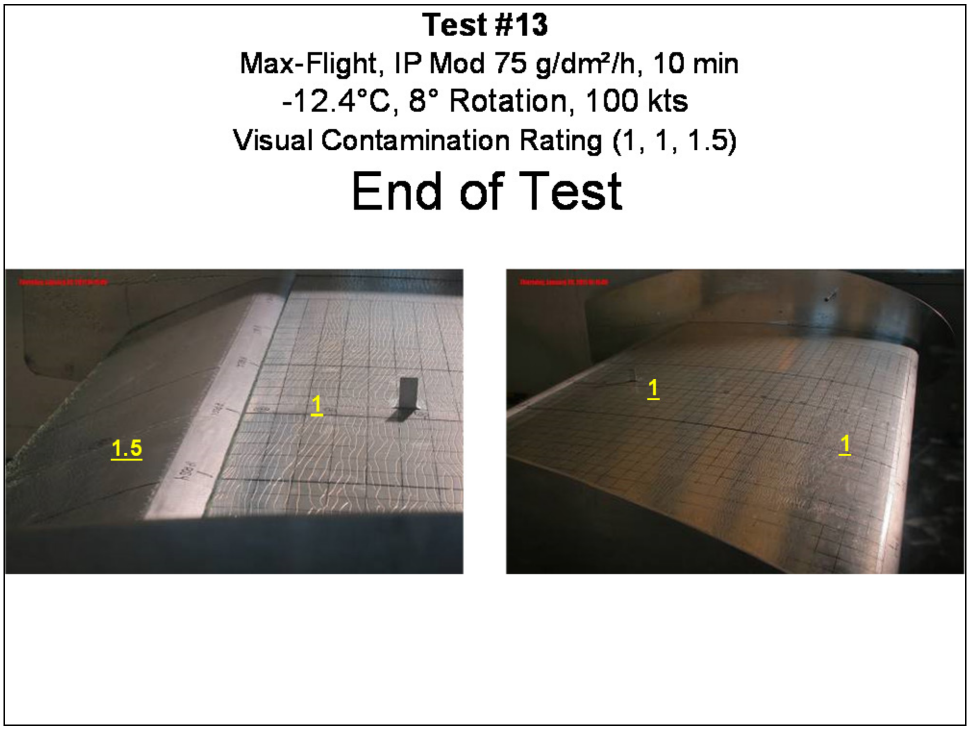
Before Rotation

Photo 7.23: Test #13 – End of Rotation



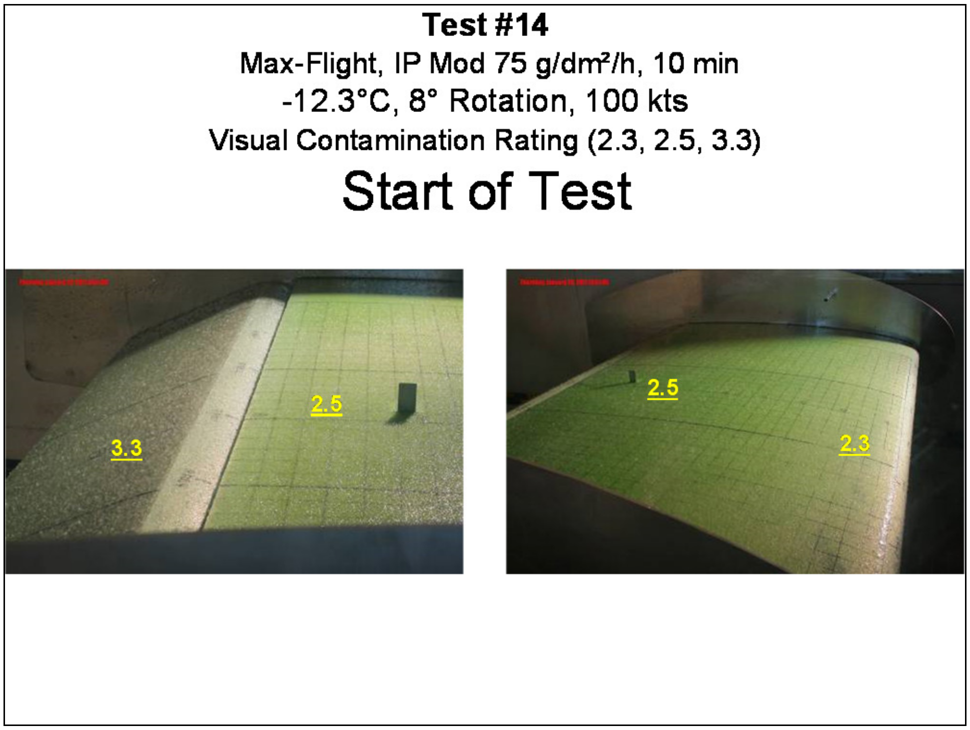
Test #13
Max-Flight, IP Mod 75 g/dm²/h, 10 min
-12.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1.3, 1.7), 8 Lift Loss = 3.73%
End of Rotation

Photo 7.24: Test #13 – End of Test



Test #13
Max-Flight, IP Mod 75 g/dm²/h, 10 min
-12.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1.5)
End of Test

Photo 7.25: Test #14 – Start of Test



Test #14

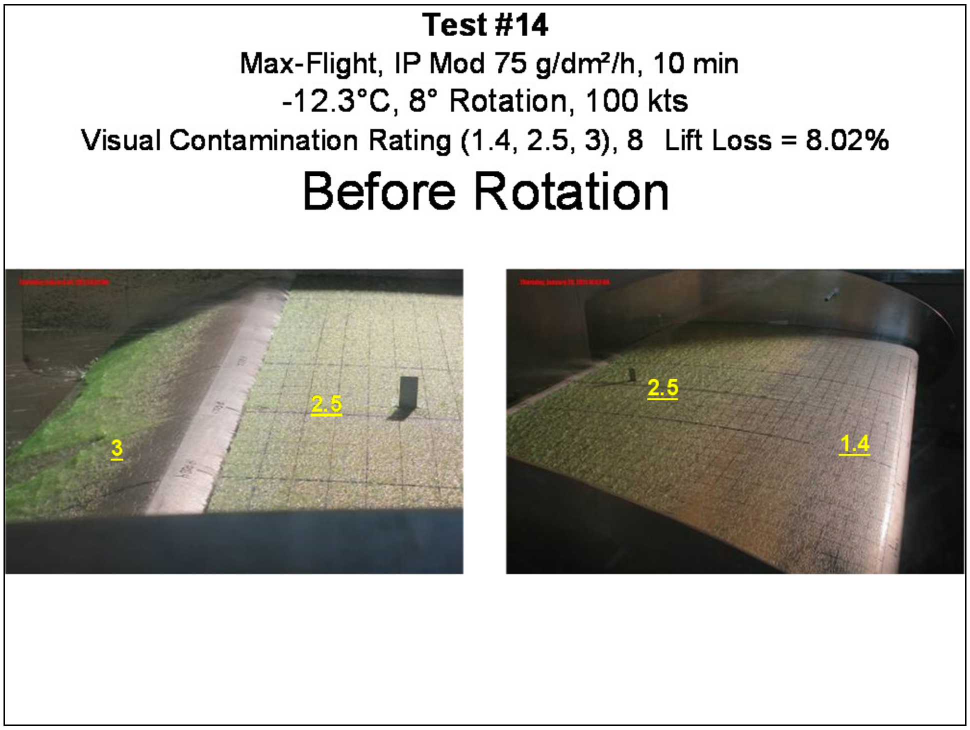
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-12.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.3, 2.5, 3.3)

Start of Test

Photo 7.26: Test #14 – Before Rotation



Test #14

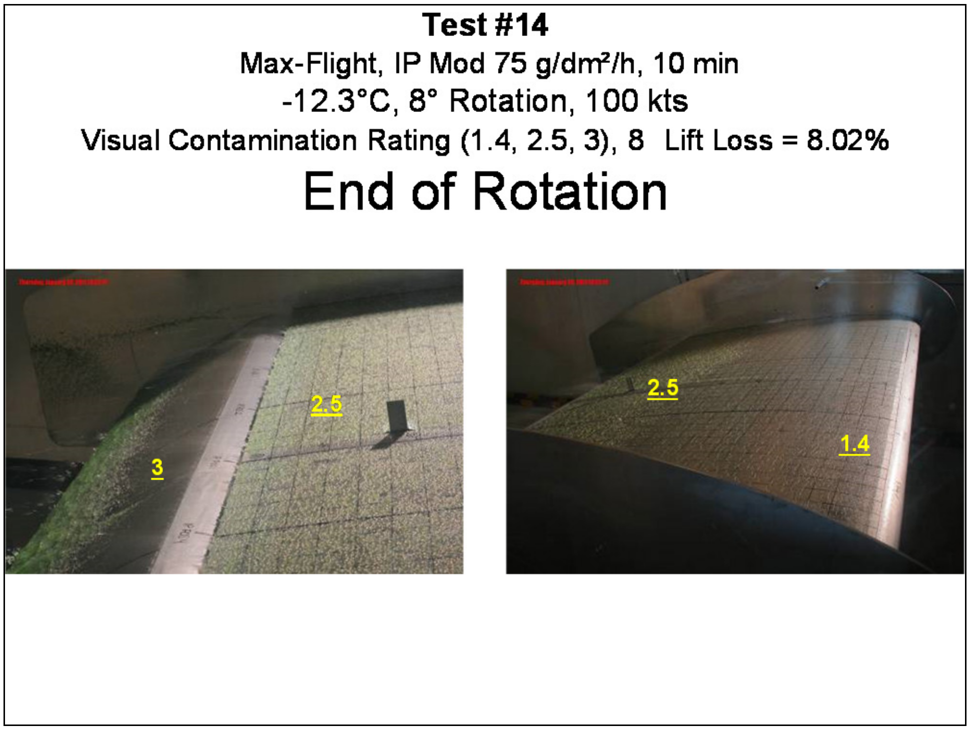
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-12.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.4, 2.5, 3), 8 Lift Loss = 8.02%

Before Rotation

Photo 7.27: Test #14 – End of Rotation



Test #14

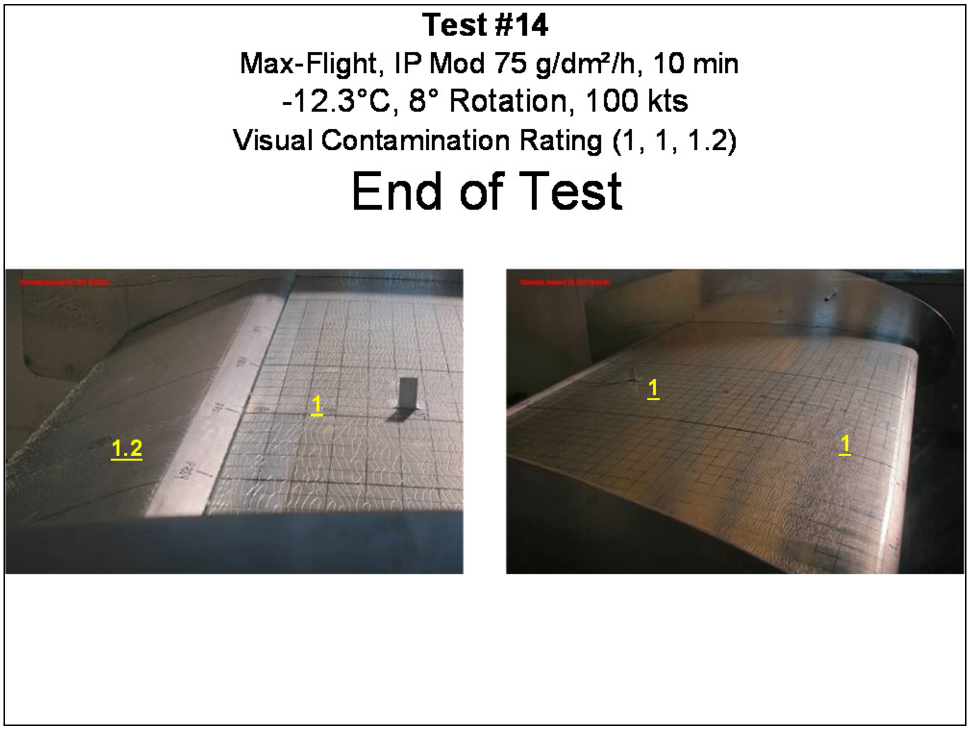
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-12.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.4, 2.5, 3), 8 Lift Loss = 8.02%

End of Rotation

Photo 7.28: Test #14 – End of Test



Test #14

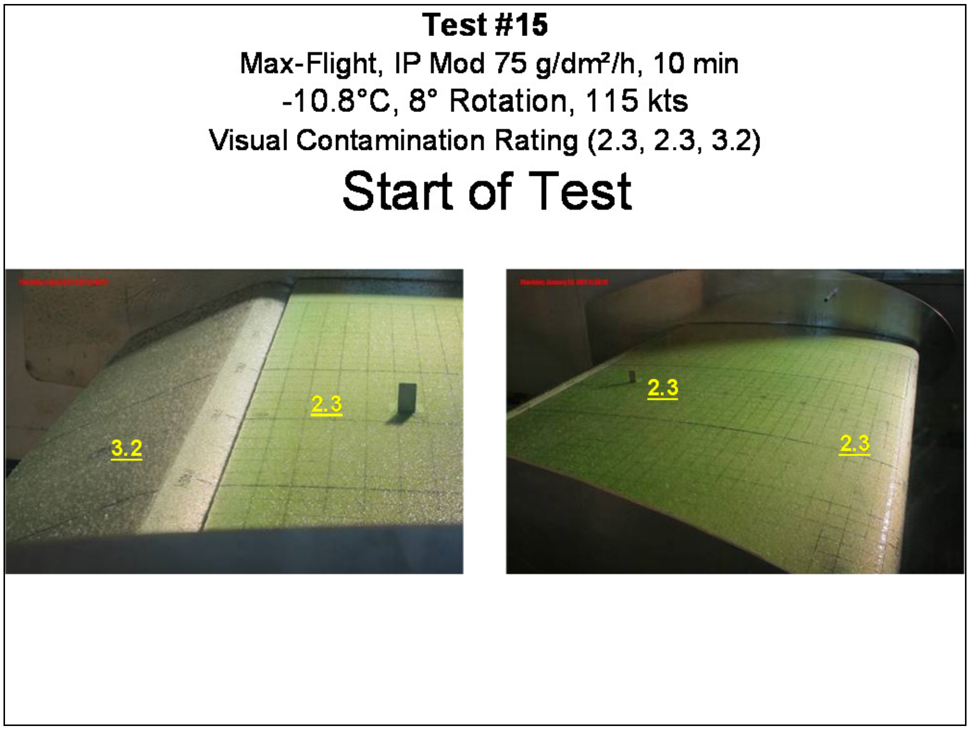
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-12.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.2)

End of Test

Photo 7.29: Test #15 – Start of Test



Test #15

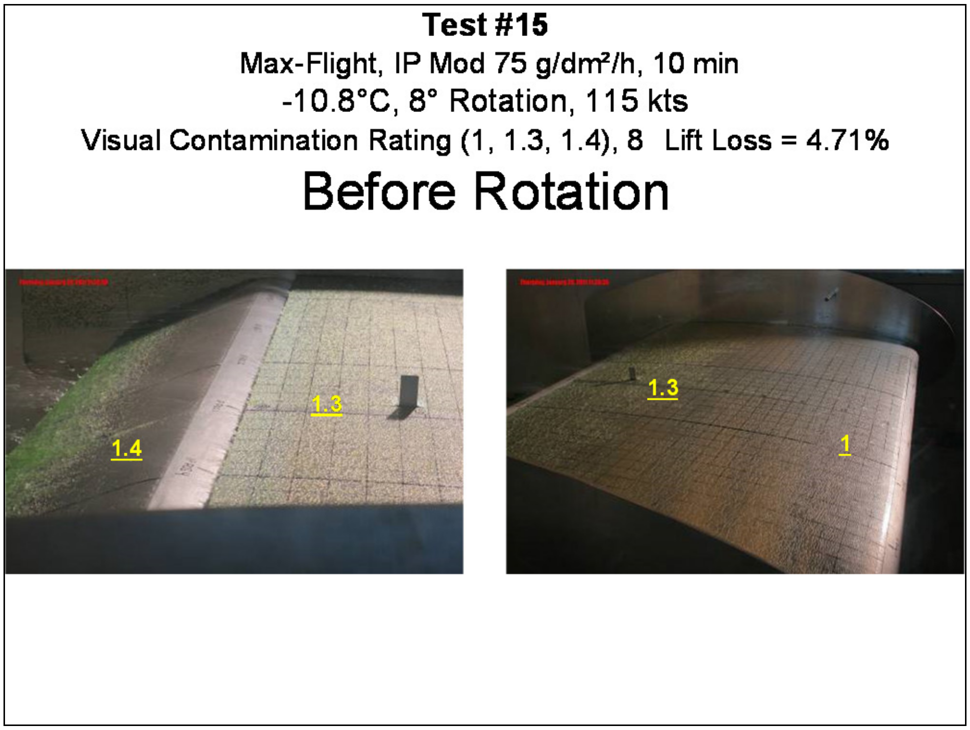
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (2.3, 2.3, 3.2)

Start of Test

Photo 7.30: Test #15 – Before Rotation



Test #15

Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.3, 1.4), 8 Lift Loss = 4.71%

Before Rotation

Photo 7.31: Test #15 – End of Rotation

Test #15
Max-Flight, IP Mod 75 g/dm²/h, 10 min
-10.8°C, 8° Rotation, 115 kts
Visual Contamination Rating (1, 1.3, 1.4), 8 Lift Loss = 4.71%

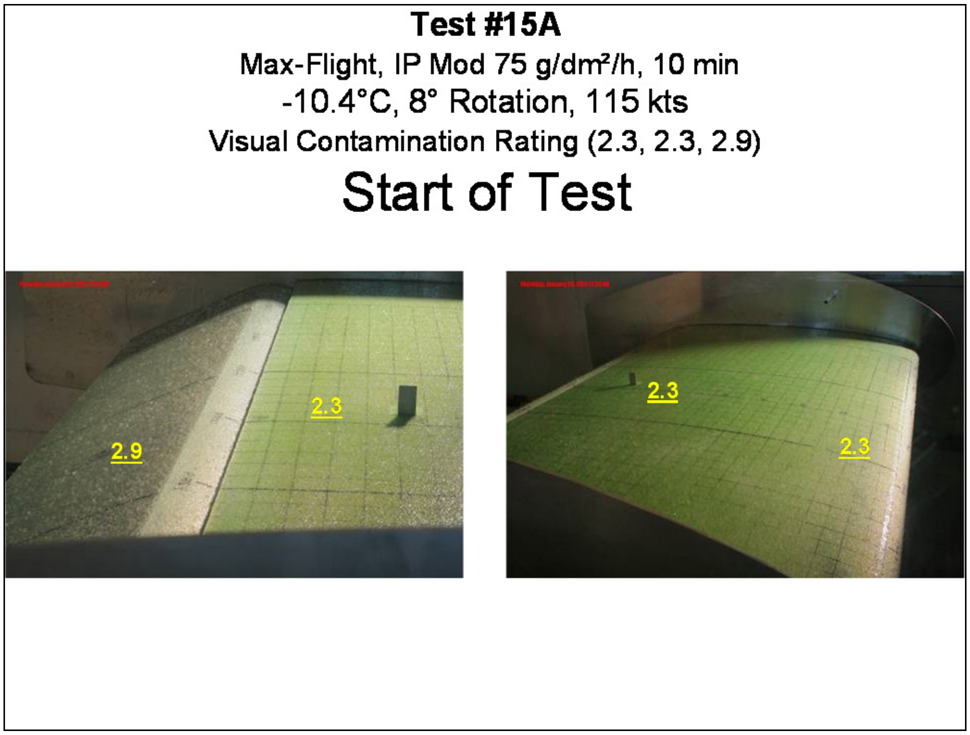
End of Rotation

Photo 7.32: Test #15 – End of Test

Test #15
Max-Flight, IP Mod 75 g/dm²/h, 10 min
-10.8°C, 8° Rotation, 115 kts
Visual Contamination Rating (1, 1, 1.1)

End of Test

Photo 7.33: Test #15A – Start of Test



Test #15A

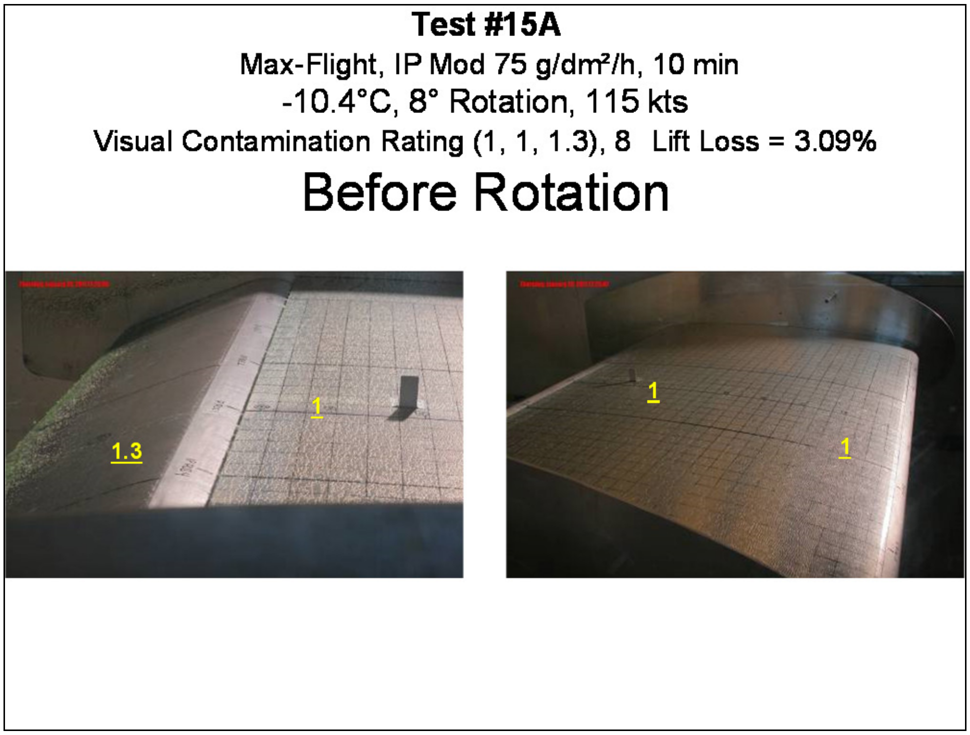
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (2.3, 2.3, 2.9)

Start of Test

Photo 7.34: Test #15A – Before Rotation



Test #15A

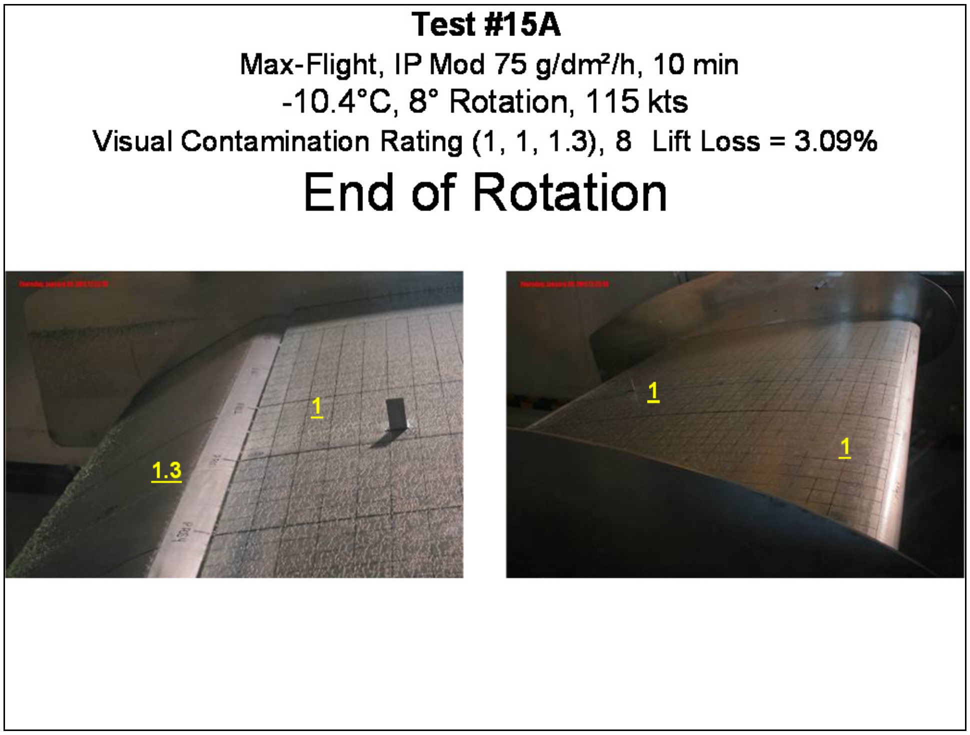
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1.3), 8 Lift Loss = 3.09%

Before Rotation

Photo 7.35: Test #15A – End of Rotation



Test #15A

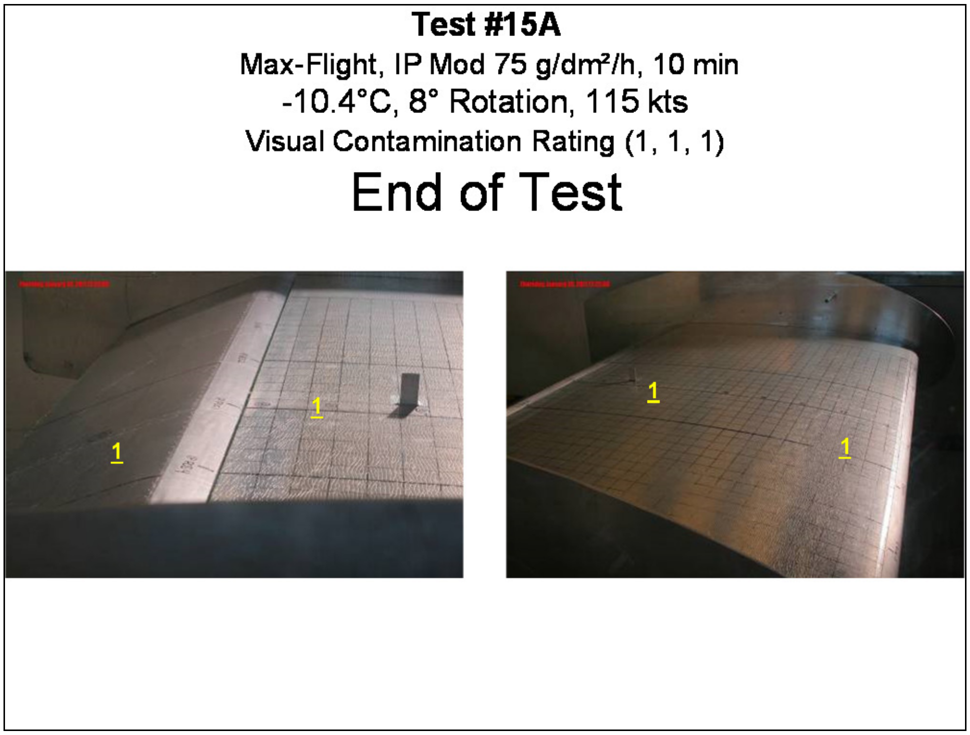
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1.3), 8 Lift Loss = 3.09%

End of Rotation

Photo 7.36: Test #15A – End of Test



Test #15A

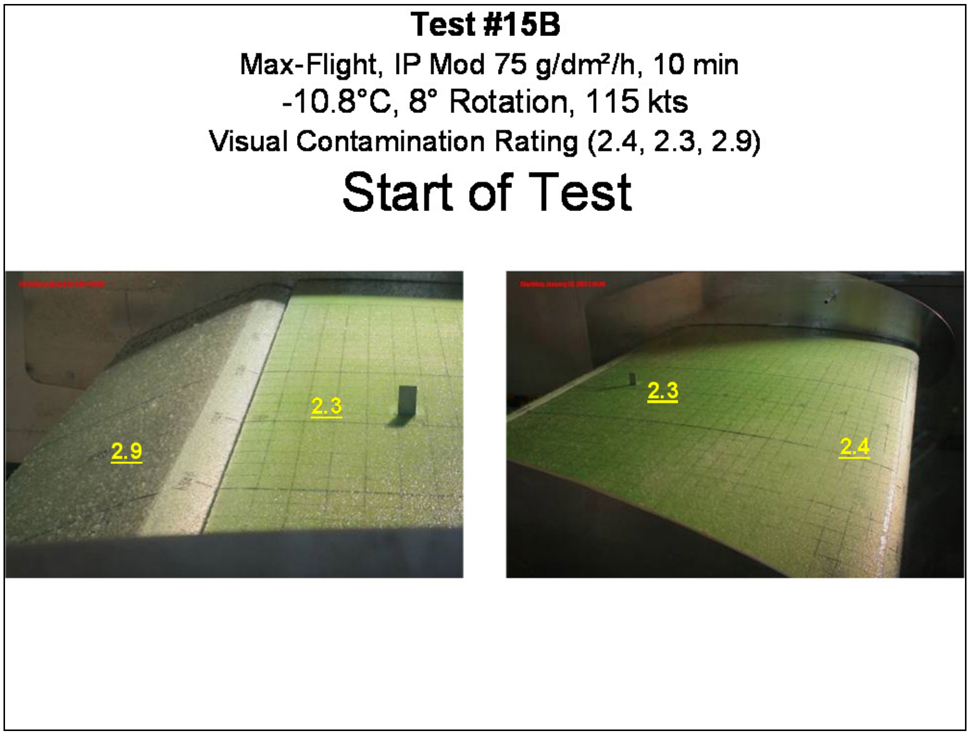
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.37: Test #15B – Start of Test



Test #15B

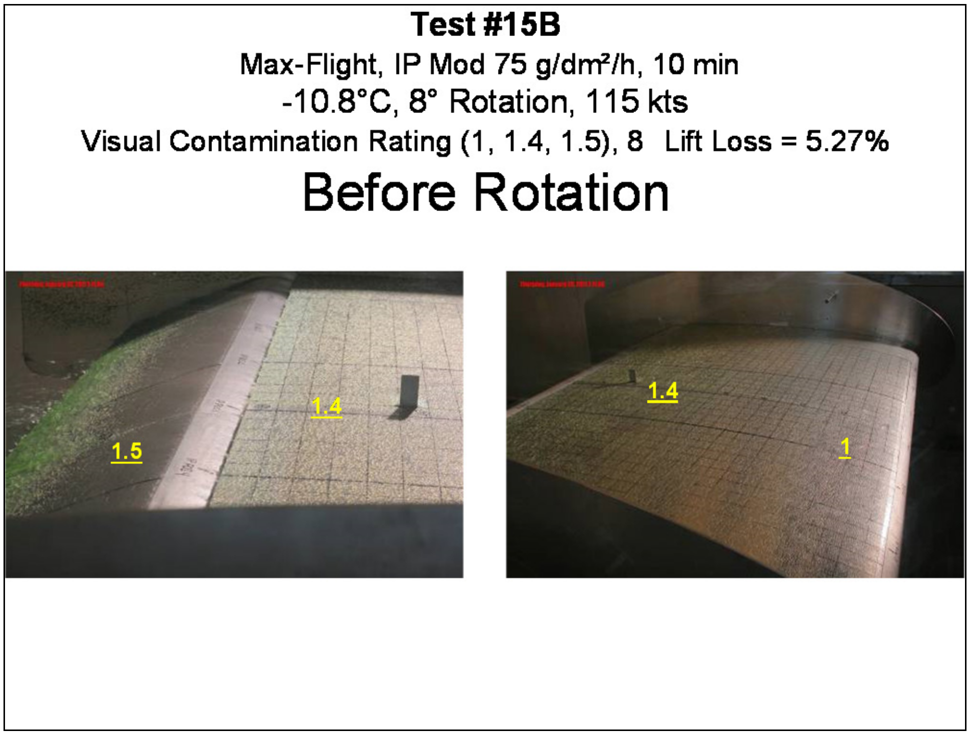
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (2.4, 2.3, 2.9)

Start of Test

Photo 7.38: Test #15B – Before Rotation



Test #15B

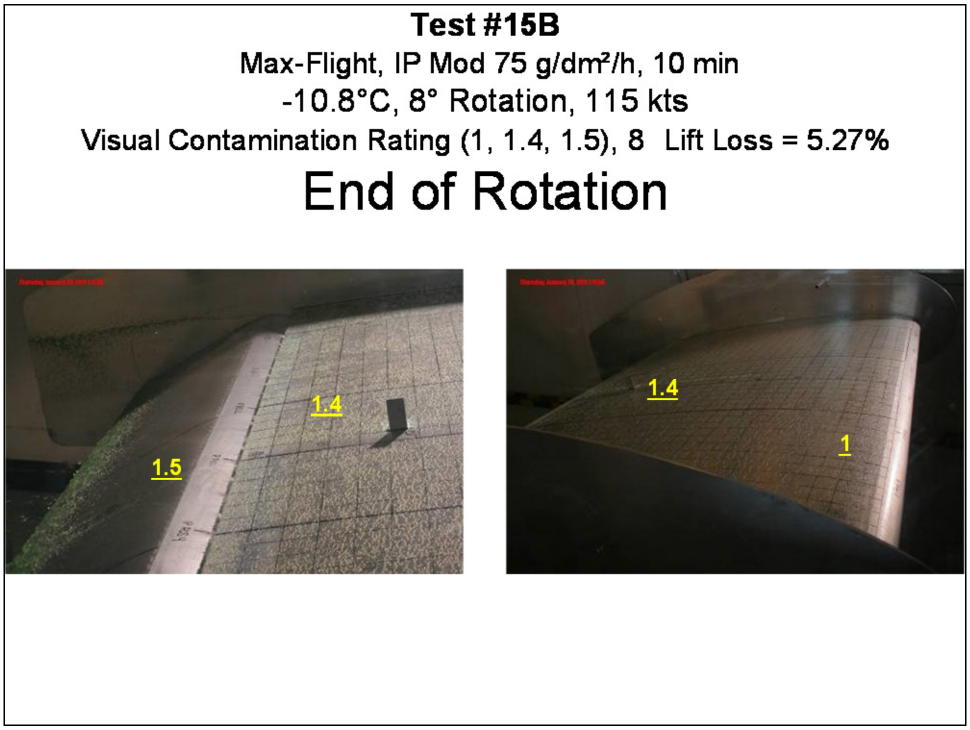
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.4, 1.5), 8 Lift Loss = 5.27%

Before Rotation

Photo 7.39: Test #15B – End of Rotation



Test #15B

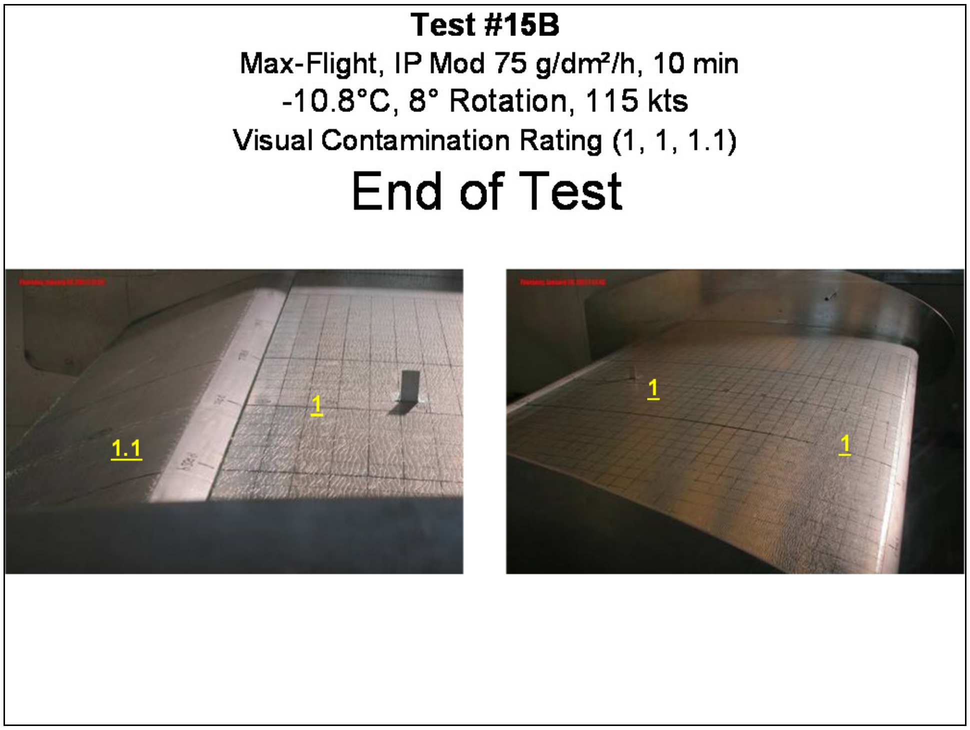
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.4, 1.5), 8 Lift Loss = 5.27%

End of Rotation

Photo 7.40: Test #15B – End of Test



Test #15B

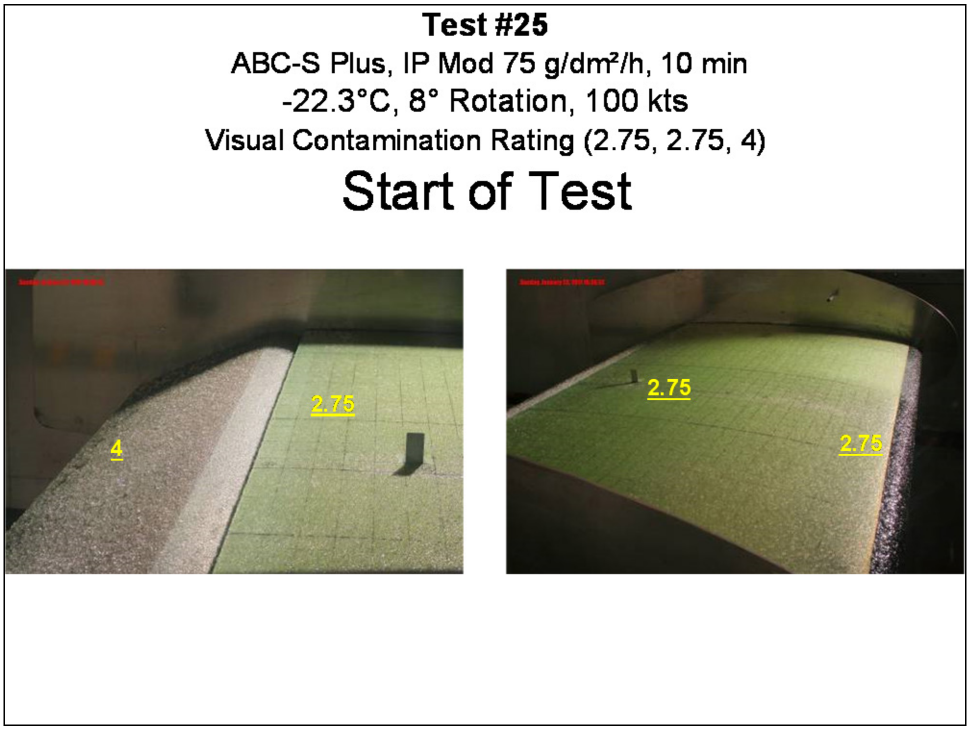
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1.1)

End of Test

Photo 7.41: Test #25 – Start of Test



Test #25

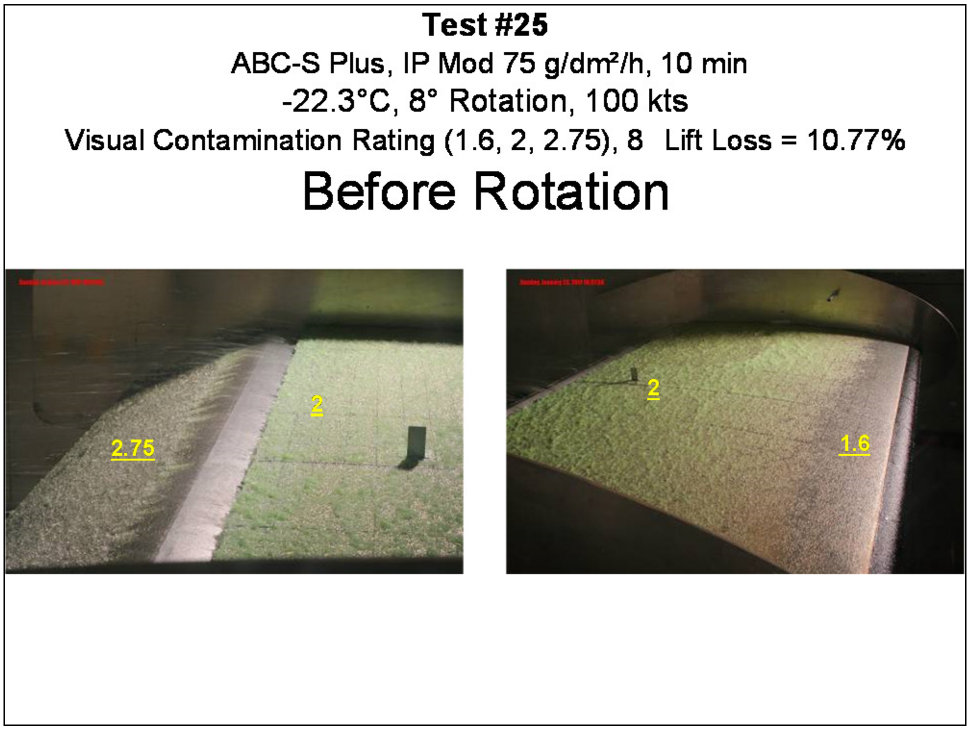
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.75, 2.75, 4)

Start of Test

Photo 7.42: Test #25 – Before Rotation



Test #25

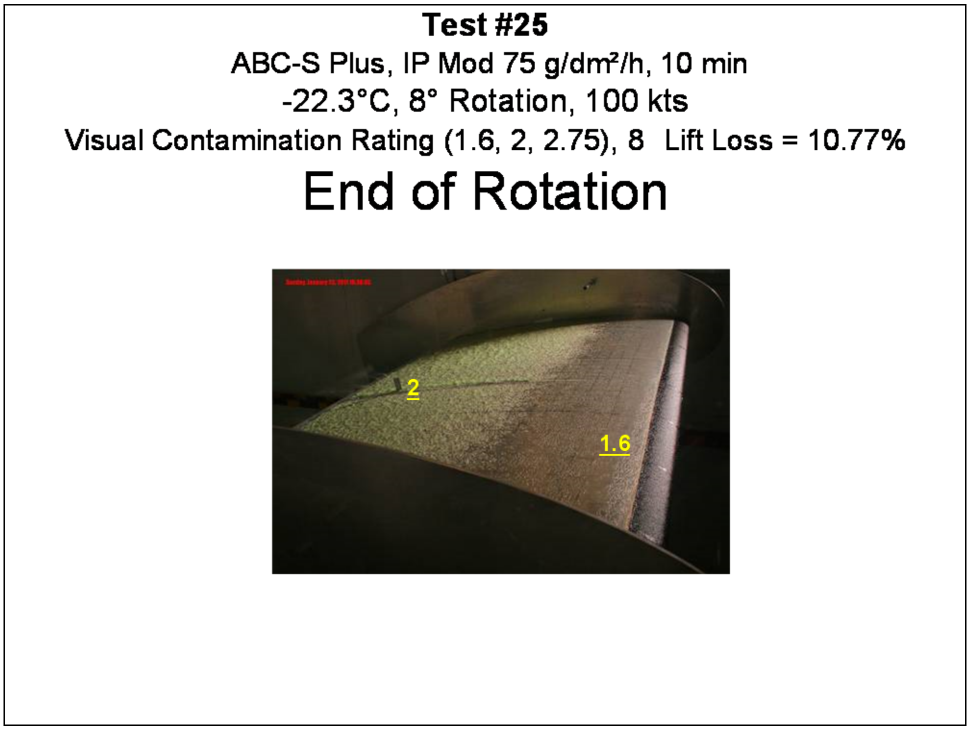
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.6, 2, 2.75), 8 Lift Loss = 10.77%

Before Rotation

Photo 7.43: Test #25 – End of Rotation



Test #25

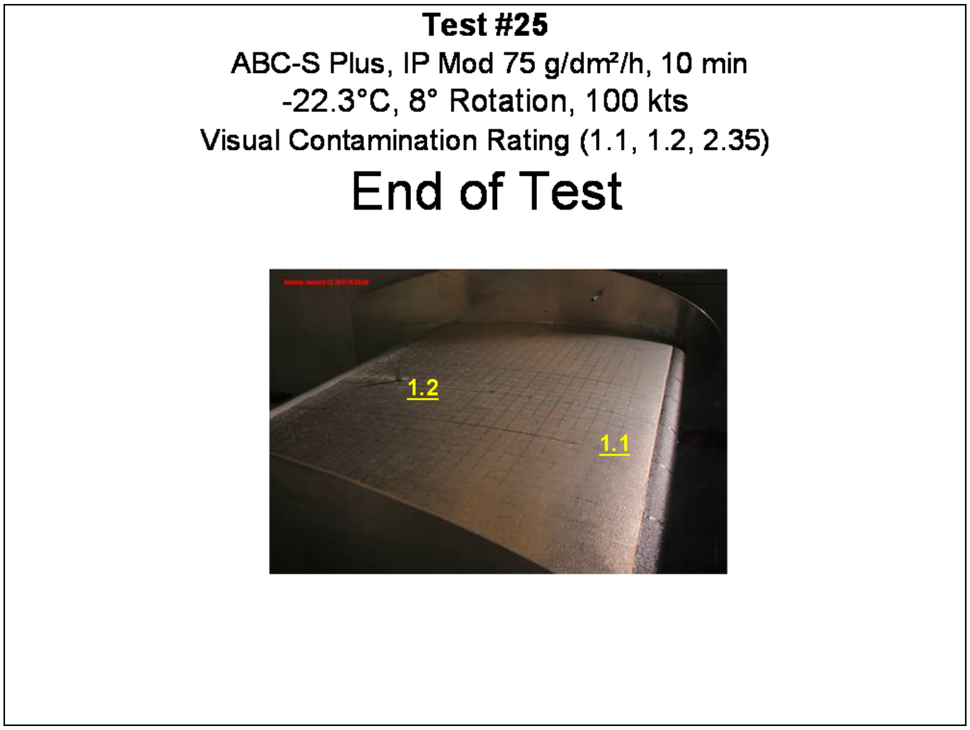
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.6, 2, 2.75), 8 Lift Loss = 10.77%

End of Rotation

Photo 7.44: Test #25 – End of Test



Test #25

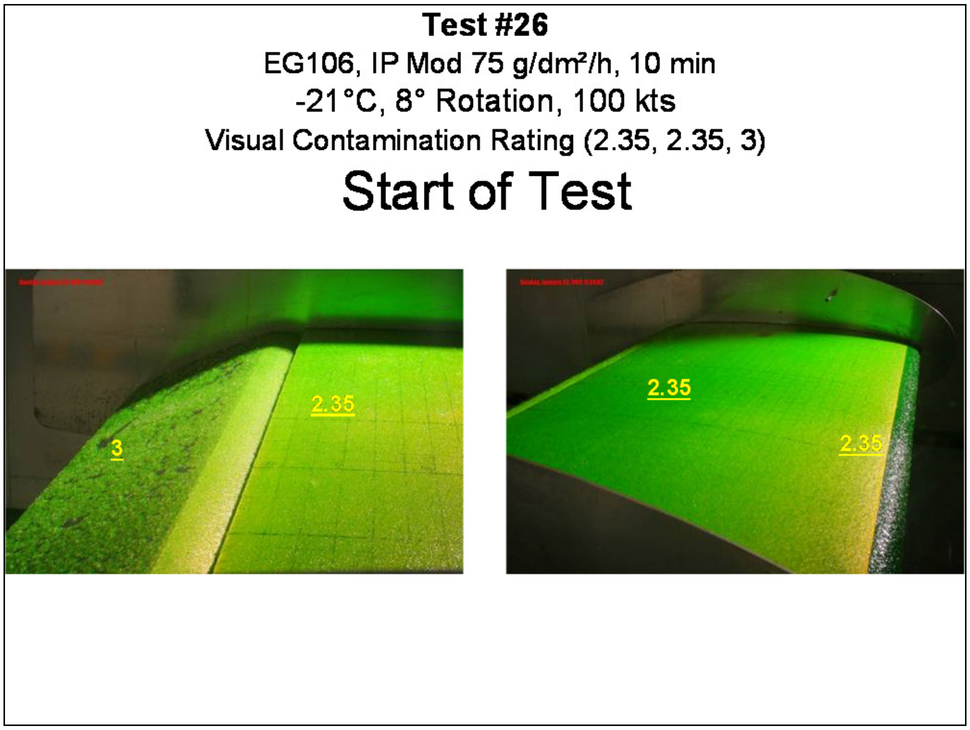
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.2, 2.35)

End of Test

Photo 7.45: Test #26 – Start of Test



Test #26

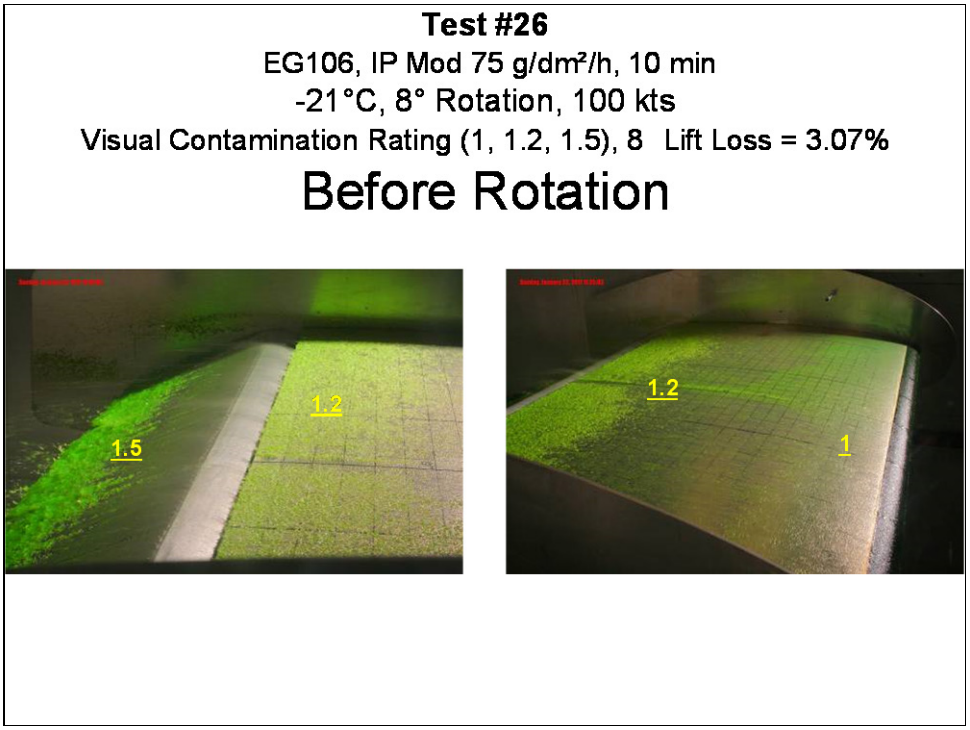
EG106, IP Mod 75 g/dm²/h, 10 min

-21°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.35, 2.35, 3)

Start of Test

Photo 7.46: Test #26 – Before Rotation



Test #26

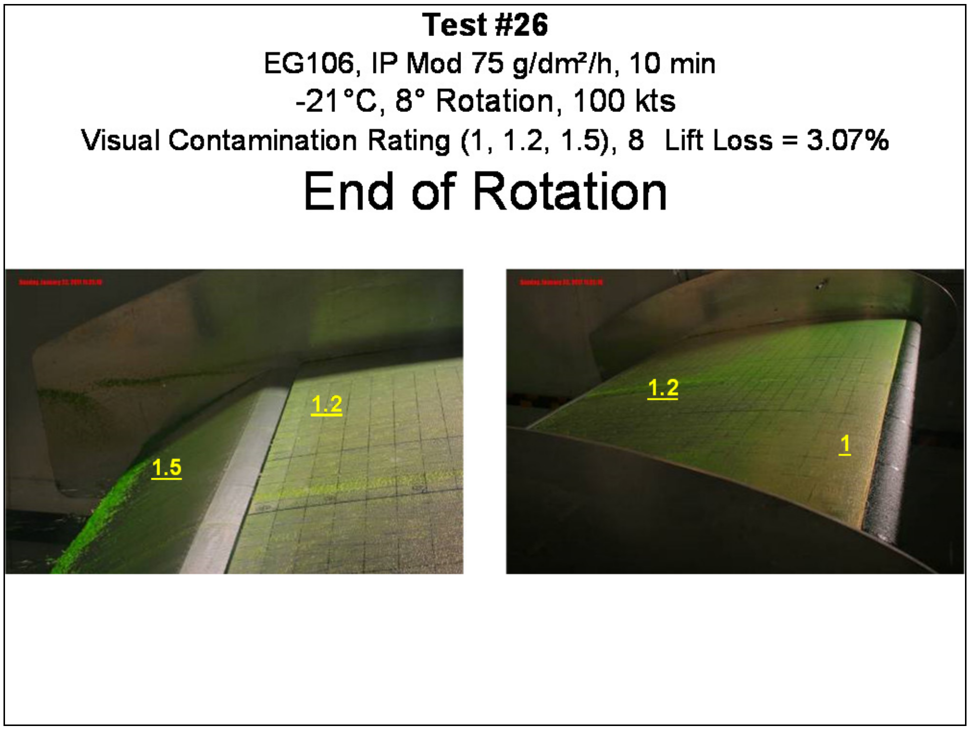
EG106, IP Mod 75 g/dm²/h, 10 min

-21°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.5), 8 Lift Loss = 3.07%

Before Rotation

Photo 7.47: Test #26 – End of Rotation



Test #26

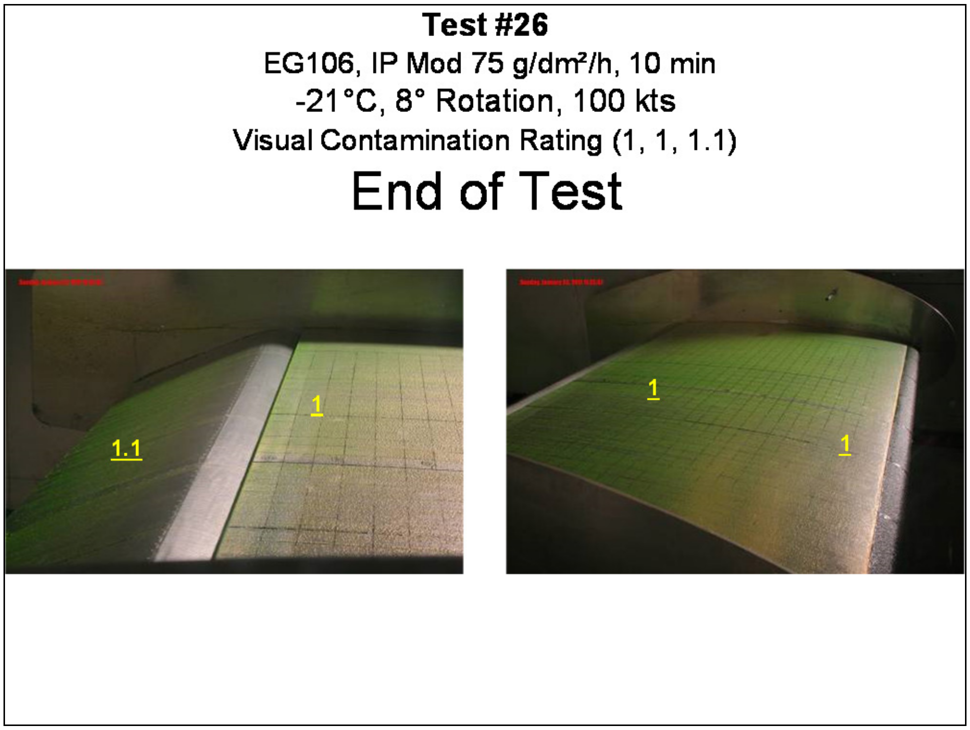
EG106, IP Mod 75 g/dm²/h, 10 min

-21°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.5), 8 Lift Loss = 3.07%

End of Rotation

Photo 7.48: Test #26 – End of Test



Test #26

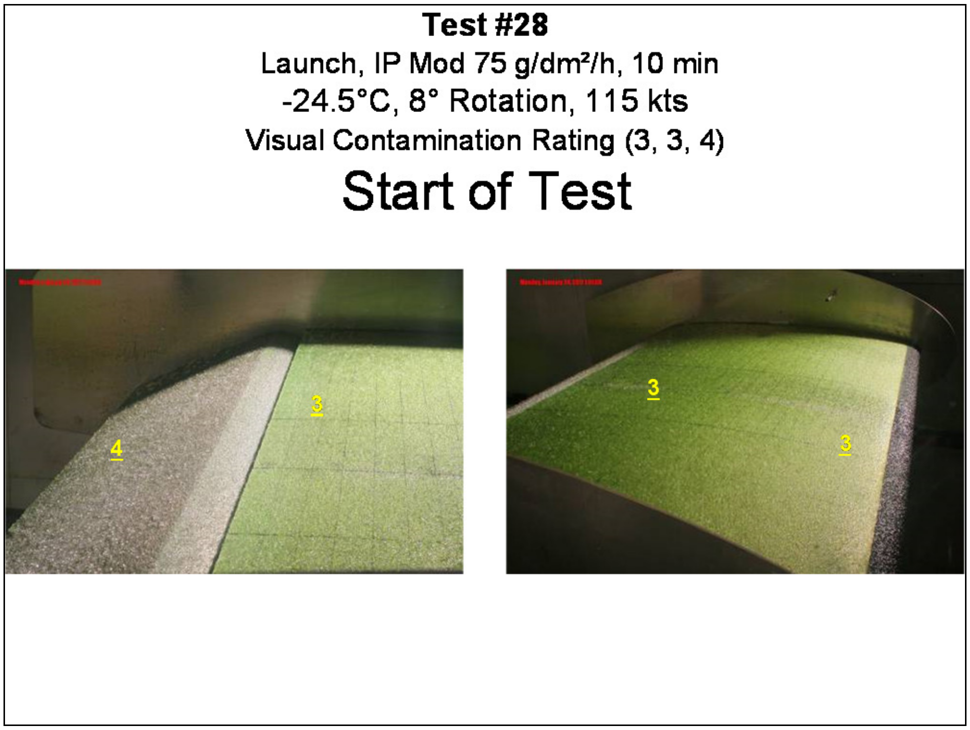
EG106, IP Mod 75 g/dm²/h, 10 min

-21°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.1)

End of Test

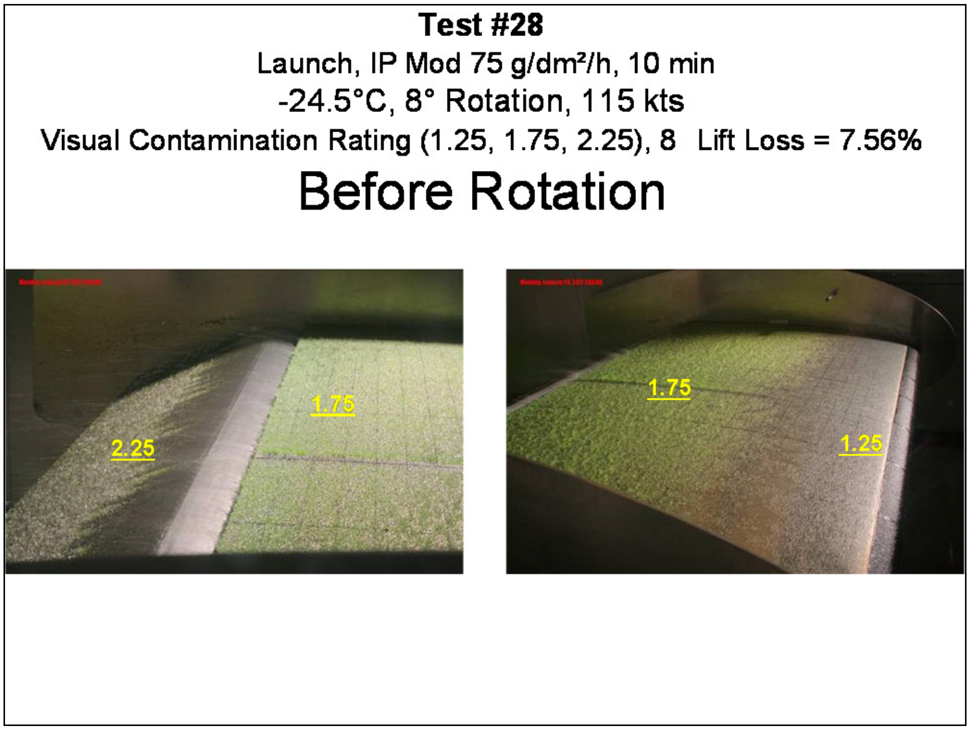
Photo 7.49: Test #28 – Start of Test



Test #28
Launch, IP Mod 75 g/dm²/h, 10 min
-24.5°C, 8° Rotation, 115 kts
Visual Contamination Rating (3, 3, 4)

Start of Test

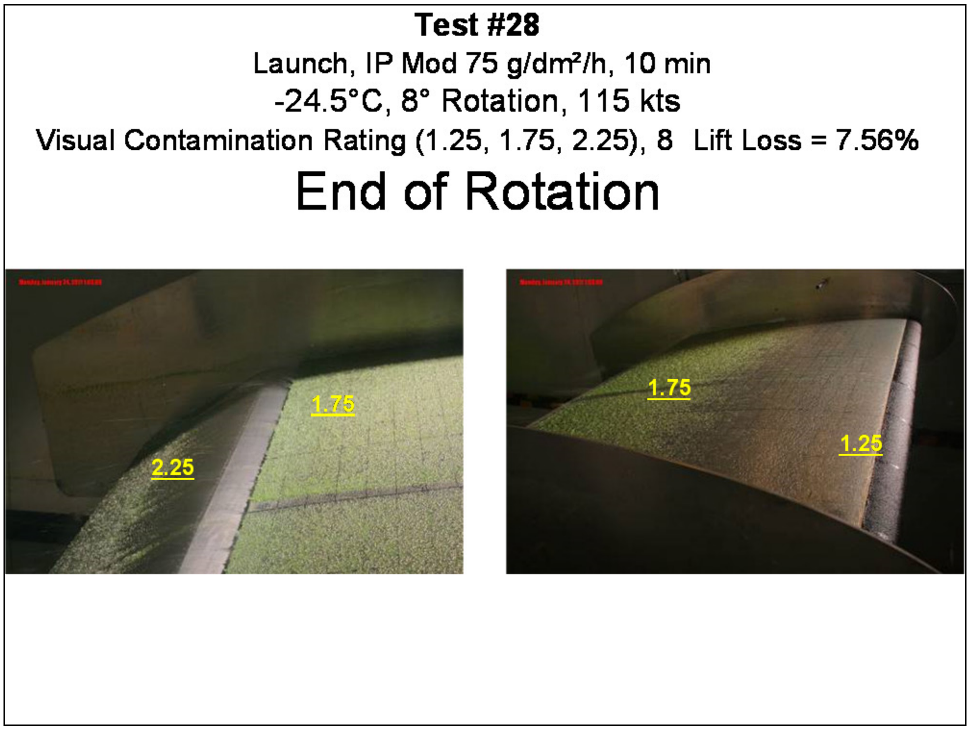
Photo 7.50: Test #28 – Before Rotation



Test #28
Launch, IP Mod 75 g/dm²/h, 10 min
-24.5°C, 8° Rotation, 115 kts
Visual Contamination Rating (1.25, 1.75, 2.25), 8 Lift Loss = 7.56%

Before Rotation

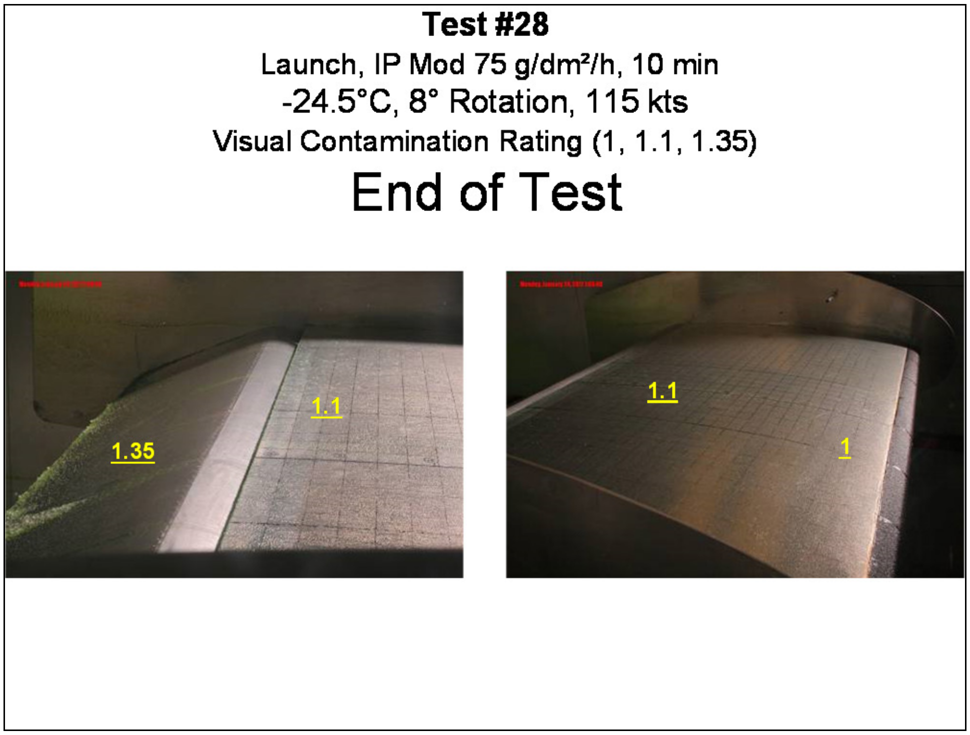
Photo 7.51: Test #28 – End of Rotation



Test #28
Launch, IP Mod 75 g/dm²/h, 10 min
-24.5°C, 8° Rotation, 115 kts
Visual Contamination Rating (1.25, 1.75, 2.25), 8 Lift Loss = 7.56%

End of Rotation

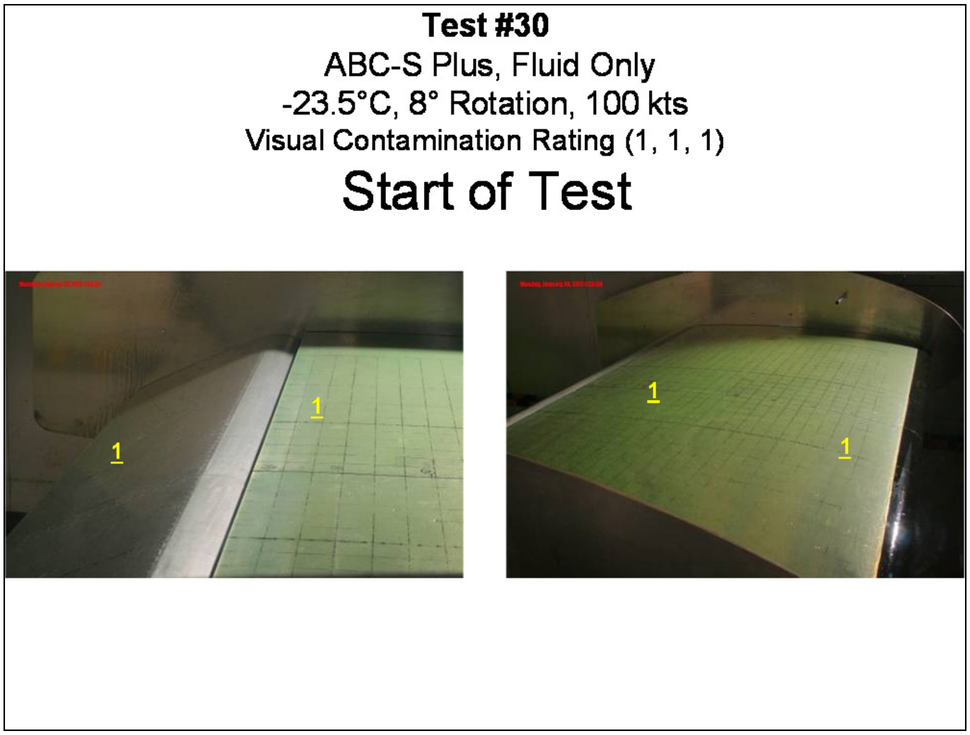
Photo 7.52: Test #28 – End of Test



Test #28
Launch, IP Mod 75 g/dm²/h, 10 min
-24.5°C, 8° Rotation, 115 kts
Visual Contamination Rating (1, 1.1, 1.35)

End of Test

Photo 7.53: Test #30 – Start of Test



Test #30

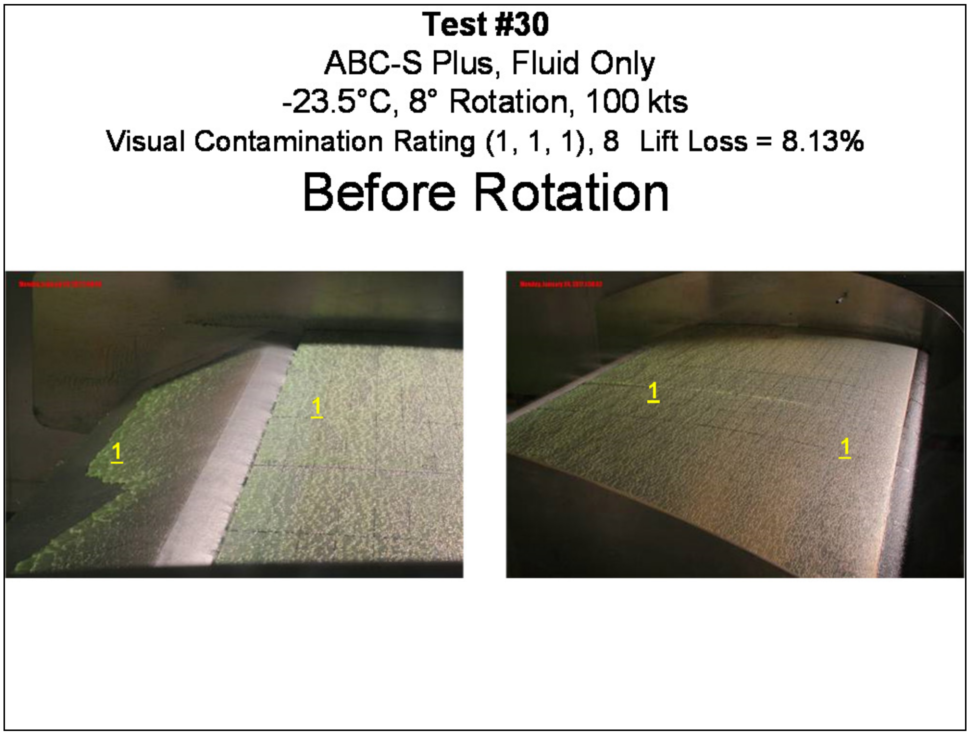
ABC-S Plus, Fluid Only

-23.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 7.54: Test #30 – Before Rotation



Test #30

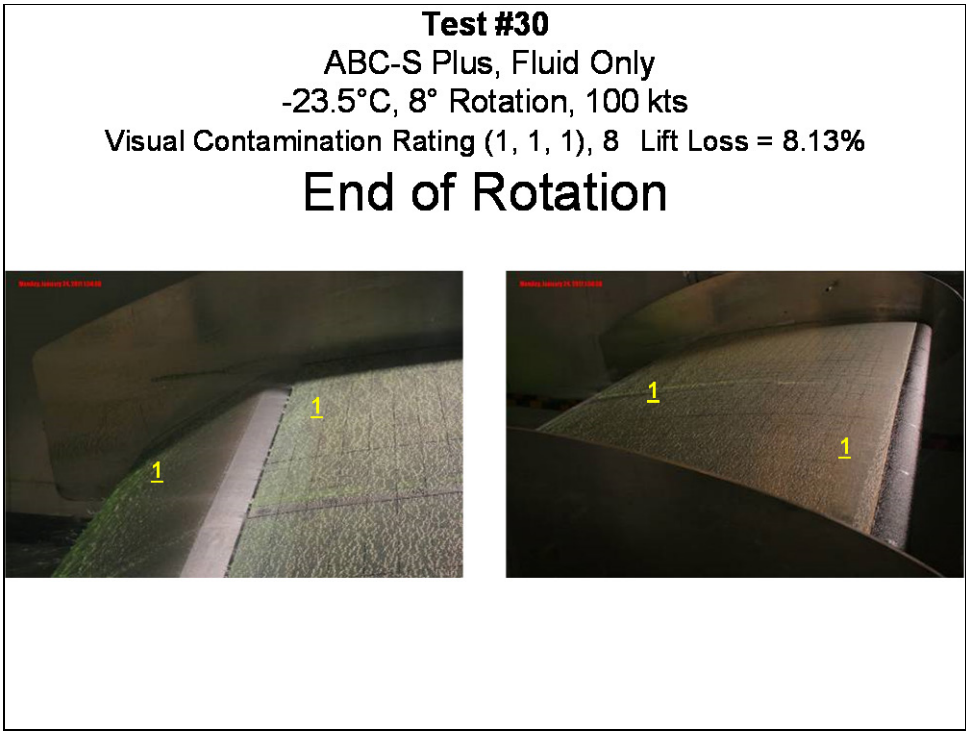
ABC-S Plus, Fluid Only

-23.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 8.13%

Before Rotation

Photo 7.55: Test 30 – End of Rotation



Test #30

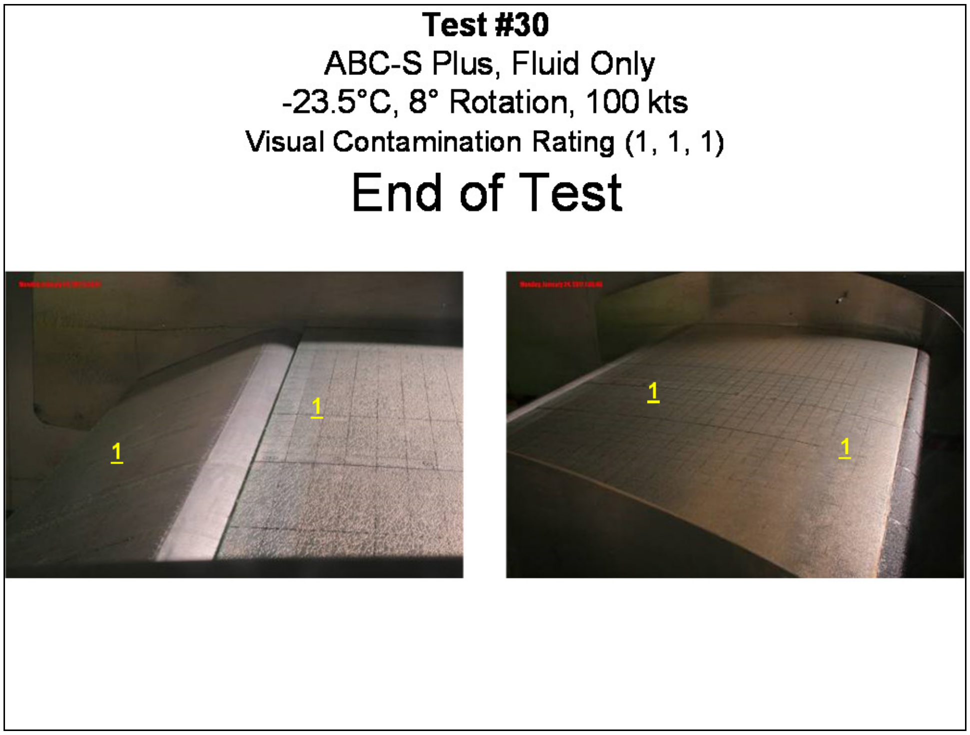
ABC-S Plus, Fluid Only

-23.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 8.13%

End of Rotation

Photo 7.56: Test #30 – End of Test



Test #30

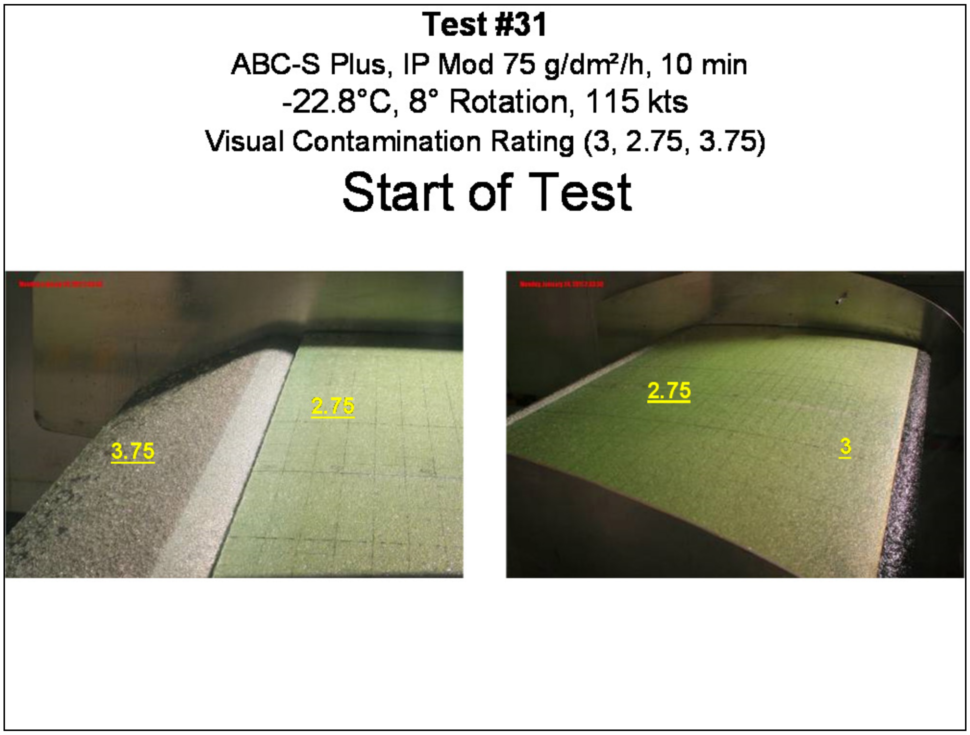
ABC-S Plus, Fluid Only

-23.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.57: Test #31 – Start of Test



Test #31

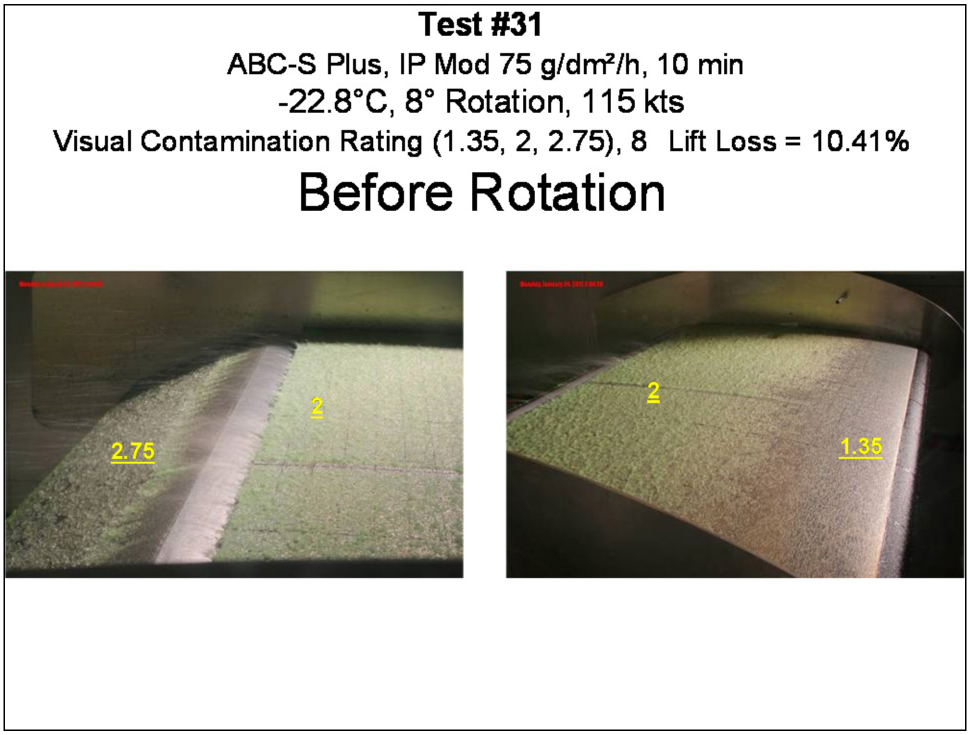
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (3, 2.75, 3.75)

Start of Test

Photo 7.58: Test #31 – Before Rotation



Test #31

ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.35, 2, 2.75), 8 Lift Loss = 10.41%

Before Rotation

Photo 7.59: Test #31 – End of Rotation

Test #31

ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.35, 2, 2.75), 8 Lift Loss = 10.41%

End of Rotation

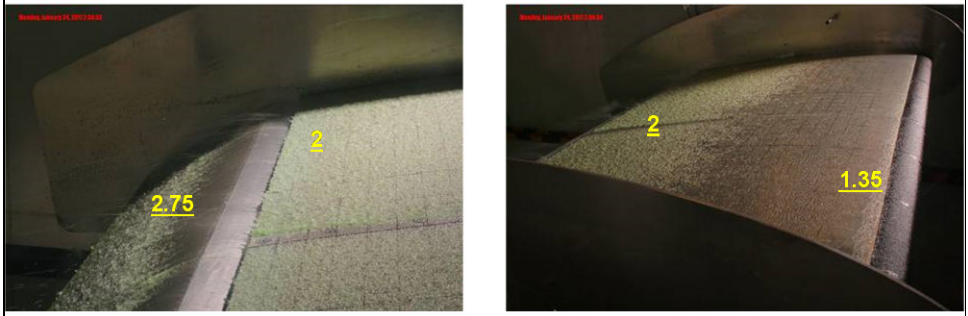


Photo 7.60: Test #31 – End of Test

Test #31

ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-22.8°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.15, 1.45)

End of Test

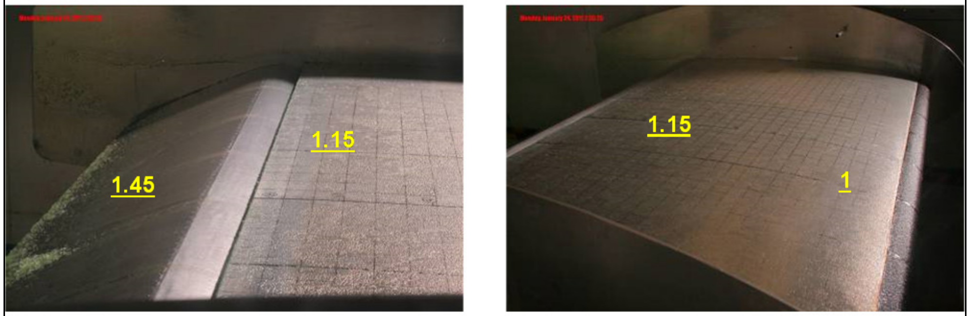
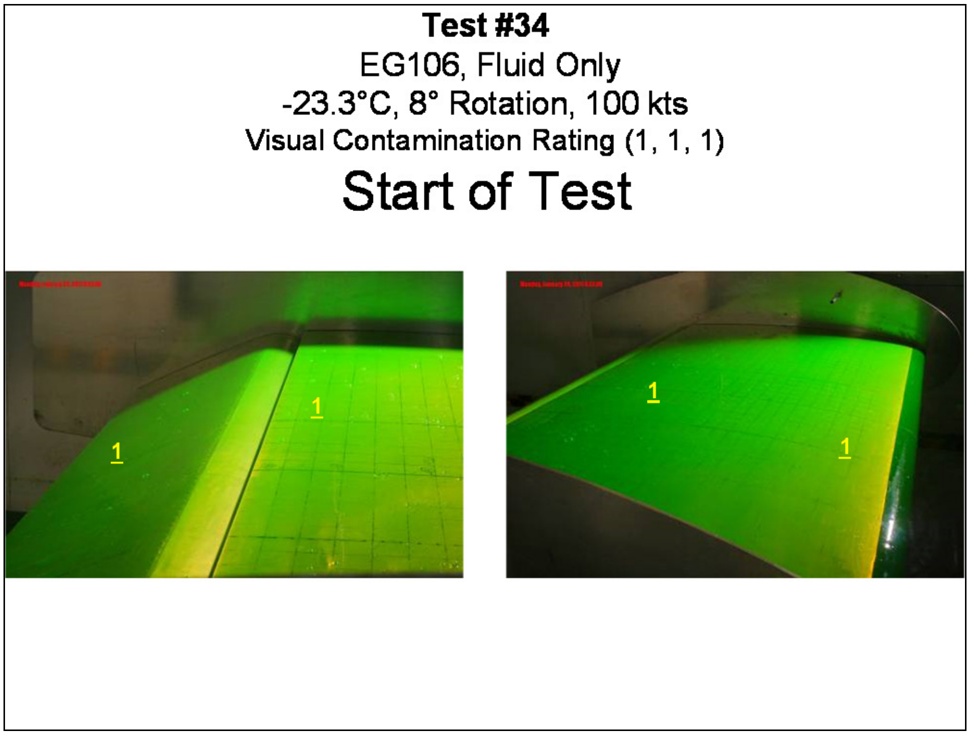
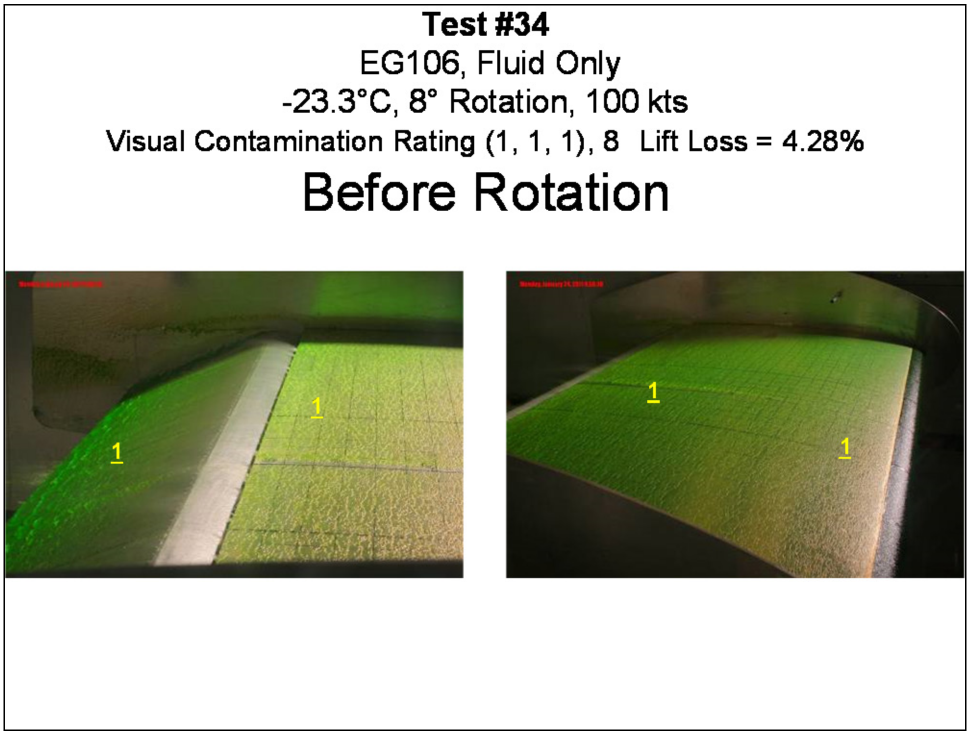


Photo 7.61: Test #34 – Start of Test



Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 7.62: Test #34 – Before Rotation



Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 4.28%
Before Rotation

Photo 7.63: Test #34 – End of Rotation

Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 4.28%
End of Rotation

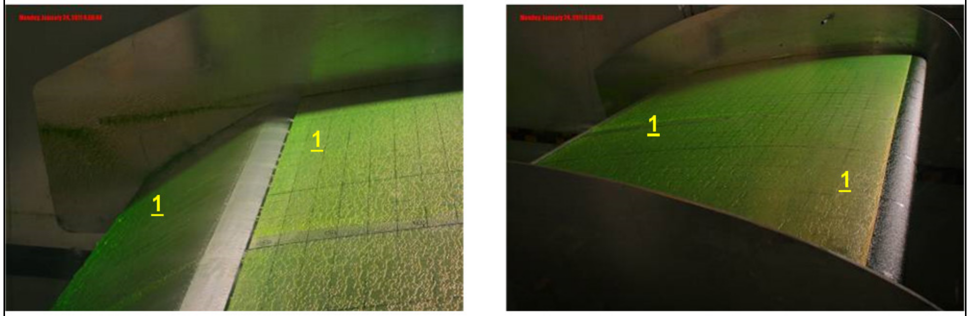


Photo 7.64: Test #34 – End of Test

Test #34
EG106, Fluid Only
-23.3°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

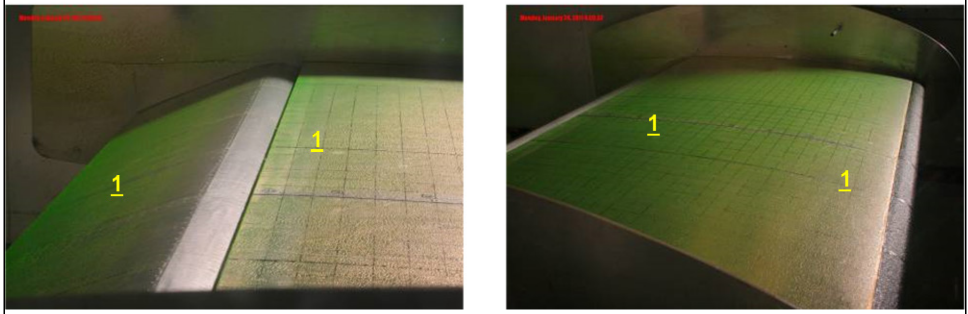
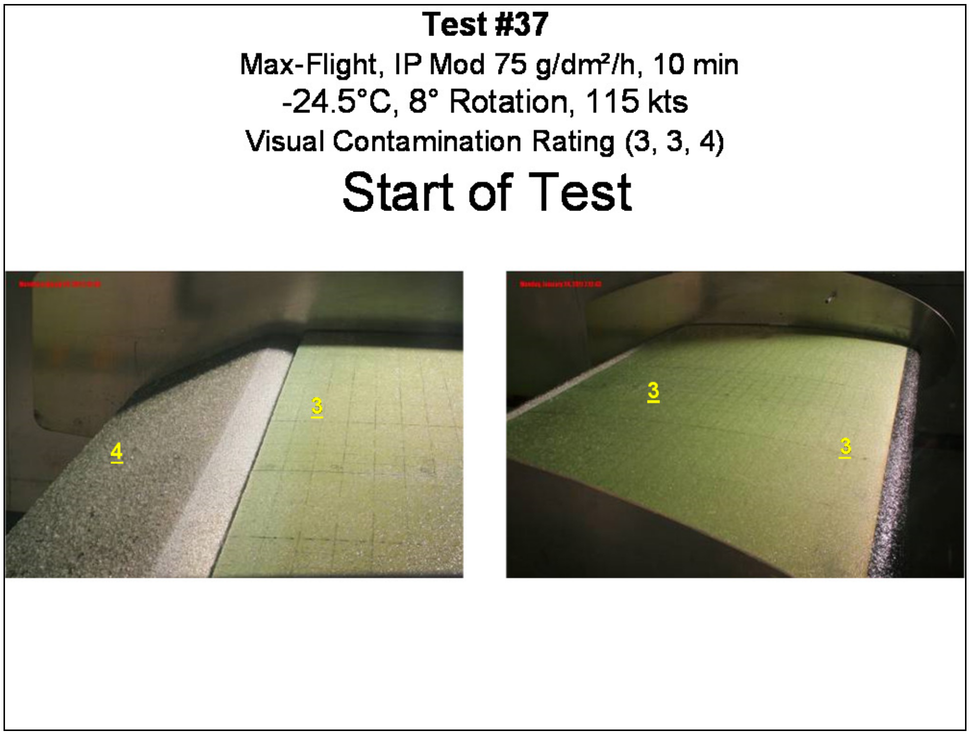


Photo 7.65: Test #37 – Start of Test



Test #37

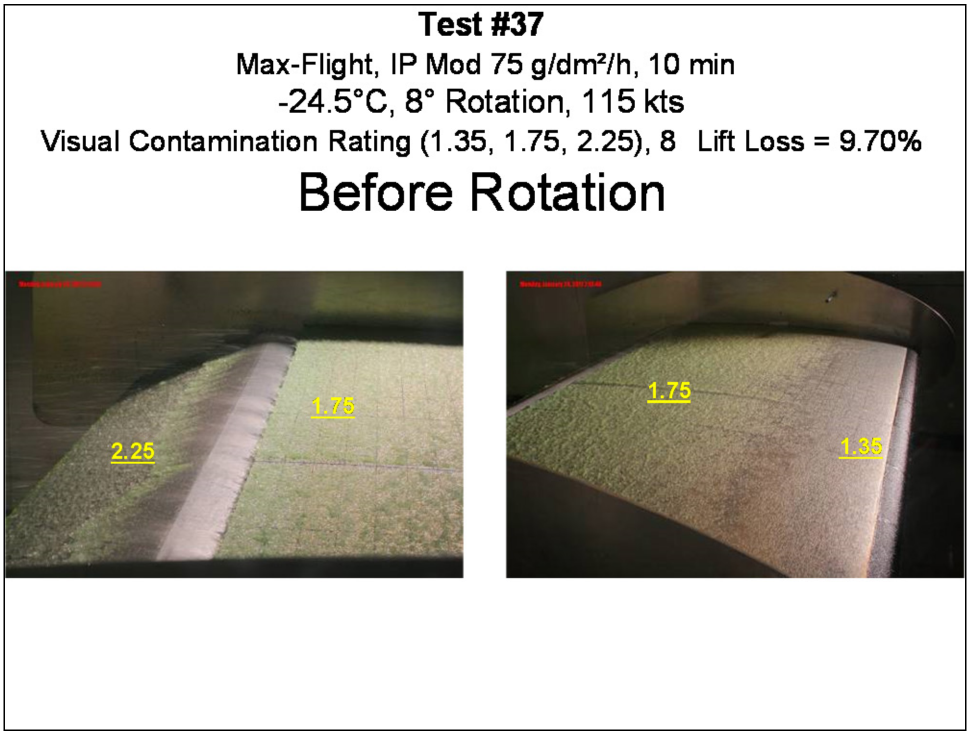
Max-Flight, IP Mod 75 $g/dm^2/h$, 10 min

-24.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (3, 3, 4)

Start of Test

Photo 7.66: Test #37 – Before Rotation



Test #37

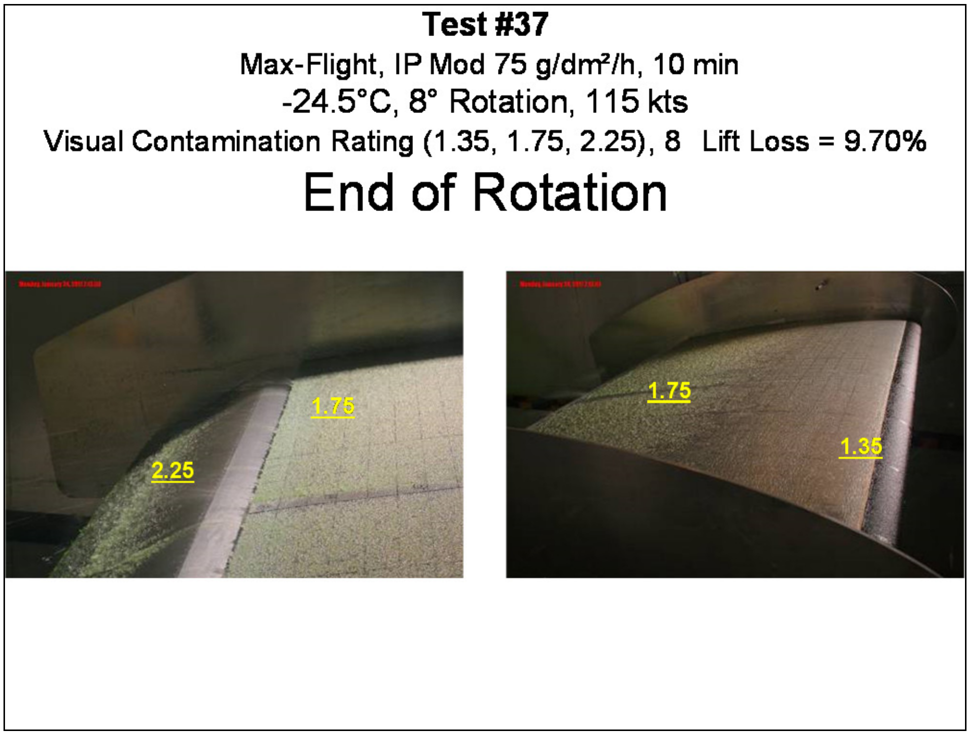
Max-Flight, IP Mod 75 $g/dm^2/h$, 10 min

-24.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.35, 1.75, 2.25), 8 Lift Loss = 9.70%

Before Rotation

Photo 7.67: Test #37 – End of Rotation



Test #37

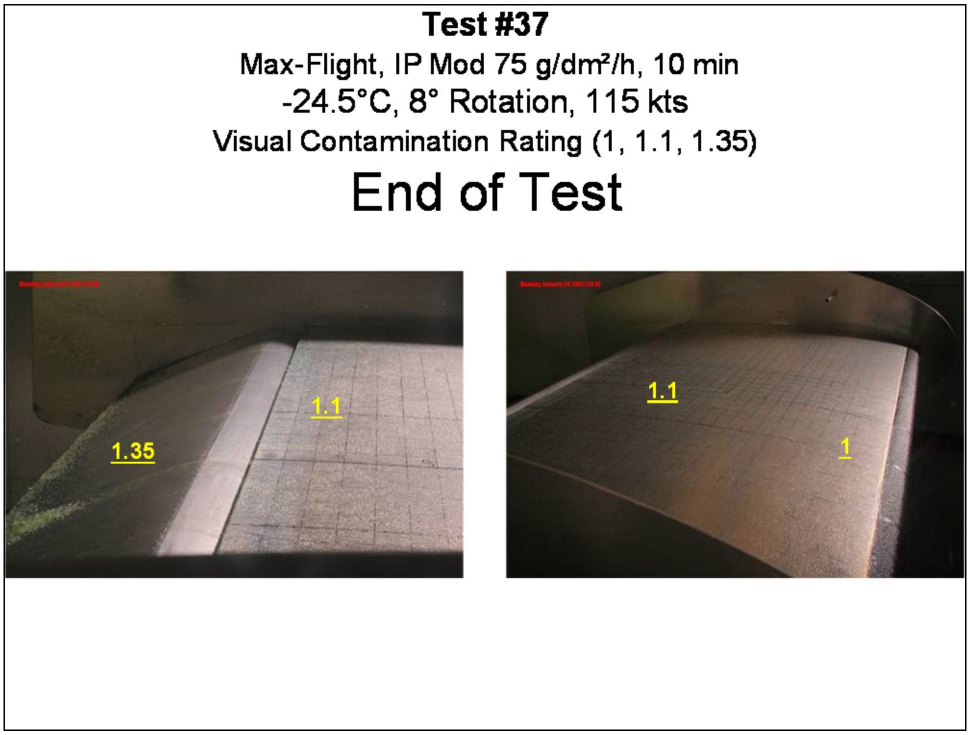
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-24.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.35, 1.75, 2.25), 8 Lift Loss = 9.70%

End of Rotation

Photo 7.68: Test #37 – End of Test



Test #37

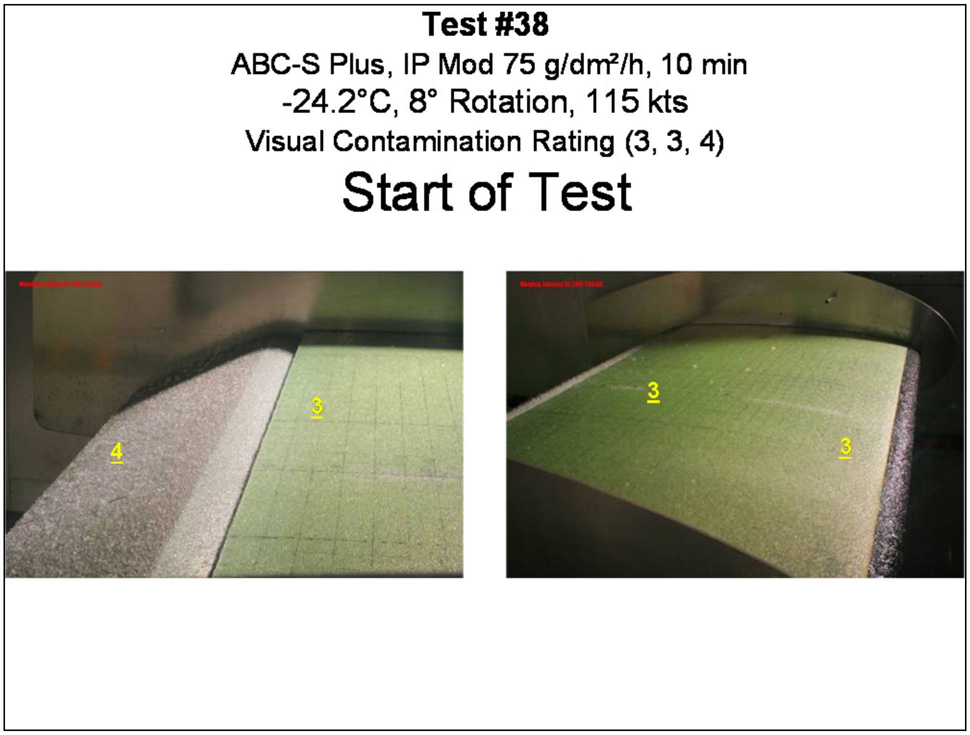
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-24.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.1, 1.35)

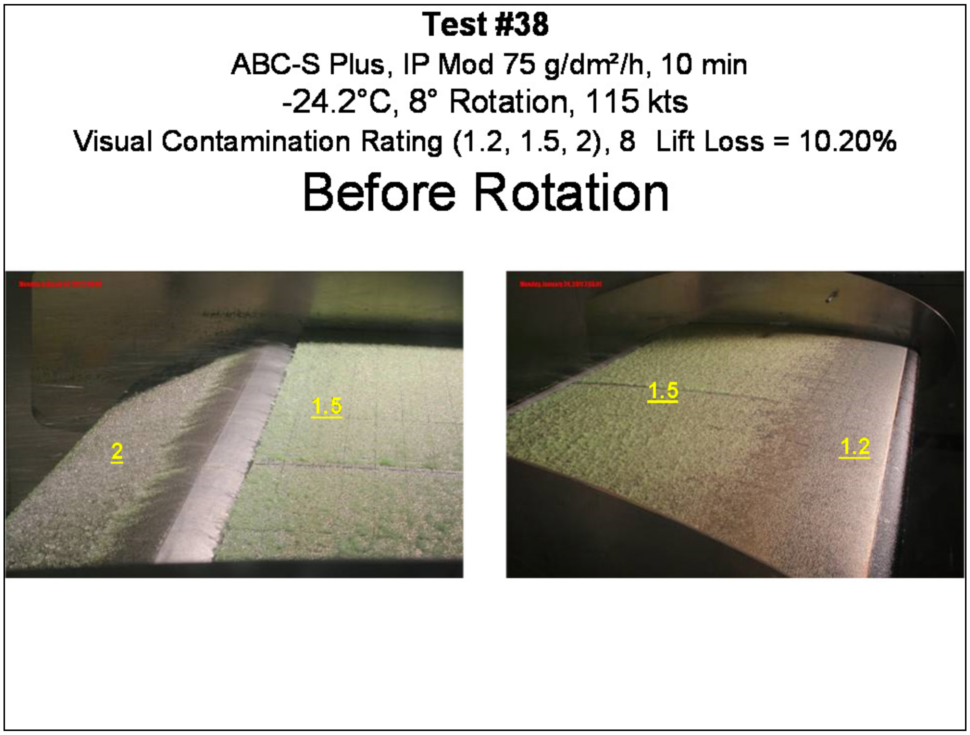
End of Test

Photo 7.69: Test #38 – Start of Test



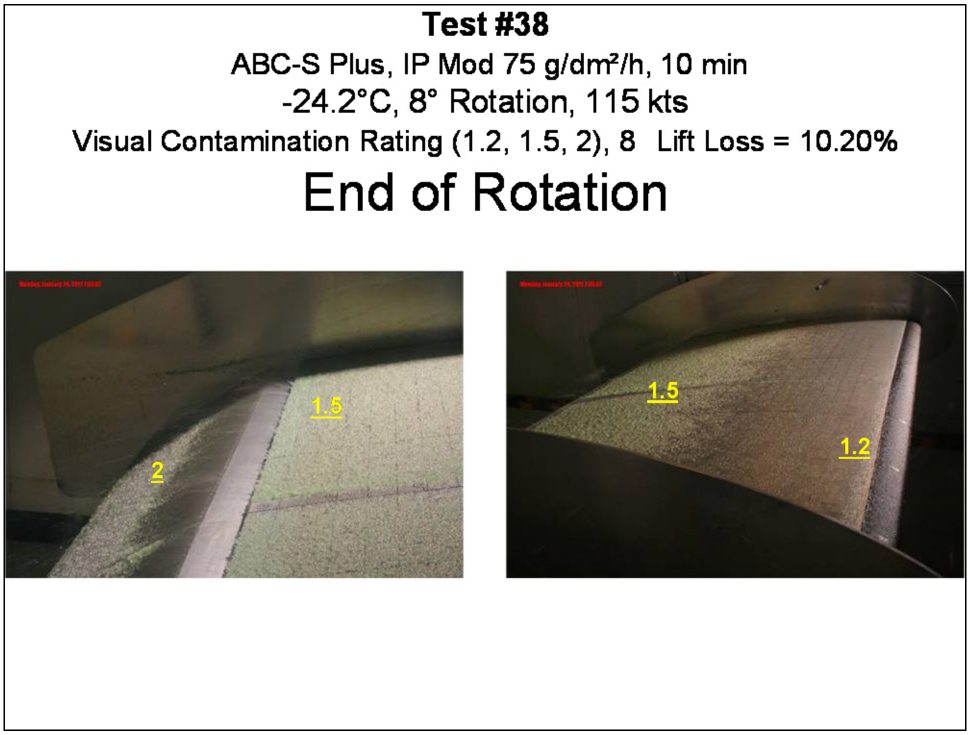
Test #38
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min
-24.2°C, 8° Rotation, 115 kts
Visual Contamination Rating (3, 3, 4)
Start of Test

Photo 7.70: Test #38 – Before Rotation



Test #38
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min
-24.2°C, 8° Rotation, 115 kts
Visual Contamination Rating (1.2, 1.5, 2), 8 Lift Loss = 10.20%
Before Rotation

Photo 7.71: Test #38 – End of Rotation



Test #38

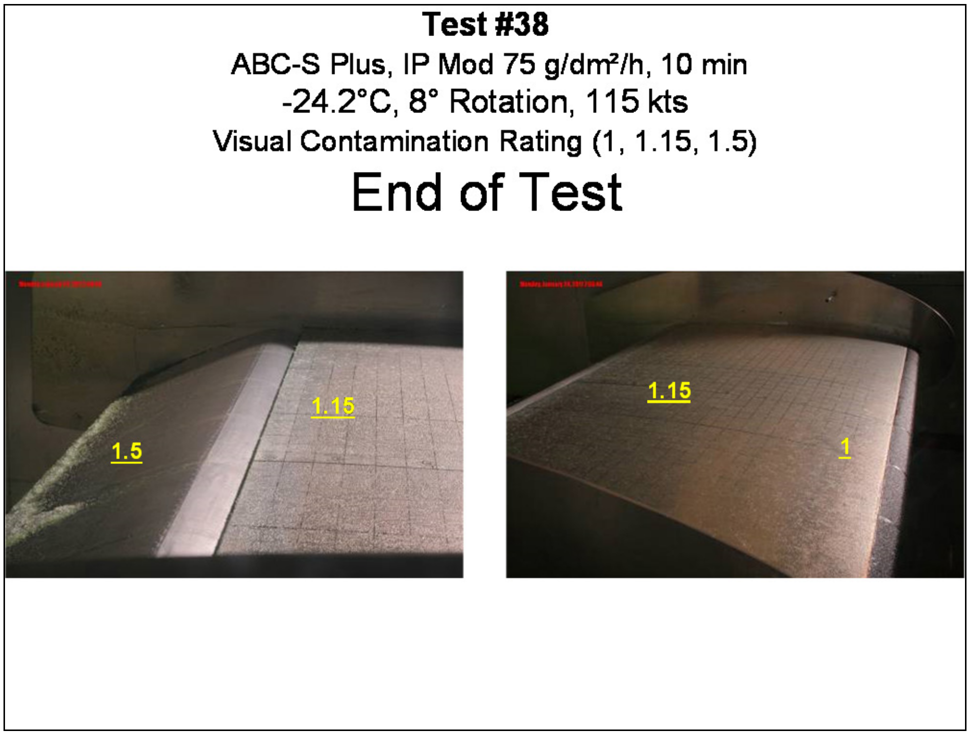
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-24.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.2, 1.5, 2), 8 Lift Loss = 10.20%

End of Rotation

Photo 7.72: Test #38 – End of Test



Test #38

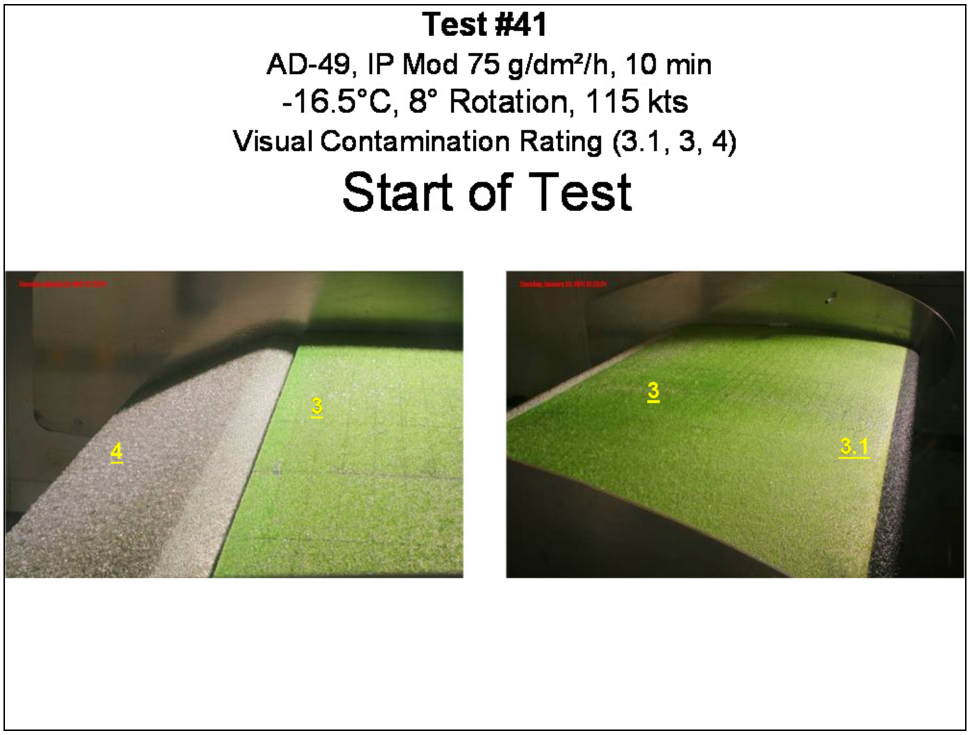
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-24.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.15, 1.5)

End of Test

Photo 7.73: Test #41 – Start of Test



Test #41

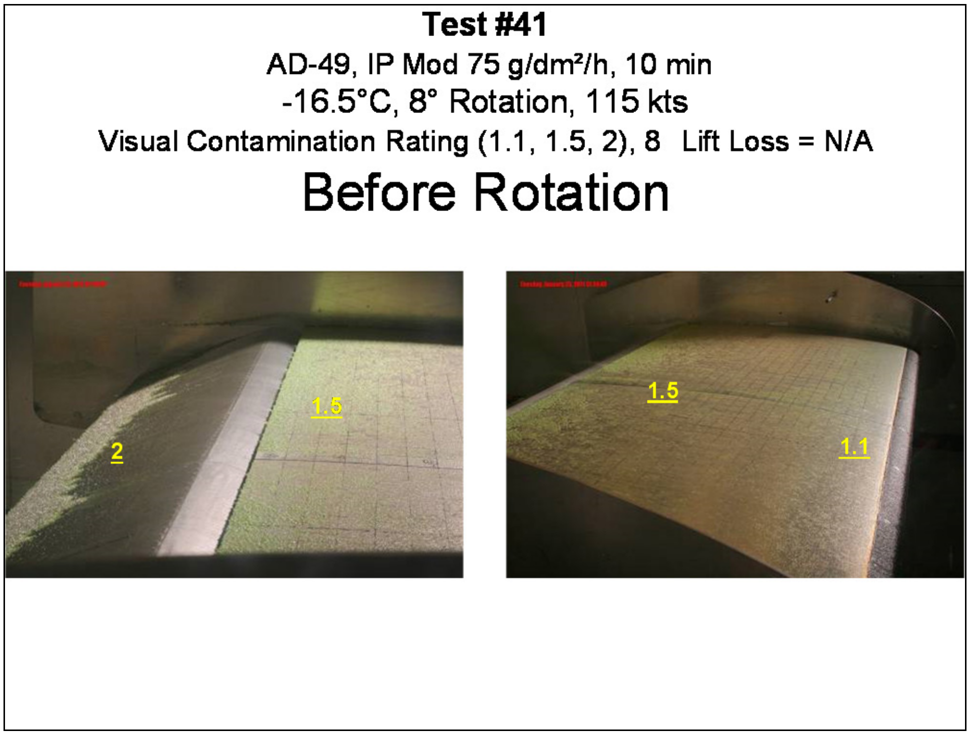
AD-49, IP Mod 75 g/dm²/h, 10 min

-16.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (3.1, 3, 4)

Start of Test

Photo 7.74: Test #41 – Before Rotation



Test #41

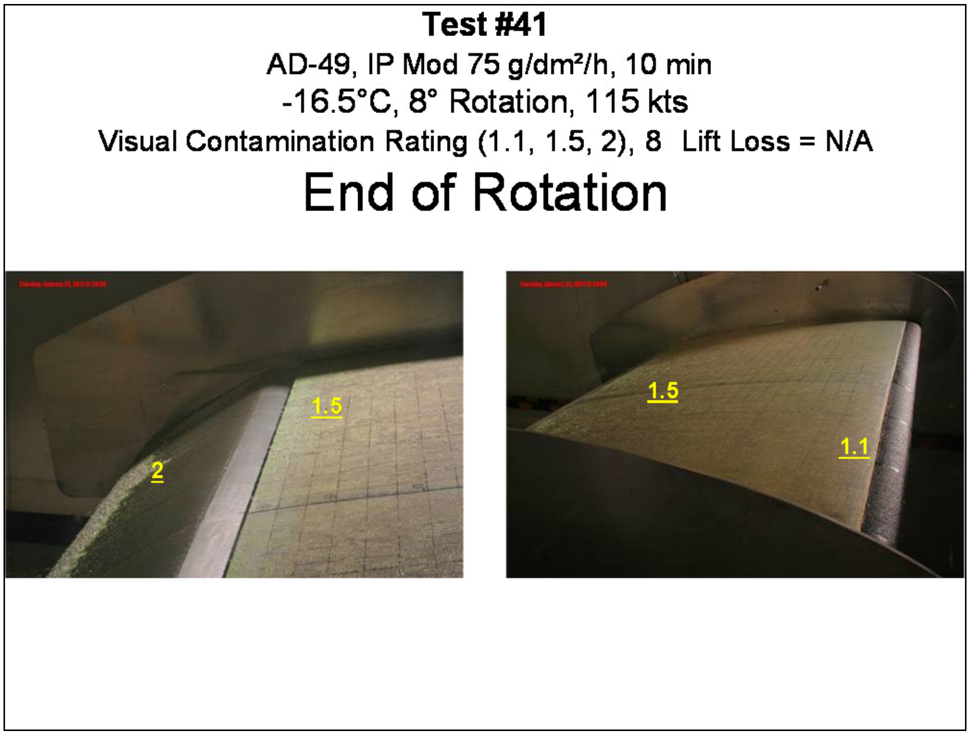
AD-49, IP Mod 75 g/dm²/h, 10 min

-16.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.1, 1.5, 2), 8 Lift Loss = N/A

Before Rotation

Photo 7.75: Test #41 – End of Rotation



Test #41

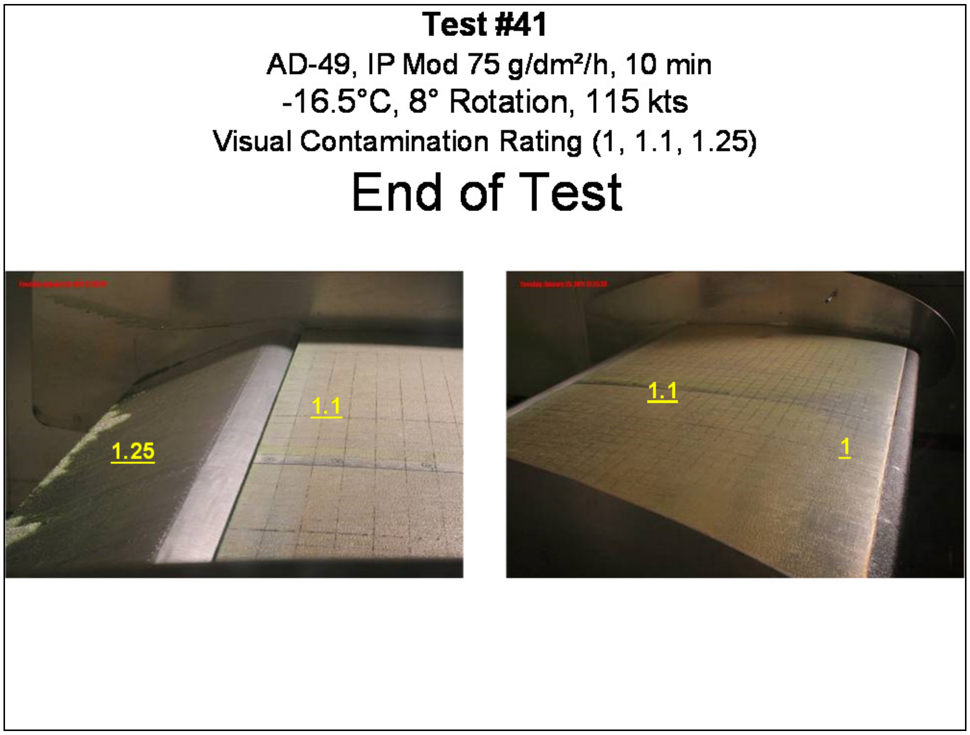
AD-49, IP Mod 75 g/dm²/h, 10 min

-16.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.1, 1.5, 2), 8 Lift Loss = N/A

End of Rotation

Photo 7.76: Test #41 – End of Test



Test #41

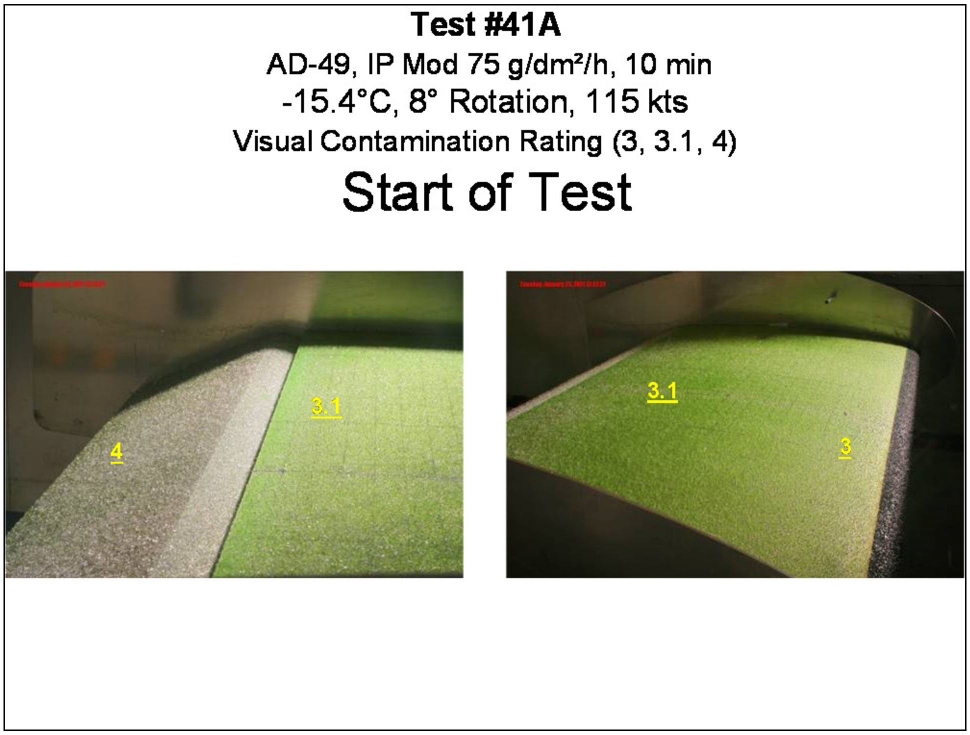
AD-49, IP Mod 75 g/dm²/h, 10 min

-16.5°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.1, 1.25)

End of Test

Photo 7.77: Test #41A – Start of Test



Test #41A

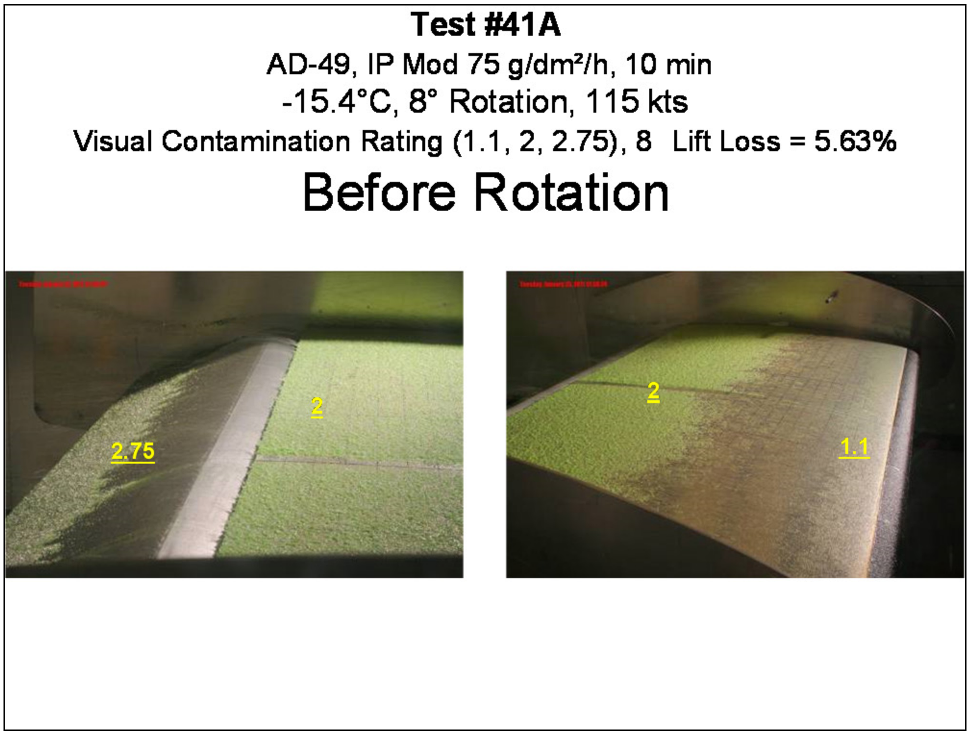
AD-49, IP Mod 75 g/dm²/h, 10 min

-15.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (3, 3.1, 4)

Start of Test

Photo 7.78: Test #41A – Before Rotation



Test #41A

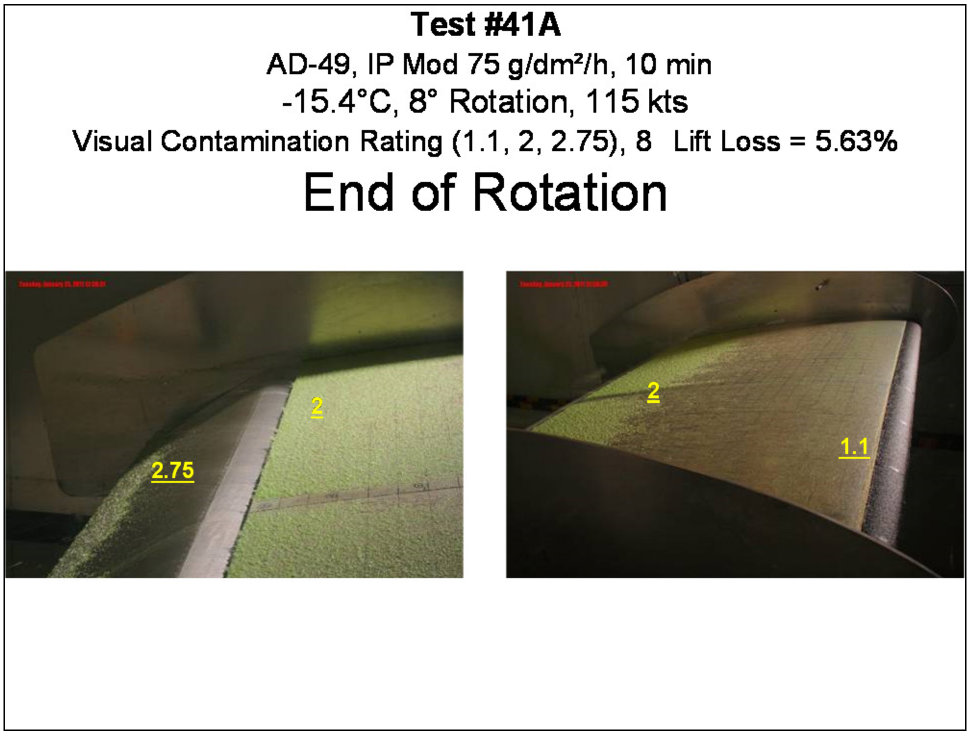
AD-49, IP Mod 75 g/dm²/h, 10 min

-15.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.1, 2, 2.75), 8 Lift Loss = 5.63%

Before Rotation

Photo 7.79: Test #41A – End of Rotation



Test #41A

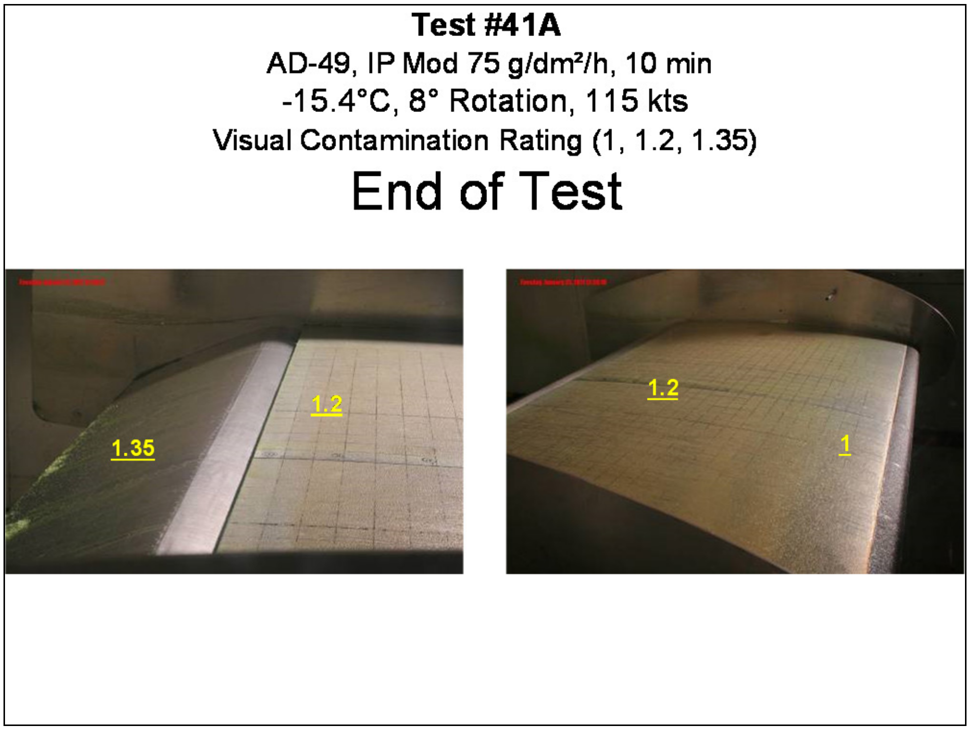
AD-49, IP Mod 75 g/dm²/h, 10 min

-15.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.1, 2, 2.75), 8 Lift Loss = 5.63%

End of Rotation

Photo 7.80: Test #41A – End of Test



Test #41A

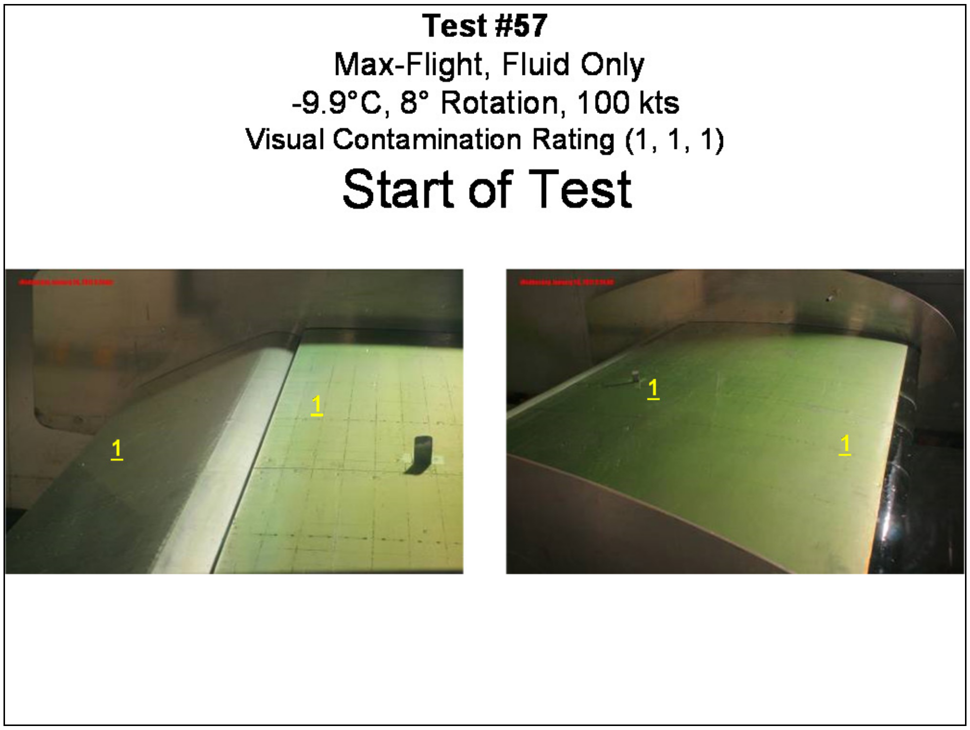
AD-49, IP Mod 75 g/dm²/h, 10 min

-15.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.2, 1.35)

End of Test

Photo 7.81: Test #57 – Start of Test



Test #57

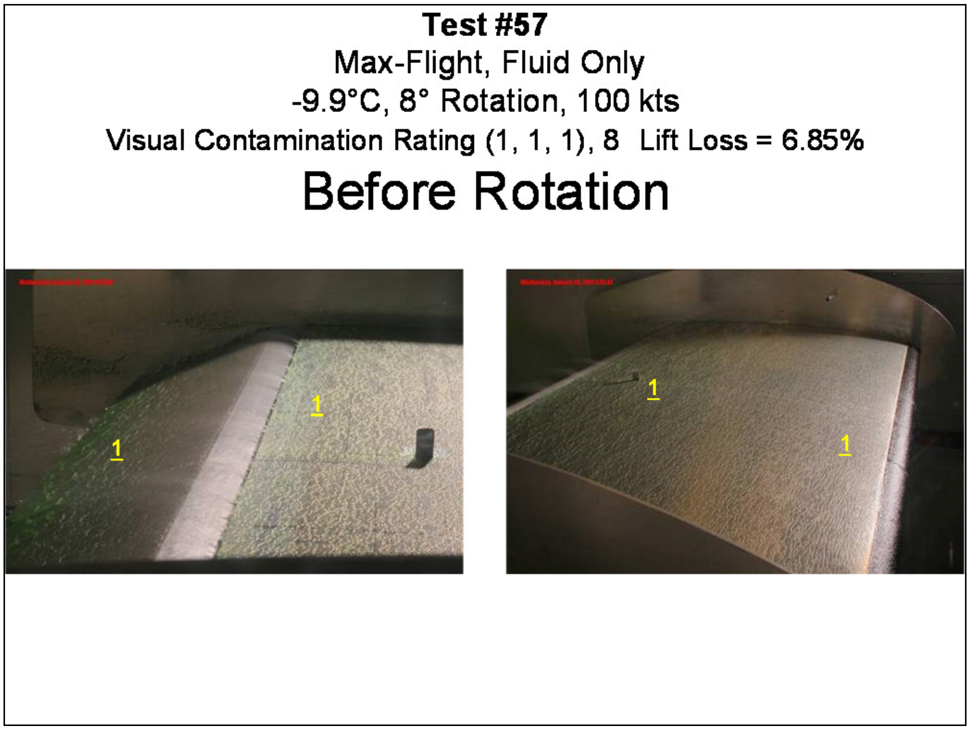
Max-Flight, Fluid Only

-9.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 7.82: Test #57 – Before Rotation



Test #57

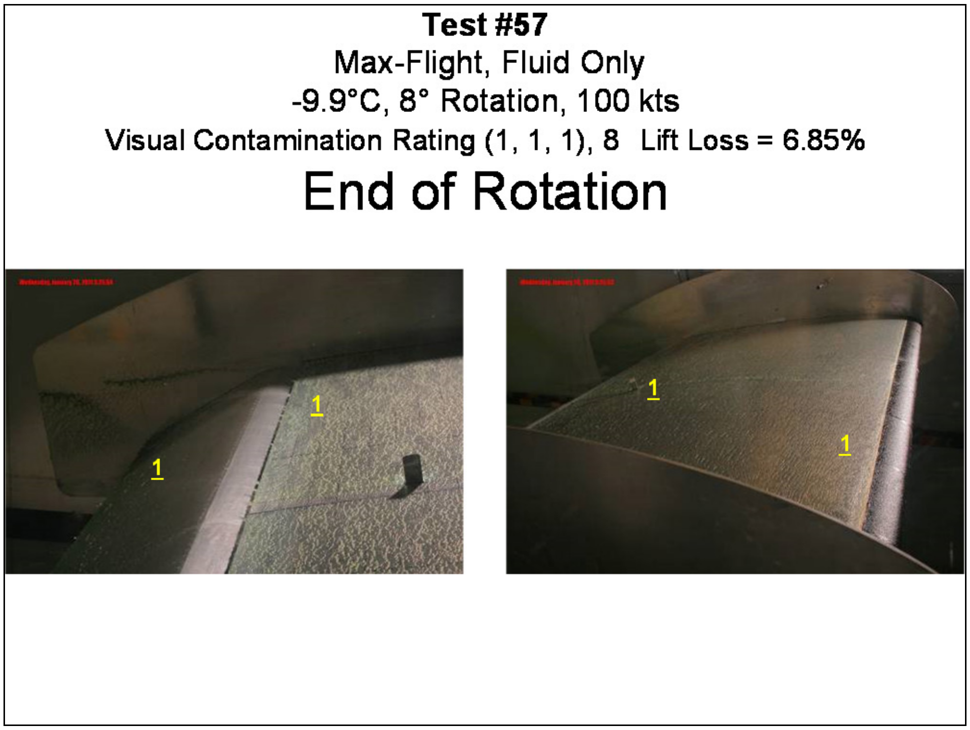
Max-Flight, Fluid Only

-9.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.85%

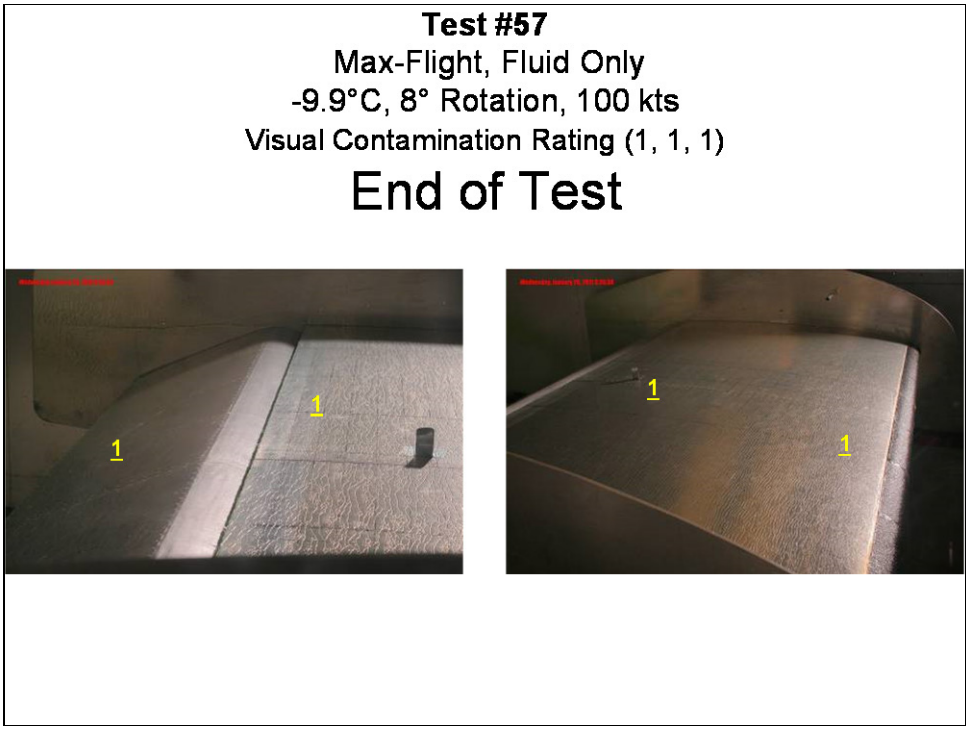
Before Rotation

Photo 7.83: Test #57 – End of Rotation



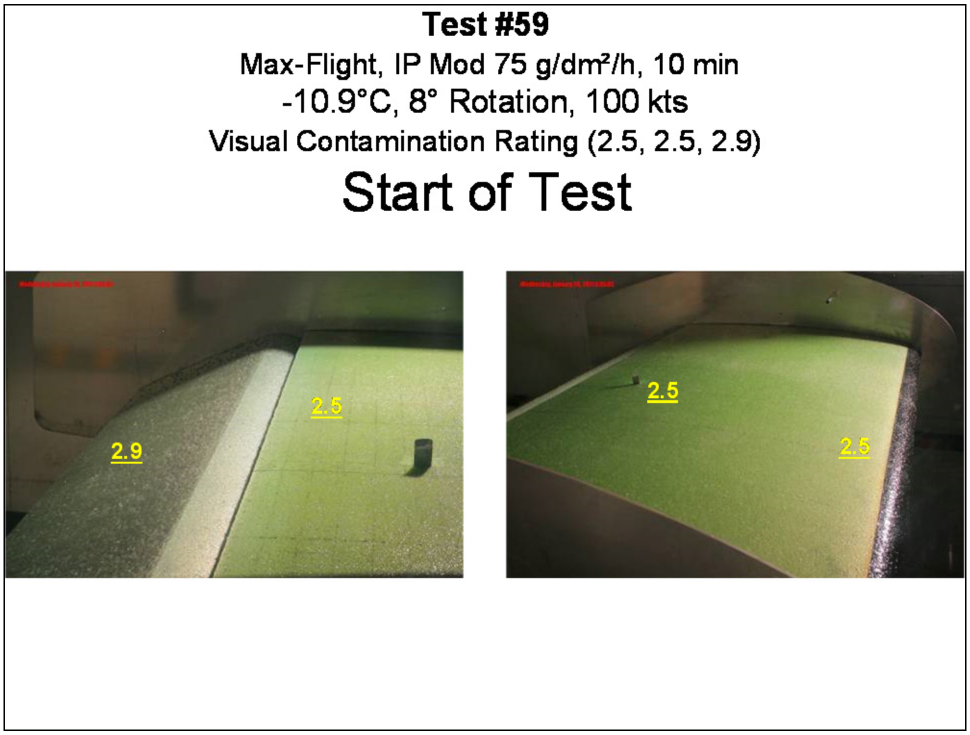
Test #57
Max-Flight, Fluid Only
-9.9°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.85%
End of Rotation

Photo 7.84: Test #57 – End of Test



Test #57
Max-Flight, Fluid Only
-9.9°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 7.85: Test #59 – Start of Test



Test #59

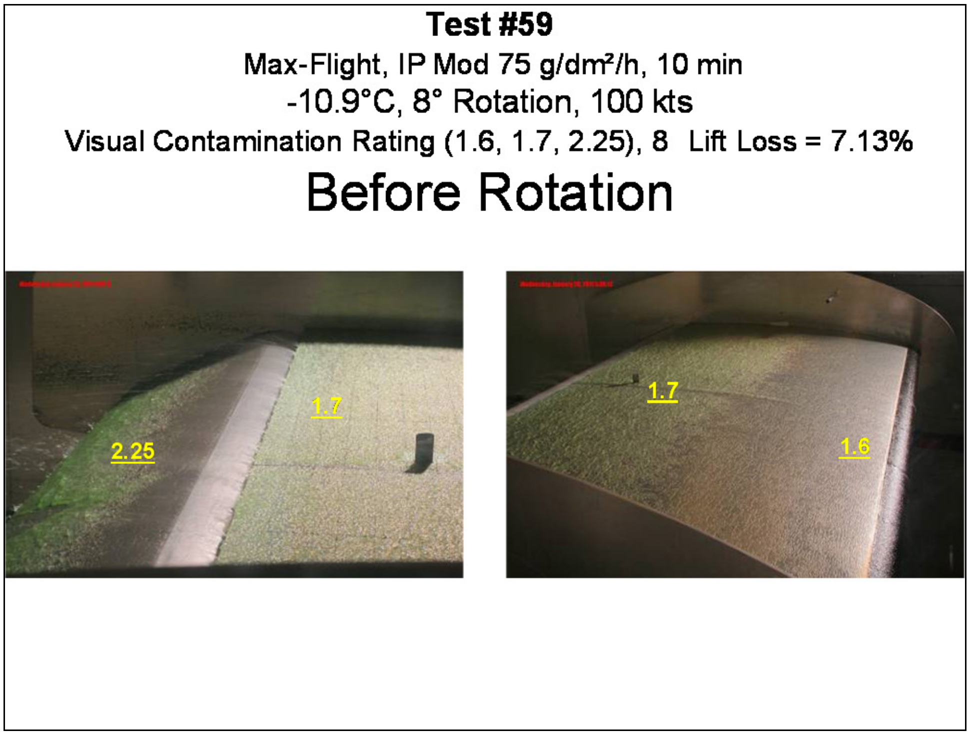
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.5, 2.5, 2.9)

Start of Test

Photo 7.86: Test #59 – Before Rotation



Test #59

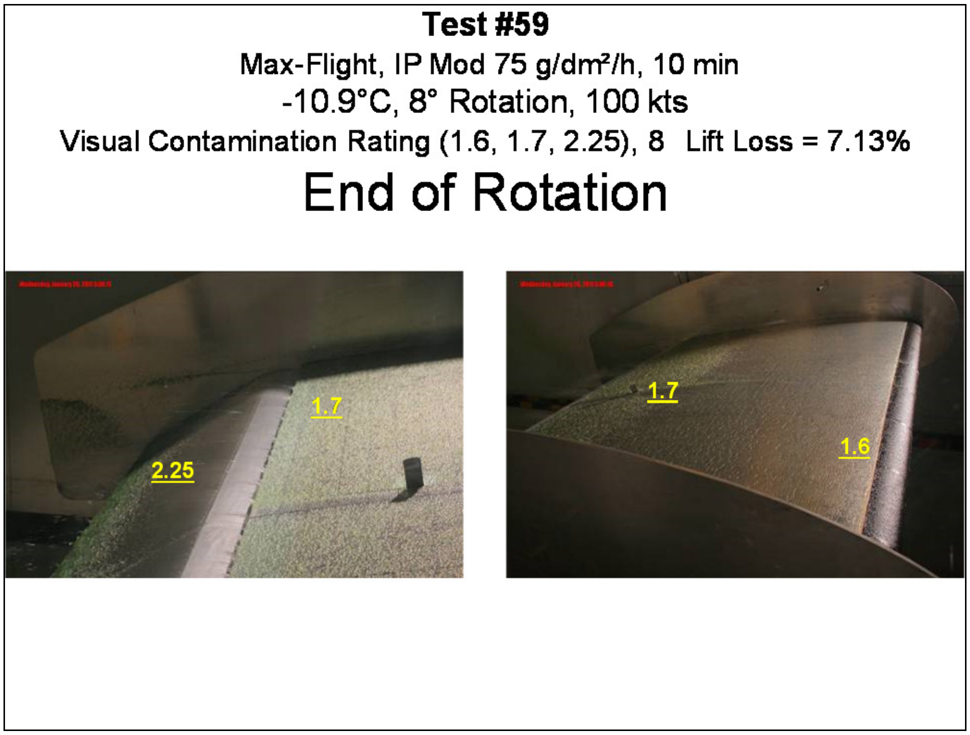
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.6, 1.7, 2.25), 8 Lift Loss = 7.13%

Before Rotation

Photo 7.87: Test #59 – End of Rotation



Test #59

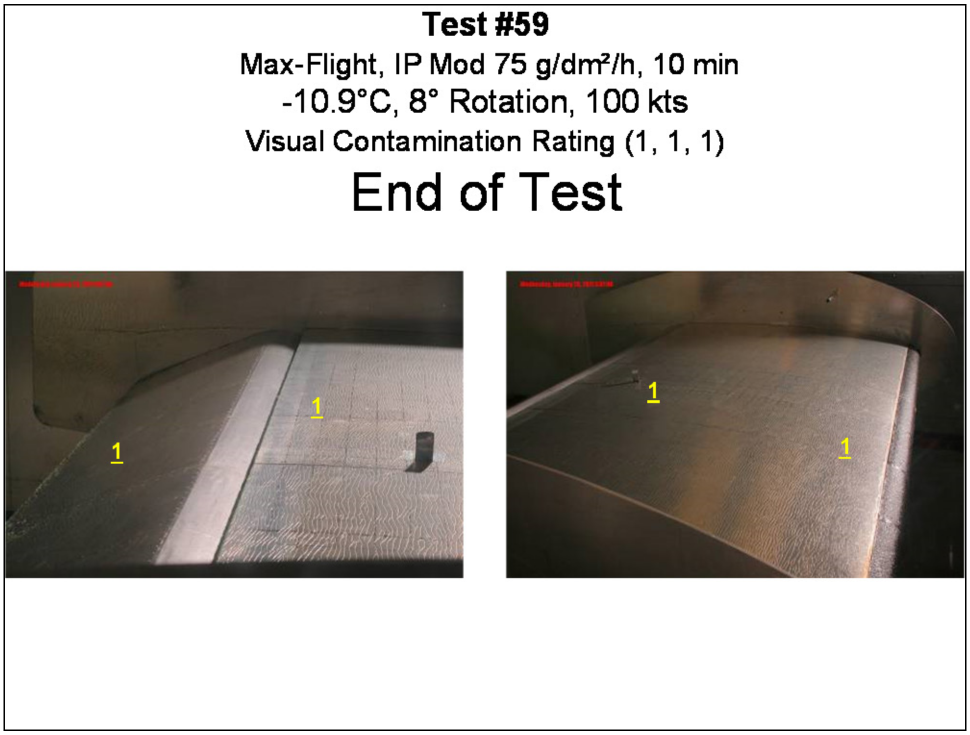
Max-Flight, IP Mod 75 $g/dm^2/h$, 10 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.6, 1.7, 2.25), 8 Lift Loss = 7.13%

End of Rotation

Photo 7.88: Test #59 – End of Test



Test #59

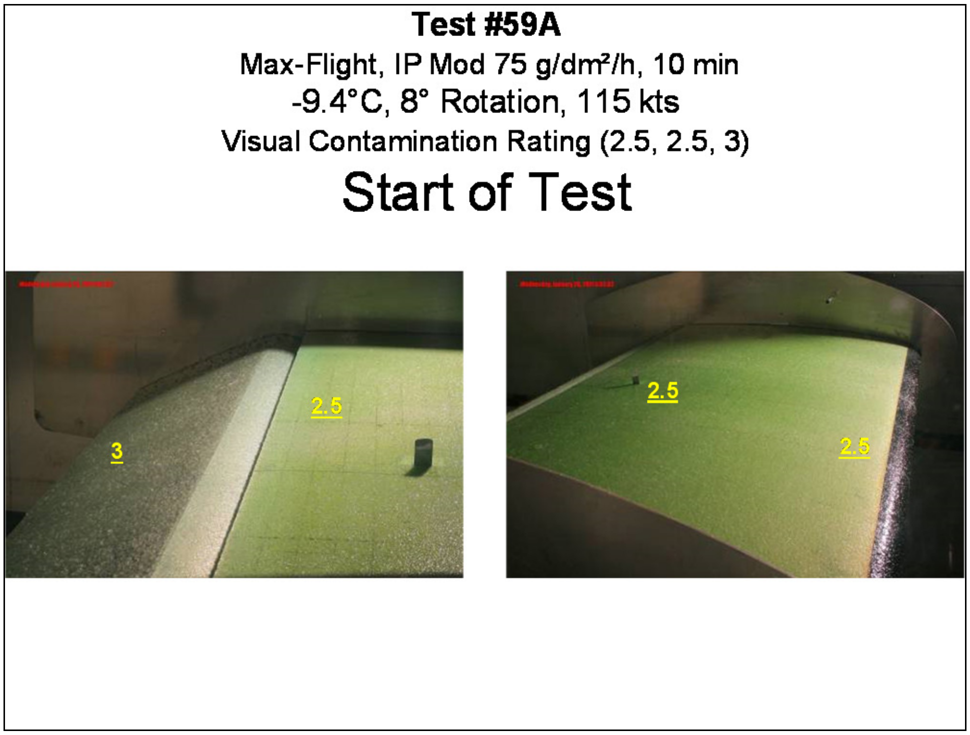
Max-Flight, IP Mod 75 $g/dm^2/h$, 10 min

-10.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.89: Test #59A – Start of Test



Test #59A

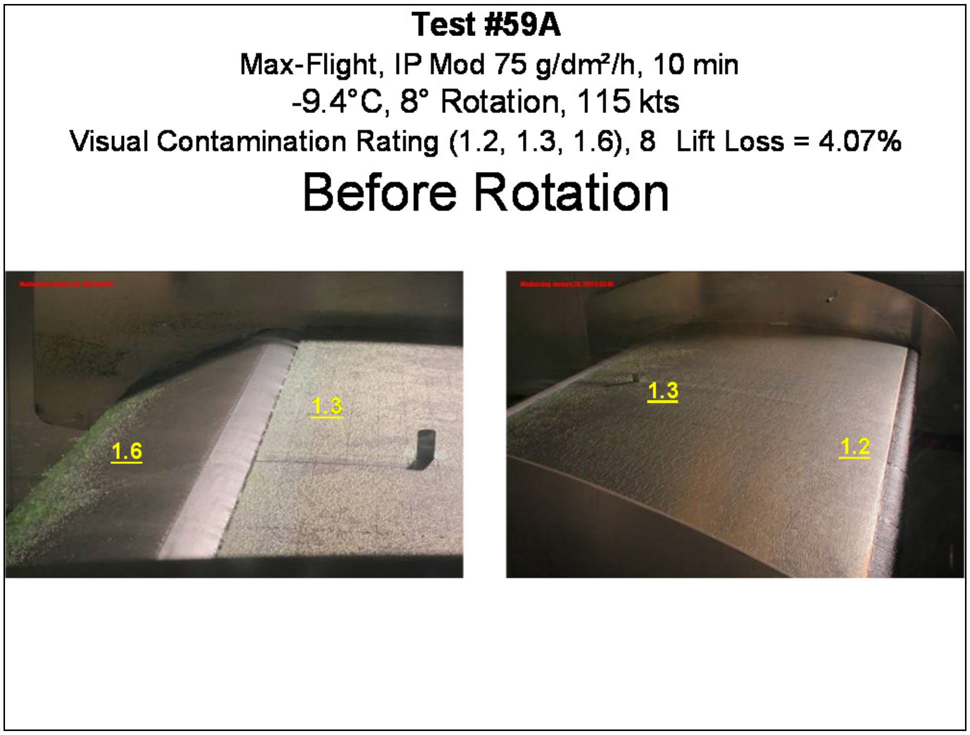
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-9.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (2.5, 2.5, 3)

Start of Test

Photo 7.90: Test #59A – Before Rotation



Test #59A

Max-Flight, IP Mod 75 g/dm²/h, 10 min

-9.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.2, 1.3, 1.6), 8 Lift Loss = 4.07%

Before Rotation

Photo 7.91: Test #59A – End of Rotation

Test #59A

Max-Flight, IP Mod 75 g/dm²/h, 10 min

-9.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.2, 1.3, 1.6), 8 Lift Loss = 4.07%

End of Rotation

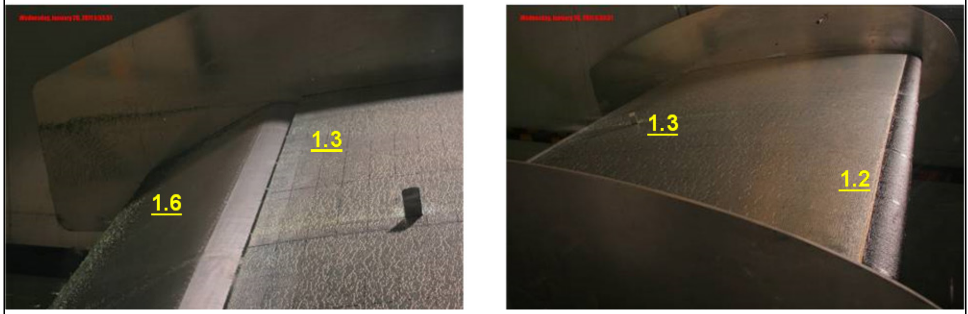


Photo 7.92: Test #59A – End of Test

Test #59A

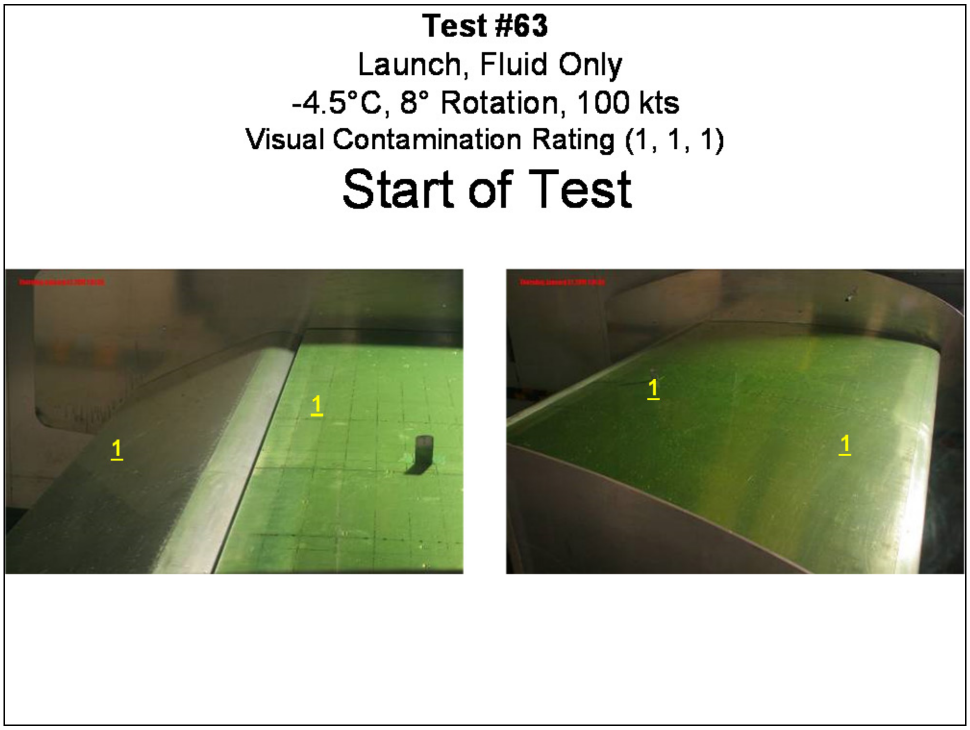
Max-Flight, IP Mod 75 g/dm²/h, 10 min

-9.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1, 1.1)

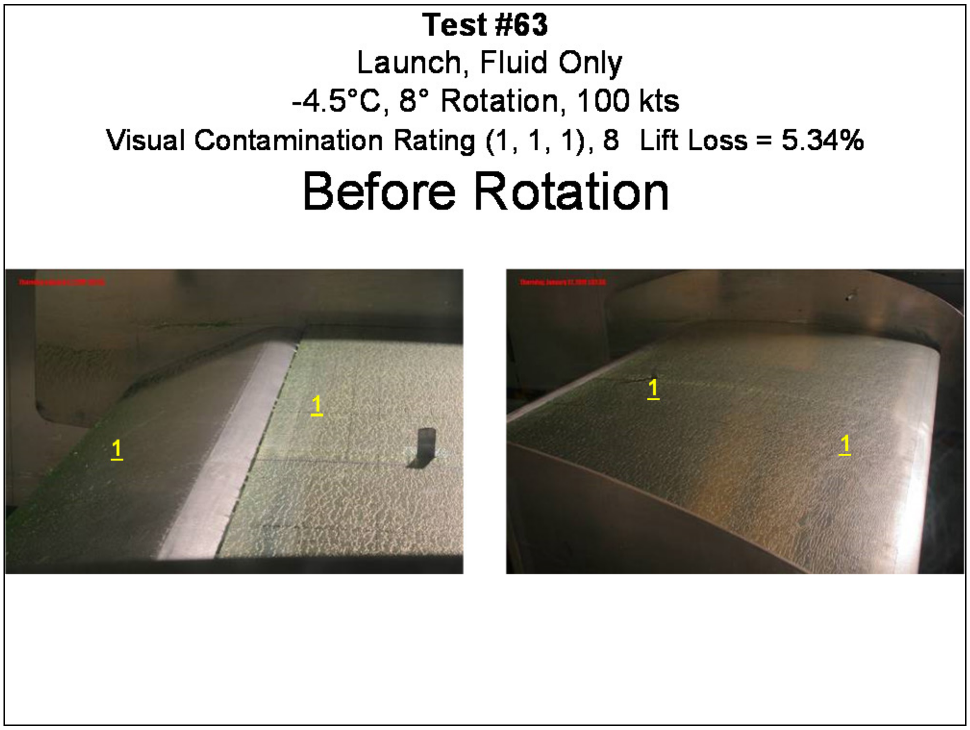
End of Test

Photo 7.93: Test #63 – Start of Test



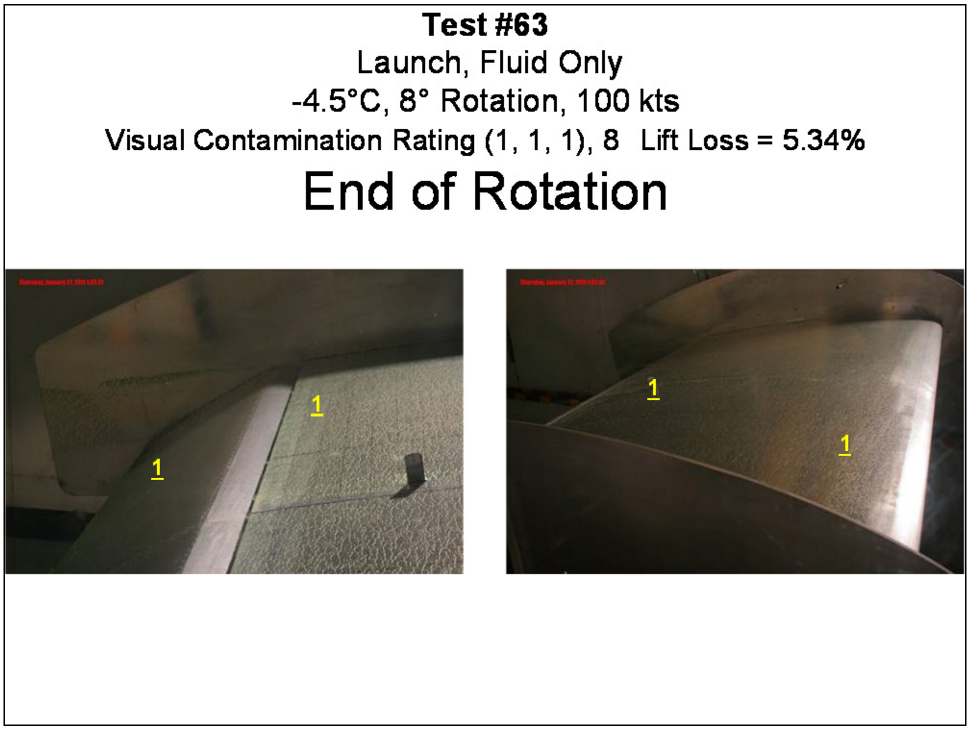
Test #63
Launch, Fluid Only
-4.5°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 7.94: Test #63 – Before Rotation



Test #63
Launch, Fluid Only
-4.5°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.34%
Before Rotation

Photo 7.95: Test #63 – End of Rotation



Test #63

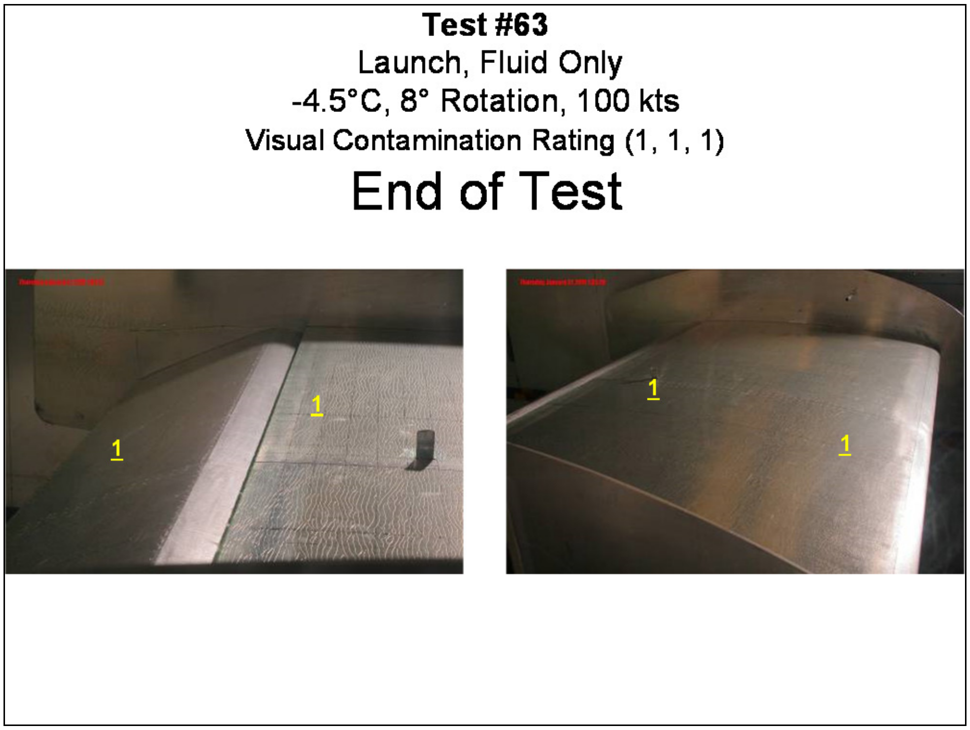
Launch, Fluid Only

-4.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.34%

End of Rotation

Photo 7.96: Test #63 – End of Test



Test #63

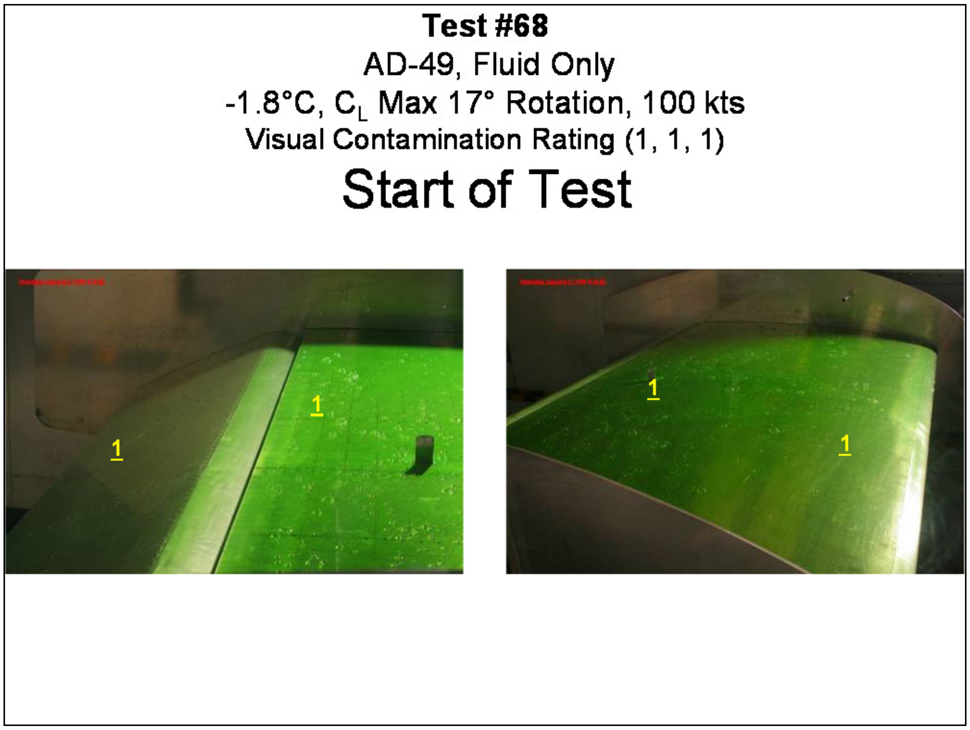
Launch, Fluid Only

-4.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

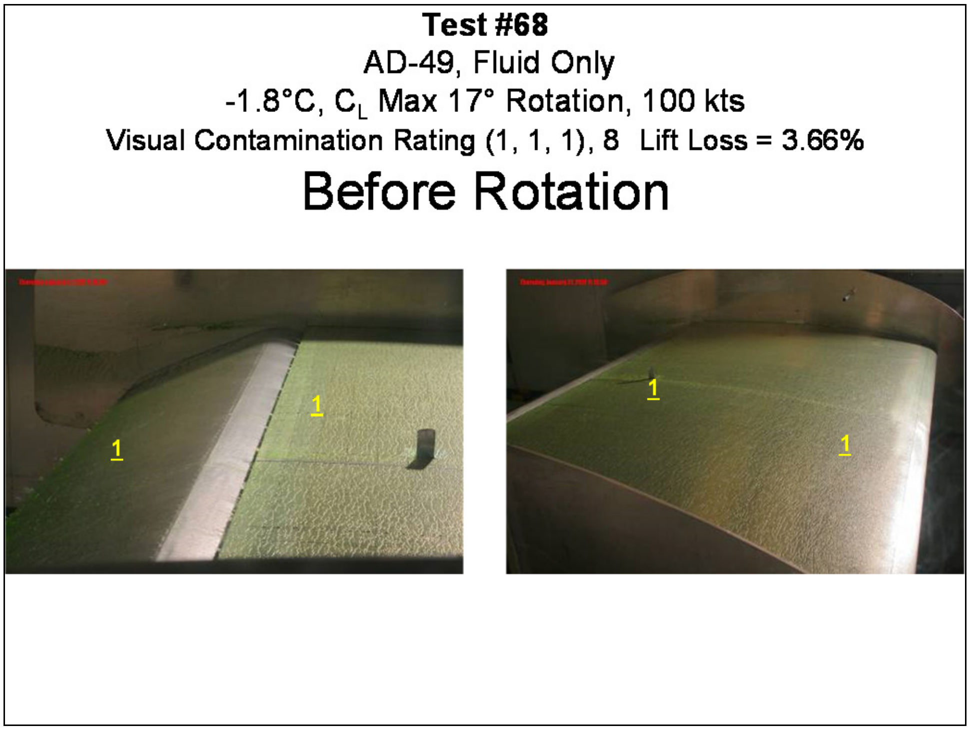
End of Test

Photo 7.97: Test #68 – Start of Test



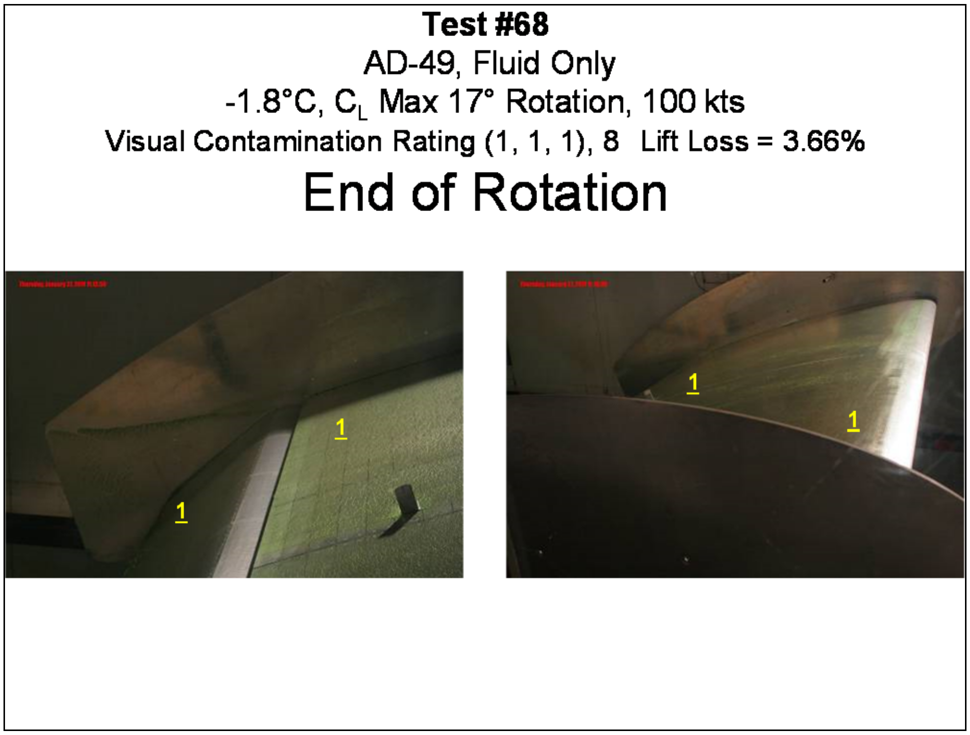
Test #68
AD-49, Fluid Only
-1.8°C, C_L Max 17° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 7.98: Test #68 – Before Rotation



Test #68
AD-49, Fluid Only
-1.8°C, C_L Max 17° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.66%
Before Rotation

Photo 7.99: Test #68 – End of Rotation



Test #68

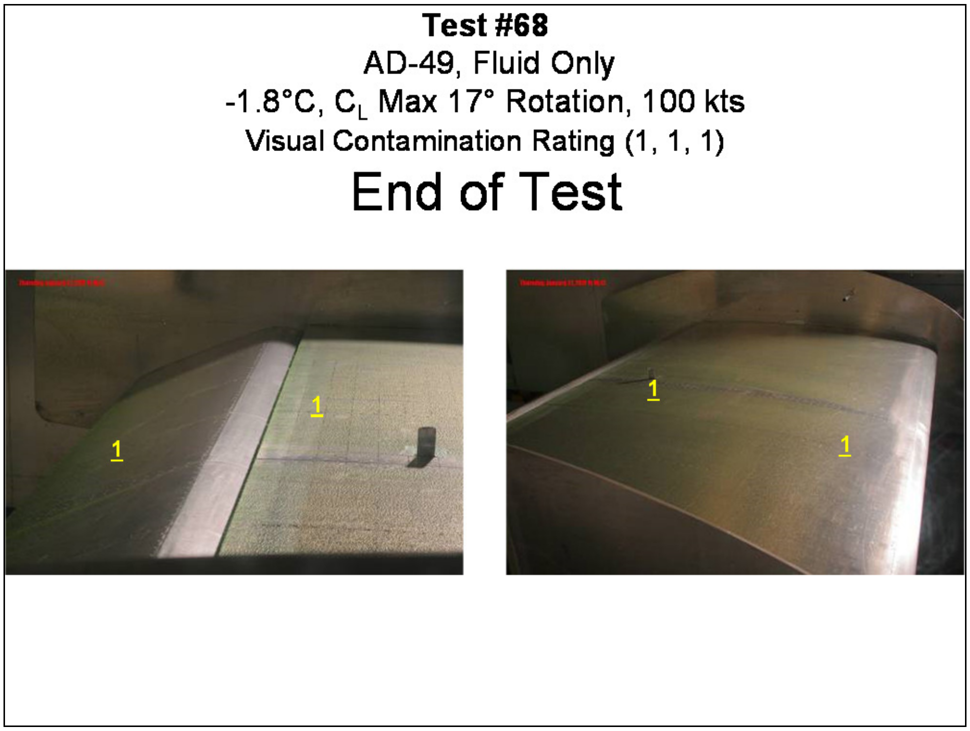
AD-49, Fluid Only

-1.8°C, C_L Max 17° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.66%

End of Rotation

Photo 7.100: Test #68 – End of Test



Test #68

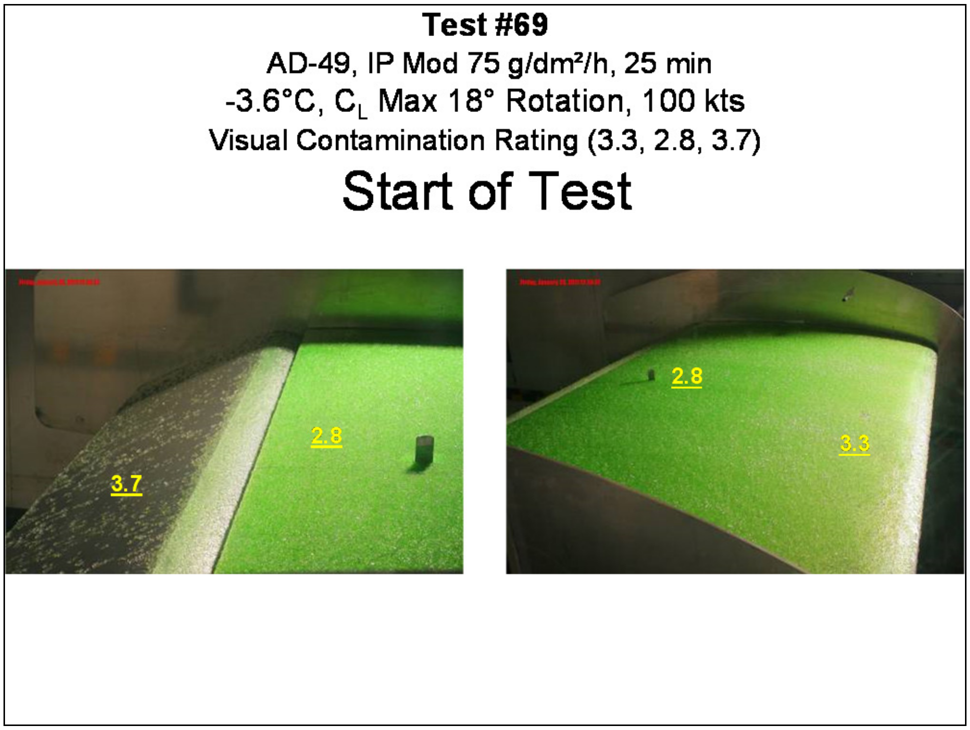
AD-49, Fluid Only

-1.8°C, C_L Max 17° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.101: Test #69 – Start of Test



Test #69

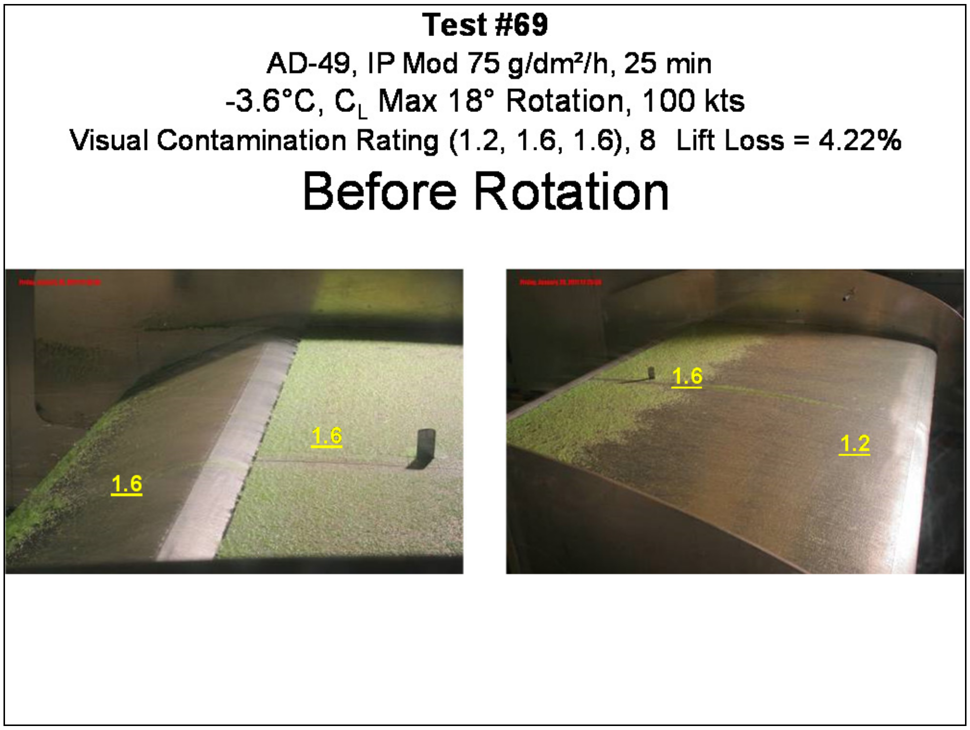
AD-49, IP Mod 75 g/dm²/h, 25 min

-3.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (3.3, 2.8, 3.7)

Start of Test

Photo 7.102: Test #69 – Before Rotation



Test #69

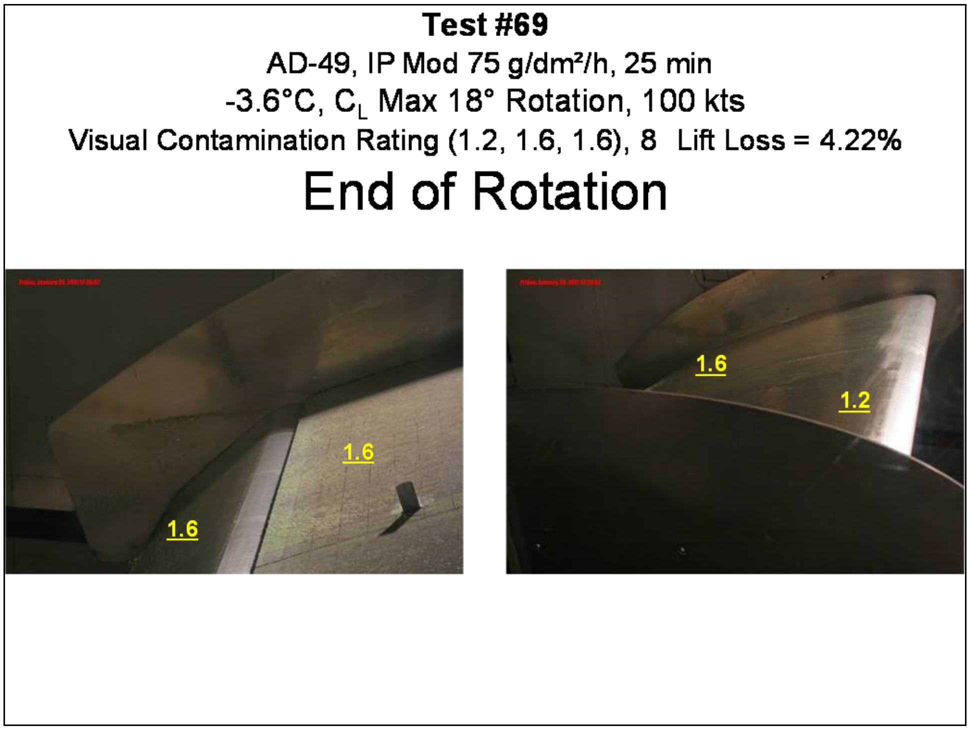
AD-49, IP Mod 75 g/dm²/h, 25 min

-3.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.6, 1.6), 8 Lift Loss = 4.22%

Before Rotation

Photo 7.103: Test #69 – End of Rotation



Test #69

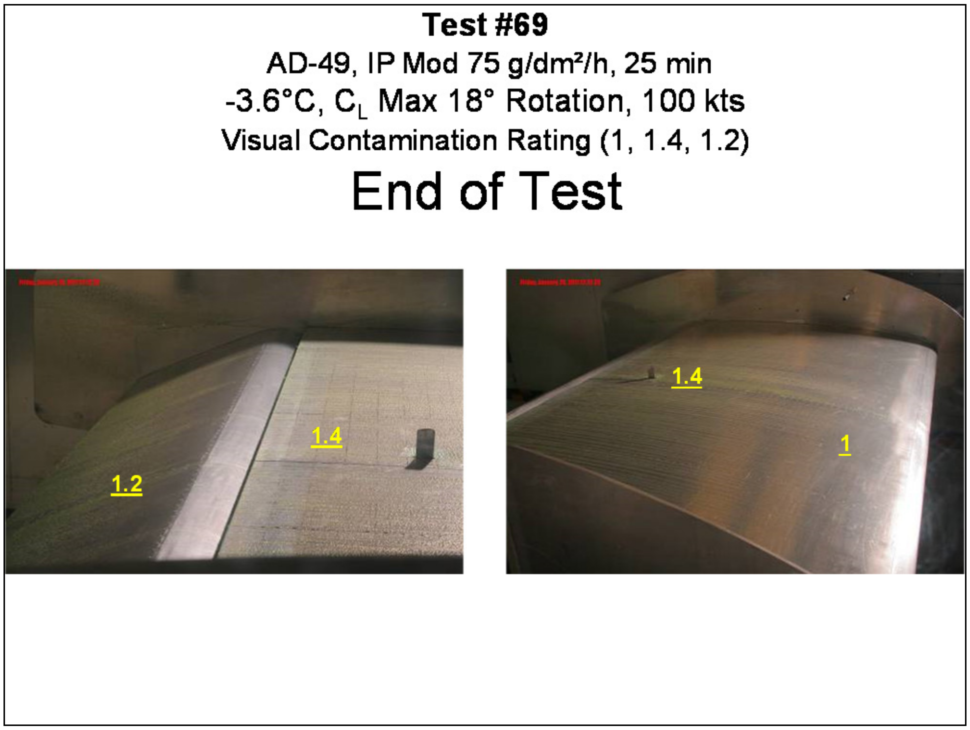
AD-49, IP Mod 75 g/dm²/h, 25 min

-3.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.6, 1.6), 8 Lift Loss = 4.22%

End of Rotation

Photo 7.104: Test #69 – End of Test



Test #69

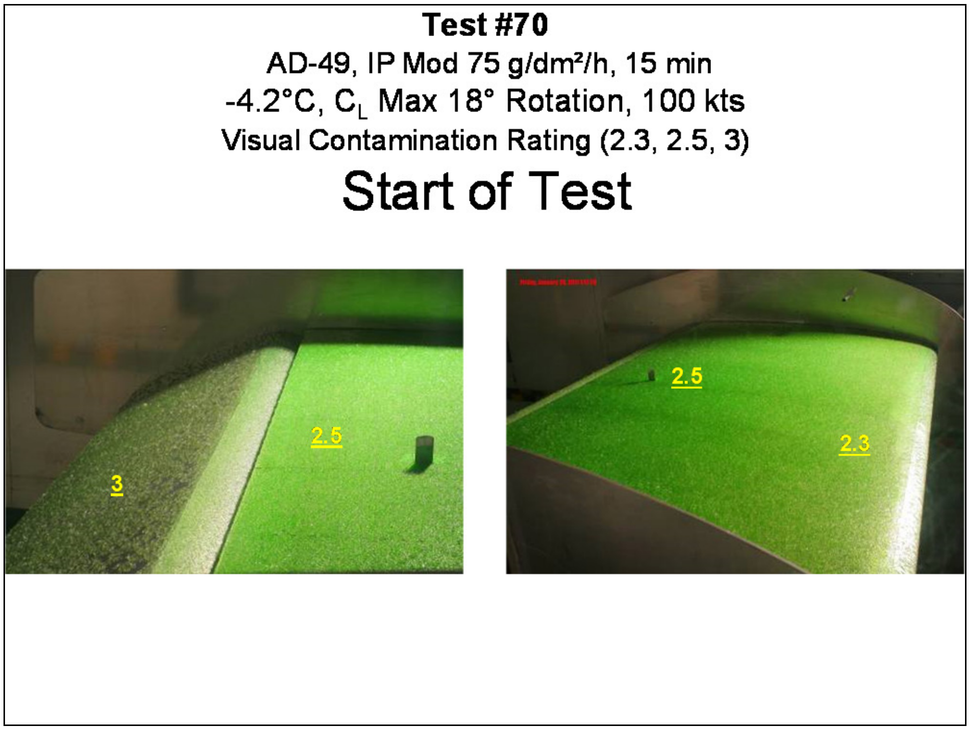
AD-49, IP Mod 75 g/dm²/h, 25 min

-3.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1.4, 1.2)

End of Test

Photo 7.105: Test #70 – Start of Test



Test #70

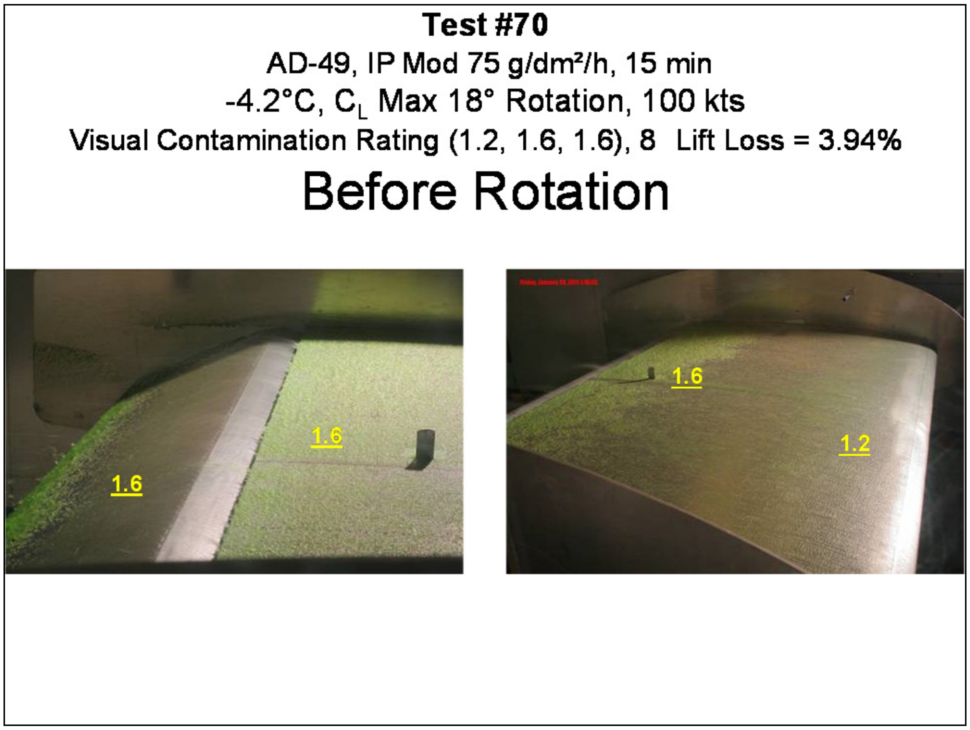
AD-49, IP Mod 75 g/dm²/h, 15 min

-4.2°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (2.3, 2.5, 3)

Start of Test

Photo 7.106: Test #70 – Before Rotation



Test #70

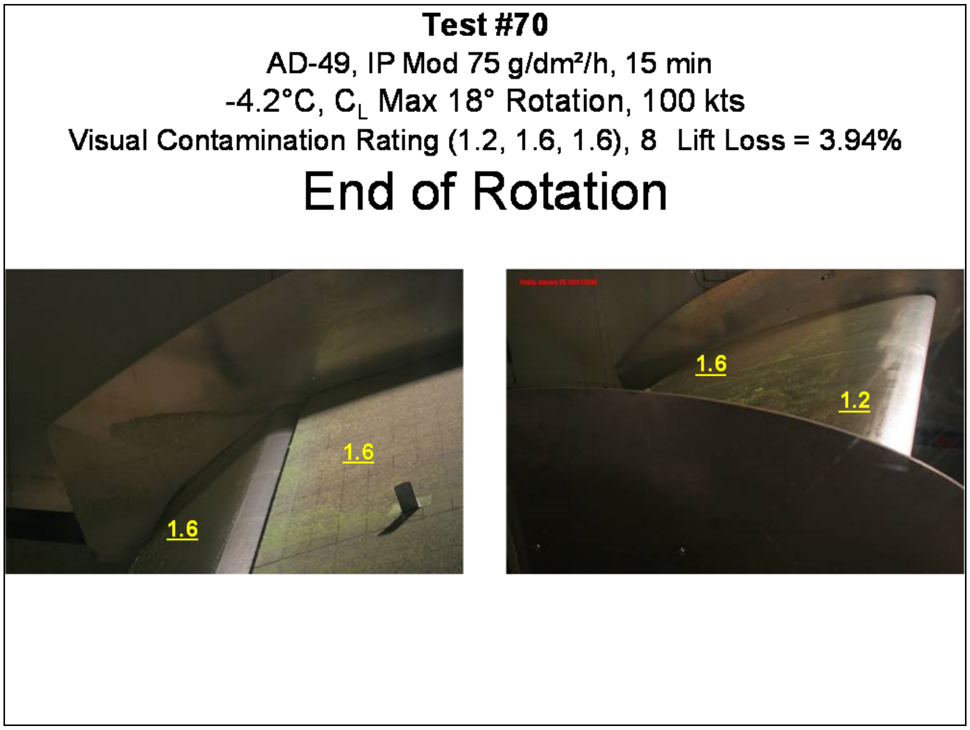
AD-49, IP Mod 75 g/dm²/h, 15 min

-4.2°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.6, 1.6), 8 Lift Loss = 3.94%

Before Rotation

Photo 7.107: Test #70 – End of Rotation



Test #70

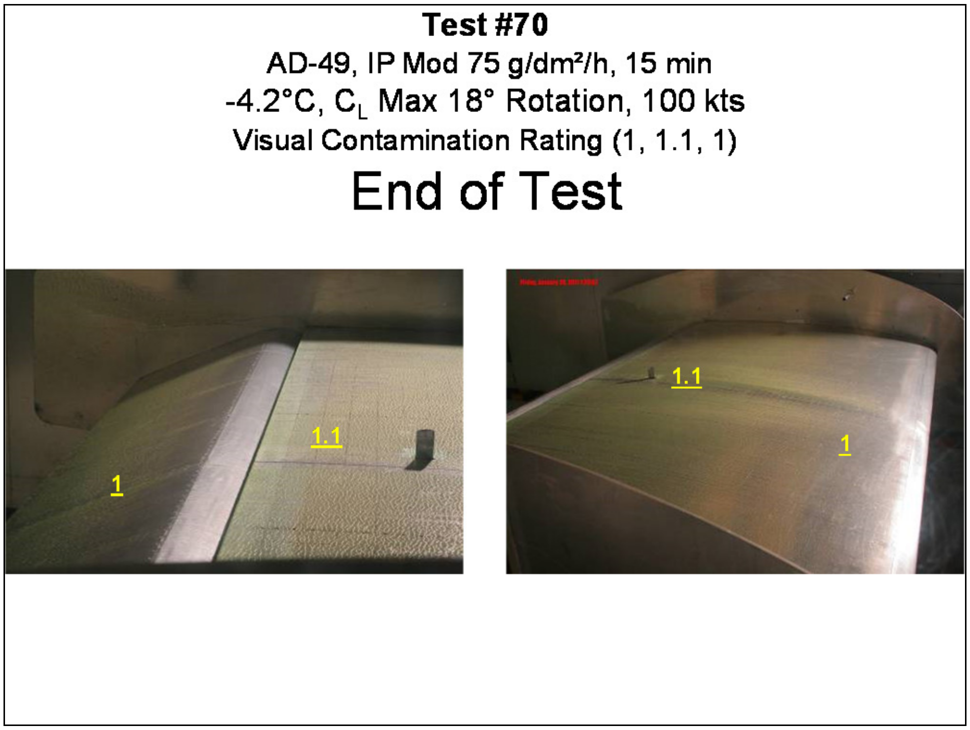
AD-49, IP Mod 75 g/dm²/h, 15 min

-4.2°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.6, 1.6), 8 Lift Loss = 3.94%

End of Rotation

Photo 7.108: Test #70 – End of Test



Test #70

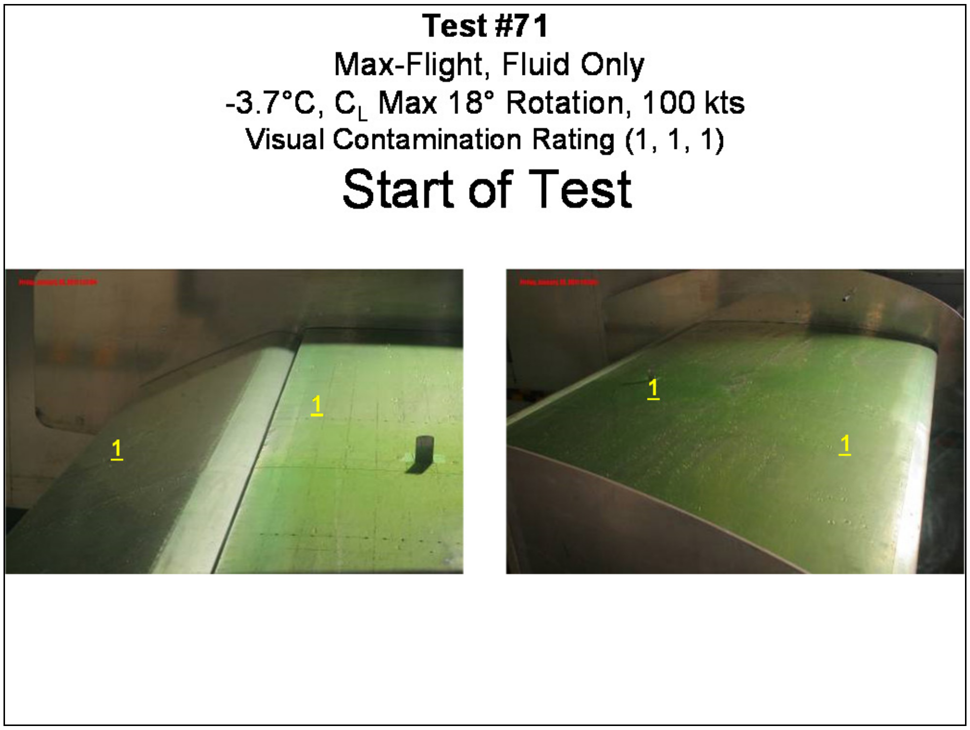
AD-49, IP Mod 75 g/dm²/h, 15 min

-4.2°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1.1, 1)

End of Test

Photo 7.109: Test #71 – Start of Test



Test #71

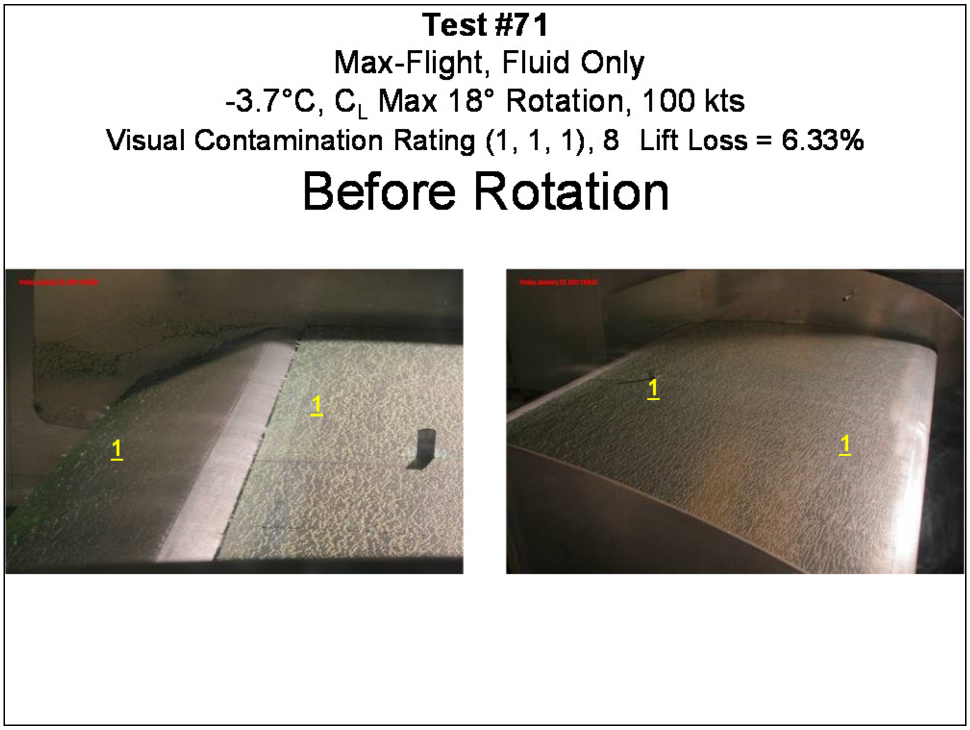
Max-Flight, Fluid Only

-3.7°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 7.110: Test #71 – Before Rotation



Test #71

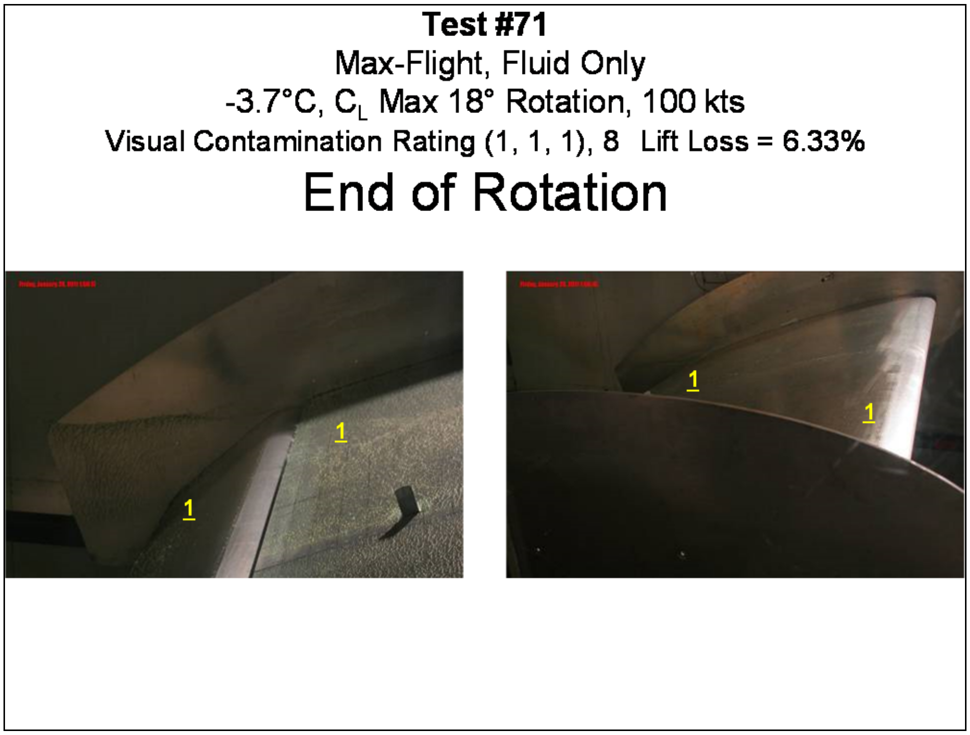
Max-Flight, Fluid Only

-3.7°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.33%

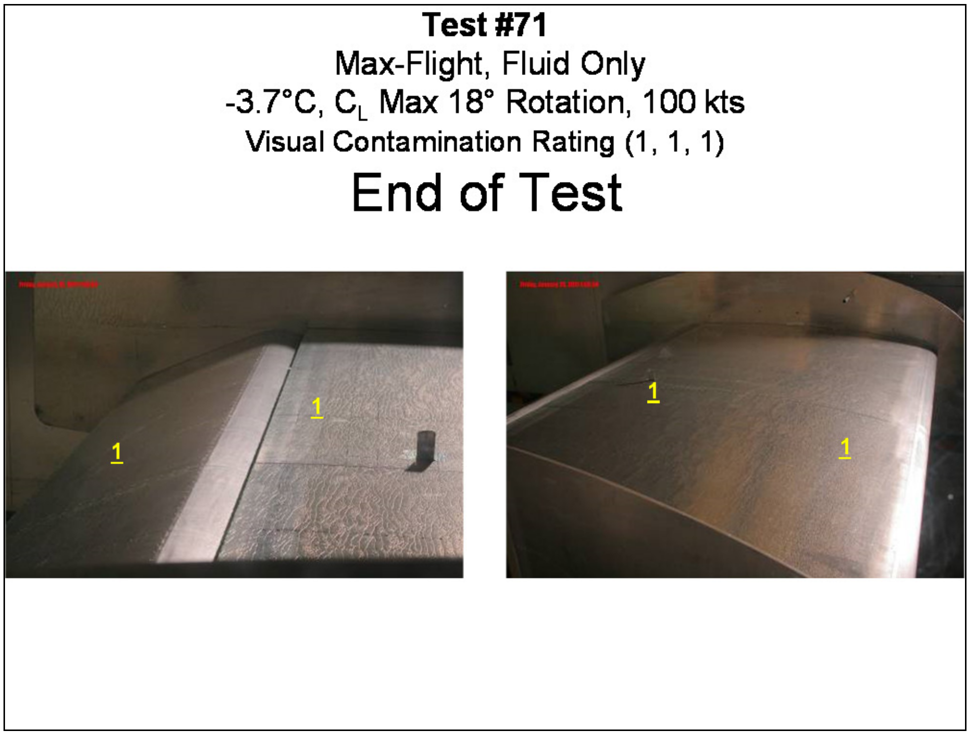
Before Rotation

Photo 7.111: Test #71 – End of Rotation



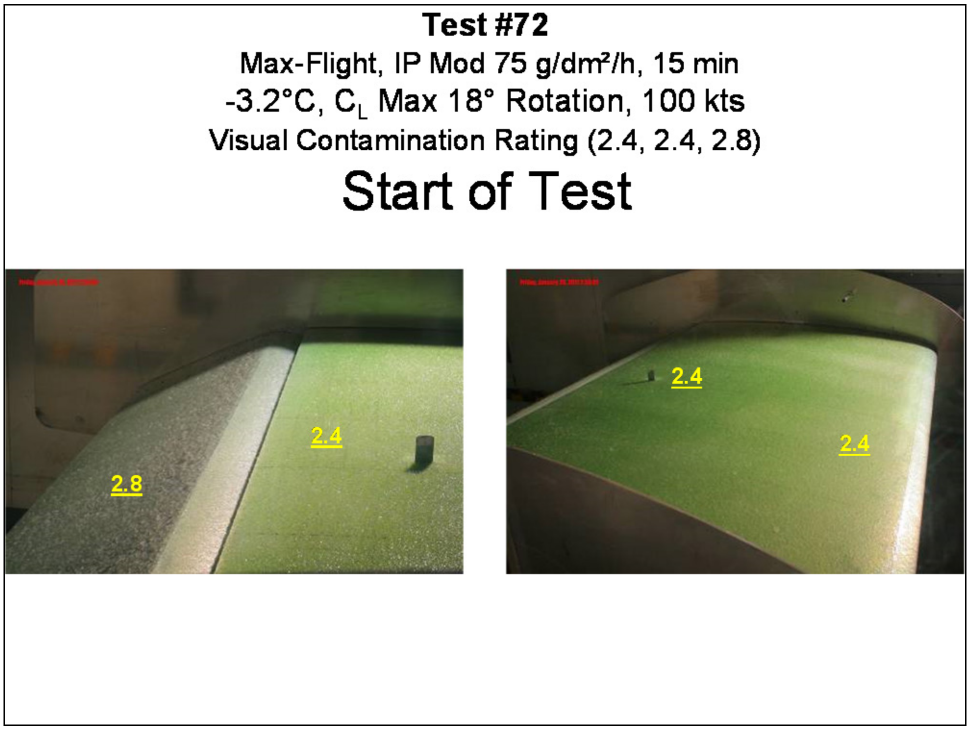
Test #71
Max-Flight, Fluid Only
-3.7°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.33%
End of Rotation

Photo 7.112: Test #71 – End of Test



Test #71
Max-Flight, Fluid Only
-3.7°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 7.113: Test #72 – Start of Test



Test #72

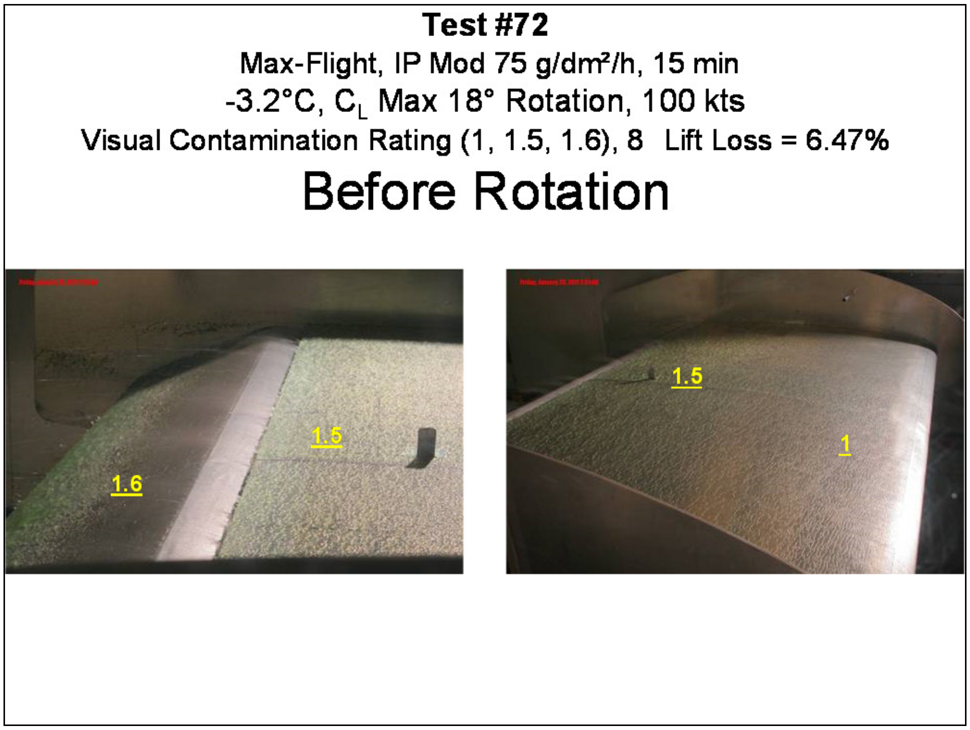
Max-Flight, IP Mod 75 g/dm²/h, 15 min

-3.2°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (2.4, 2.4, 2.8)

Start of Test

Photo 7.114: Test #72 – Before Rotation



Test #72

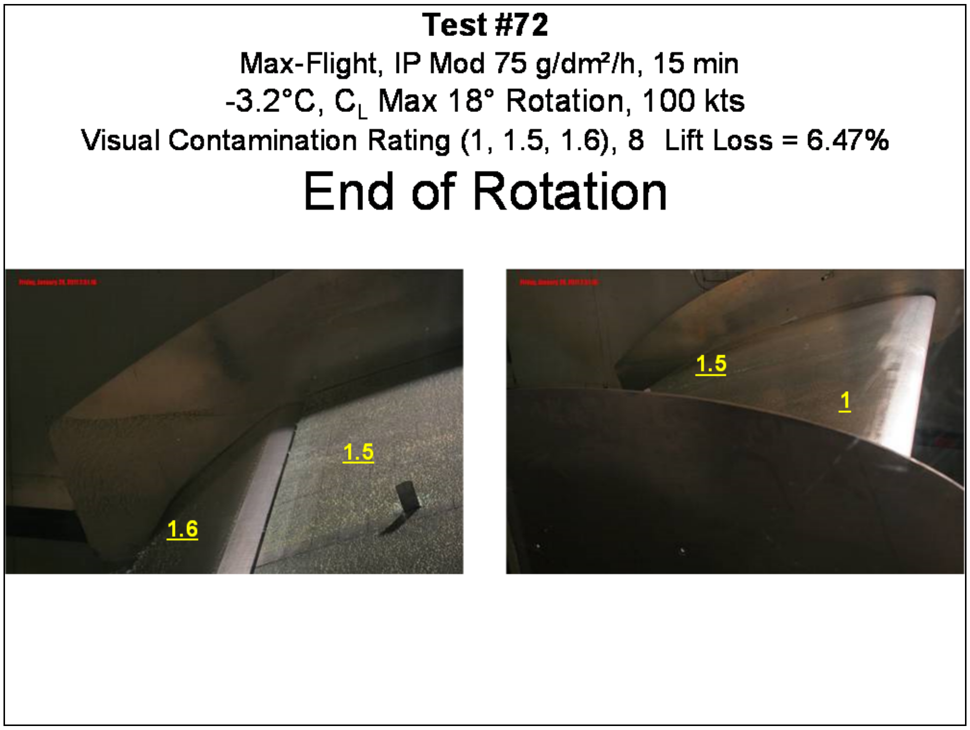
Max-Flight, IP Mod 75 g/dm²/h, 15 min

-3.2°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1.5, 1.6), 8 Lift Loss = 6.47%

Before Rotation

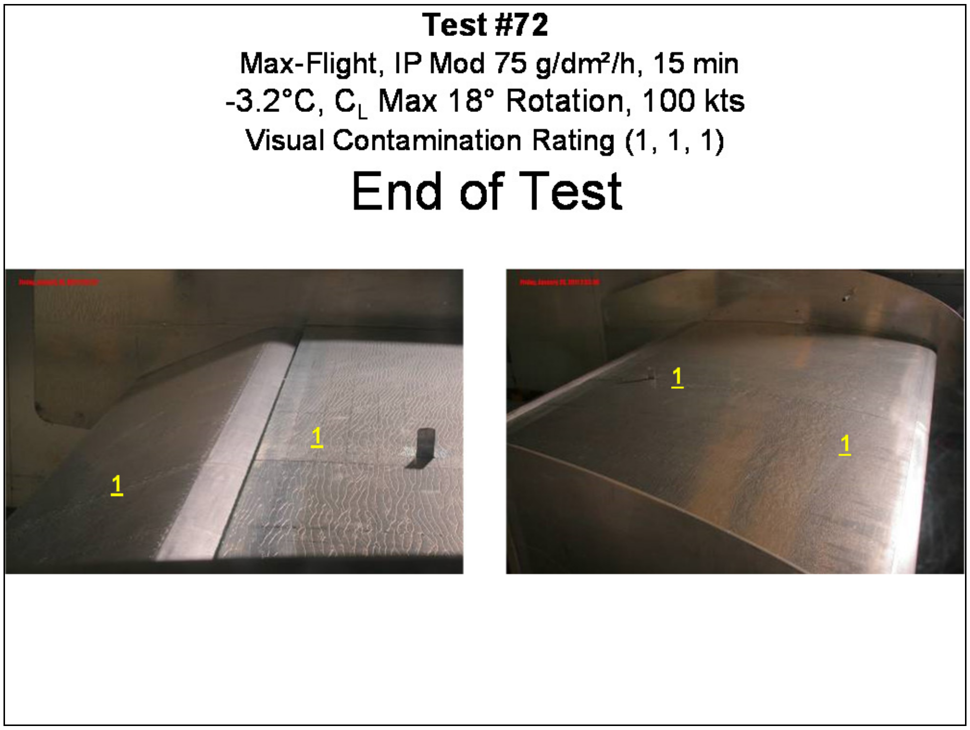
Photo 7.115: Test #72 – Before Rotation



Test #72
Max-Flight, IP Mod 75 g/dm²/h, 15 min
-3.2°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1.5, 1.6), 8 Lift Loss = 6.47%

End of Rotation

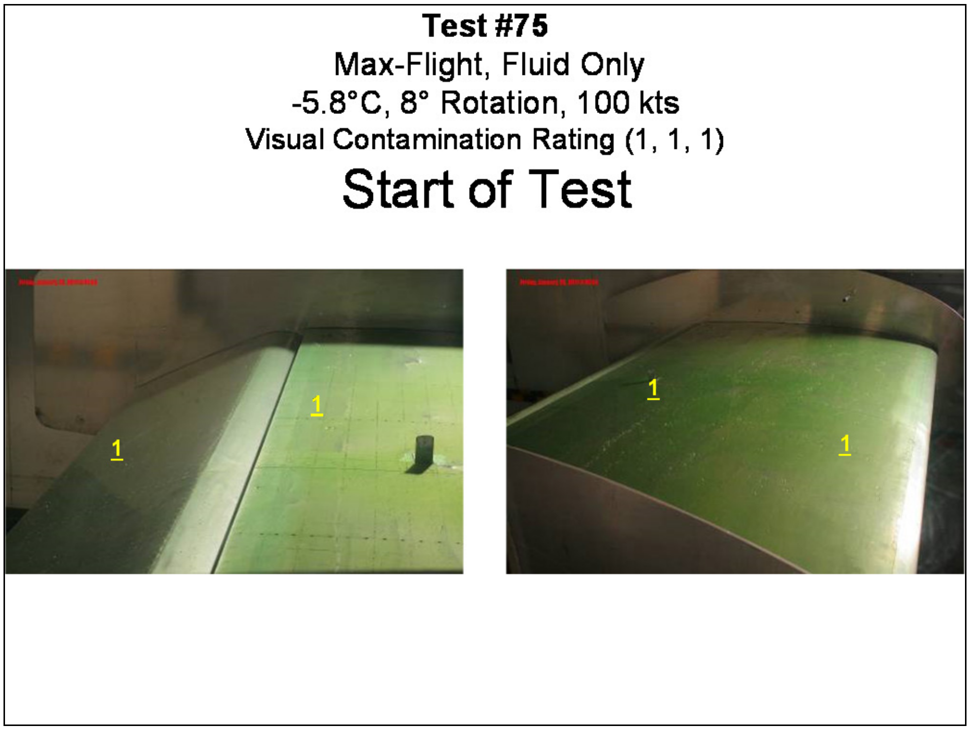
Photo 7.116: Test #72 – End of Test



Test #72
Max-Flight, IP Mod 75 g/dm²/h, 15 min
-3.2°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.117: Test #75 – Start of Test



Test #75

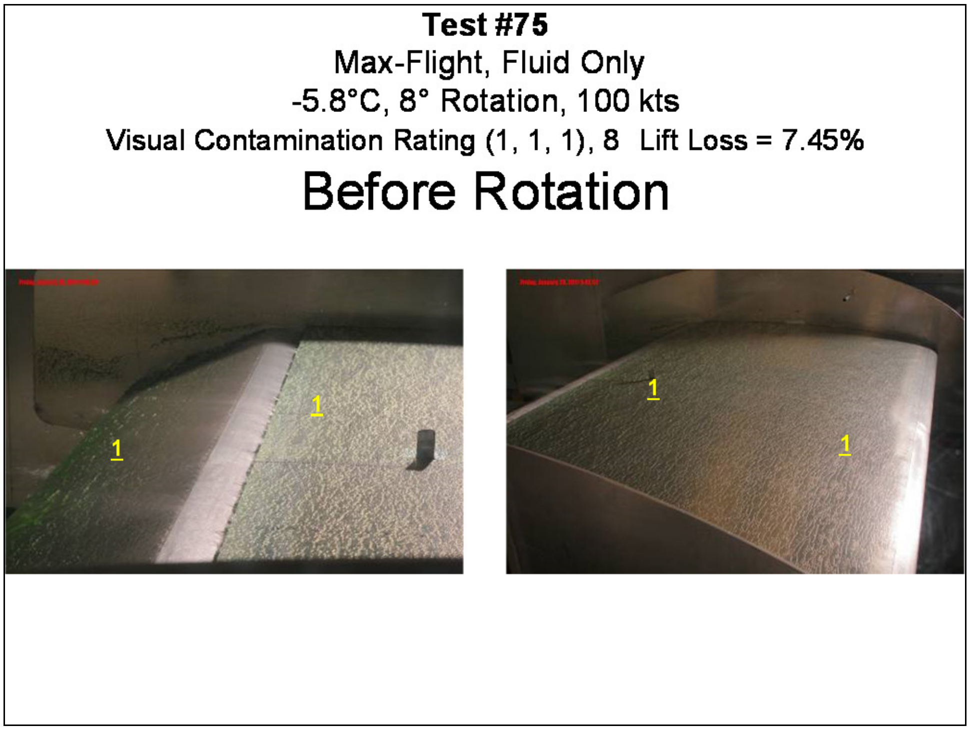
Max-Flight, Fluid Only

-5.8°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 7.118: Test #75 – Before Rotation



Test #75

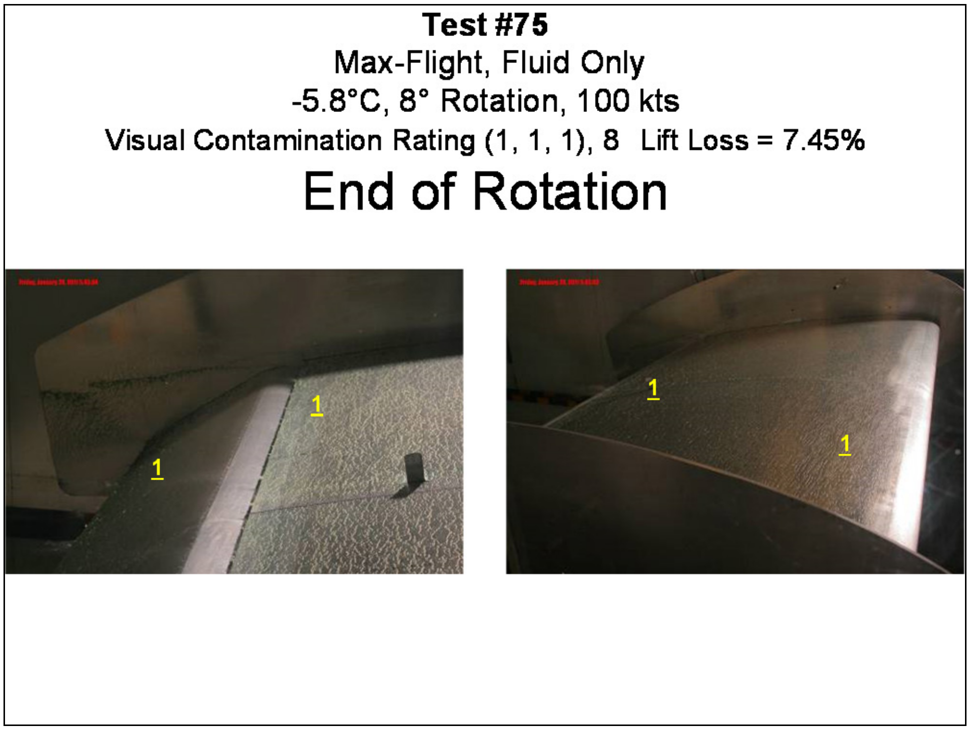
Max-Flight, Fluid Only

-5.8°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 7.45%

Before Rotation

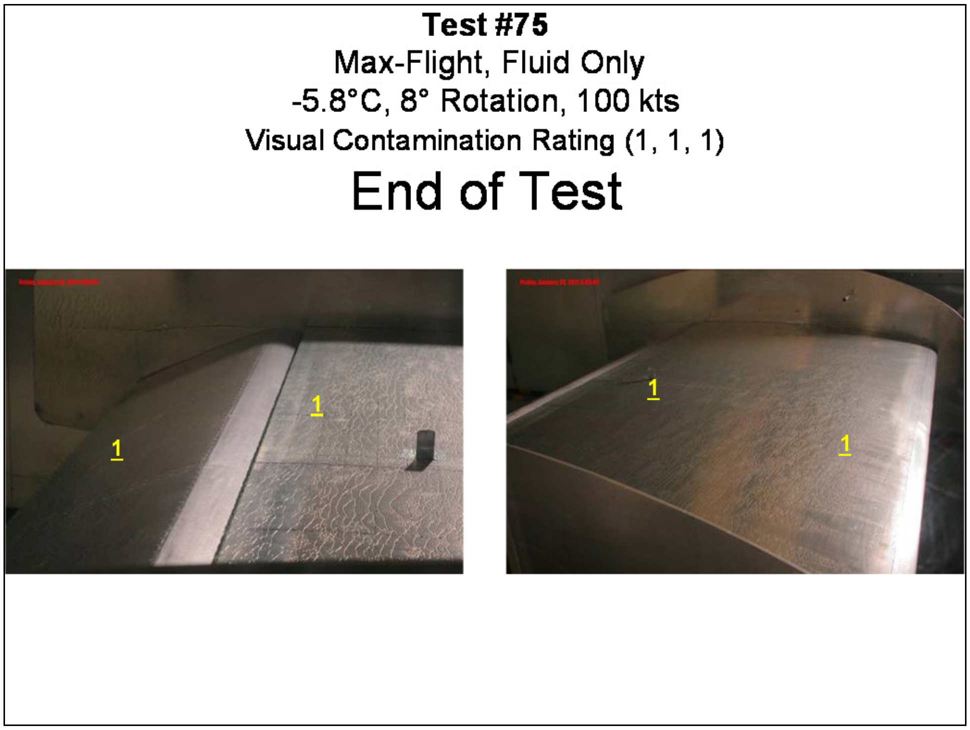
Photo 7.119: Test #75 – End of Rotation



Test #75
Max-Flight, Fluid Only
-5.8°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 7.45%

End of Rotation

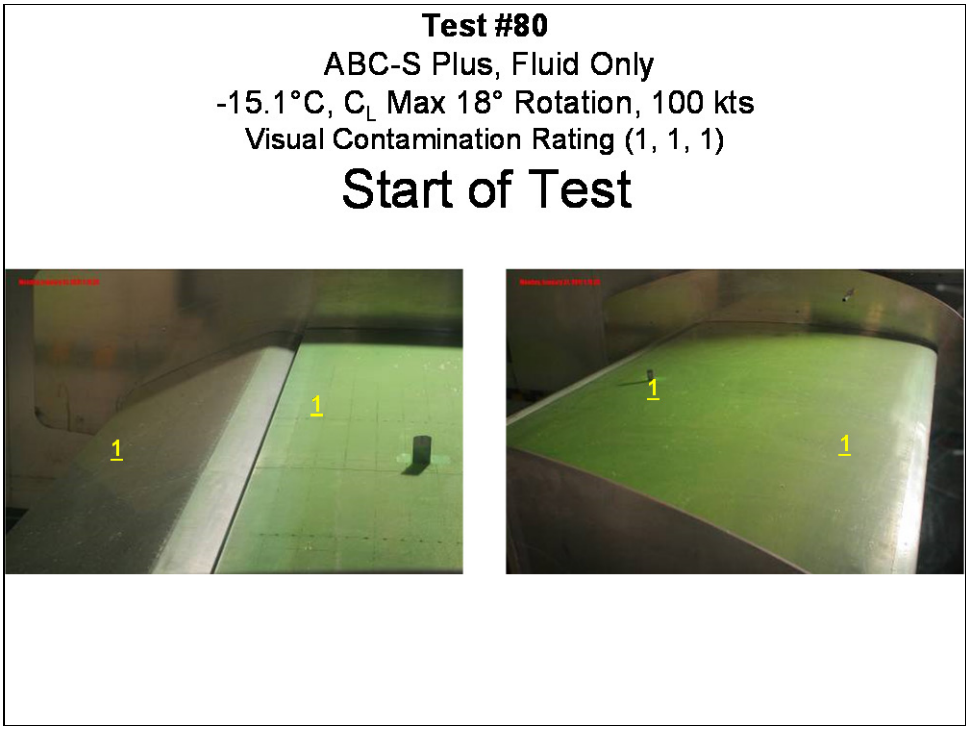
Photo 7.120: Test #75 – End of Test



Test #75
Max-Flight, Fluid Only
-5.8°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.121: Test #80 – Start of Test



Test #80

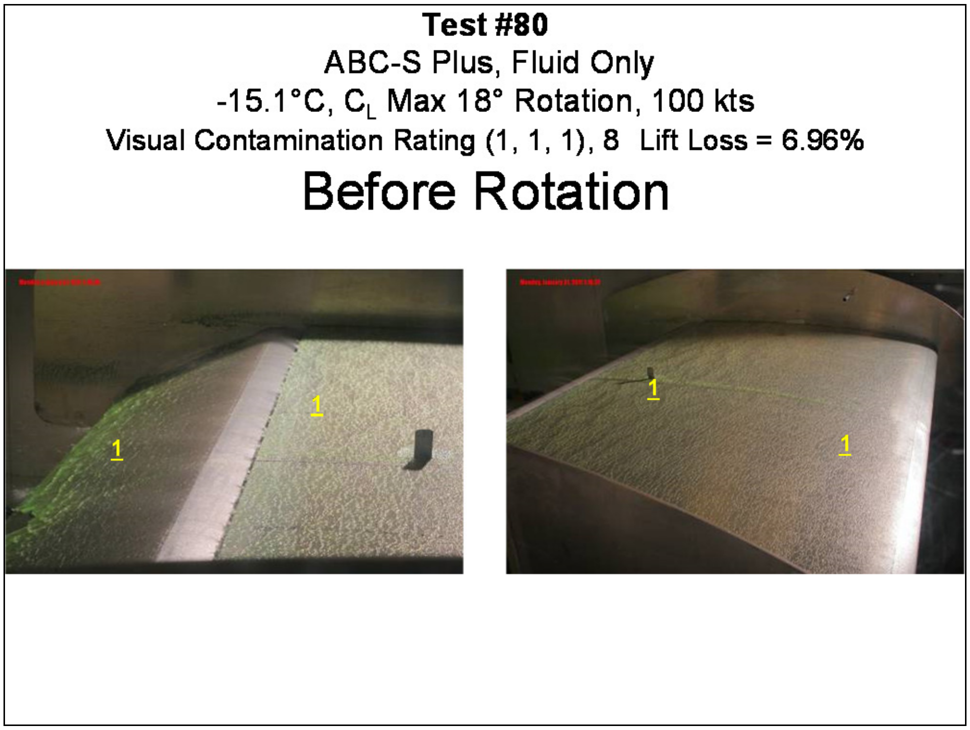
ABC-S Plus, Fluid Only

-15.1°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 7.122: Test #80 – Before Rotation



Test #80

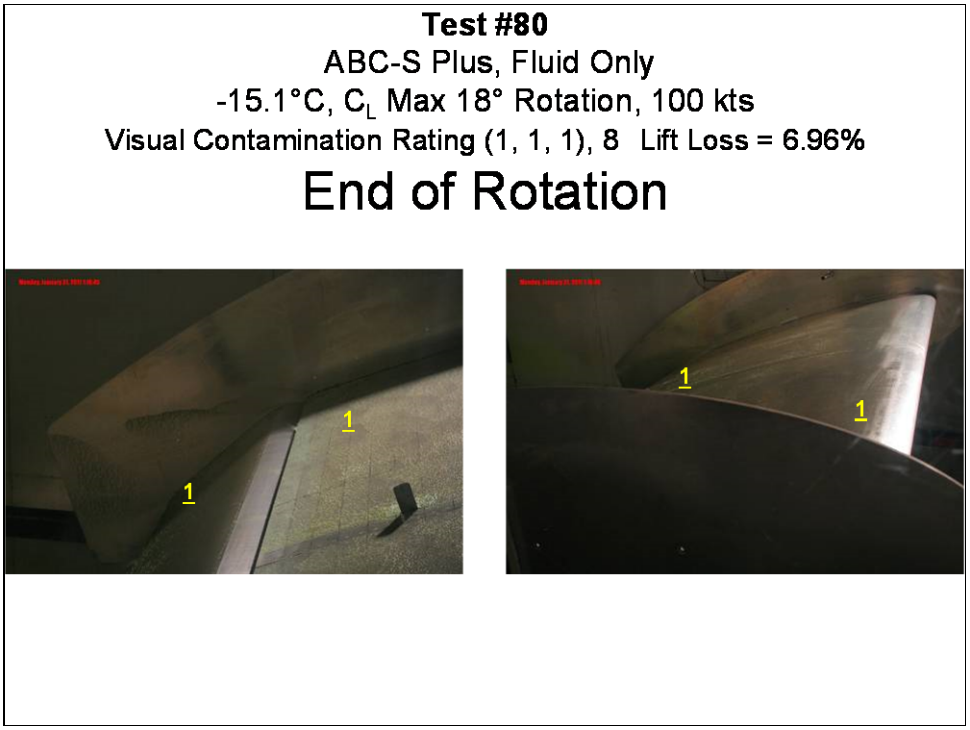
ABC-S Plus, Fluid Only

-15.1°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.96%

Before Rotation

Photo 7.123: Test #80 – End of Rotation



Test #80

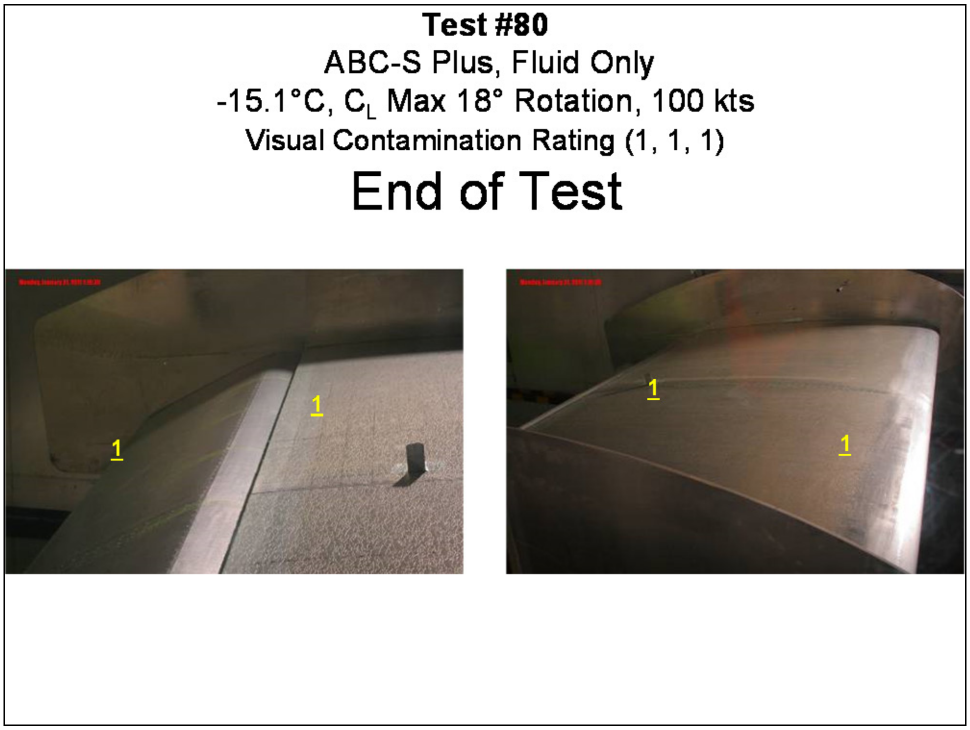
ABC-S Plus, Fluid Only

-15.1°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8   Lift Loss = 6.96%

End of Rotation

Photo 7.124: Test #80 – End of Test



Test #80

ABC-S Plus, Fluid Only

-15.1°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.125: Test #81 – Start of Test

Test #81
ABC-S Plus, Fluid Only
-17.7°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

Start of Test

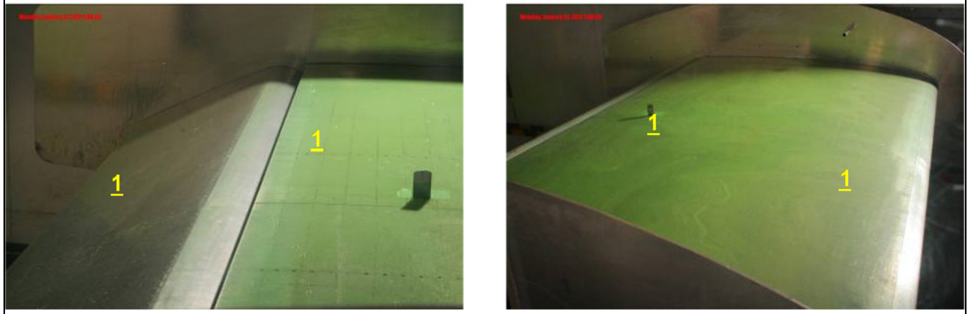


Photo 7.126: Test #81 – Before Rotation

Test #81
ABC-S Plus, Fluid Only
-17.7°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 7.10%

Before Rotation

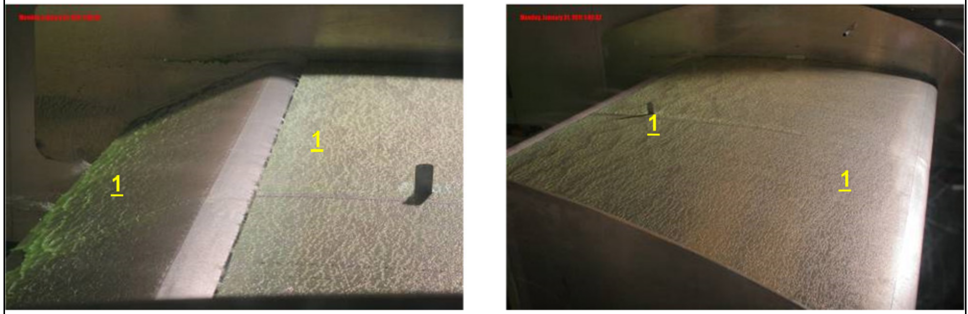
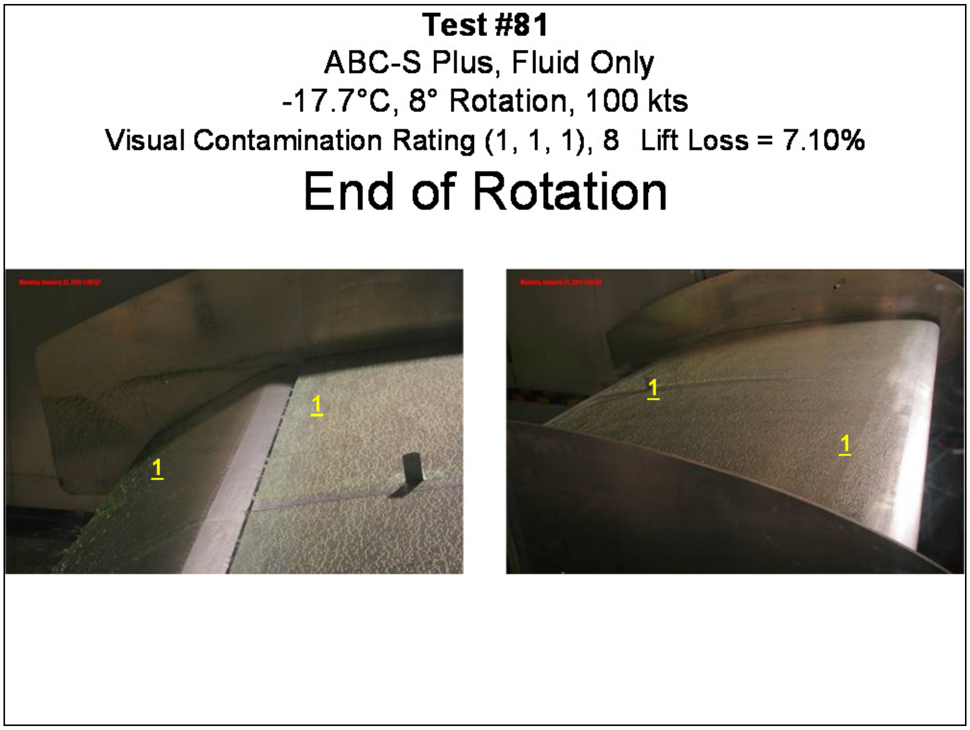
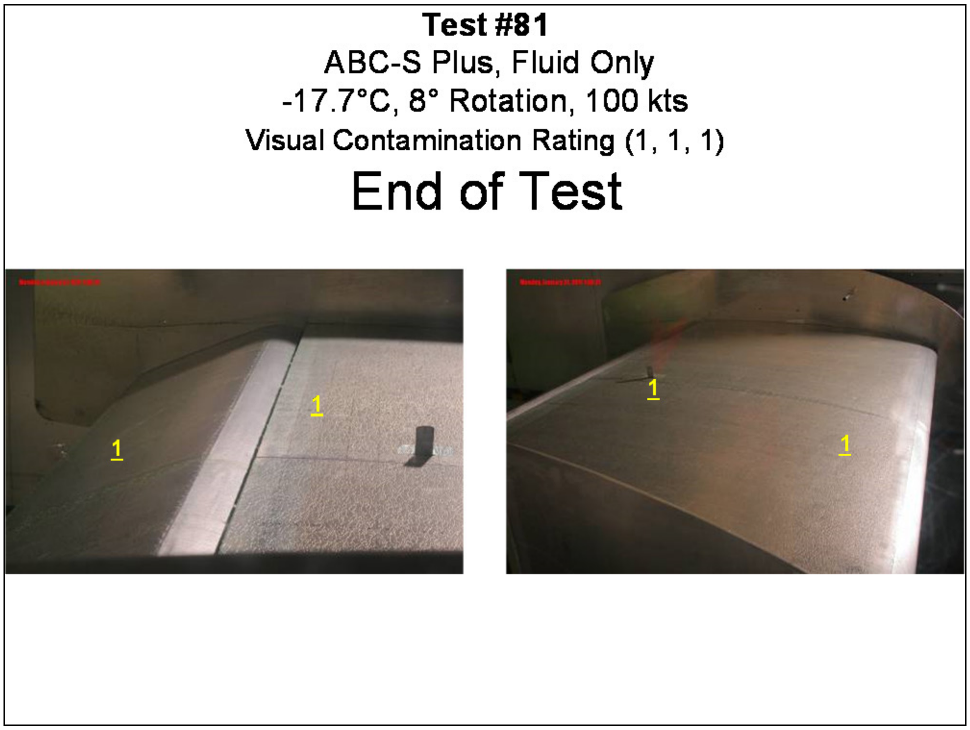


Photo 7.127: Test #81 – End of Rotation



Test #81
ABC-S Plus, Fluid Only
-17.7°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 7.10%
End of Rotation

Photo 7.128: Test #81 – End of Test



Test #81
ABC-S Plus, Fluid Only
-17.7°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 7.129: Test #92 - Start of Test

Test #92

ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-13.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (2.5, 2.6, 3.4)

Start of Test

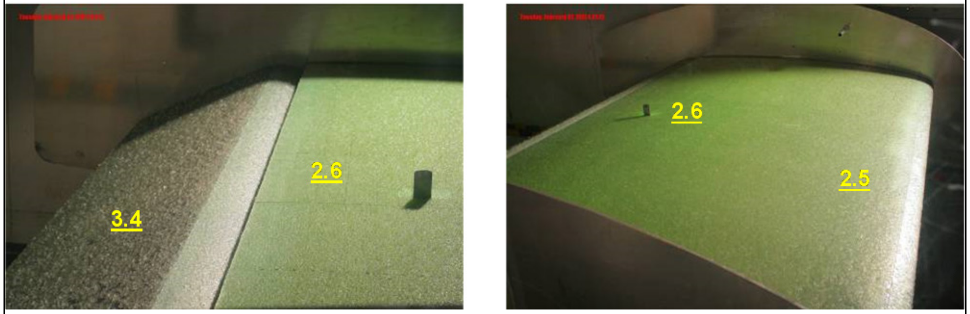


Photo 7.130: Test #92 – Before Rotation

Test #92

ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-13.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.8, 2.6), 8 Lift Loss = 12.8%

Before Rotation

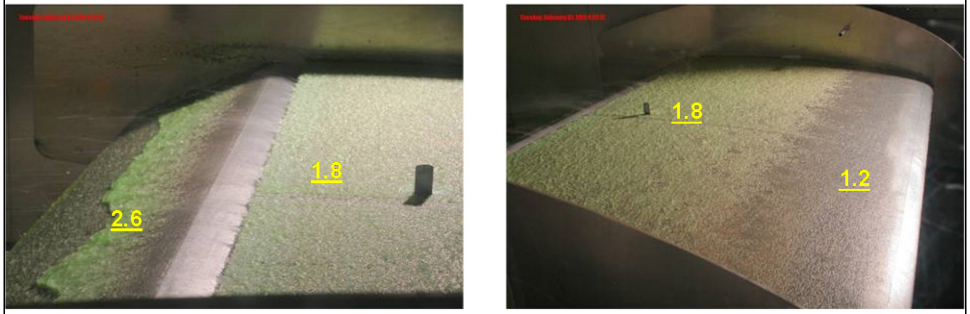
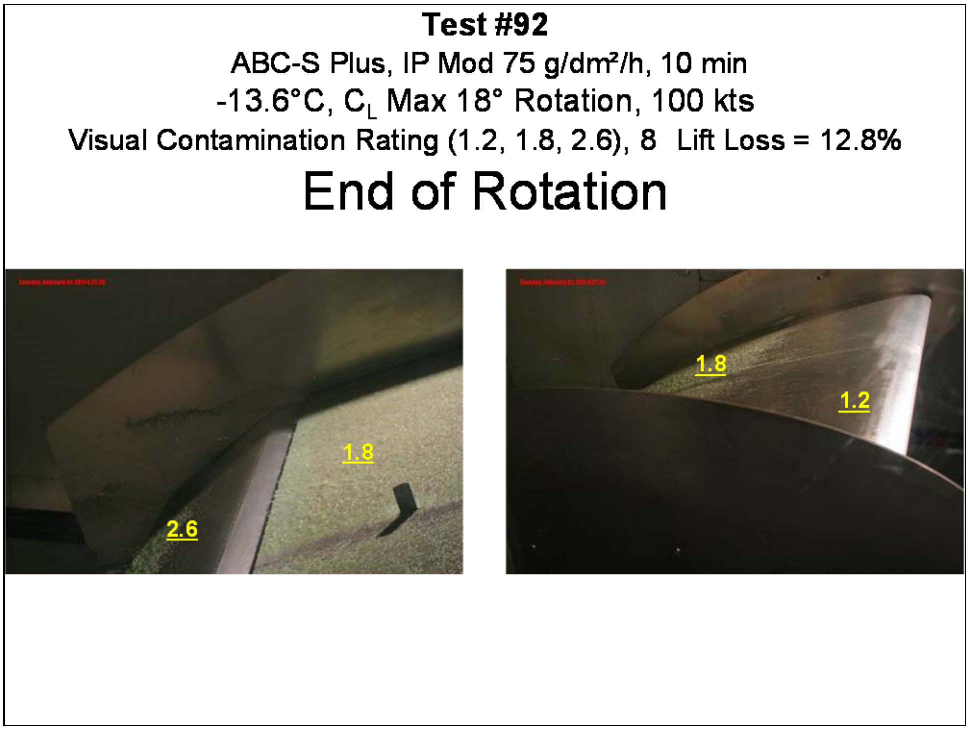


Photo 7.131: Test #92 – End of Rotation



Test #92

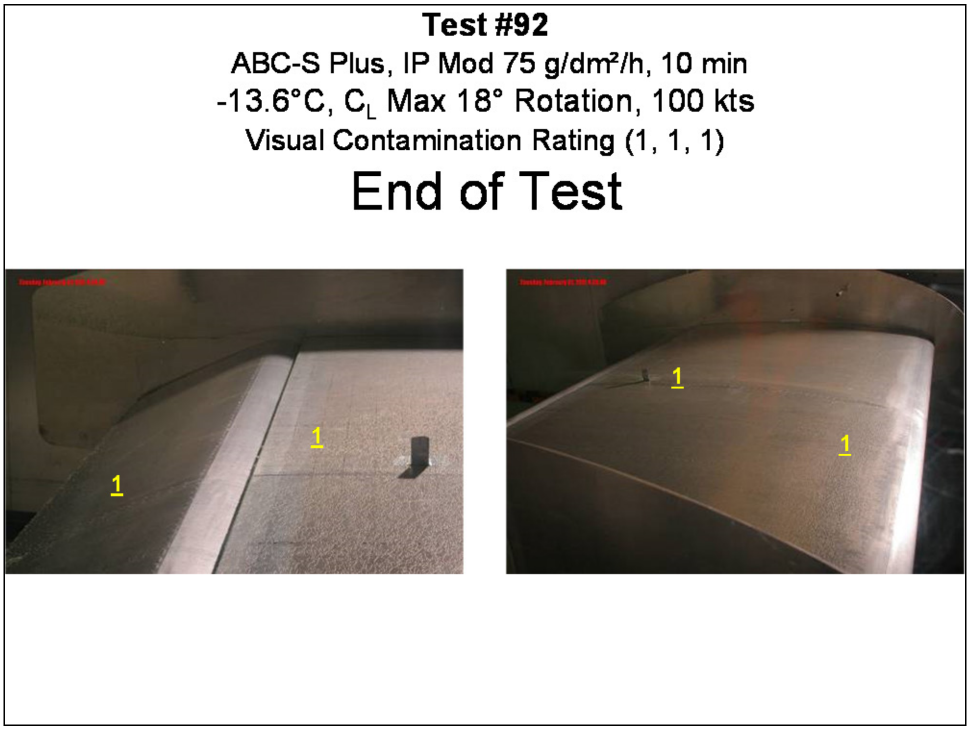
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-13.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.8, 2.6), 8 Lift Loss = 12.8%

End of Rotation

Photo 7.132: Test #92 – End of Test



Test #92

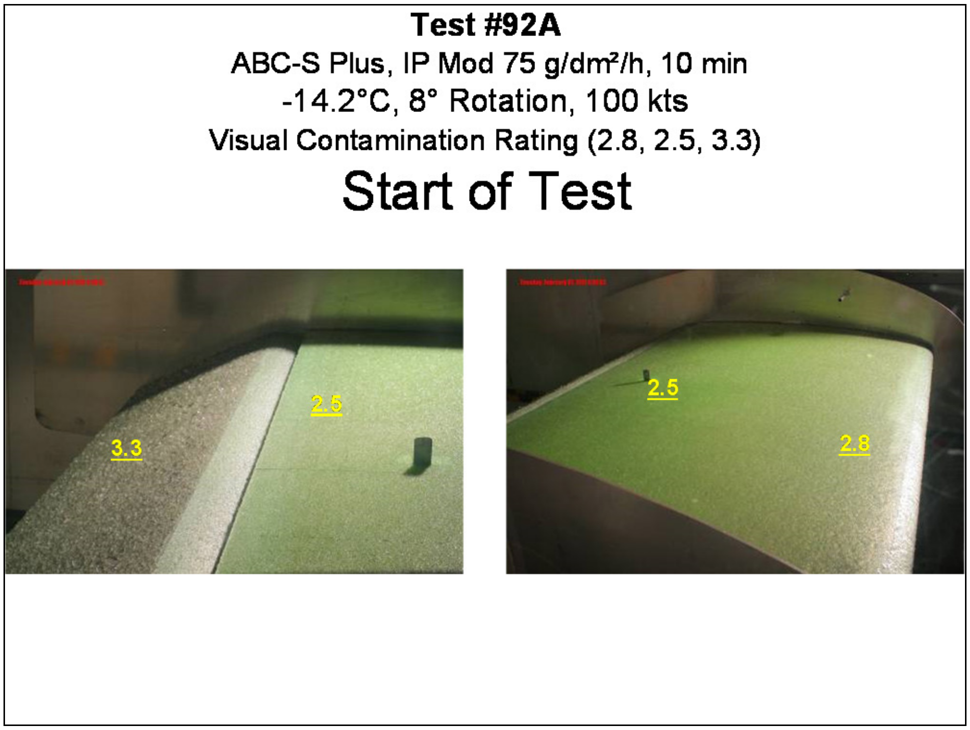
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-13.6°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.133: Test #92A – Start of Test



Test #92A

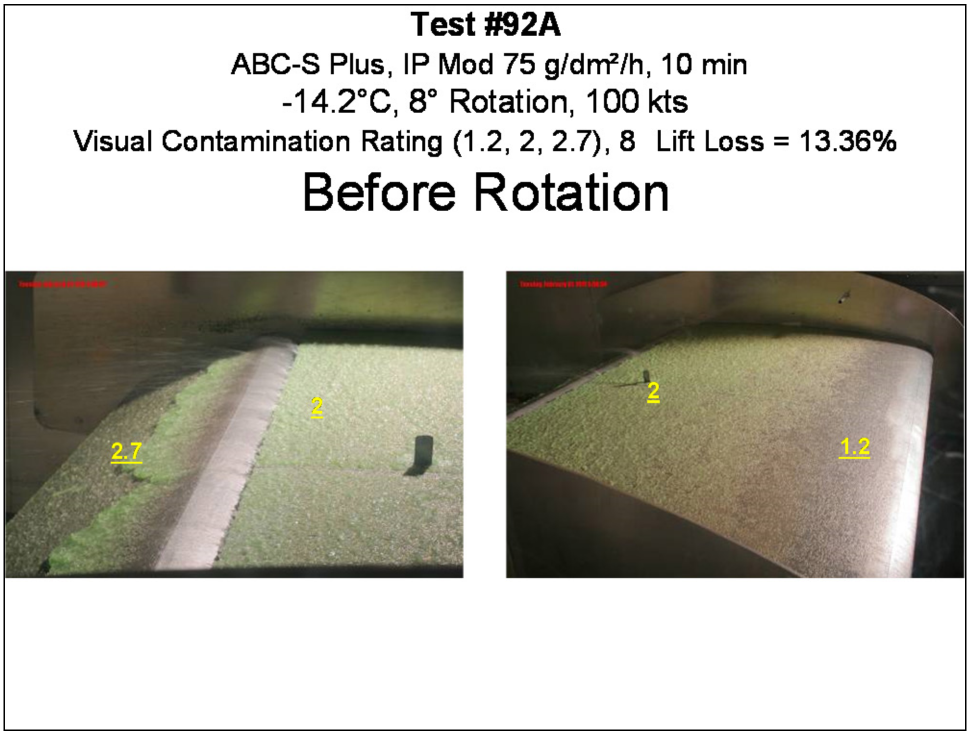
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.8, 2.5, 3.3)

Start of Test

Photo 7.134: Test #92A – Before Rotation



Test #92A

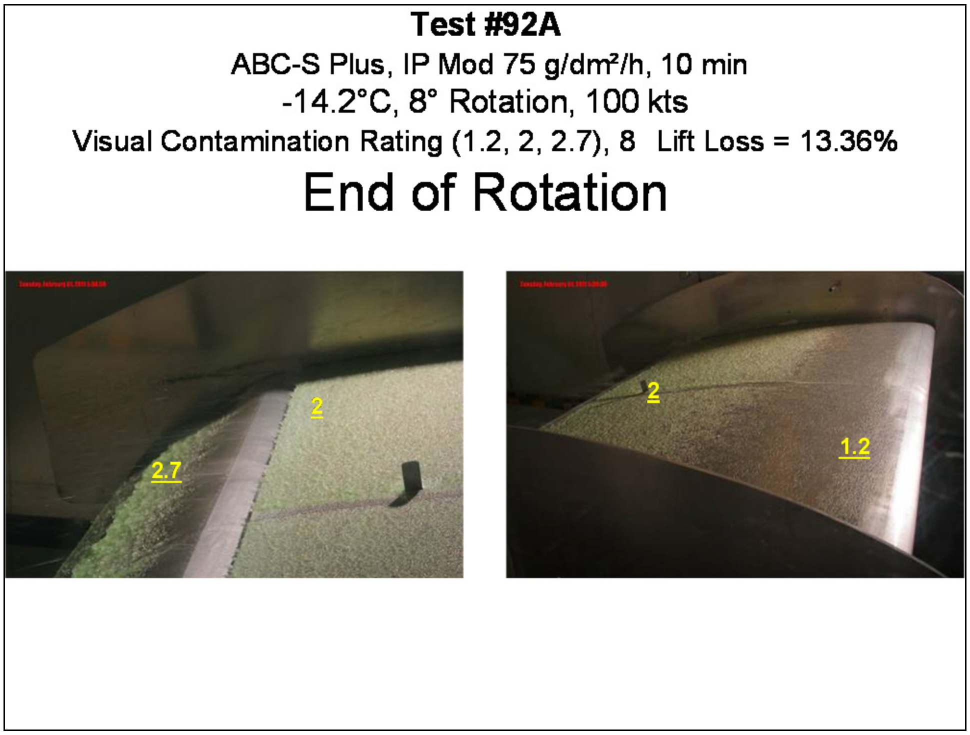
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 2, 2.7), 8 Lift Loss = 13.36%

Before Rotation

Photo 7.135: Test #92A – End of Rotation



Test #92A

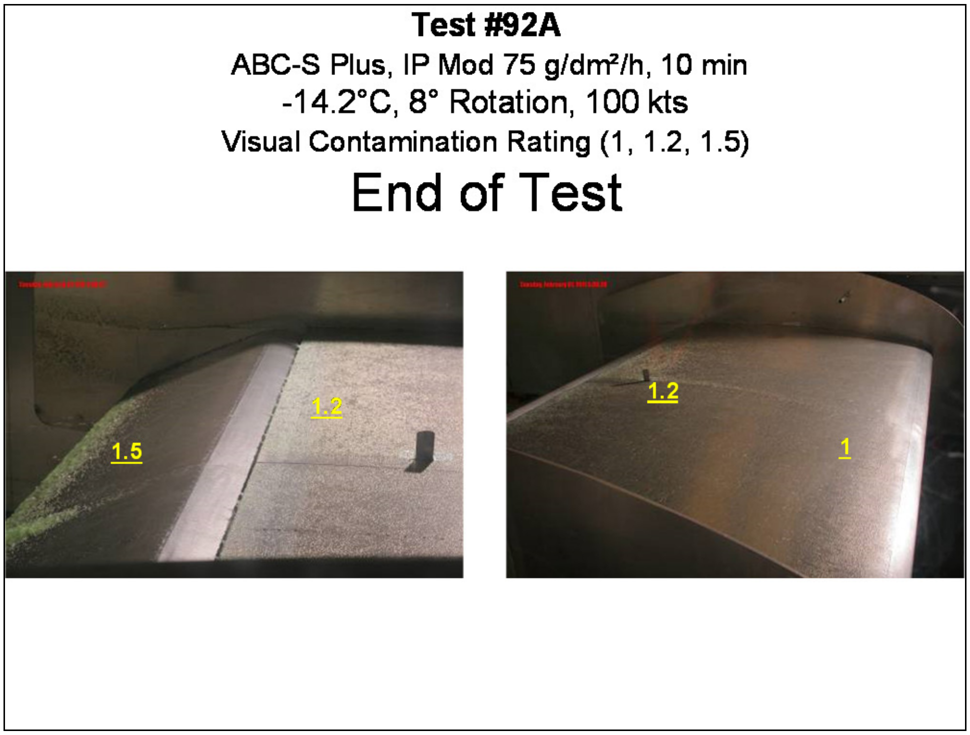
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 2, 2.7), 8 Lift Loss = 13.36%

End of Rotation

Photo 7.136: Test #92A – End of Test



Test #92A

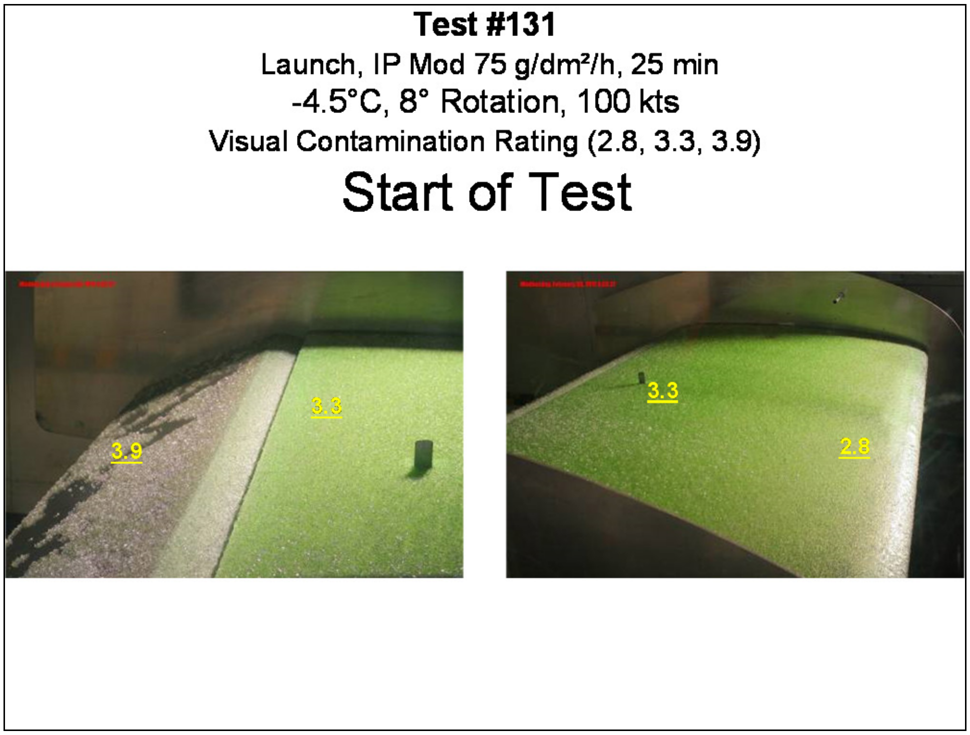
ABC-S Plus, IP Mod 75 g/dm²/h, 10 min

-14.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.2, 1.5)

End of Test

Photo 7.137: Test #131 – Start of Test



Test #131

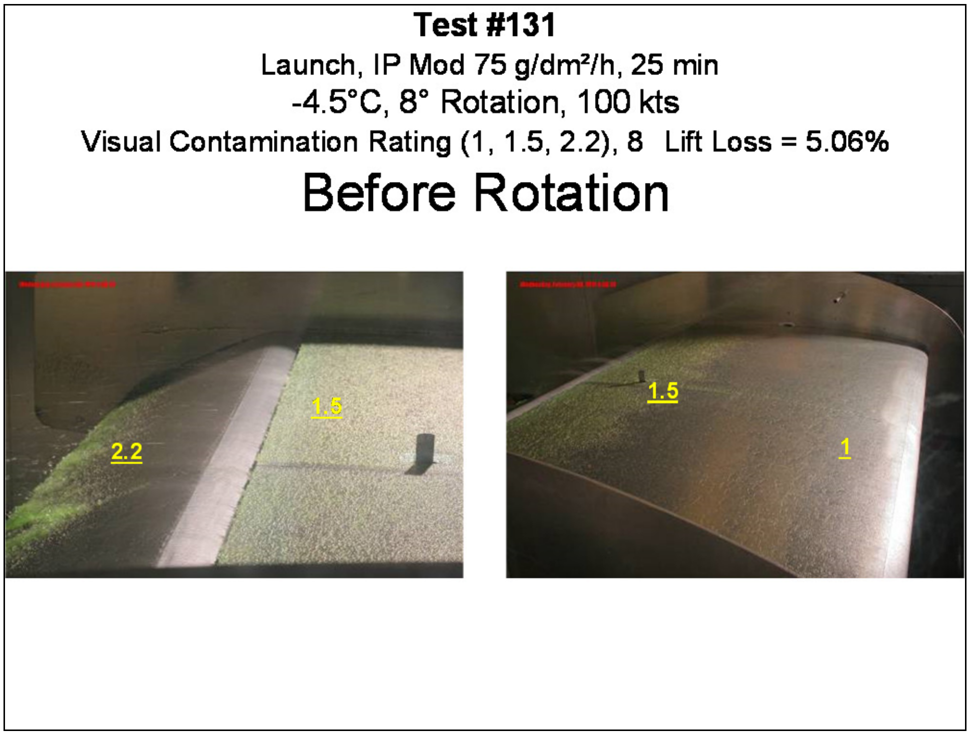
Launch, IP Mod 75 g/dm²/h, 25 min

-4.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.8, 3.3, 3.9)

Start of Test

Photo 7.138: Test #131 – Before Rotation



Test #131

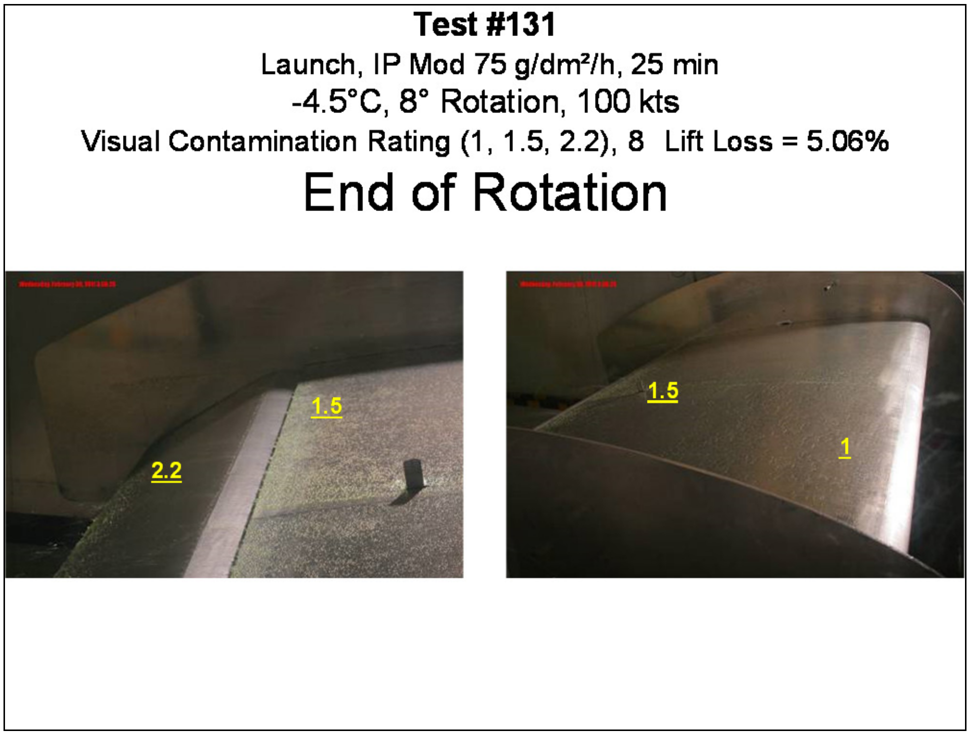
Launch, IP Mod 75 g/dm²/h, 25 min

-4.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.5, 2.2), 8 Lift Loss = 5.06%

Before Rotation

Photo 7.139: Test #131 – End of Rotation



Test #131

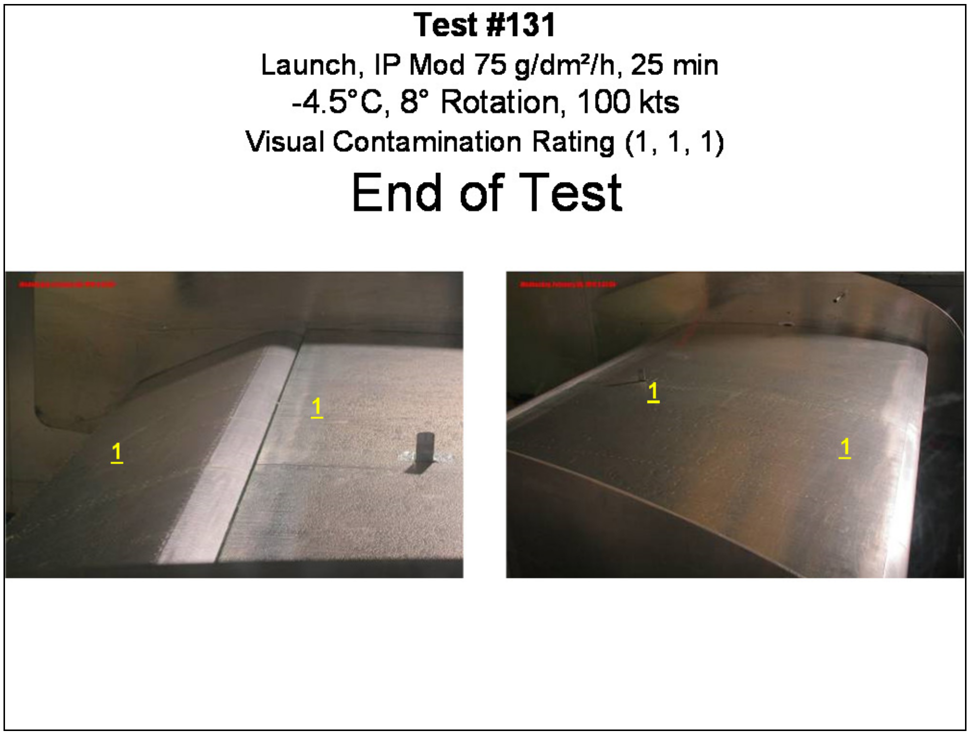
Launch, IP Mod 75 g/dm²/h, 25 min

-4.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.5, 2.2), 8 Lift Loss = 5.06%

End of Rotation

Photo 7.140: Test #131 – End of Test



Test #131

Launch, IP Mod 75 g/dm²/h, 25 min

-4.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 7.141: Test #132 – Start of Test

Test #132

Max-Flight, IP Mod 75 g/dm²/h, 25 min

-5.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.8, 3, 3.9)

Start of Test

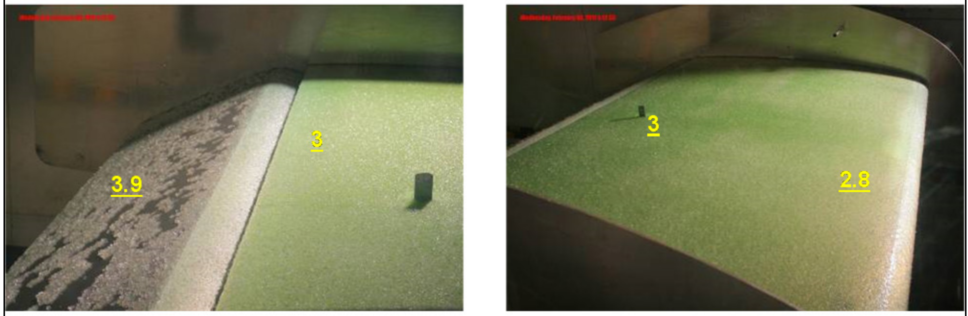


Photo 7.142: Test #132 – Before Rotation

Test #132

Max-Flight, IP Mod 75 g/dm²/h, 25 min

-5.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.6, 2), 8 Lift Loss = 6.89%

Before Rotation

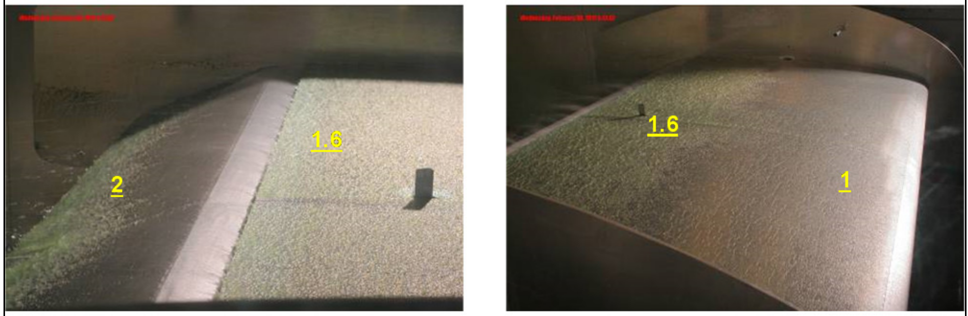
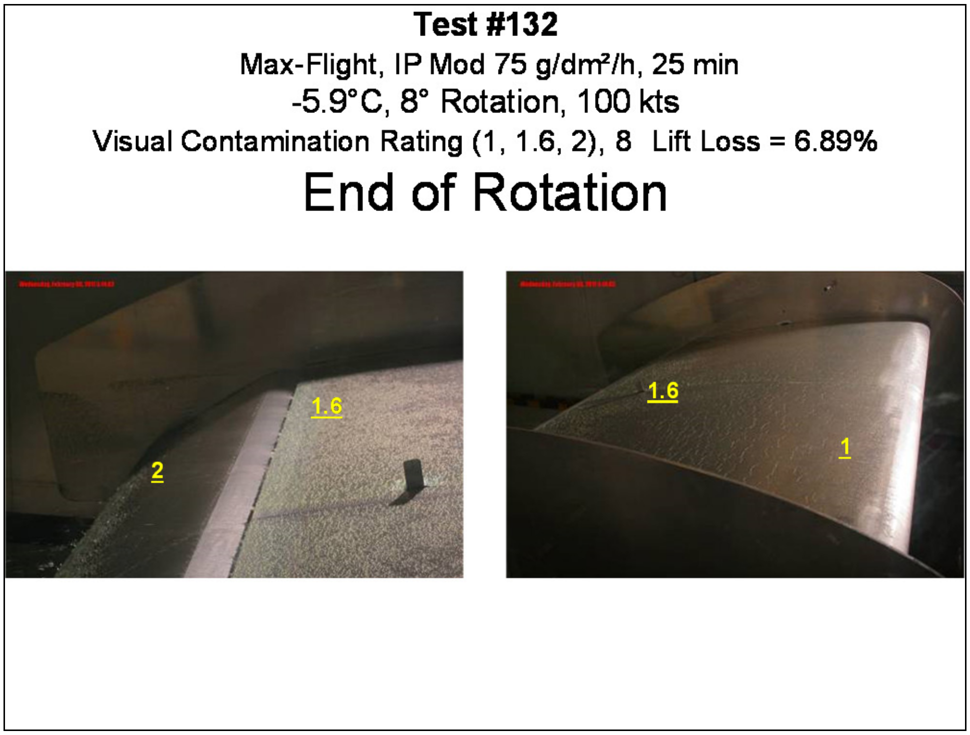
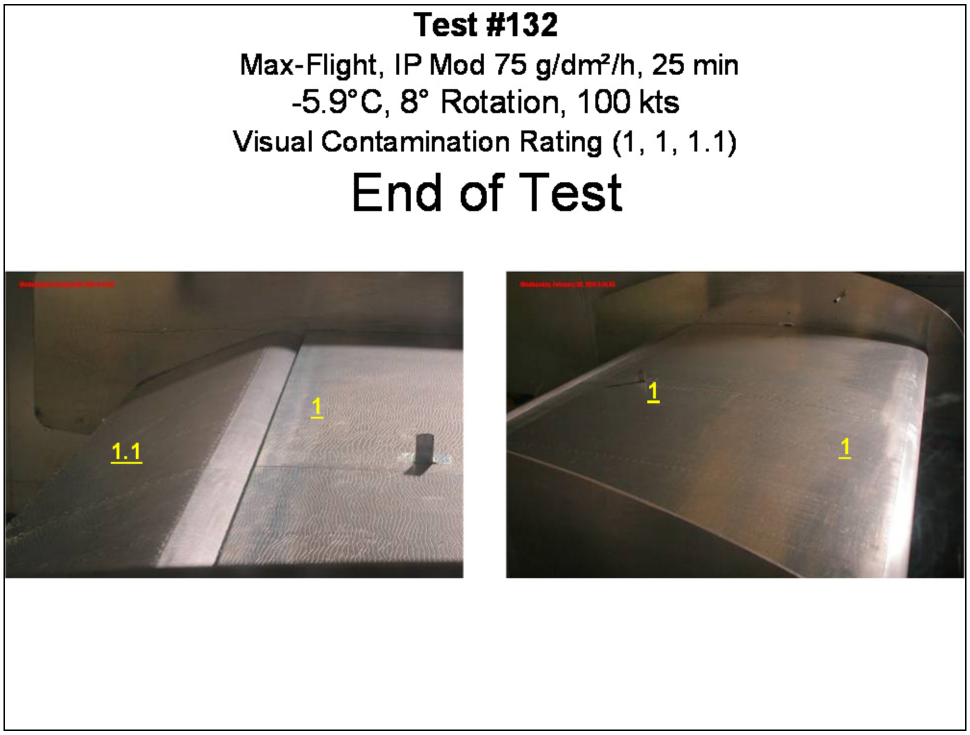


Photo 7.143: Test #132 – End of Rotation



Test #132
Max-Flight, IP Mod 75 g/dm²/h, 25 min
-5.9°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1.6, 2), 8 Lift Loss = 6.89%
End of Rotation

Photo 7.144: Test #132 – End of Test



Test #132
Max-Flight, IP Mod 75 g/dm²/h, 25 min
-5.9°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1.1)
End of Test

8. LIGHT ICE PELLETS MIXED WITH LIGHT FREEZING RAIN ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Previous testing in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Light Freezing Rain;
- Section 9: Light Ice Pellets and Moderate Rain;
- Section 10: Light Ice Pellets and Light Snow;
- Section 11: Light Ice Pellets and Moderate Snow; and
- Section 12: Light Ice Pellets and Light Rain.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellets and Light Freezing Rain conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

8.1 Overview of Tests

A summary of the Light Ice Pellet and Light Freezing Rain tests conducted in the wind tunnel is shown in Table 8.1. The table provides relevant information for each of the tests, as well as the final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1. The following is a brief description of the column headings for Table 8.1:

Test #:	Exclusive number identifying each test.
Date:	Date when the test was conducted.

Fluid:	Aircraft deicing fluid specified by product name; all fluids were in the “neat” 100/0 dilution.
Condition:	Simulated precipitation condition.
Precipitation Rate (g/dm²/h):	Simulated freezing precipitation rate (or combination of different precipitation rates). “N/A” indicates that no precipitation was applied.
Precip. Time (min.):	Total time of exposure to simulated precipitation.
Tunnel Temp. at Start of Test (ºC):	The tunnel air temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Flap Angle (º):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended).
Speed (kts):	Maximum speed attained at time of rotation.
Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present.

	3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
CL at 8° During Rotation:	Calculated lift coefficient at the 8° wing rotation angle position; data provided by the NRC.
% Lift Loss:	% Lift Loss calculated based on the comparison of the 8° lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).
Associated Baseline Run:	The associated fluid only baseline run based on fluid selection.

Table 8.1: Summary of 2010-11 Light Ice Pellets and Light Freezing Rain Testing

Test No.	Date	Fluid	Associated Fluid Only Test	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
102	2-Feb-11	AD-49	5A	IP- / ZR-	IP:25,ZR:25	10	-6.2	-7.1	20	100	3.2 , 2.1 , 2.8	1.1 , 1.6 , 1.6	1.326	6.75
103	2-Feb-11	Max-Flight	75	IP- / ZR-	IP:25,ZR:25	10	-6.5	-8.6	20	100	2.5 , 2.4 , 3.1	1.1 , 1.5 , 1.8	1.314	7.59
128	9-Feb-11	AD-49	5A	IP- / ZR-	IP:2 ,ZR:25	25	-3.2	-3.8	20	100	2.5 , 2.5 , 2.7	1.1 , 1.3 , 1.5	1.363	4.15
5A	19-Jan-11	AD-49	-	Fluid Only	-	-	-10.4	-8.2	8	100	1 , 1 , 1	1 , 1 , 1	1.367	-
75	28-Jan-11	Max-Flight	-	Fluid Only	-	-	-5.8	-4.2	8	100	1 , 1 , 1	1 , 1 , 1	1.316	-

8.2 Data Collected

8.2.1 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.2. Fluid thickness measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix G shows the fluid thickness measurements collected during the contaminated fluid tests.

8.2.2 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.3. Skin temperature measurements were recorded at the following intervals:

- Before fluid application;
- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix H shows the wing temperature measurements recorded during the contaminated fluid tests.

8.2.3 Fluid Brix Data

Fluid Brix measurements were recorded at the following intervals by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.4. Fluid Brix measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and

- After the simulated takeoff test.

Appendix I shows the fluid Brix measurements collected during the contaminated fluid tests.

8.3 Photos

High-speed digital photographs of each test were taken; wide-angle photos were taken of the leading edge, and close-up photos were taken of the trailing edge. For each test, photo summaries have been compiled comprising four stages:

- Start of test;
- Before Rotation (just before the wing began to pitch);
- End of Rotation (end of the rotation cycle when the wing position is returned to 4 degrees); and
- End of test.

The photos taken during the light ice pellet mixed with light freezing rain testing have been presented along with the fluid only (baseline) tests for comparison purposes. Photos 8.1 to 8.20 show the photo summaries of the tests conducted in accordance with the order presented in Table 8.1. A complete set of photos will be provided to the TDC in electronic format.

8.4 Summary of Results

8.4.1 OAT -5°C and Above

One test (#128) was conducted with exposure times of 25 minutes in this cell: See Table 8.2 for a summary of the tests.

Test #128, conducted at a temperature of -3.2°C with a PG fluid, demonstrated a satisfactory result. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 4.15 percent, which is below the 5.4 percent lower limit. The results of this test do not suggest a need to change the current allowance time of 25 minutes. See Table 8.3 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that the current allowance time of 25 minutes for this cell is acceptable and validated.

Table 8.2: Light Ice Pellets and Light Freezing Rain Allowance Time Tests Winter 2010-11

Light Ice Pellets and Light Freezing Rain	**OAT -5°C and Above**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	25 minutes **Test # 128**	10 minutes **Test # 102, 103**	**Caution: No allowance times currently exist**

Table 8.3: Summary of Light Ice Pellets and Light Freezing Rain Allowance Time Test Results

OAT -5°C AND ABOVE (25 MINUTES)

Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
128	*AD-49*	*-3.2*	IP:25 ,ZR:25	*25*	2.5 , 2.5 , 2.7	GOOD	1.1 , 1.3 , 1.5	REVIEW	*4.15*	REVIEW	REVIEW

Notes:

CONCLUSION: ALLOWANCE TIME AT 25 MINUTES IS GOOD

OAT LESS THAN -5°C TO -10°C (10 MINUTES)

Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
102	*AD-49*	*-6.2*	IP:25 , ZR:25	*10*	3.2 , 2.1 , 2.8	REVIEW	1.1 , 1.6 , 1.6	REVIEW	*6.75*	REVIEW	REVIEW
103	*Max-Flight*	*-6.5*	IP:25 ,ZR:25	*10*	2.5 , 2.4 , 3.1	REVIEW	1.1 , 1.5 , 1.8	REVIEW	*7.59*	REVIEW	REVIEW

Notes:

CONCLUSION: ALLOWANCE TIME AT 10 MINUTES IS GOOD

8.4.2 OAT Less than -5°C to -10°C

Two tests were conducted with exposure times of 10 minutes in this cell: Tests #102 and #103. See Table 8.2 for a summary of the tests.

Test #102, conducted at a temperature of -8.2°C with a PG fluid, demonstrated a satisfactory result. The visual rating at the start of test and the results at rotation were deemed satisfactory. The lift loss at 8° was 6.75 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a need to change the current allowance time of 10 minutes. See Table 8.3 for the details of this test.

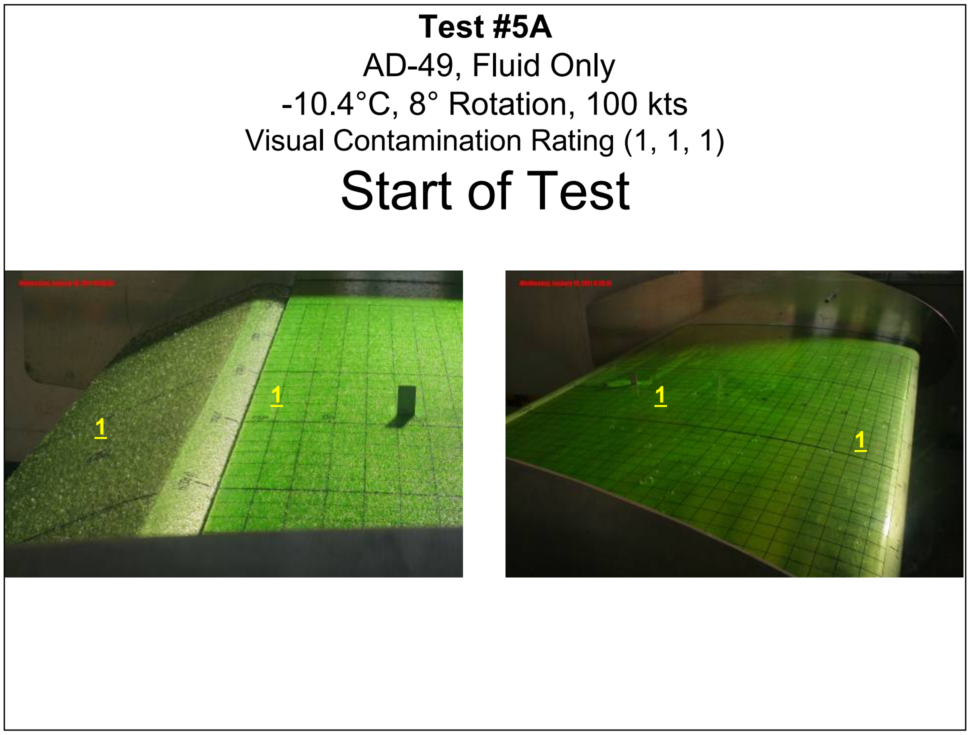
Test #103, conducted at a temperature of -6.5°C with a PG fluid, demonstrated a satisfactory result. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 7.59 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test do not suggest a need to change the current allowance time of 10 minutes. See Table 8.3 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that the current allowance time of 10 minutes for this cell is acceptable and validated.

8.4.3 OAT Less than -10°C

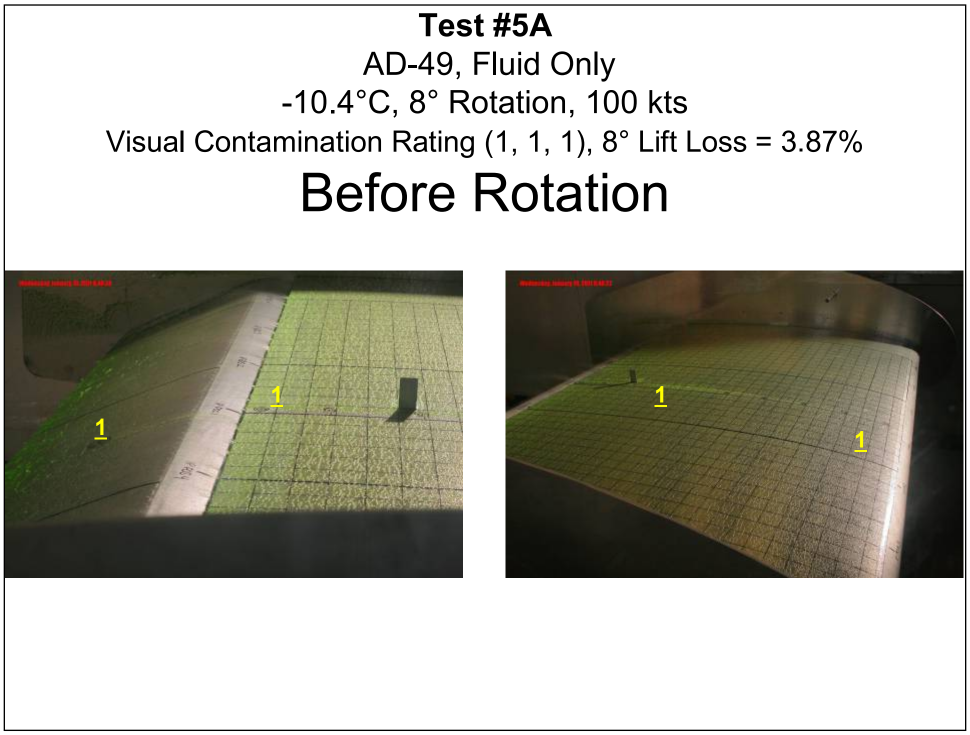
No allowance times currently exist in this cell.

Photo 8.1: Test # 5A – Start of Test



Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 8.2: Test #5A – Before Rotation



Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8° Lift Loss = 3.87%
Before Rotation

Photo 8.3: Test #5A – End of Rotation

Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8° Lift Loss = 3.87%

End of Rotation

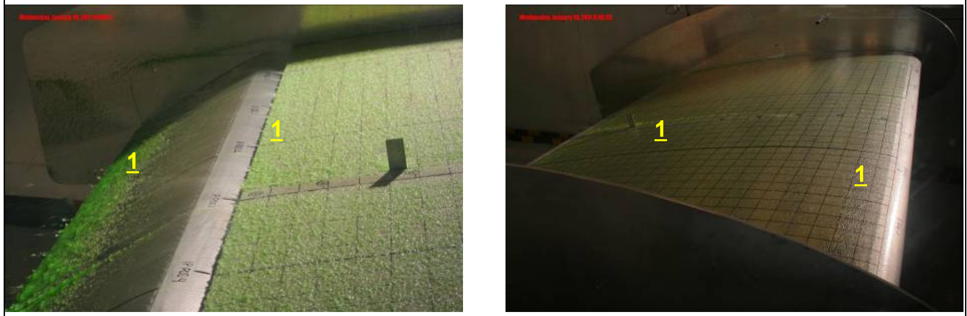


Photo 8.4: Test #5A – End of Test

Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

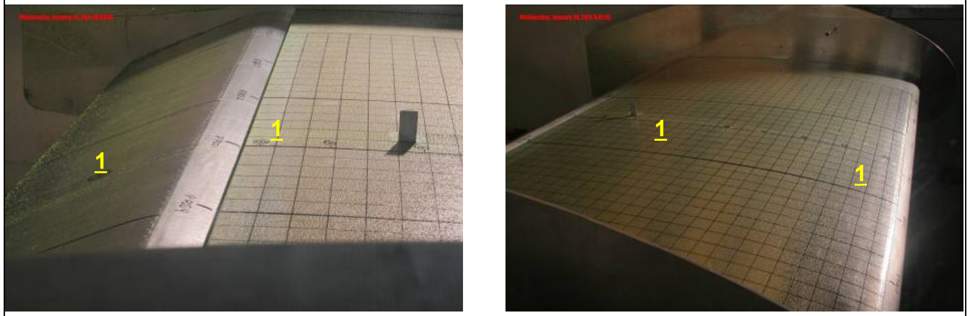
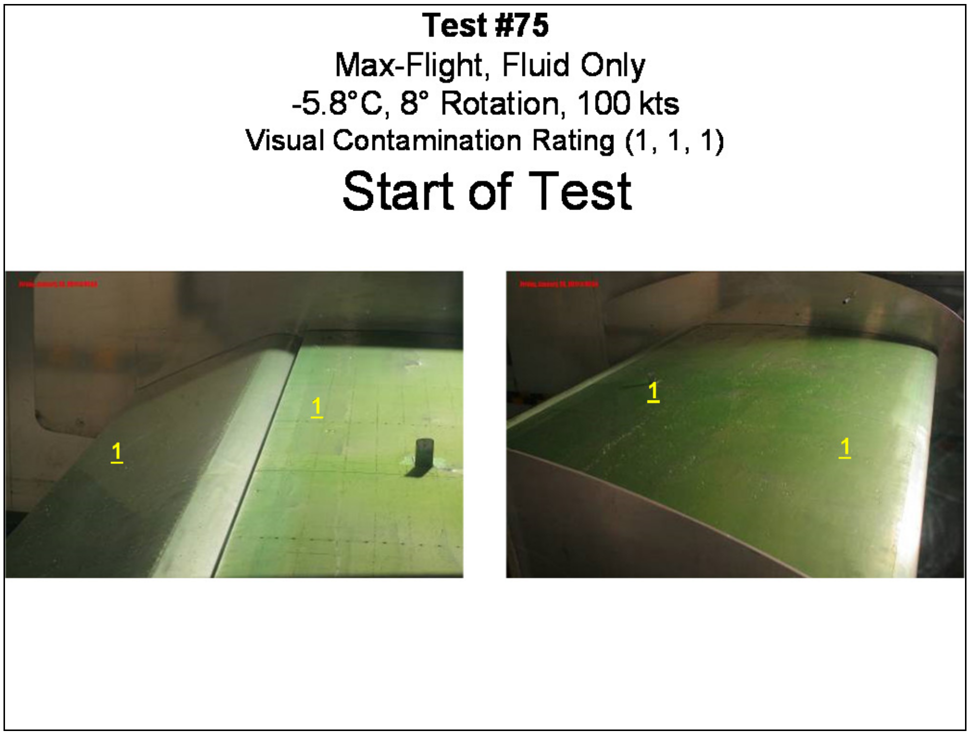
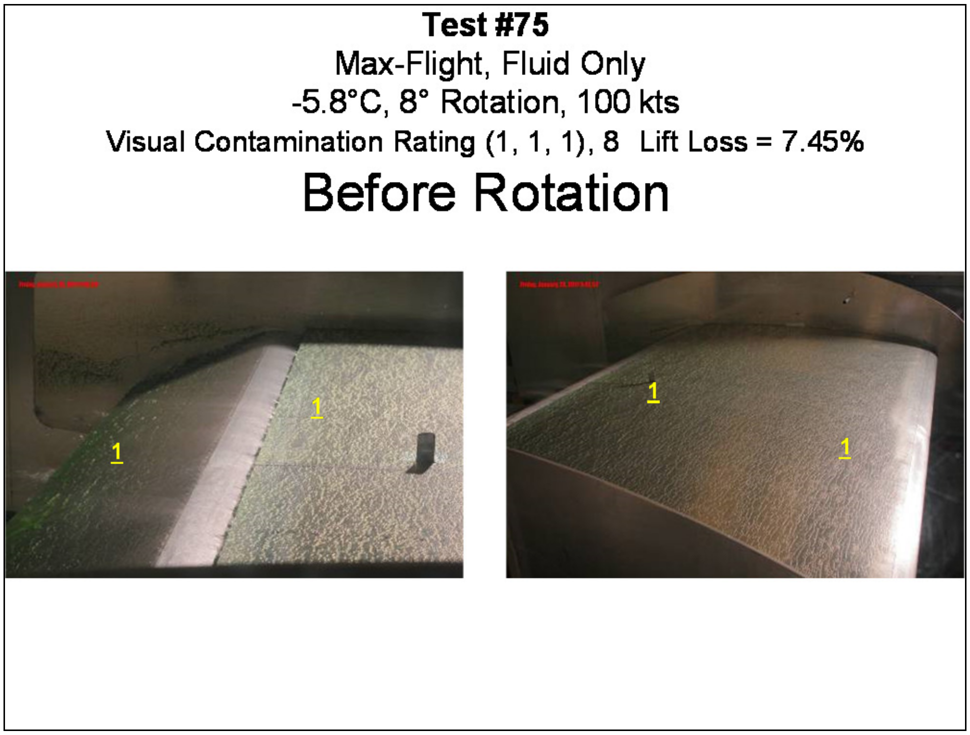


Photo 8.5: Test #75 – Start of Test



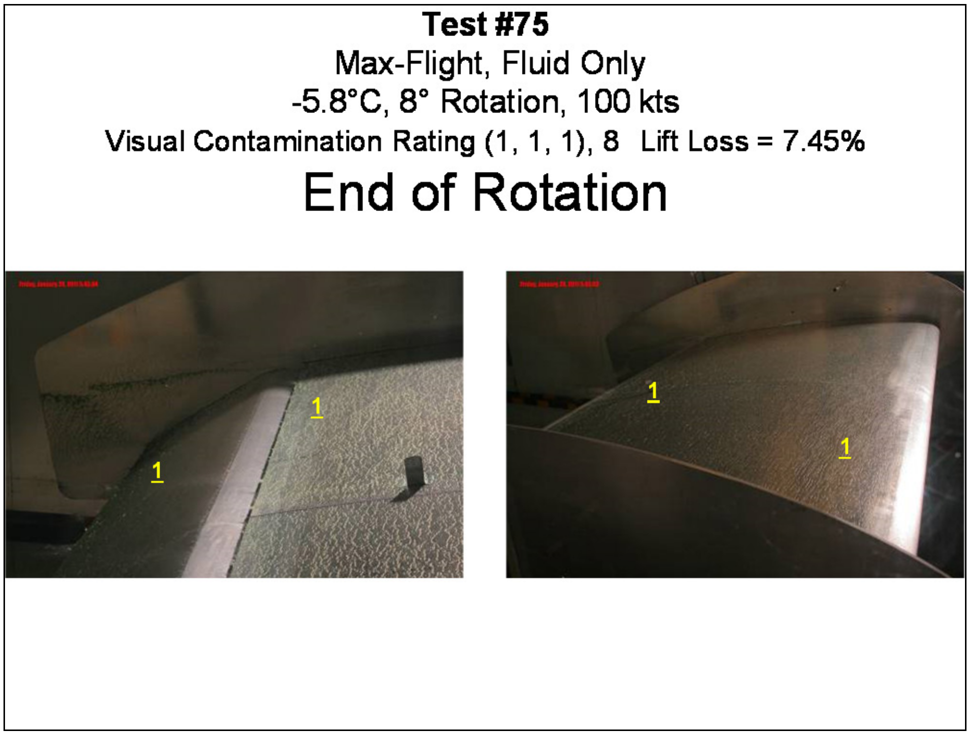
Test #75
Max-Flight, Fluid Only
-5.8°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 8.6: Test #75 – Before Rotation



Test #75
Max-Flight, Fluid Only
-5.8°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 7.45%
Before Rotation

Photo 8.7: Test #75 – End of Rotation



Test #75

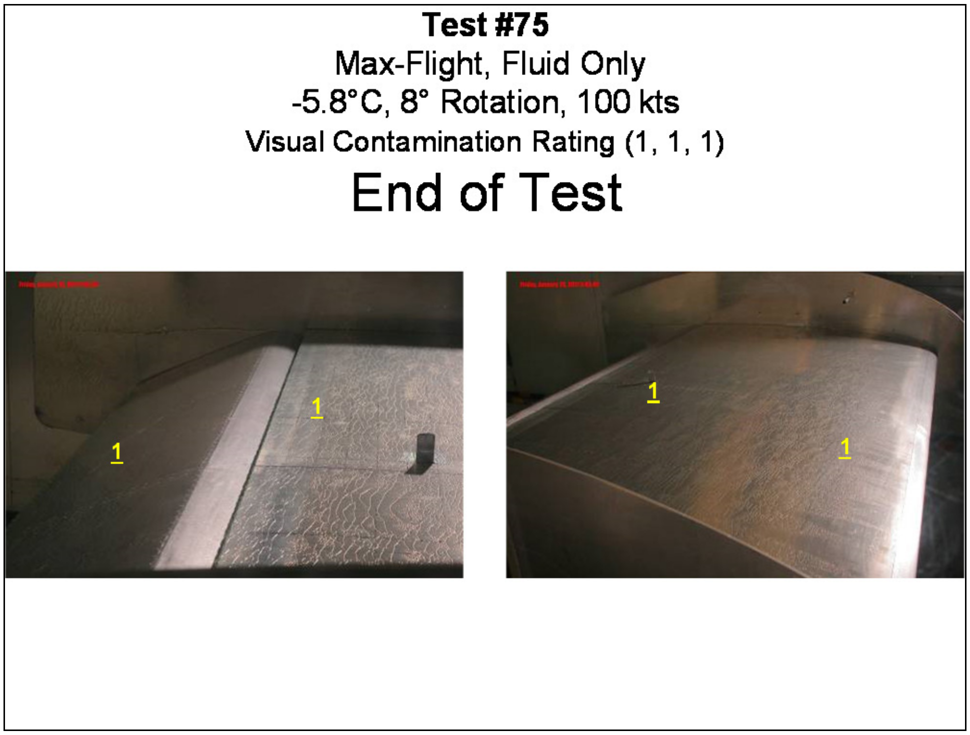
Max-Flight, Fluid Only

-5.8°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 7.45%

End of Rotation

Photo 8.8: Test #75 – End of Test



Test #75

Max-Flight, Fluid Only

-5.8°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 8.9: Test #102 – Start of Test

Test #102

AD-49, IP- + ZR- 25 + 25 g/dm²/h, 10 min
-6.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (3.2, 2.1, 2.8)

Start of Test

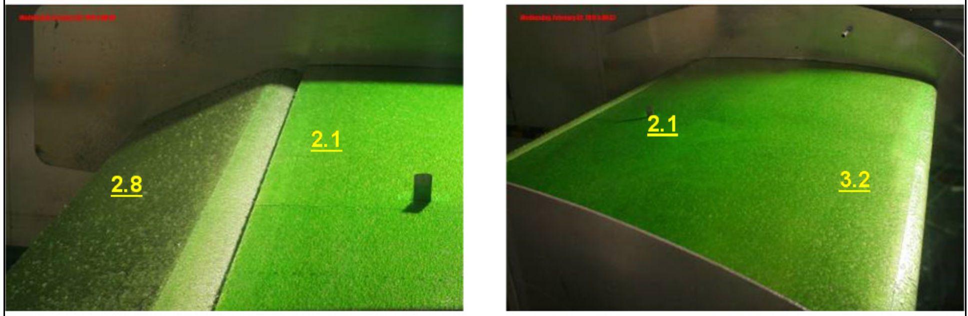


Photo 8.10: Test #102 – Before Rotation

Test #102

AD-49, IP- + ZR- 25 + 25 g/dm²/h, 10 min
-6.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1.1, 1.6, 1.6), 8 Lift Loss = 6.75%

Before Rotation

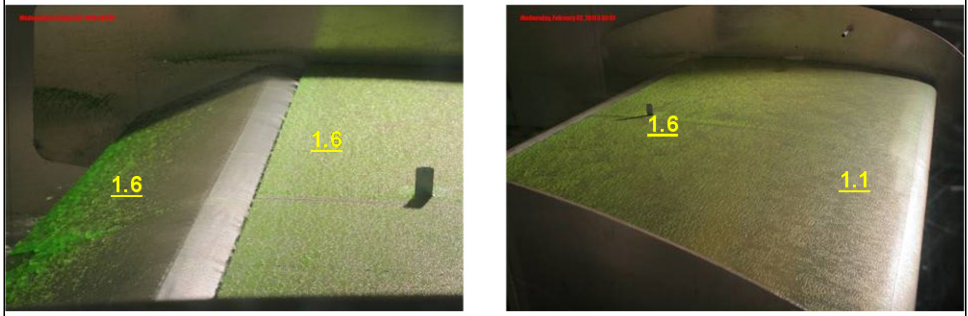
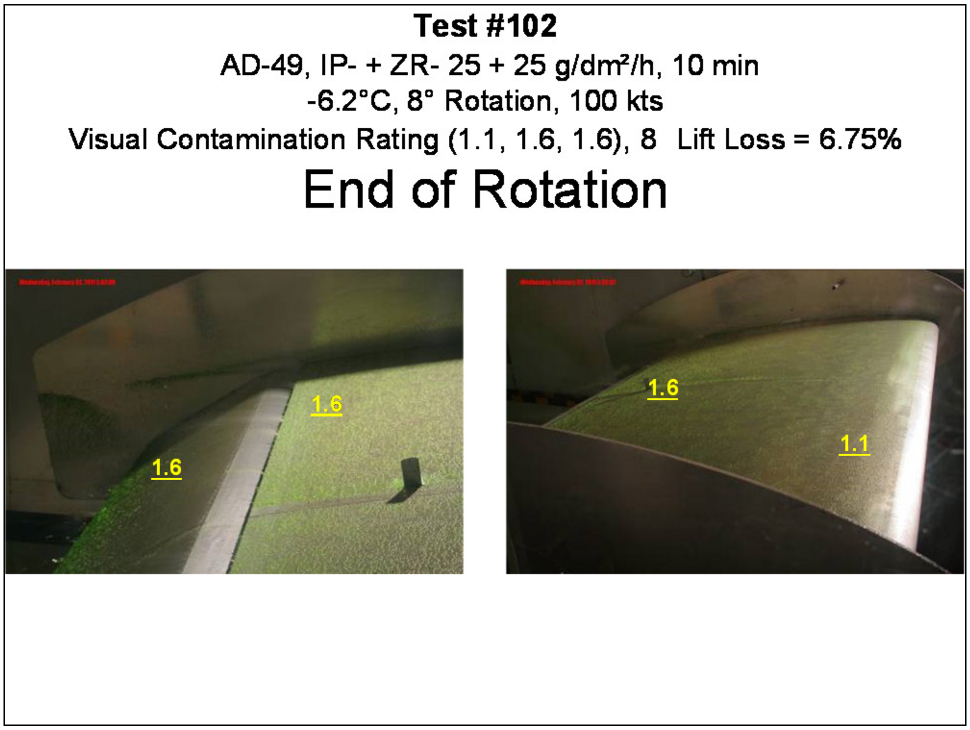


Photo 8.11: Test #102 – End of Rotation



Test #102

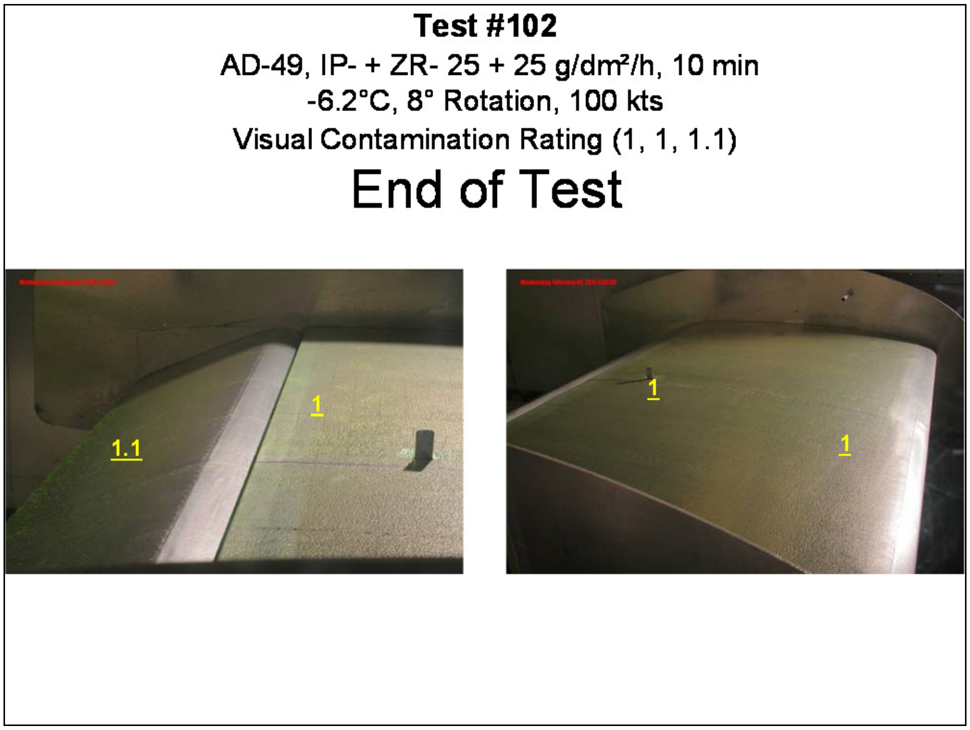
AD-49, IP- + ZR- 25 + 25 g/dm²/h, 10 min

-6.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.6, 1.6), 8 Lift Loss = 6.75%

End of Rotation

Photo 8.12: Test #102 – End of Test



Test #102

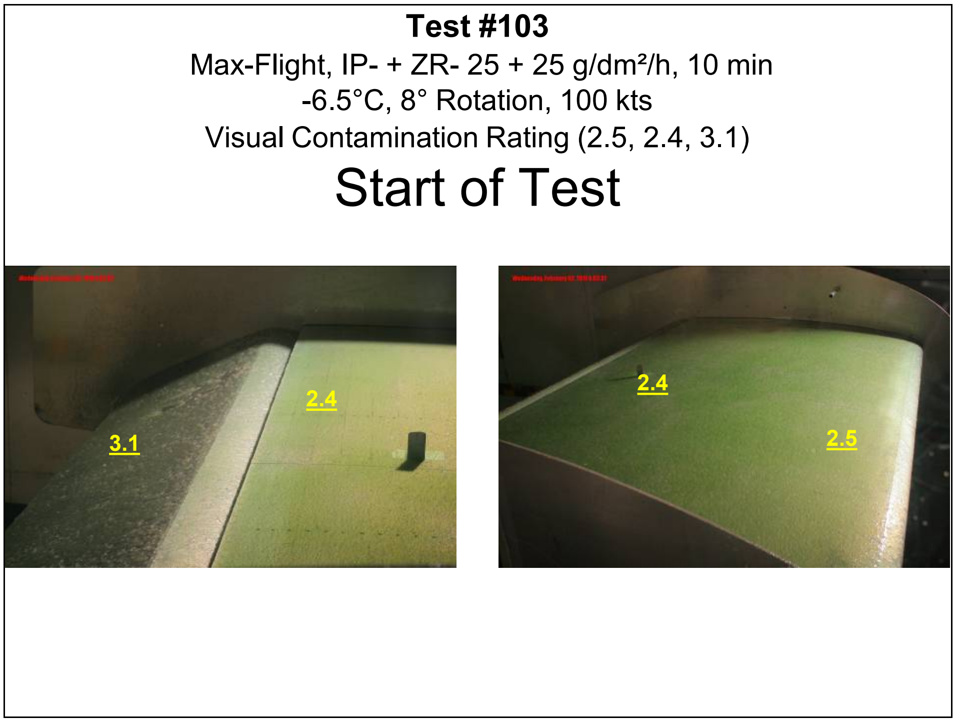
AD-49, IP- + ZR- 25 + 25 g/dm²/h, 10 min

-6.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.1)

End of Test

Photo 8.13: Test #103 – Start of Test



Test #103

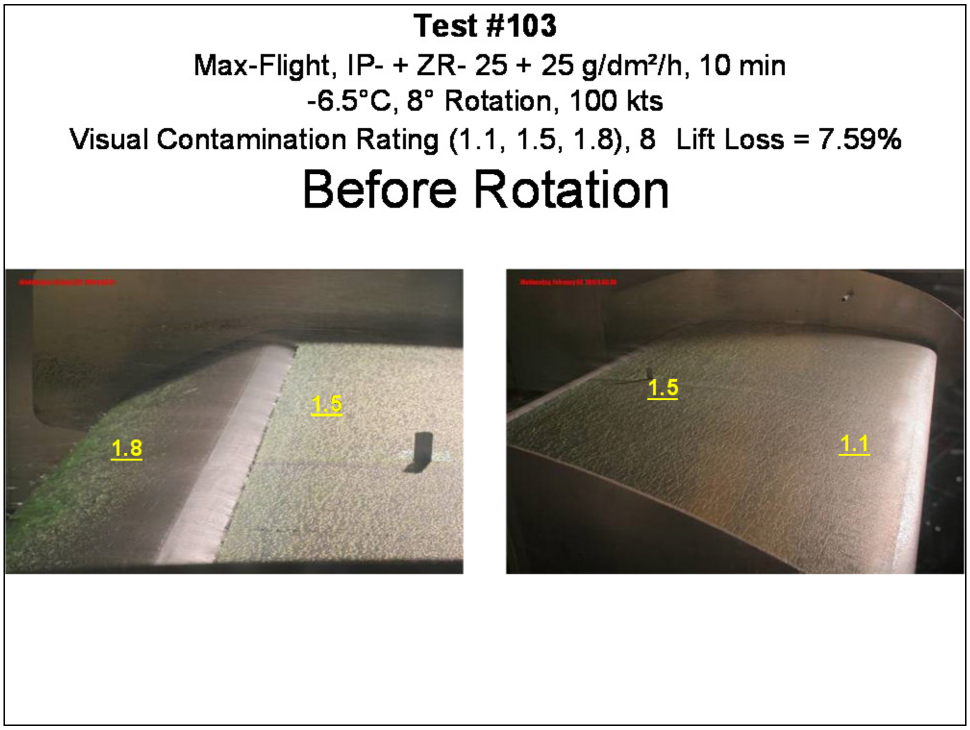
Max-Flight, IP- + ZR- 25 + 25 g/dm²/h, 10 min

-6.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.5, 2.4, 3.1)

Start of Test

Photo 8.14: Test #103 – Before Rotation



Test #103

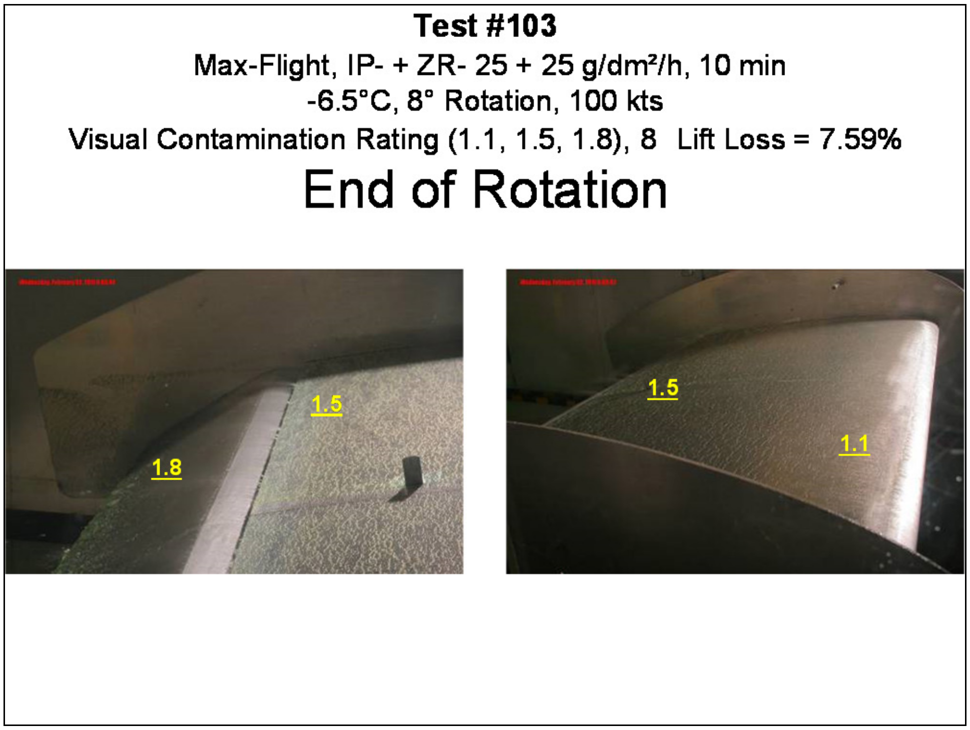
Max-Flight, IP- + ZR- 25 + 25 g/dm²/h, 10 min

-6.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.5, 1.8), 8 Lift Loss = 7.59%

Before Rotation

Photo 8.15: Test #103 – End of Rotation



Test #103

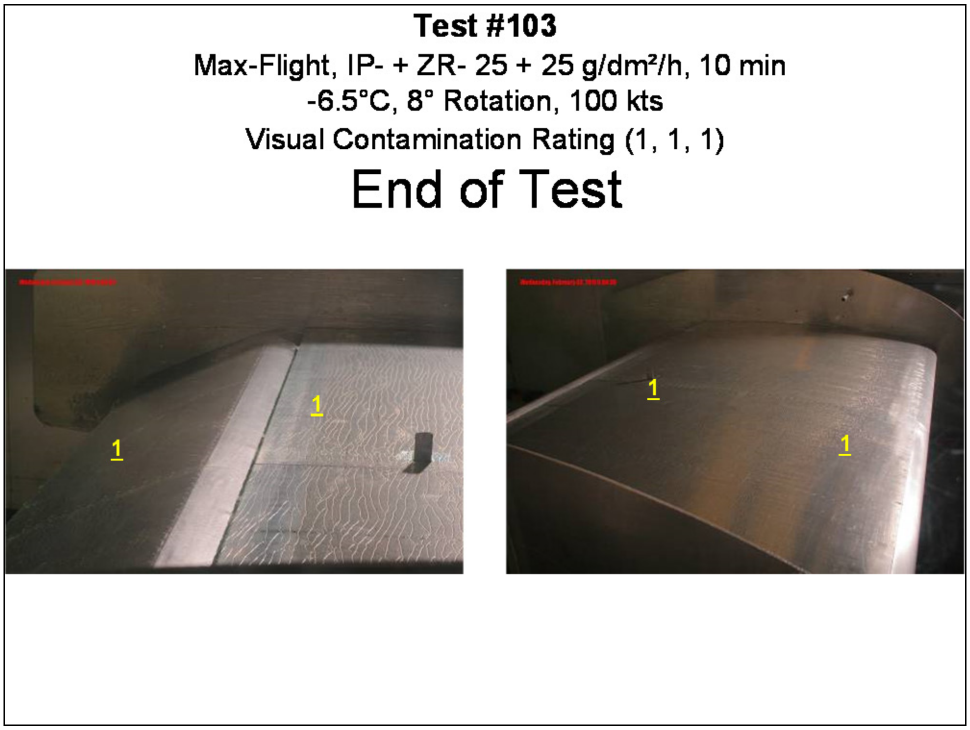
Max-Flight, IP- + ZR- 25 + 25 g/dm²/h, 10 min

-6.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.5, 1.8), 8 Lift Loss = 7.59%

End of Rotation

Photo 8.16: Test #103 – End of Test



Test #103

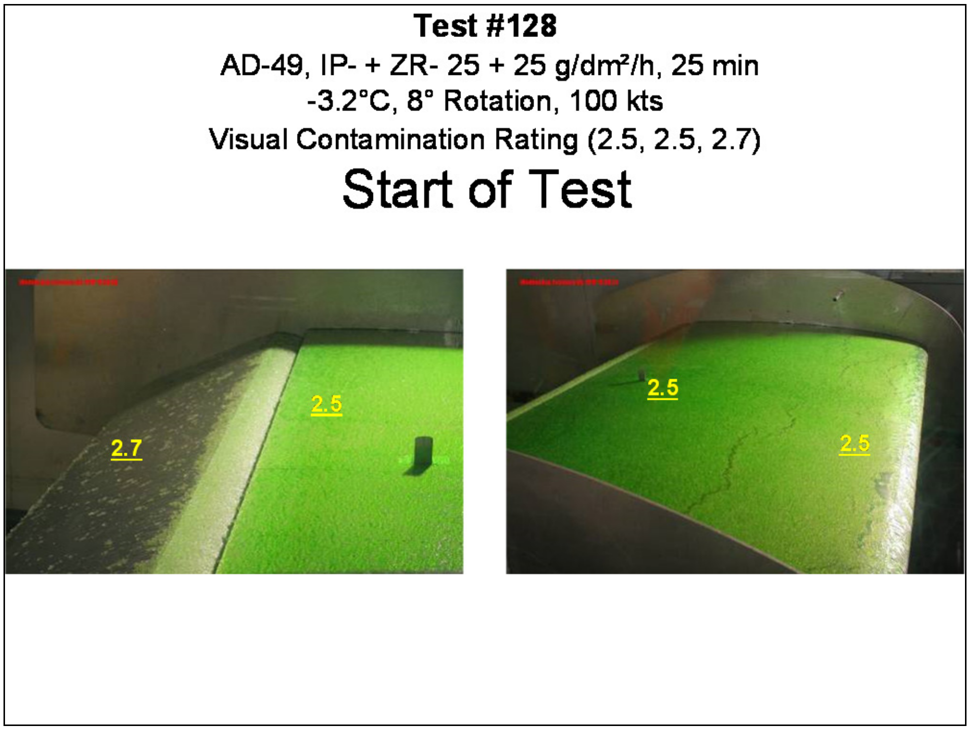
Max-Flight, IP- + ZR- 25 + 25 g/dm²/h, 10 min

-6.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 8.17: Test #128 – Start of Test



Test #128

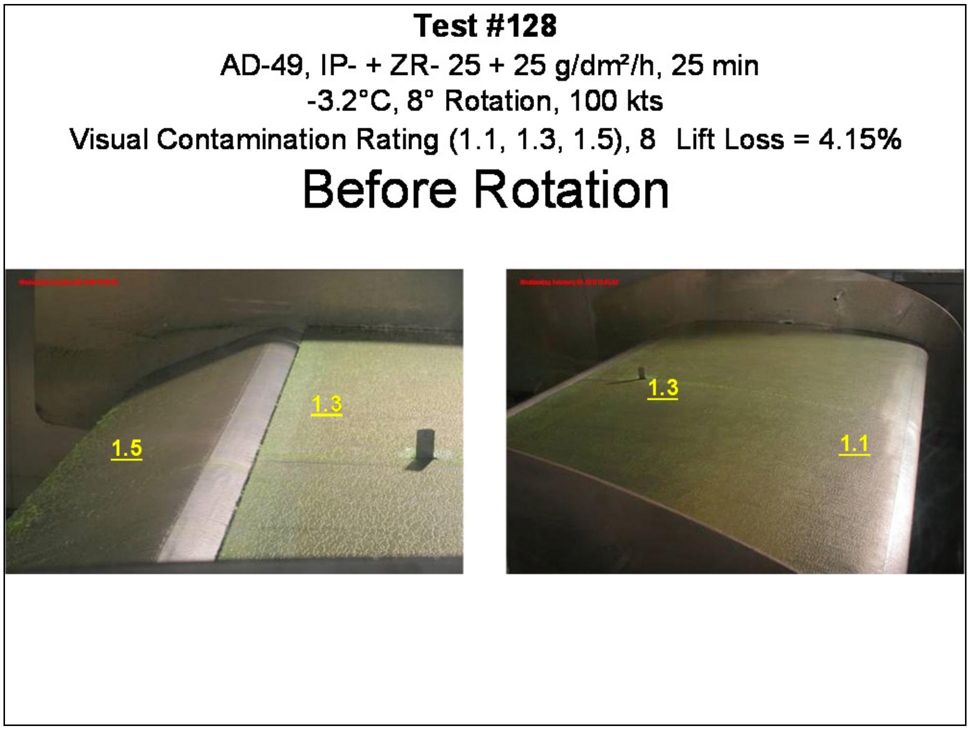
AD-49, IP- + ZR- 25 + 25 g/dm²/h, 25 min

-3.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.5, 2.5, 2.7)

Start of Test

Photo 8.18: Test #128 – Before Rotation



Test #128

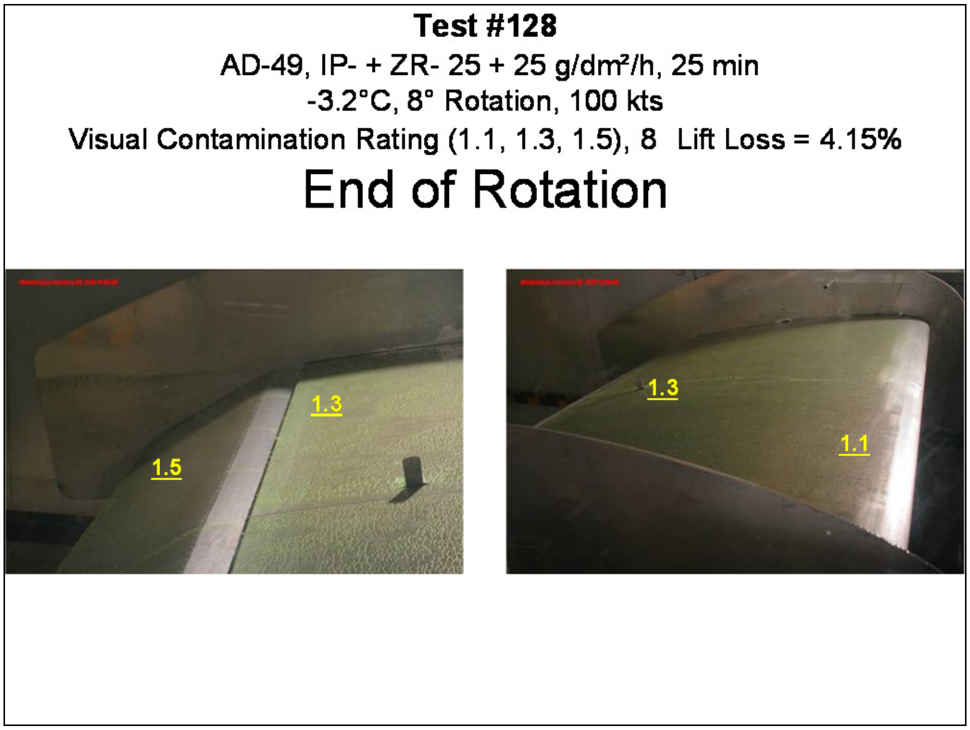
AD-49, IP- + ZR- 25 + 25 g/dm²/h, 25 min

-3.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.3, 1.5), 8 Lift Loss = 4.15%

Before Rotation

Photo 8.19: Test #128 – End of Rotation



Test #128

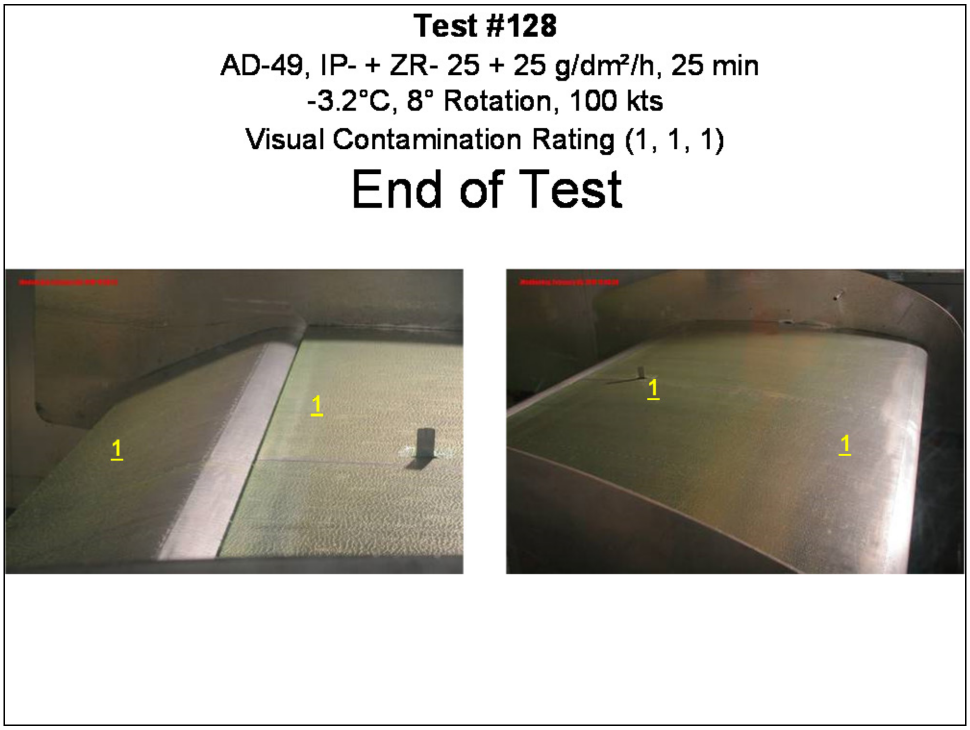
AD-49, IP- + ZR- 25 + 25 g/dm²/h, 25 min

-3.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.3, 1.5), 8 Lift Loss = 4.15%

End of Rotation

Photo 8.20: Test #128 – End of Test



Test #128

AD-49, IP- + ZR- 25 + 25 g/dm²/h, 25 min

-3.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

9. LIGHT ICE PELLETS MIXED WITH MODERATE RAIN ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Previous testing in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Light Freezing Rain;
- Section 9: Light Ice Pellets and Moderate Rain;
- Section 10: Light Ice Pellets and Light Snow;
- Section 11: Light Ice Pellets and Moderate Snow; and
- Section 12: Light Ice Pellets and Light Rain.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellets and Moderate Rain conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

9.1 Overview of Tests

A summary of the Light Ice Pellets and Moderate Rain tests conducted in the wind tunnel is shown in Table 9.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1. The following is a brief description of the column headings for Table 9.1.

Test #:	Exclusive number identifying each test.
Date:	Date when the test was conducted.

Fluid:	Aircraft deicing fluid specified by product name; all fluids were in the "neat" 100/0 dilution.
Condition:	Simulated precipitation condition.
Precipitation Rate (g/dm²/h):	Simulated freezing precipitation rate (or combination of different precipitation rates). "N/A" indicates that no precipitation was applied.
Precip. Time (min.):	Total time of exposure to simulated precipitation.
Tunnel Temp. at Start of Test (ºC):	The tunnel air temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Flap Angle (º):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended).
Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present.

	3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
CL at 8º During Rotation:	Calculated lift coefficient at the 8° wing rotation angle position; data provided by the NRC.
% Lift Loss:	% Lift Loss calculated based on the comparison of the 8° lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).
Associated Baseline Run:	The associated fluid only baseline run based on fluid selection.

Table 9.1: Summary of 2010-11 Light Ice Pellets and Moderate Rain Testing

Test No.	*Date*	*Fluid*	*Associated Fluid Only Test*	*Condition*	*Precipitation Rate (g/dm²/h)*	*Precipitation Time (min)*	*Tunnel Temp. at Start of Test (°C)*	*AVG Wing Temp. Before Test (°C)*	*Flap Angle (°)*	*Speed (kts)*	*Visual Cont. Rating Before Takeoff (LE, TE, Flap)*	*Visual Cont. Rating at Rotation (LE, TE, Flap)*	*CL at 8° During Rotation*	*8° Lift Loss (%)*
115	*7-Feb-11*	*EG 106*	*52*	*IP- / R Mod*	*IP:25 , R:75*	*25*	*1.4*	*1.5*	*20*	*100*	*2.3 , 1.3 , 1.6*	*1 , 1 , 1*	*1.416*	*0.42*
116	*7-Feb-11*	*ABC-S+*	*54*	*IP- / R Mod*	*IP:25 , R:75*	*25*	*3*	*2.9*	*20*	*100*	*1.2 , 1.3 , 1.3*	*1 , 1 , 1.1*	*1.388*	*2.39*
52	*25-Jan-11*	*EG 106*	*-*	*Fluid Only*	*-*	*-*	*-13.4*	*-12.6*	*20*	*100*	*1 , 1 , 1*	*1 , 1 , 1*	*1.363*	*2.78*
54	*26-Jan-11*	*ABC-S+*	*-*	*Fluid Only*	*-*	*-*	*-12.1*	*-13.3*	*20*	*100*	*1 , 1 , 1*	*1 , 1 , 1*	*1.321*	*5.78*

9.2 Data Collected

9.2.1 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.2. Fluid thickness measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix G shows the fluid thickness measurements collected during the contaminated fluid tests.

9.2.2 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.3. Skin temperature measurements were recorded at the following intervals:

- Before fluid application;
- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix H shows the wing temperature measurements recorded during the contaminated fluid tests.

9.2.3 Fluid Brix Data

Fluid Brix measurements were recorded at the following intervals by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.4. Fluid Brix measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix I shows the fluid Brix measurements collected during the contaminated fluid tests.

9.3 Photos

High-speed digital photographs of each test were taken; wide-angle photos were taken of the leading edge, and close-up photos were taken of the trailing edge. For each test, photo summaries have been compiled comprising four stages:

- Start of test;
- Before Rotation (just before the wing began to pitch);
- End of Rotation (end of the rotation cycle when the wing position is returned to 4 degrees); and
- End of test.

The photos taken during the light ice pellets mixed with moderate rain testing have been presented along with the fluid only (baseline) tests for comparison purposes. In each case, the fluid only photo is presented first, followed by the contaminated fluid photo. Photos 9.1 to 9.16 show the photo summaries of the tests conducted in accordance with the order presented in Table 9.1. A complete set of photos will be provided to the TDC in electronic format.

9.4 Summary of Results

9.4.1 OAT -5°C and Above

Two tests were conducted with exposure times of 25 minutes in this cell: #115 and #116. See Table 9.2 for a summary of the tests.

Test #115, conducted with EG fluid, demonstrated very good results. The temperature during this test run was +1.4°C. The lift coefficient and the visual rating results were deemed good. The 8° lift loss was 0.42 percent, well below the 5.4 percent lower limit. Due to the positive results that were displayed, there is potential to further expand the current allowance time for EG fluids; however, more testing would be required. See Table 9.3 for the details of this test.

Test #116, conducted with PG fluid, demonstrated very good results. The temperature during this test run was +3.0°C. The lift coefficient and the visual rating results were deemed good. The 8° lift loss was 2.39 percent, well below the

5.4 percent lower limit. Due to the positive results that were displayed, there is potential to further expand the current allowance time for PG fluids. More testing would be required. See Table 9.3 for the details of this test.

In conclusion, these tests demonstrated positive results, indicating that the current allowance time of 25 minutes for this cell is acceptable and validated.

Table 9.2: Light Ice Pellet Light Ice Pellets and Moderate Rain Allowance Time Tests Winter 2010-11

Light Ice Pellets Mixed with Moderate Rain	**OAT -5°C and Above (No allowance times below 0°C)**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	25 minutes **Test # 115, 116**	**Caution: No allowance times currently exist**	

9.4.2 OAT Less than -5°C to -10°C

No allowance times currently exist in this cell.

9.4.3 OAT Less than -10°C

No allowance times currently exist in this cell.

Table 9.3: Summary of Light Ice Pellet Light Ice Pellets and Moderate Rain Allowance Time Test Results

OAT -5°C AND ABOVE (25 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
115	*EG 106*	*1.4*	IP:25 , R:75	*25*	2.3 , 1.3 , 1.6	GOOD	1 , 1 , 1	GOOD	*0.42*	GOOD	GOOD
116	*ABC-S+*	*3*	IP:25 , R:75	*25*	1.2 , 1.3 , 1.3	GOOD	1 , 1 , 1.1	GOOD	*2.39*	GOOD	GOOD

Notes:

CONCLUSION: ALLOWANCE TIME AT 25 MINUTES IS GOOD

OAT LESS THAN -5°C TO -10°C (30 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status

Notes:

CONCLUSION: NO ALLOWANCE TIMES CURRENTLY EXIST

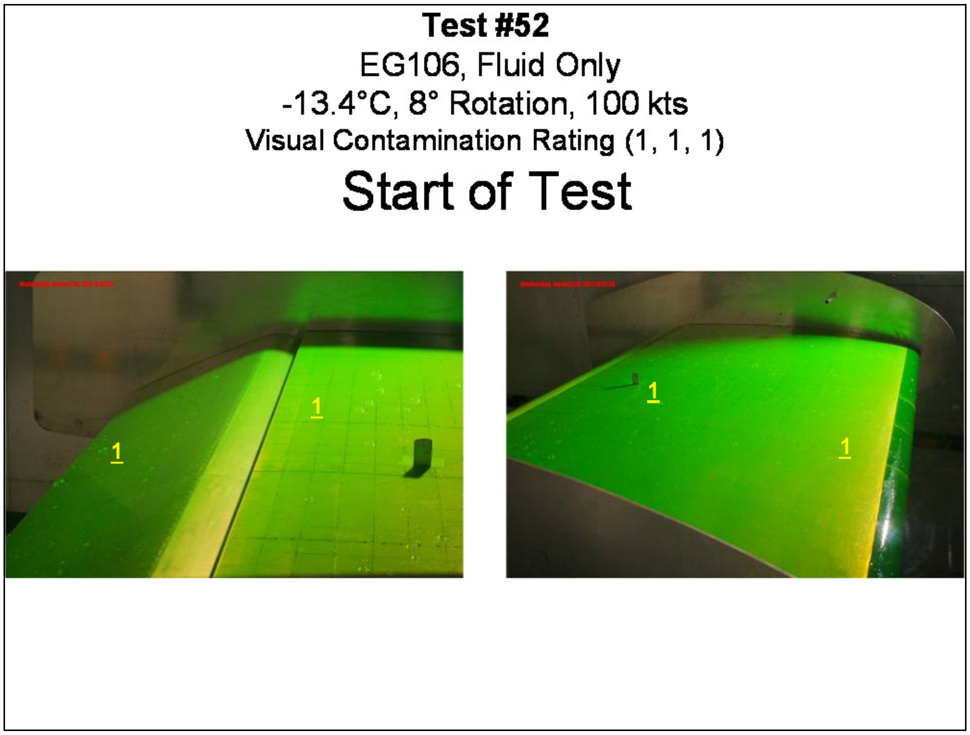
OAT LESS THAN -10°C (30 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status

Notes:

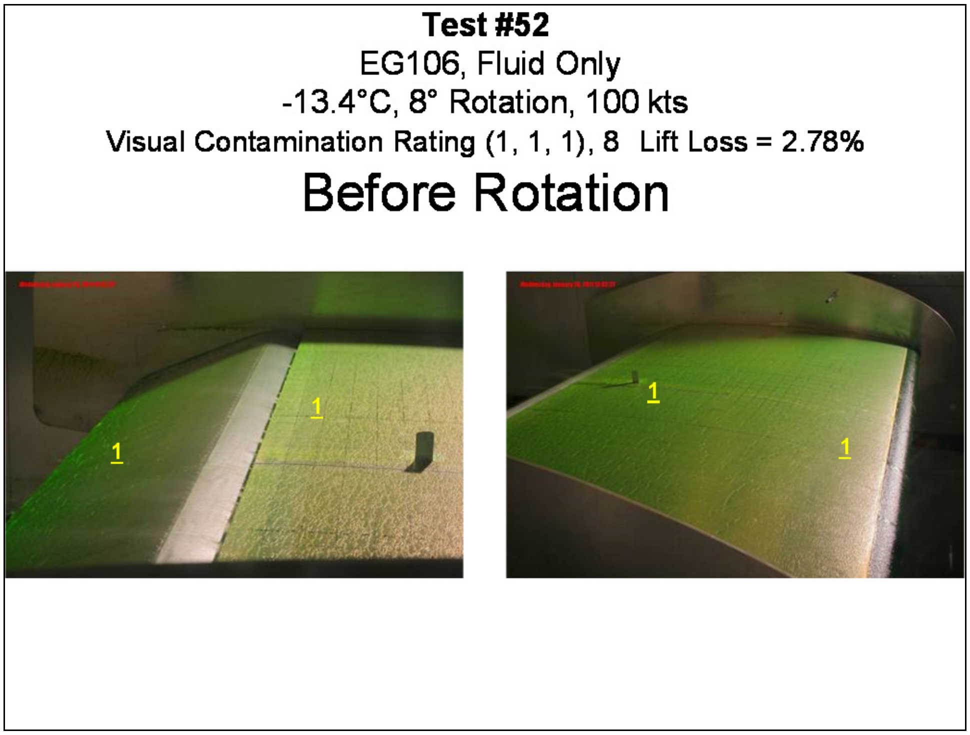
CONCLUSION: NO ALLOWANCE TIMES CURRENTLY EXIST

Photo 9.1: Test #52 – Start of Test



Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 9.2: Test #52 – Before Rotation



Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%
Before Rotation

Photo 9.3: Test #52 – End of Rotation

Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%

End of Rotation

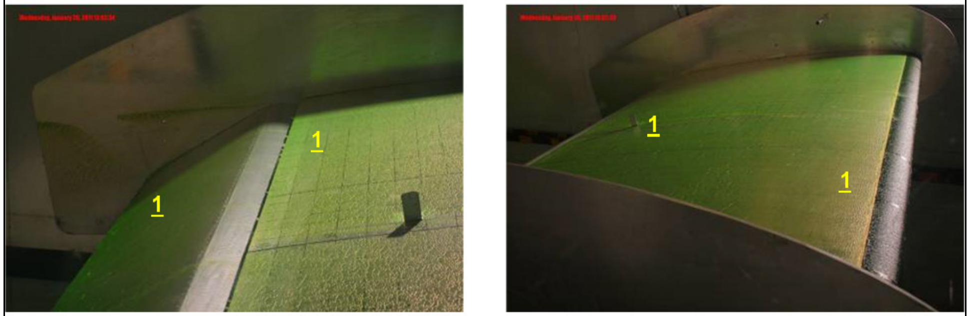


Photo 9.4: Test #52 – End of Test

Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

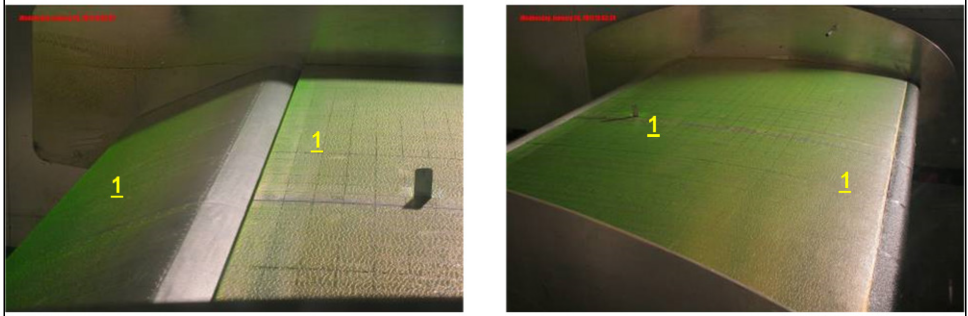
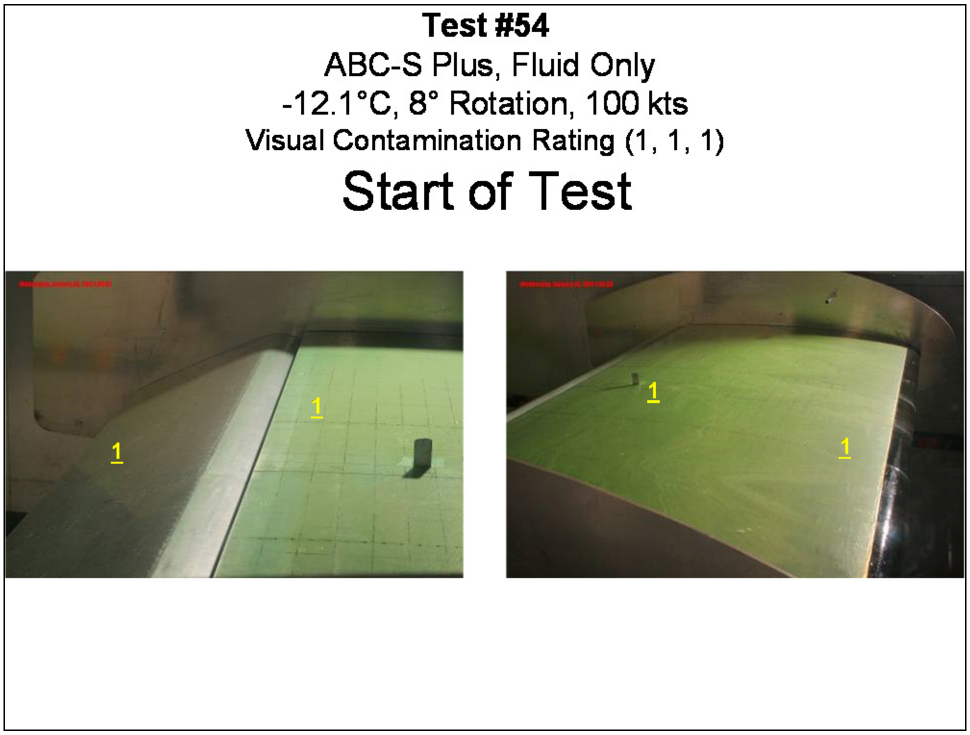


Photo 9.5: Test #54 – Start of Test



Test #54

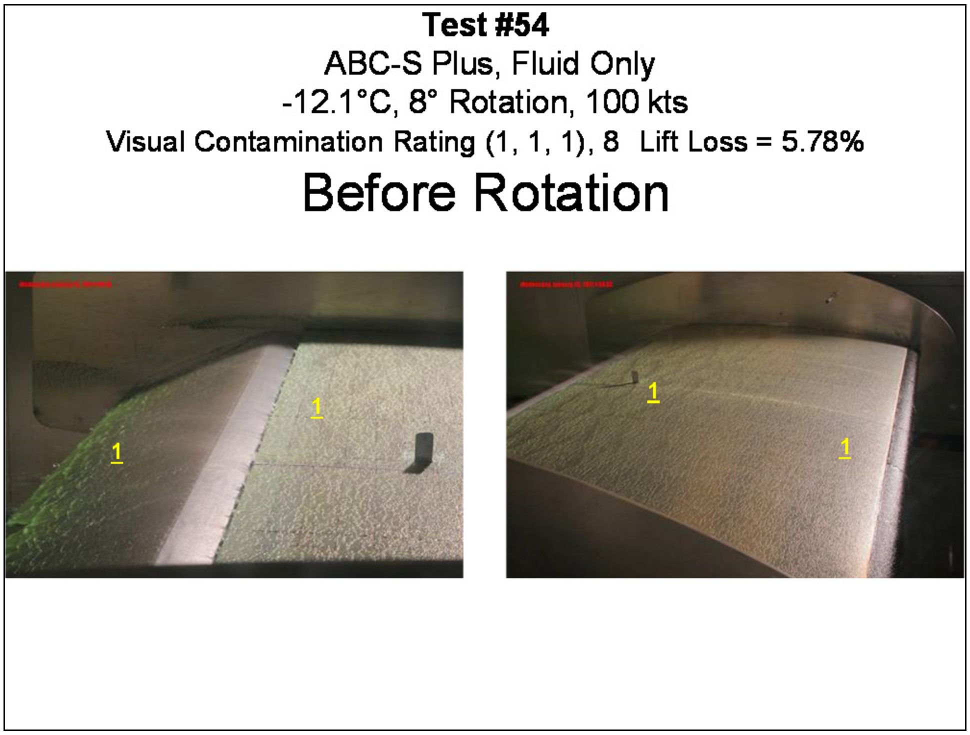
ABC-S Plus, Fluid Only

-12.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 9.6: Test #54 – Before Rotation



Test #54

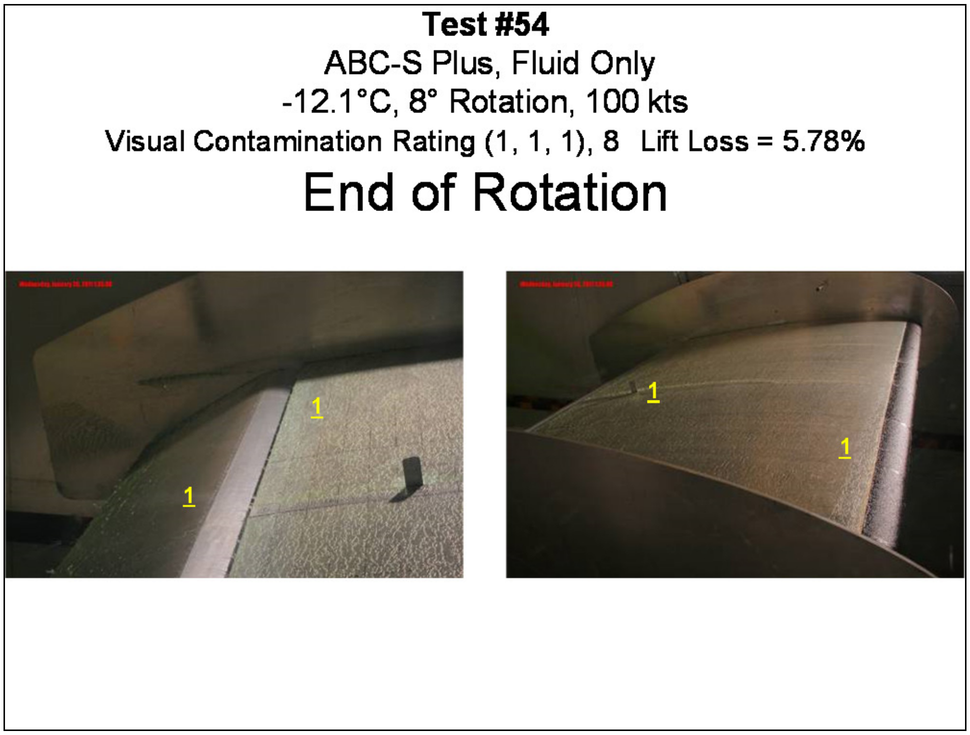
ABC-S Plus, Fluid Only

-12.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.78%

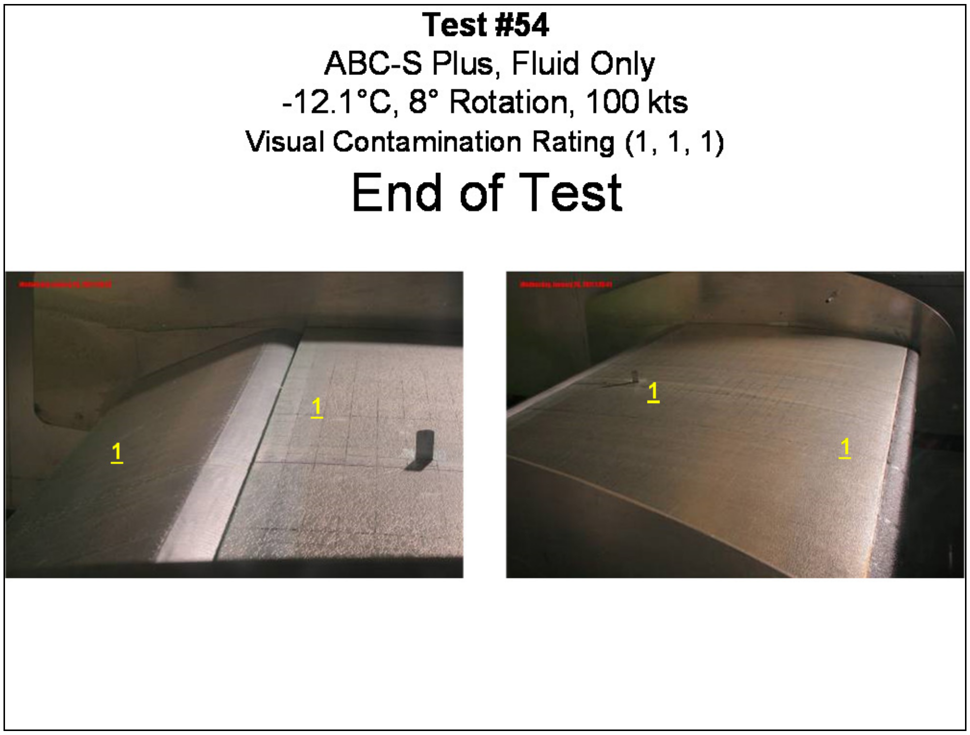
Before Rotation

Photo 9.7: Test #54 – End of Rotation



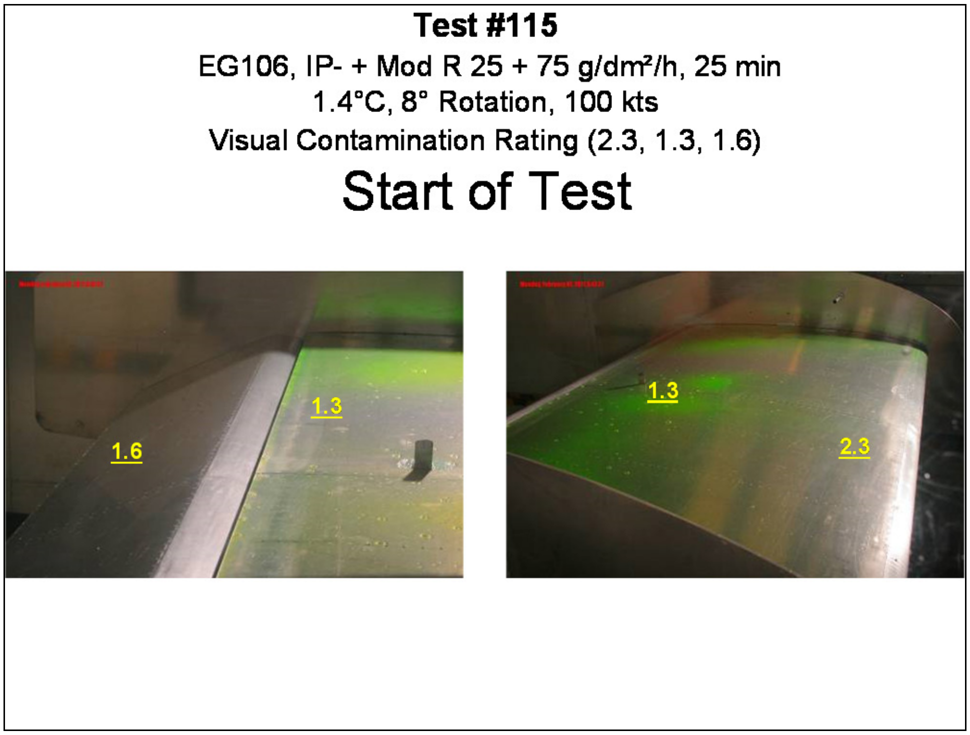
Test #54
ABC-S Plus, Fluid Only
-12.1°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.78%
End of Rotation

Photo 9.8: Test #54 – End of Test



Test #54
ABC-S Plus, Fluid Only
-12.1°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 9.9: Test #115 – Start of Test



Test #115

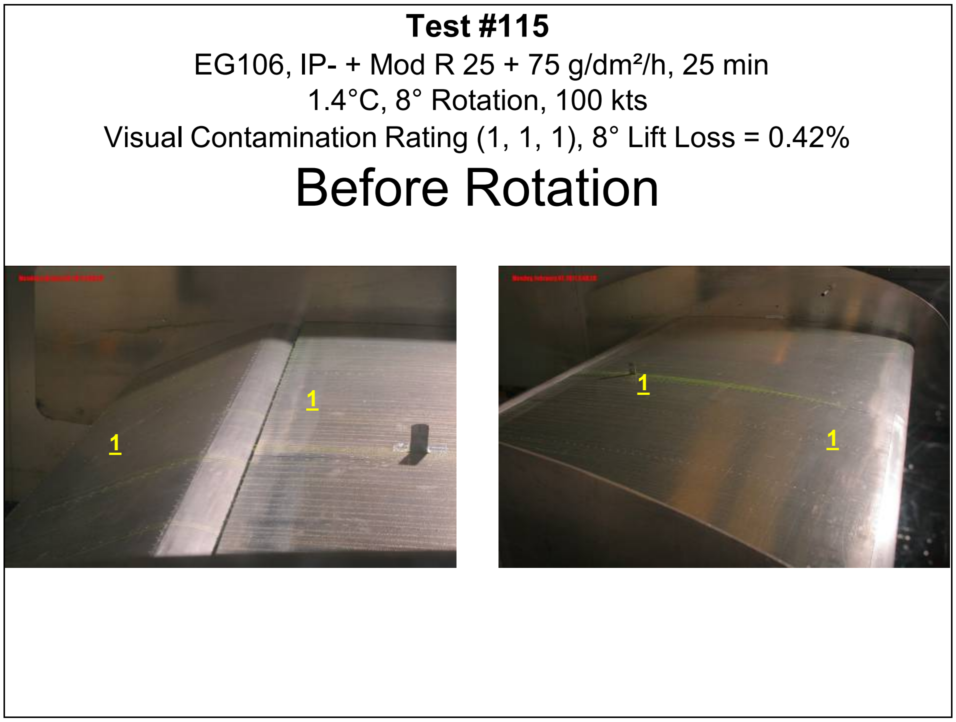
EG106, IP- + Mod R 25 + 75 g/dm²/h, 25 min

1.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.3, 1.3, 1.6)

Start of Test

Photo 9.10: Test #115 – Before Rotation



Test #115

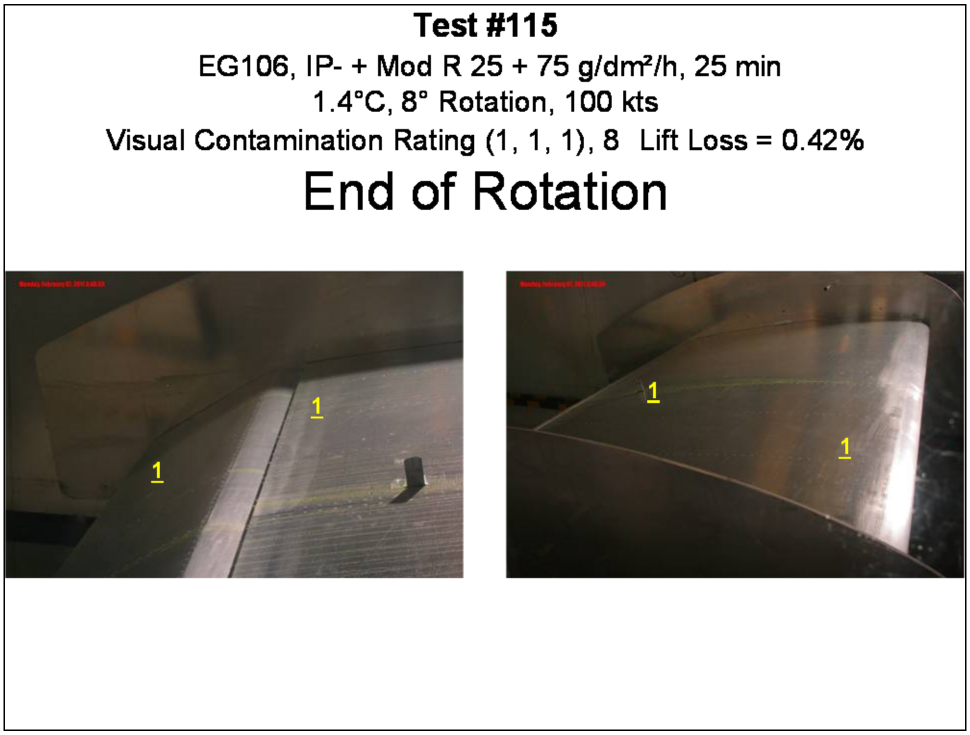
EG106, IP- + Mod R 25 + 75 g/dm²/h, 25 min

1.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8° Lift Loss = 0.42%

Before Rotation

Photo 9.11: Test #115 – End of Rotation



Test #115

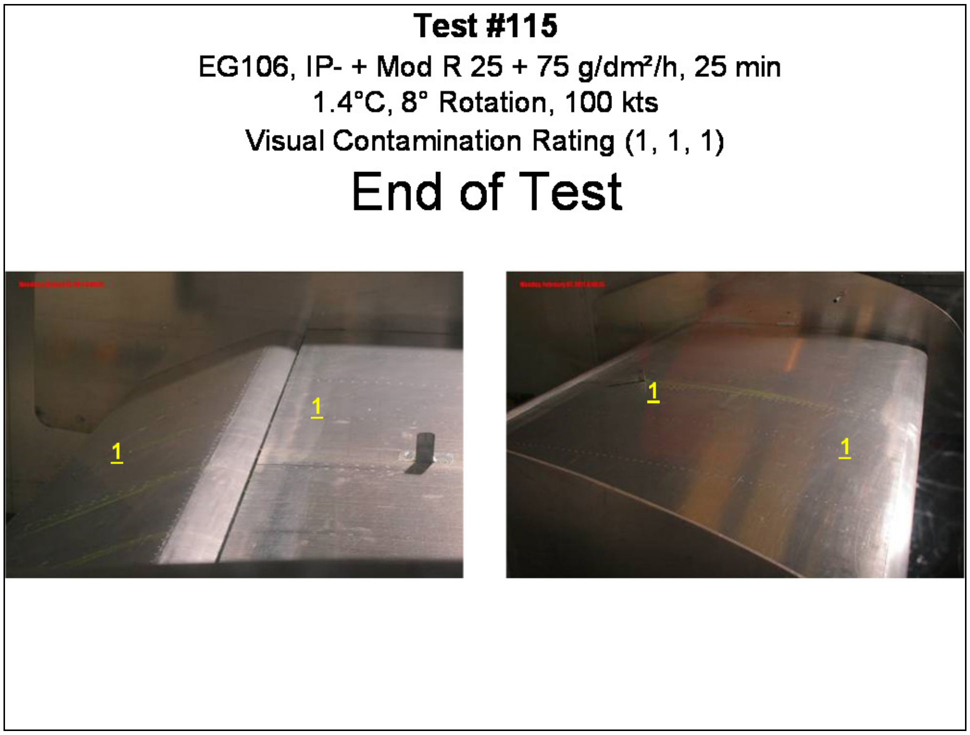
EG106, IP- + Mod R 25 + 75 g/dm²/h, 25 min

1.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 0.42%

End of Rotation

Photo 9.12: Test #115 – End of Test



Test #115

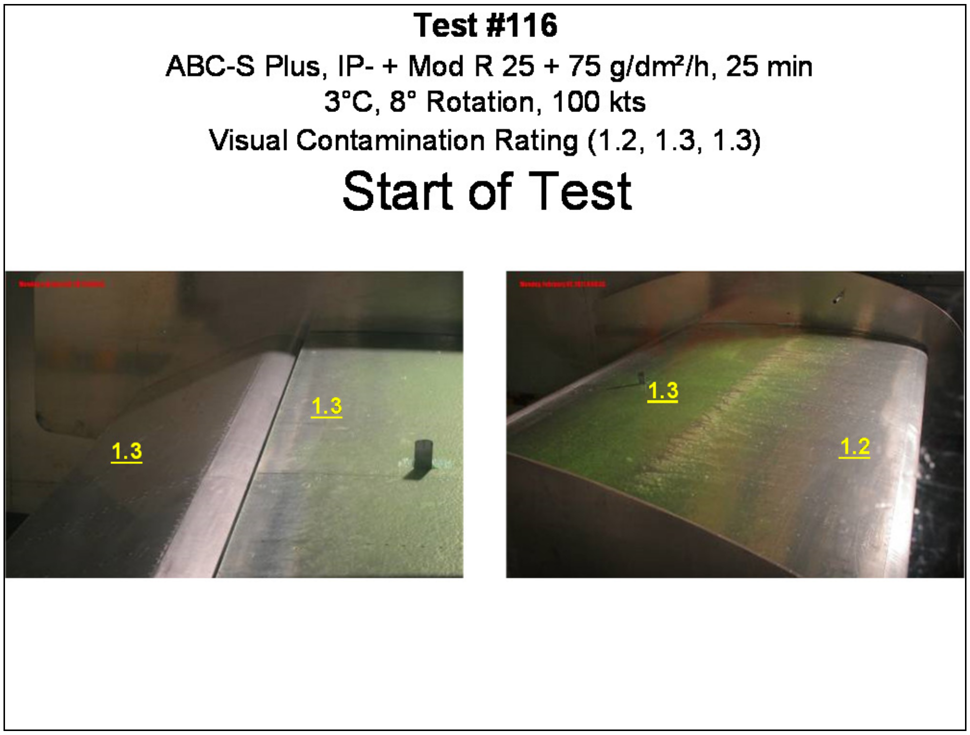
EG106, IP- + Mod R 25 + 75 g/dm²/h, 25 min

1.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 9.13: Test #116 – Start of Test



Test #116

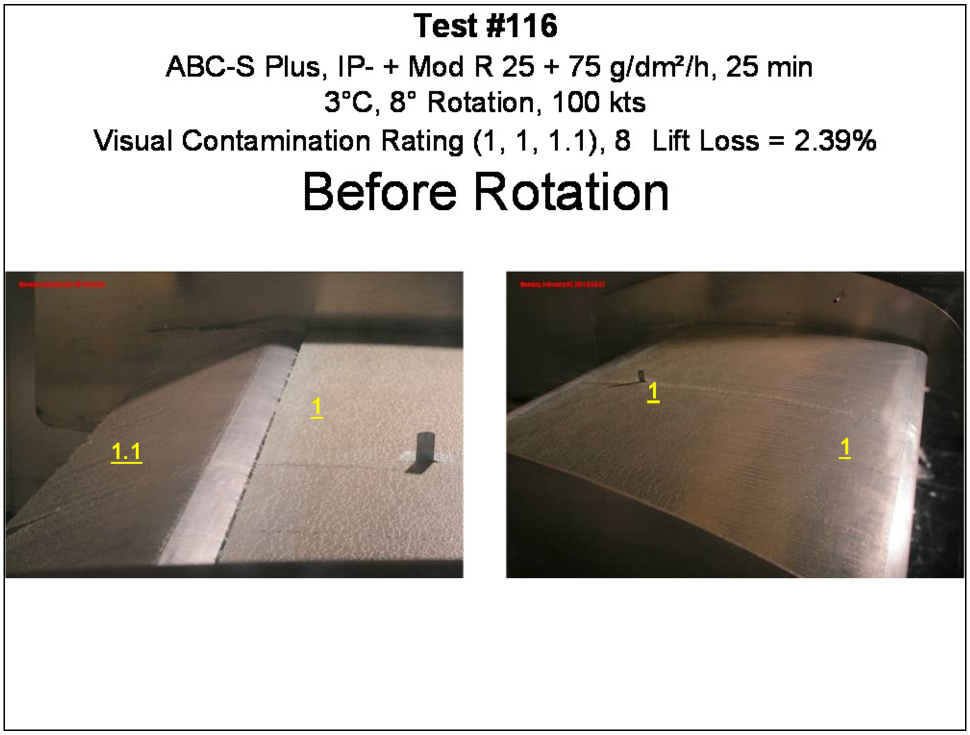
ABC-S Plus, IP- + Mod R 25 + 75 g/dm²/h, 25 min

3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.3, 1.3)

Start of Test

Photo 9.14: Test #116 – Before Rotation



Test #116

ABC-S Plus, IP- + Mod R 25 + 75 g/dm²/h, 25 min

3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.1), 8 Lift Loss = 2.39%

Before Rotation

Photo 9.15: Test #116 – End of Rotation

Test #116

ABC-S Plus, IP- + Mod R 25 + 75 g/dm²/h, 25 min

3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.1), 8 Lift Loss = 2.39%

End of Rotation

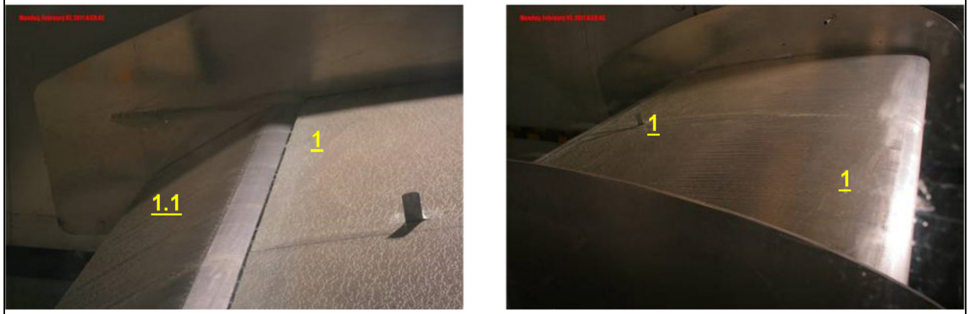


Photo 9.16: Test #116 – End of Test

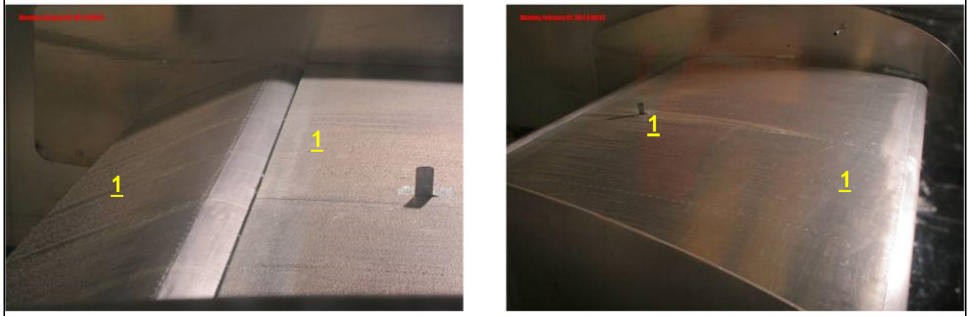
Test #116

ABC-S Plus, IP- + Mod R 25 + 75 g/dm²/h, 25 min

3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test



10. LIGHT ICE PELLETS MIXED WITH LIGHT SNOW ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Previous testing in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Light Freezing Rain;
- Section 9: Light Ice Pellets and Moderate Rain;
- Section 10: Light Ice Pellets and Light Snow;
- Section 11: Light Ice Pellets and Moderate Snow; and
- Section 12: Light Ice Pellets and Light Rain.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellets and Light Snow conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

10.1 Overview of Tests

A summary of the Light Ice Pellets and Light Snow tests conducted in the wind tunnel is shown in Table 10.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1. The following is a brief description of the column headings for Table 10.1:

Test #:	Exclusive number identifying each test.
Date:	Date when the test was conducted.

Fluid:	Aircraft deicing fluid specified by product name; all fluids were in the “neat” 100/0 dilution.
Condition:	Simulated precipitation condition.
Precipitation Rate (g/dm²/h):	Simulated freezing precipitation rate (or combination of different precipitation rates). “N/A” indicates that no precipitation was applied.
Precip. Time (min.):	Total time of exposure to simulated precipitation.
Tunnel Temp. at Start of Test (ºC):	The tunnel air temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Flap Angle (º):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended).
Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present.

	3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
CL at 8° During Rotation:	Calculated lift coefficient at the 8° wing rotation angle position; data provided by the NRC.
% Lift Loss:	% Lift Loss calculated based on the comparison of the 8° lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).
Associated Baseline Run:	The associated fluid only baseline run based on fluid selection.

Table 10.1: Summary of 2010-11 Light Ice Pellets and Light Snow Testing

Test No.	Date	Fluid	Associated Fluid Only Test	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
45	25-Jan-11	EG 106	52	IP- / SN-	IP:25 , SN:10	15	-12.9	-15.7	20	100	2.25 , 2 , 3	1 , 1.1 , 1.25	1.369	2.35
46	25-Jan-11	Launch	70 (09-10)	IP- / SN-	IP:25 , SN:10	5	-13.5	-13.8	20	100	1.75 , 1.75 , 3	1.25 , 1.6 , 2.25	1.303	7.06
56	26-Jan-11	AD-49	5A	IP- / SN-	IP:25 , SN:10	15	-9.6	N/A	20	100	3 , 2.8 , 4	1.5 , 2 , 2.5	1.307	6.78
58	26-Jan-11	Max-Flight	57	IP- / SN-	IP:25 , SN:10	15	-11.2	-10.9	20	100	2.3 , 2.3 , 3.2	1.3 , 1.7 , 2.2	1.295	7.63
74*	28-Jan-11	Max-Flight	76*	IP- / SN-	IP:25 , SN:10	25	-4.8	-6.8	20	100	2.5 , 2.3 , 3	1 , 1.5 , 1.6	1.326	6.75
78	30-Jan-11	EG 106	52	IP- / SN-	IP:25 , SN:10	25	-13.8	-14.2	20	100	2.7 , 2.2 , 4	1 , 1.6 , 1.8	1.384	2.67
82	31-Jan-11	ABC-S+	N/A	IP- / SN-	IP:25 , SN:10	15	-16	-13.8	20	115	2.8 , 2.5 , 3.7	1.3 , 1.8 , 2.7	1.303	8.37
84	31-Jan-11	Launch	N/A	IP- / SN-	IP:25 , SN:10	10	-17.4	-15.1	20	115	3 , 2.8 , 3.9	1.2 , 1.8 , 2.5	1.303	8.37
5A	19-Jan-11	AD-49	-	Fluid only	-	-	-10.4	-8.2	20	100	1 , 1 , 1	1 , 1 , 1	1.367	3.87
70 (09-10)	29-Jan-10	Launch	-	Fluid only	-	-	-17.9	-15.8	20	100	1 , 1, 1	1 , 1, 1	1.625	5.59
52	25-Jan-11	EG 106	-	Fluid only	-	-	-13.4	-12.6	20	100	1 , 1 , 1	1 , 1 , 1	1.363	2.78
57	26-Jan-11	Max-Flight	-	Fluid only	-	-	-9.9	-11	20	100	1 , 1 , 1	1 , 1 , 1	1.306	6.85
76*	28-Jan-11	Max-Flight	-	Fluid only	-	-	-5.5	-3.4	20	100	1 , 1 , 1	1 , 1 , 1	1.328	6.61

**** CL Max Test***

10.2 Data Collected

10.2.1 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.2. Fluid thickness measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix G shows the fluid thickness measurements collected during the contaminated fluid tests.

10.2.2 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.3. Skin temperature measurements were recorded at the following intervals:

- Before fluid application;
- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix H shows the wing temperature measurements recorded during the contaminated fluid tests.

10.2.3 Fluid Brix Data

Fluid Brix measurements were recorded at the following intervals by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.4. Fluid Brix measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and

- After the simulated takeoff test.

Appendix I shows the fluid Brix measurements collected during the contaminated fluid tests.

10.3 Photos

High-speed digital photographs of each test were taken; wide-angle photos were taken of the leading edge, and close-up photos were taken of the trailing edge. For each test, photo summaries have been compiled comprising four stages:

- Start of test;
- Before Rotation (just before the wing began to pitch);
- End of Rotation (end of the rotation cycle when the wing position is returned to 4 degrees); and
- End of test.

The photos taken during the Light Ice Pellets and Light Snow testing have been presented along with the fluid only (baseline) tests for comparison purposes. In each case, the fluid only photo is presented first, followed by the contaminated fluid photo. Photos 10.1 to 10.52 show the photo summaries of the tests conducted. A complete set of photos will be provided to the TDC in electronic format.

10.4 Summary of Results

10.4.1 OAT -5°C and Above

One test (#74) was conducted with exposure times of 25 minutes in this cell. See Table 10.2 for a summary of the tests. Test #74, conducted at a temperature of -4.8°C with a PG fluid, demonstrated satisfactory results. The visual ratings at the start of test and at rotation were deemed good. The lift loss at 8° was 6.75 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test were satisfactory and did not indicate a need to change the current allowance time. See Table 10.3 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that the current allowance time of 25 minutes for this cell is acceptable and validated.

Table 10.2: Light Ice Pellets and Light Snow Allowance Time Tests Winter 2010-11

Light Ice Pellets Mixed with Light Snow	**OAT -5°C and Above**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	25 minutes **Test # 74**	15 minutes **Test # (45), 56, (58)**	**Caution: No allowance times currently exist**
		25 minutes **Test # (78)**	5 minutes **Test # 46**
			15 minutes **Test # 45, (56), 58**
			25 minutes **Test # 78**
115 kts	25 minutes	15 minutes	**Caution: No allowance times currently exist**
			10 minutes **Test # 84**
			15 minutes **Test # 82**

Table 10.3: Summary of Light Ice Pellets and Light Snow Allowance Time Test Results

<table>
<tr><th colspan="12">OAT -5°C AND ABOVE (25 MINUTES)</th></tr>
<tr><th>Run #</th><th>Fluid</th><th>Tunnel Temp. Before Test (°C)</th><th>Precipitation Rate (g/dm²/h)</th><th>Exposure Time (min)</th><th>Visual Contamination Rating Before Takeoff (LE, TE, Flap)</th><th>Before Takeoff Status</th><th>Visual Contamination Rating at Rotation (LE, TE, Flap)</th><th>At Rotation Status</th><th>% Lift Loss</th><th>Lift Loss Status</th><th>Overall Status</th></tr>
<tr><td colspan="12">100 kts</td></tr>
<tr><td>74</td><td><i>Max-Flight</i></td><td><i>-4.8</i></td><td>IP:25 , SN:10</td><td><i>25</i></td><td>2.5 , 2.3 , 3</td><td>GOOD</td><td>1 , 1.5 , 1.6</td><td>GOOD</td><td><i>6.75</i></td><td>REVIEW</td><td>REVIEW</td></tr>
<tr><td colspan="12">Notes:</td></tr>
<tr><td colspan="12">CONCLUSION: ALLOWANCE TIME AT 25 MINUTES IS <u>GOOD</u></td></tr>
</table>

<table>
<tr><th colspan="12">OAT LESS THAN -5°C TO -10°C (15 MINUTES)</th></tr>
<tr><th>Run #</th><th>Fluid</th><th>Tunnel Temp. Before Test (°C)</th><th>Precipitation Rate (g/dm²/h)</th><th>Exposure Time (min)</th><th>Visual Contamination Rating Before Takeoff (LE, TE, Flap)</th><th>Before Takeoff Status</th><th>Visual Contamination Rating at Rotation (LE, TE, Flap)</th><th>At Rotation Status</th><th>% Lift Loss</th><th>Lift Loss Status</th><th>Overall Status</th></tr>
<tr><td colspan="11">100 kts</td><td></td></tr>
<tr><td>45</td><td><i>EG 106</i></td><td><i>-12.9</i></td><td>IP:25 , SN:10</td><td><i>15</i></td><td>2.25 , 2 , 3</td><td>GOOD</td><td>1 , 1.1 , 1.25</td><td>GOOD</td><td><i>2.35</i></td><td>GOOD</td><td>GOOD</td></tr>
<tr><td>58</td><td><i>Max-Flight</i></td><td><i>-11.2</i></td><td>IP:25 , SN:10</td><td><i>15</i></td><td>2.3 , 2.3 , 3.2</td><td>GOOD</td><td>1.3 , 1.7 , 2.2</td><td>REVIEW</td><td><i>7.63</i></td><td>REVIEW</td><td>REVIEW</td></tr>
<tr><td>78</td><td><i>EG 106</i></td><td><i>-13.8</i></td><td>IP:25 , SN:10</td><td><i>25</i></td><td>2.7 , 2.2 , 4</td><td>GOOD</td><td>1 , 1.6 , 1.8</td><td>GOOD</td><td><i>2.67</i></td><td>GOOD</td><td>GOOD</td></tr>
<tr><td colspan="12">Notes:</td></tr>
<tr><td colspan="12">CONCLUSION: ALLOWANCE TIME AT 15 MINUTES IS <u>GOOD</u></td></tr>
</table>

Table 10.3: Summary of Light Ice Pellets and Light Snow Allowance Time Test Results (cont'd)

OAT LESS THAN -10°C (No Allowance Time Currently Exists)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
46	*Launch*	*-13.5*	IP:25 , SN:10	*5*	1.75 , 1.75 , 3	GOOD	1.25 , 1.6 , 2.25	REVIEW	*7.06*	REVIEW	REVIEW
45	*EG 106*	*-12.9*	IP:25 , SN:10	*15*	2.25 , 2 , 3	GOOD	1 , 1.1 , 1.25	GOOD	*2.35*	GOOD	GOOD
78	*EG 106*	*-13.8*	IP:25 , SN:10	*25*	2.7 , 2.2 , 4	GOOD	1 , 1.6 , 1.8	GOOD	*2.67*	GOOD	GOOD
56	*AD-49*	*-9.6*	IP:25 , SN:10	*15*	3 , 2.8 , 4	GOOD	1.5 , 2 , 2.5	REVIEW	*6.78*	REVIEW	REVIEW
115 kts											
82	*ABC-S+*	*-16*	IP:25 , SN:10	*15*	2.8 , 2.5 , 3.7	GOOD	1.3 , 1.8 , 2.7	REVIEW	*8.37*	REVIEW	REVIEW
84	*Launch*	*-17.4*	IP:25 , SN:10	*10*	3 , 2.8 , 3.9	GOOD	1.2 , 1.8 , 2.5	REVIEW	*8.37*	REVIEW	REVIEW
Notes: CONCLUSION: POTENTIAL ALLOWANCE TIME AT 15 MINUTES IS GOOD, COULD GO TO 25 FOR EG FLUIDS											

10.4.2 OAT Less than -5°C to -10°C

One test (#56) was conducted with exposure times of 15 minutes in this cell. See Table 10.2 for a summary of the tests. Test #56, conducted at a temperature of -9.6°C with a PG fluid, demonstrated good results. The visual rating at the start of test was good and at rotation deemed satisfactory. The lift loss at 8° was 6.78 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a need to change the current allowance time of 15 minutes. See Table 10.3 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that the current allowance time of 15 minutes for this cell is acceptable and validated.

10.4.3 OAT Less than -10°C

Four tests were conducted in this cell. Test #46 was conducted with an exposure time of 5 minutes; Tests #45 and #58 were conducted with an exposure time of 15 minutes; and Test #78 was conducted with an exposure time of 25 minutes. Two other tests, #84 and #82, were 115 knot tests conducted at 10 minutes and 15 minutes, respectively. See Table 10.2 for a summary of the tests.

Test #45, conducted at an exposure time of 15 minutes and at a temperature of -12.9°C with an EG fluid, demonstrated good results. The visual rating at the start of test and the results at rotation were deemed good. The lift loss at 8° was 2.35 percent, which is well below the 5.4 percent lower limit. The results of this test support a potential allowance time of 15 minutes or greater for EG fluids. See Table 10.3 for the details of this test.

Test #46, conducted at an exposure time of 5 minutes and at a temperature of -13.5°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory. The lift loss at 8° was 7.06 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test support a potential allowance time of 5 minutes for PG fluids; however, further review is required. See Table 10.3 for the details of this test.

Test #58, conducted at an exposure time of 15 minutes and at a temperature of -11.2°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 7.63 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test suggest a potential allowance time of 5 minutes for PG fluids; however, further review is required. See Table 10.3 for the details of this test.

Test #78, conducted at an exposure time of 25 minutes and at a temperature of -13.8°C with an EG fluid, demonstrated good results. The visual rating at the start of test and the results at rotation were deemed good. The lift loss at 8° was 2.67 percent, which is well below the 5.4 percent lower limit. The results of this test support a potential allowance time of 25 minutes or greater for EG fluids. See Table 10.3 for the details of this test.

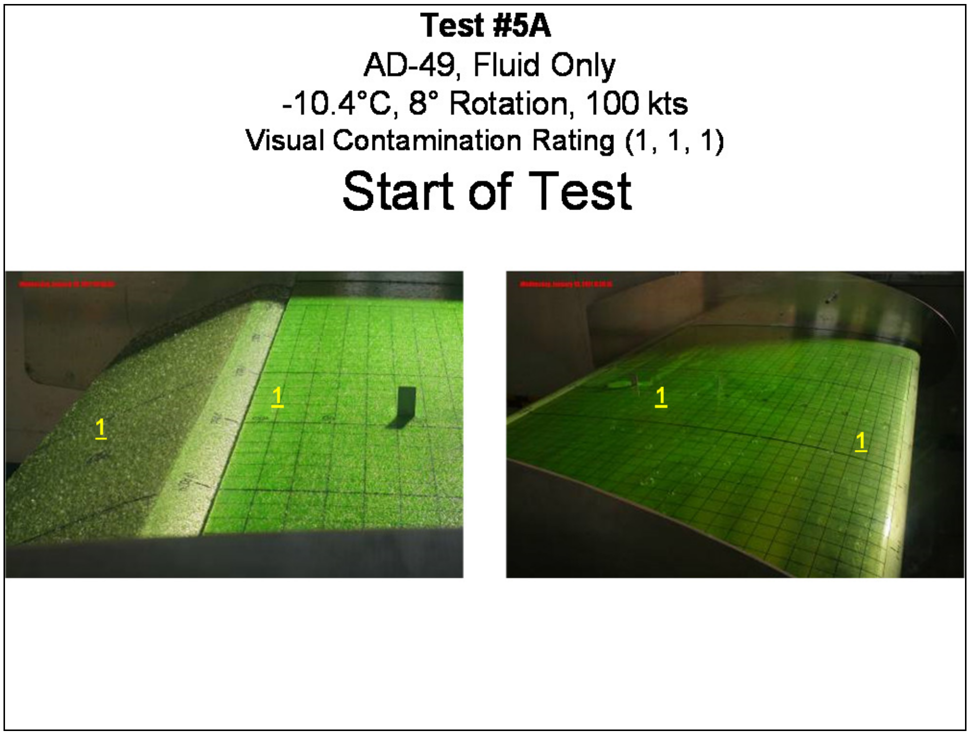
Test #82, conducted at an exposure time of 15 minutes and at a temperature of -16.0°C with a PG fluid, demonstrated satisfactory results. This test was conducted at a speed of 115 knots. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 8.37 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test support a potential allowance time of 15 minutes for PG fluids; however, further review is required. See Table 10.3 for the details of this test.

Test #84, conducted at an exposure time of 10 minutes and at a temperature of -17.4°C with a PG fluid, demonstrated satisfactory results. This test was conducted at a speed of 115 knots. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 8.37 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test support a potential allowance time of 10 minutes for PG fluids; however, further review is required. See Table 10.3 for the details of this test.

In conclusion, there is a potential to develop allowance times up to 15 minutes for PG fluids; however, this is contingent on further review of the lift loss criteria for an acceptable test. For EG fluids, there is a potential to expand the allowance times to 25 minutes; however, further data and review are required.

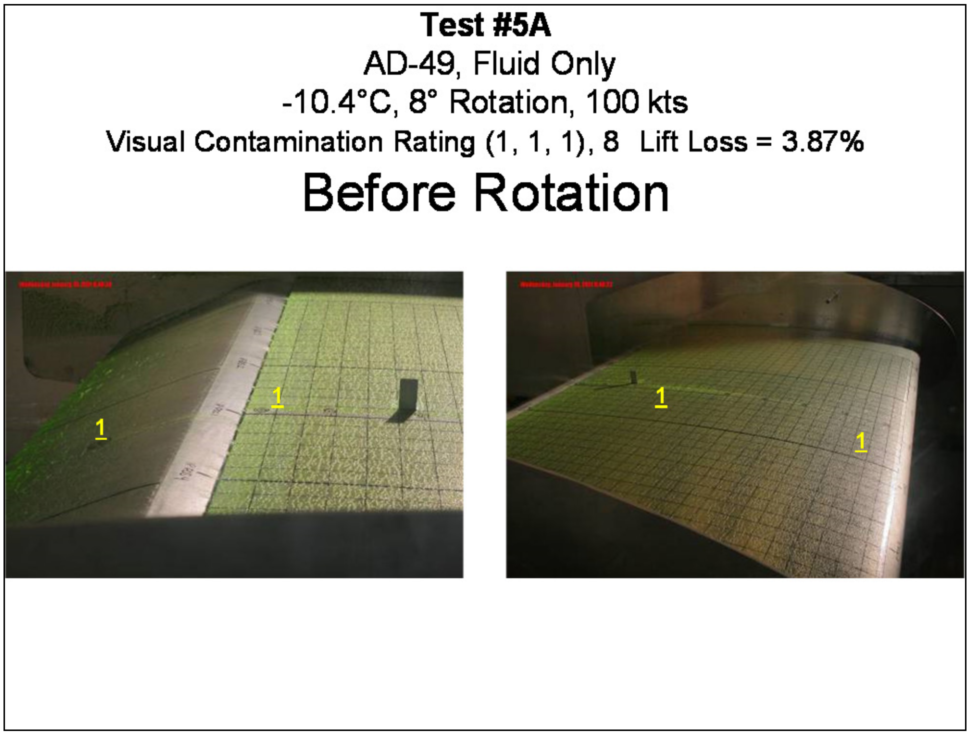
This page intentionally left blank.

Photo 10.1: Test #5A – Start of Test



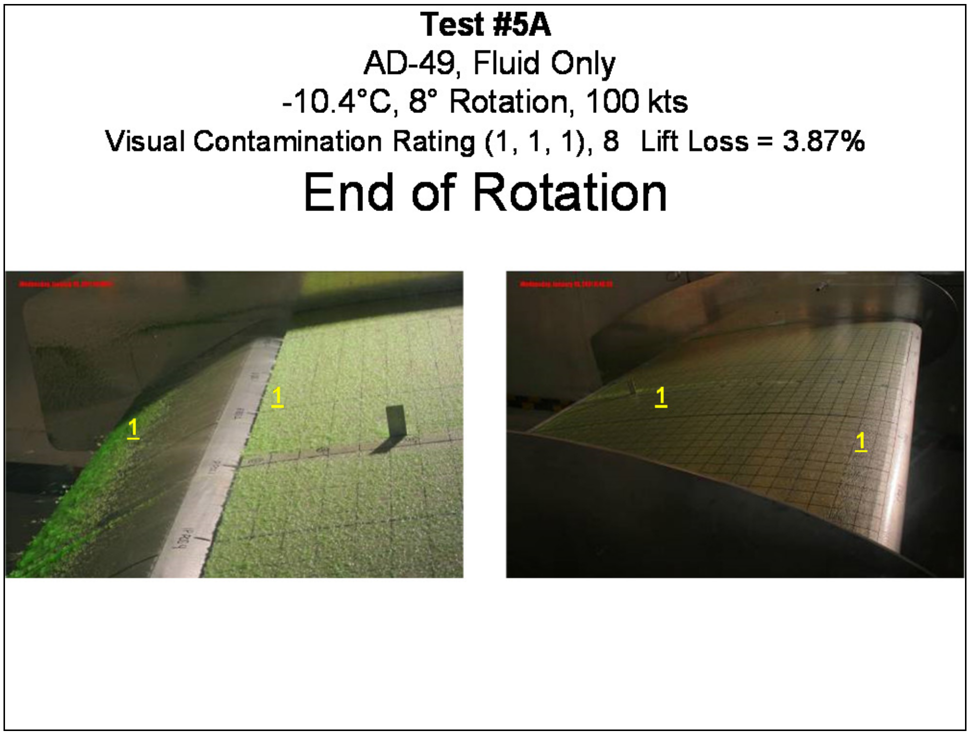
Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 10.2: Test #5A – Before Rotation



Test #5A
AD-49, Fluid Only
-10.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.87%
Before Rotation

Photo 10.3: Test #5A – End of Rotation



Test #5A

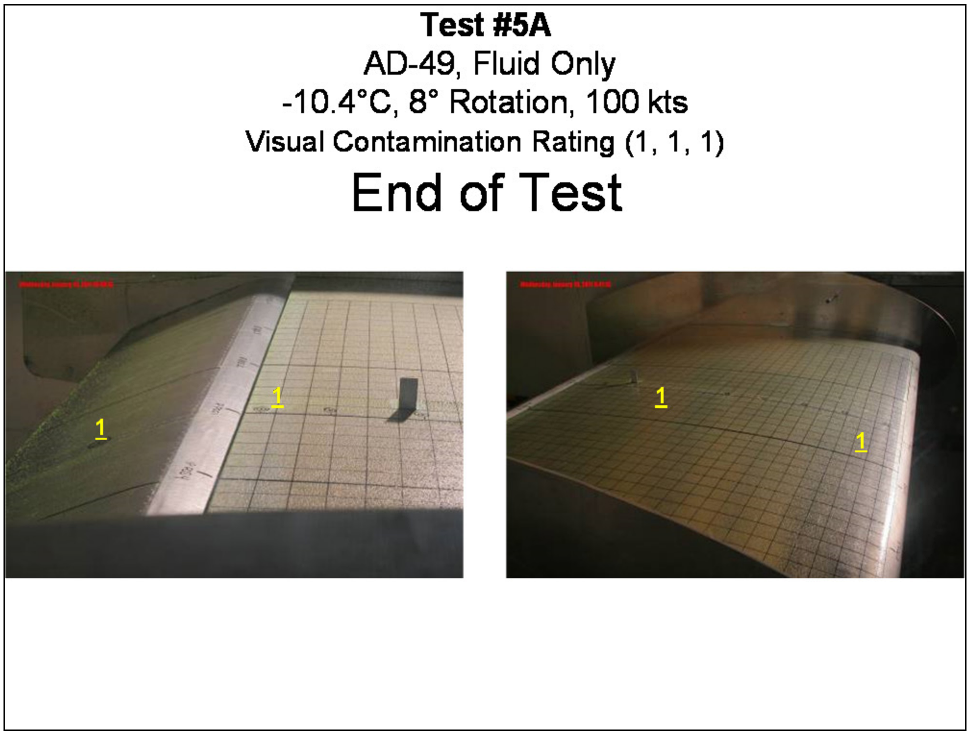
AD-49, Fluid Only

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.87%

End of Rotation

Photo 10.4: Test #5A – End of Test



Test #5A

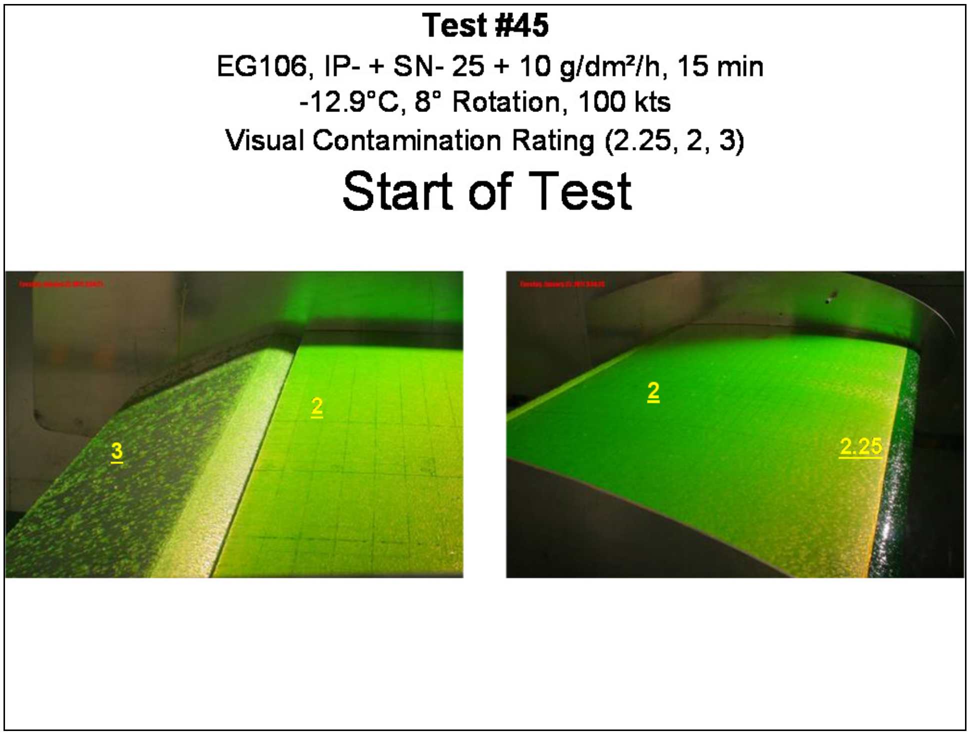
AD-49, Fluid Only

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 10.5: Test #45 – Start of Test



Test #45

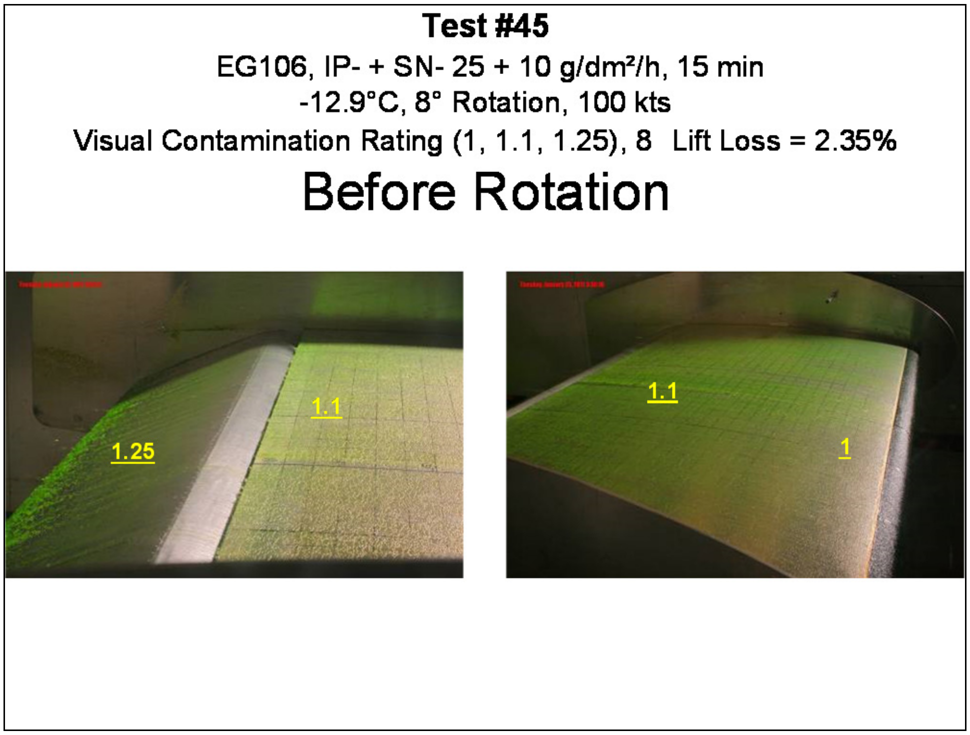
EG106, IP- + SN- 25 + 10 g/dm²/h, 15 min

-12.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.25, 2, 3)

Start of Test

Photo 10.6: Test #45 – Before Rotation



Test #45

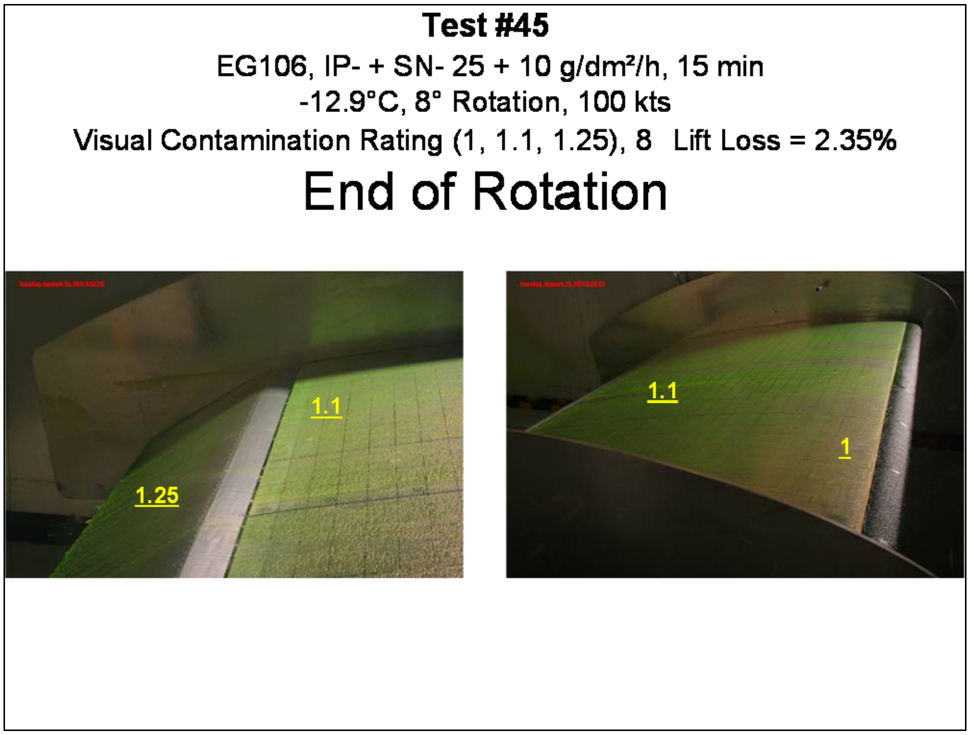
EG106, IP- + SN- 25 + 10 g/dm²/h, 15 min

-12.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.1, 1.25), 8 Lift Loss = 2.35%

Before Rotation

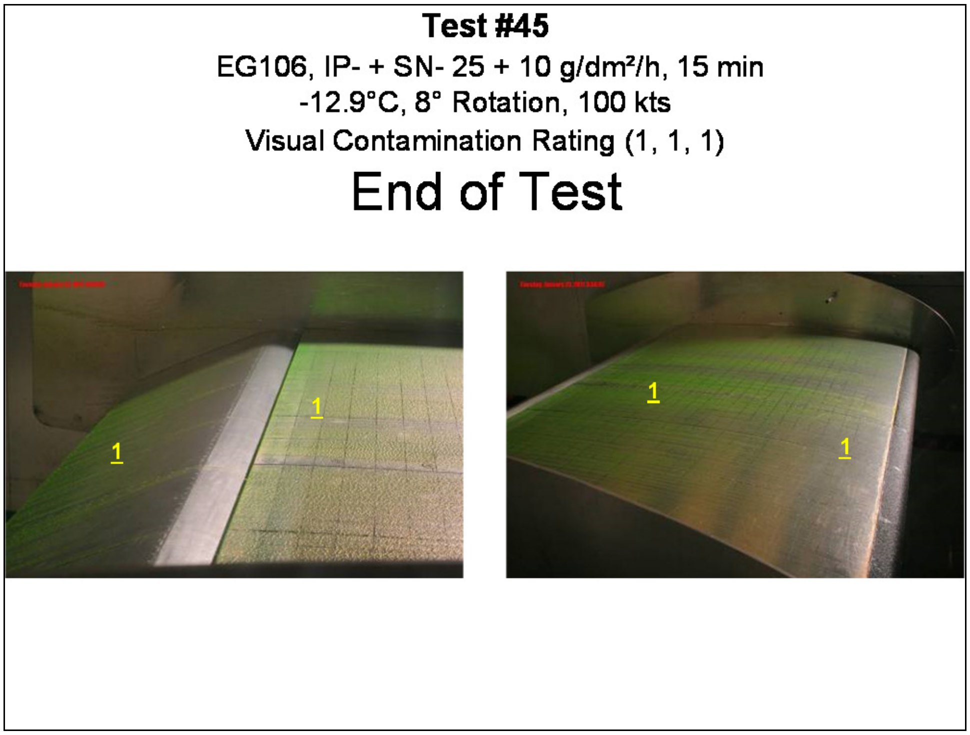
Photo 10.7: Test #45 – End of Rotation



Test #45
EG106, IP- + SN- 25 + 10 g/dm²/h, 15 min
-12.9°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1.1, 1.25), 8 Lift Loss = 2.35%

End of Rotation

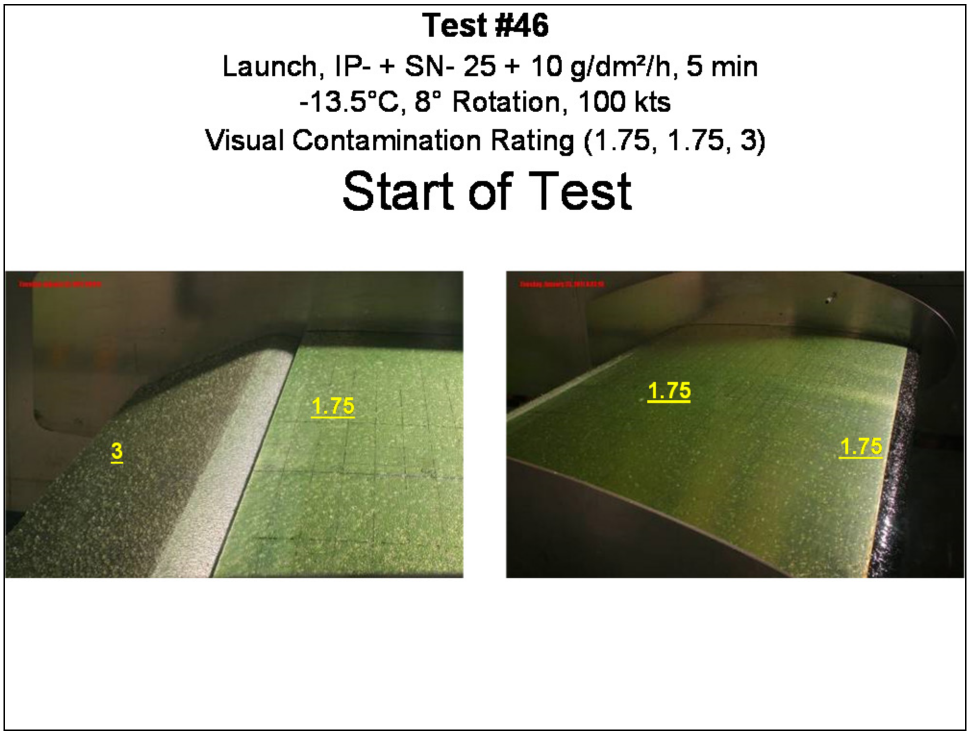
Photo 10.8: Test #45 – End of Test



Test #45
EG106, IP- + SN- 25 + 10 g/dm²/h, 15 min
-12.9°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

Photo 10.9: Test #46 – Start of Test



Test #46

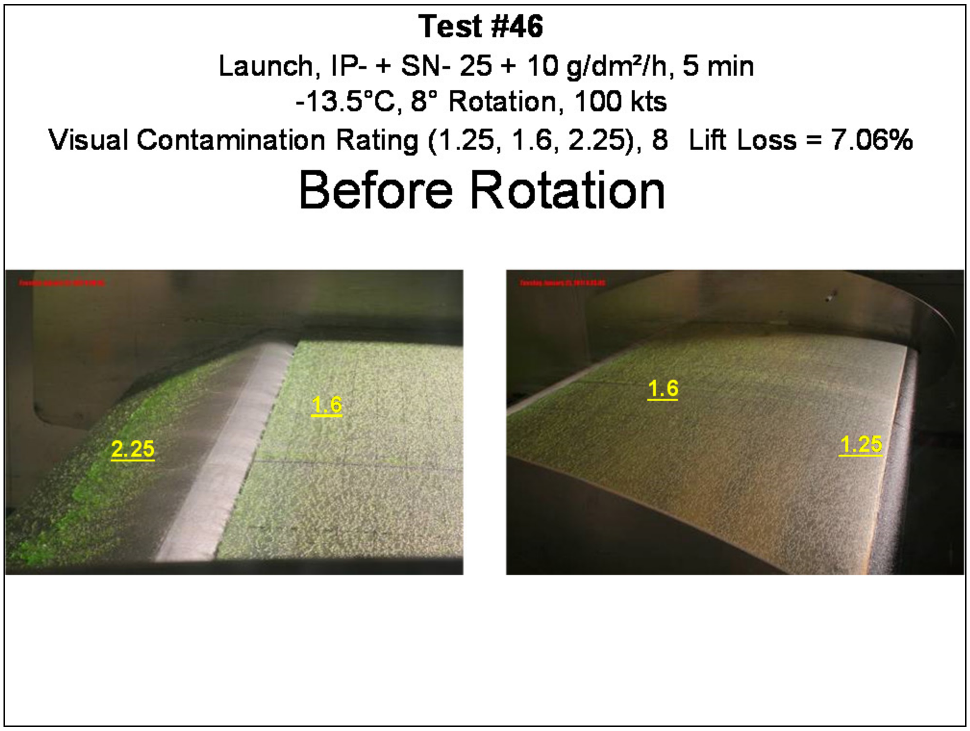
Launch, IP- + SN- 25 + 10 g/dm²/h, 5 min

-13.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.75, 1.75, 3)

Start of Test

Photo 10.10: Test #46 – Before Rotation



Test #46

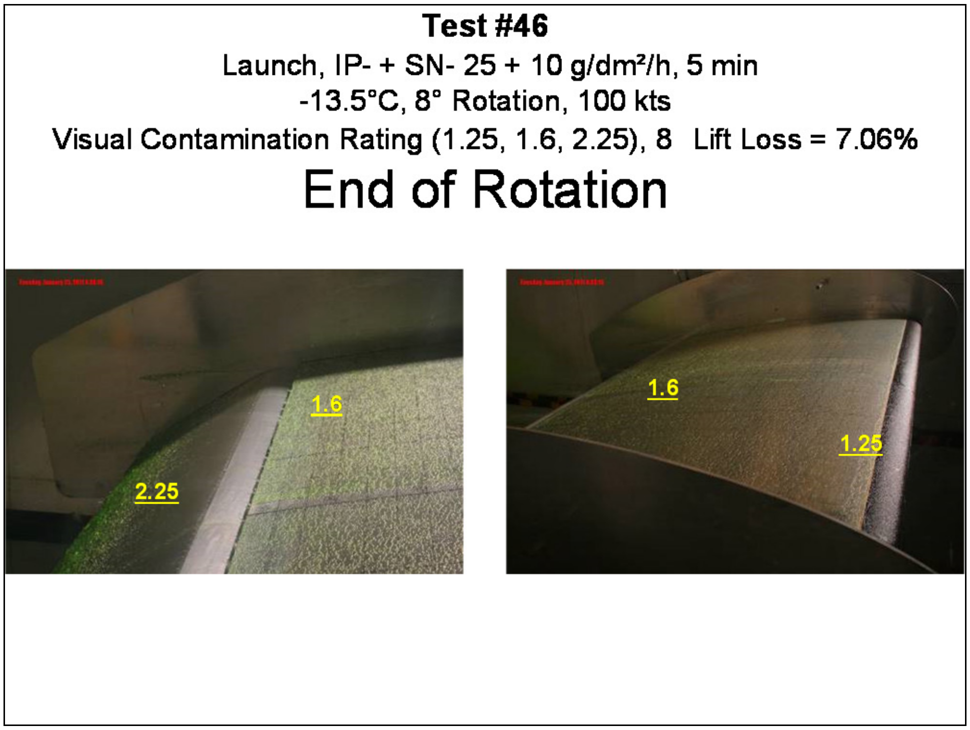
Launch, IP- + SN- 25 + 10 g/dm²/h, 5 min

-13.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.25, 1.6, 2.25), 8 Lift Loss = 7.06%

Before Rotation

Photo 10.11: Test #46 – End of Rotation



Test #46

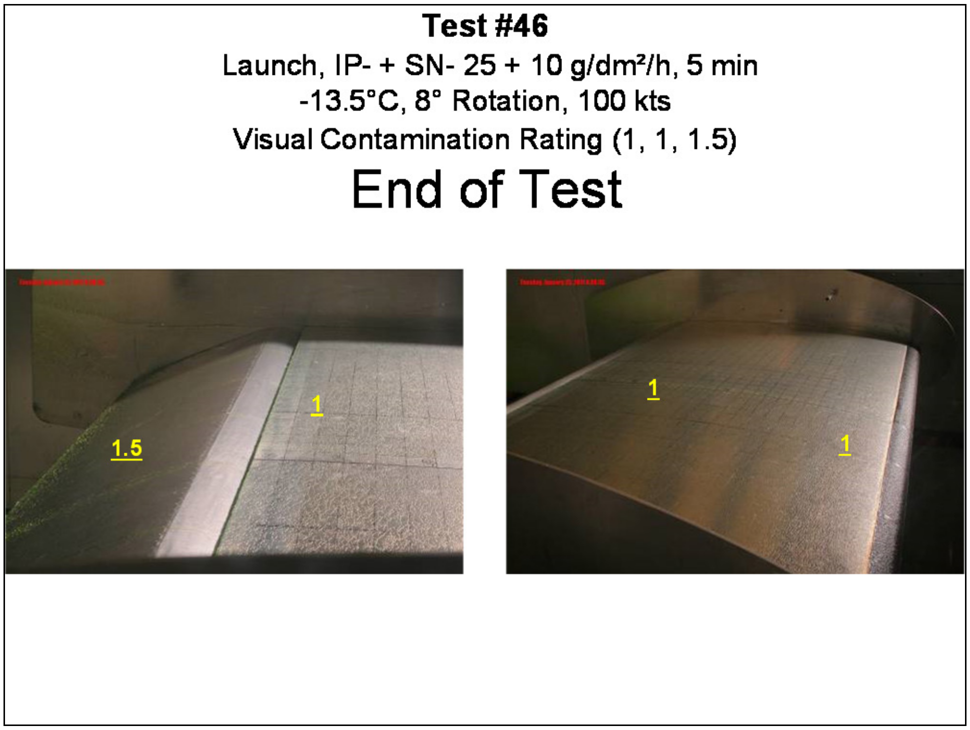
Launch, IP- + SN- 25 + 10 g/dm²/h, 5 min

-13.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.25, 1.6, 2.25), 8 Lift Loss = 7.06%

End of Rotation

Photo 10.12: Test #46 – End of Test



Test #46

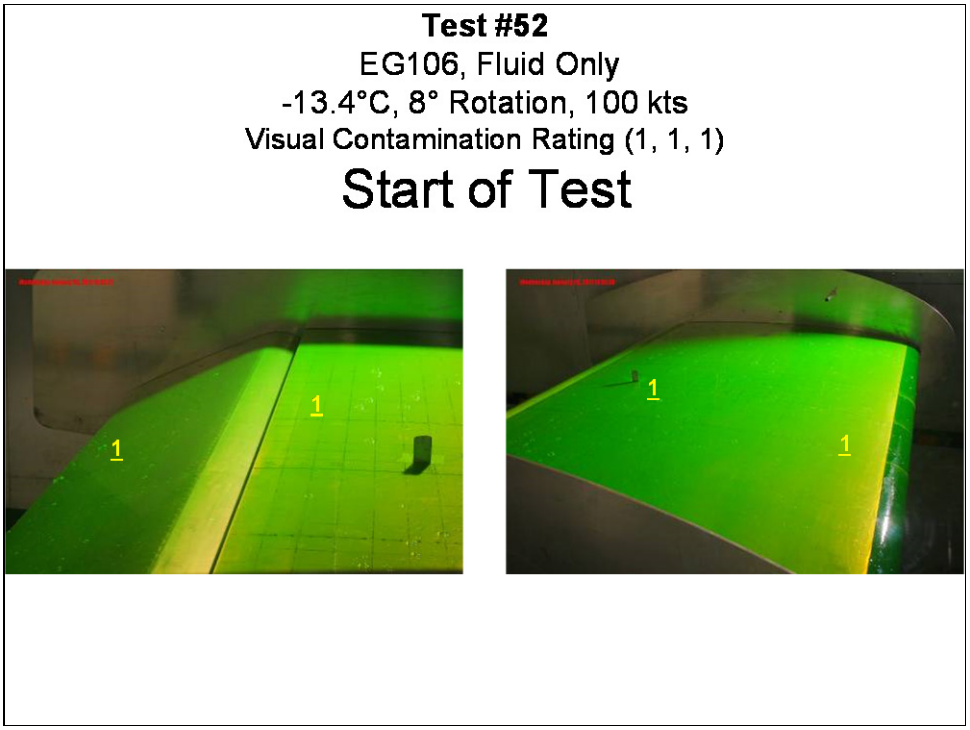
Launch, IP- + SN- 25 + 10 g/dm²/h, 5 min

-13.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.5)

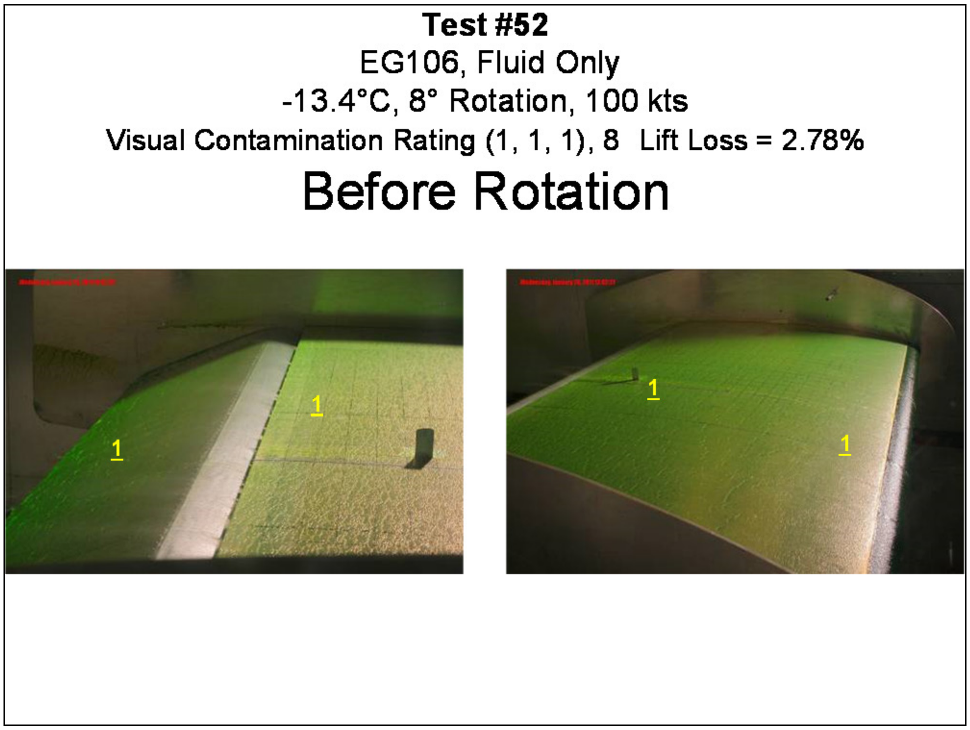
End of Test

Photo 10.13: Test #52 – Start of Test



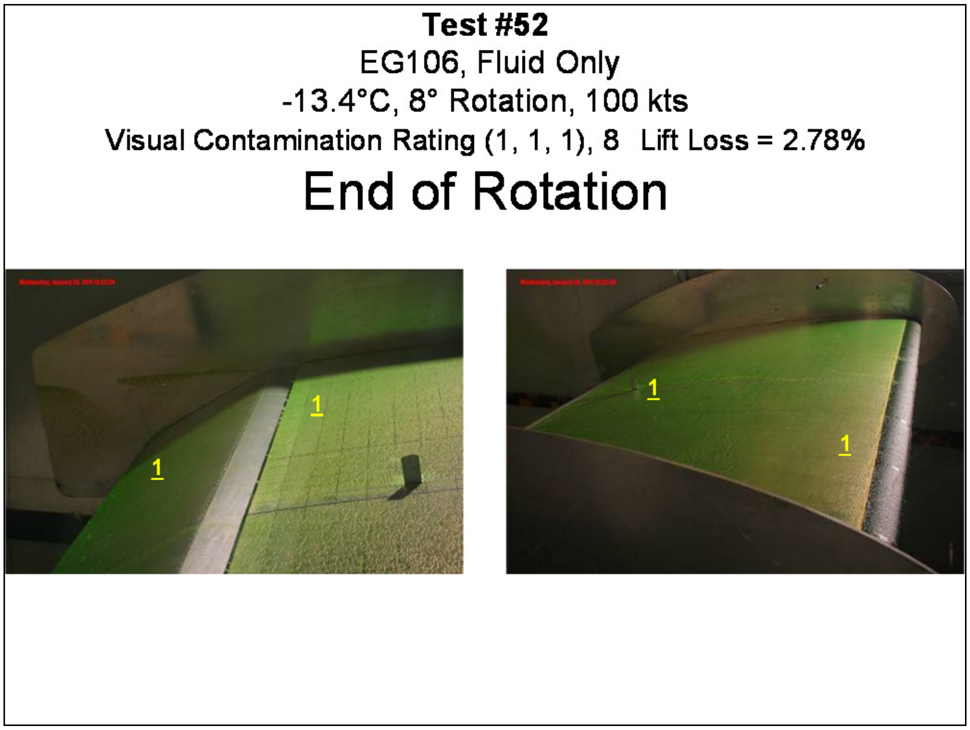
Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 10.14: Test #52 – Before Rotation



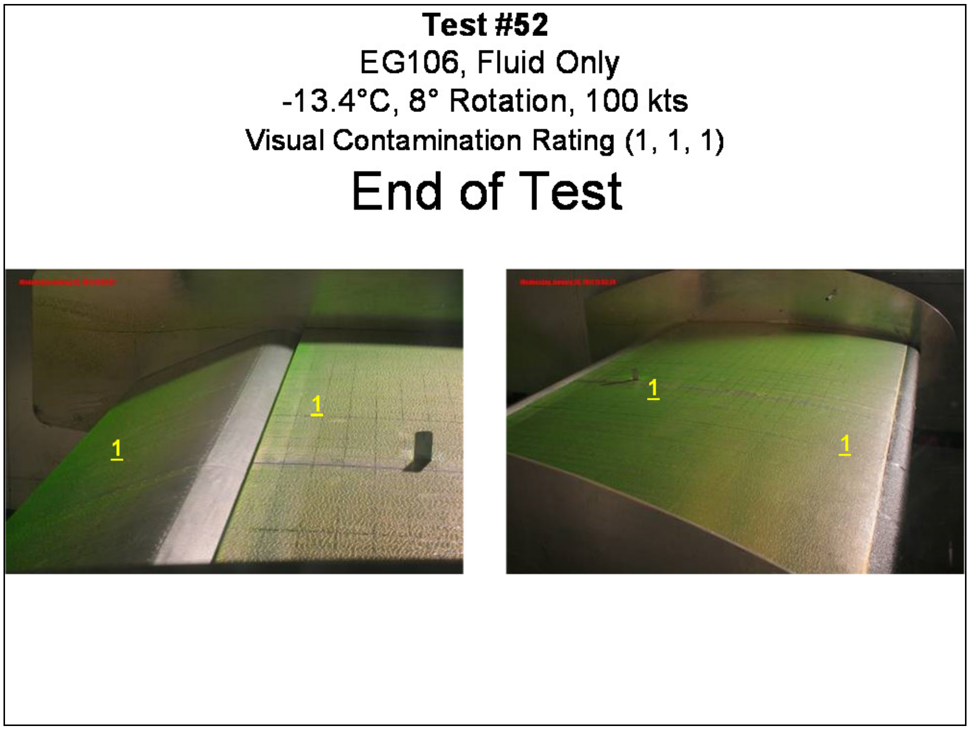
Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%
Before Rotation

Photo 10.15: Test #52 – End of Rotation



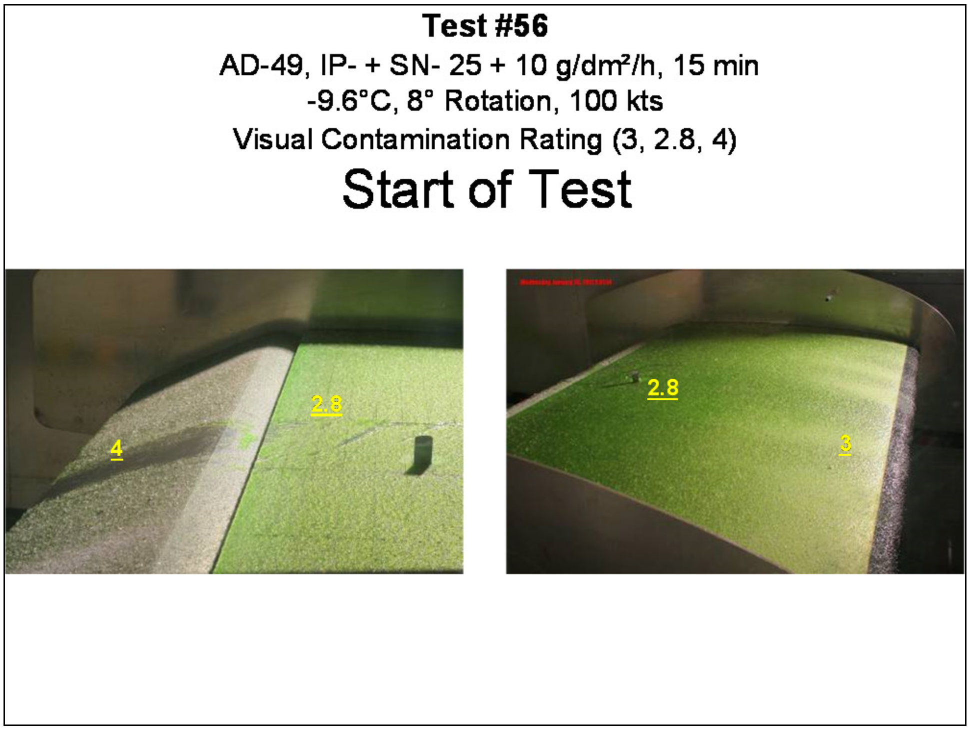
Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%
End of Rotation

Photo 10.16: Test #52 – End of Test



Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 10.17: Test #56 – Start of Test



Test #56

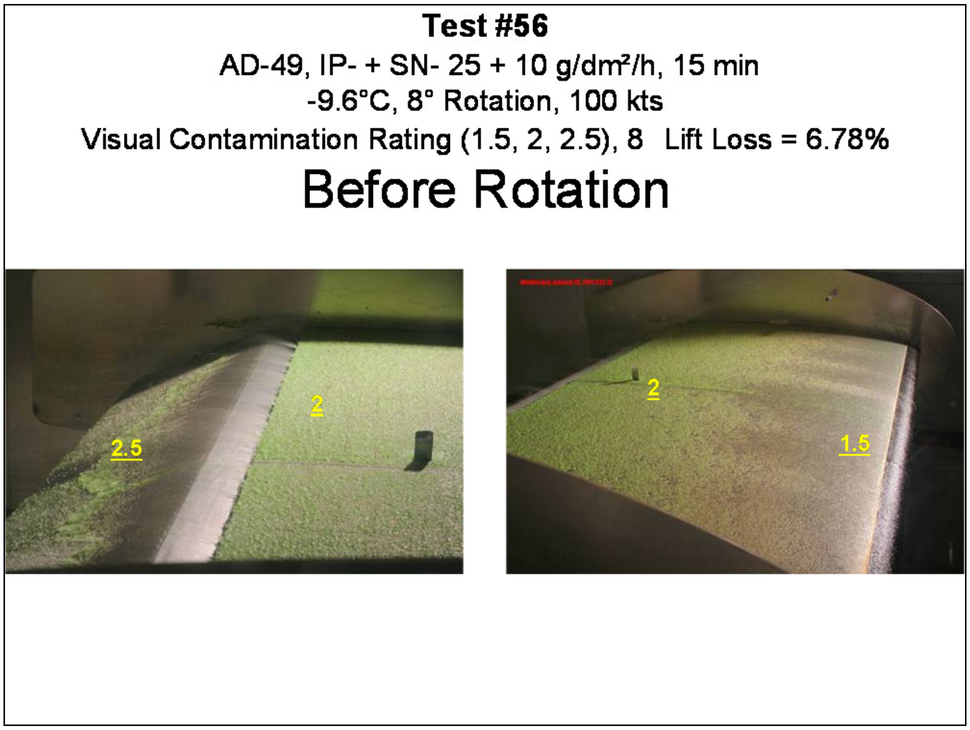
AD-49, IP- + SN- 25 + 10 g/dm²/h, 15 min

-9.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (3, 2.8, 4)

Start of Test

Photo 10.18: Test #56 – Before Rotation



Test #56

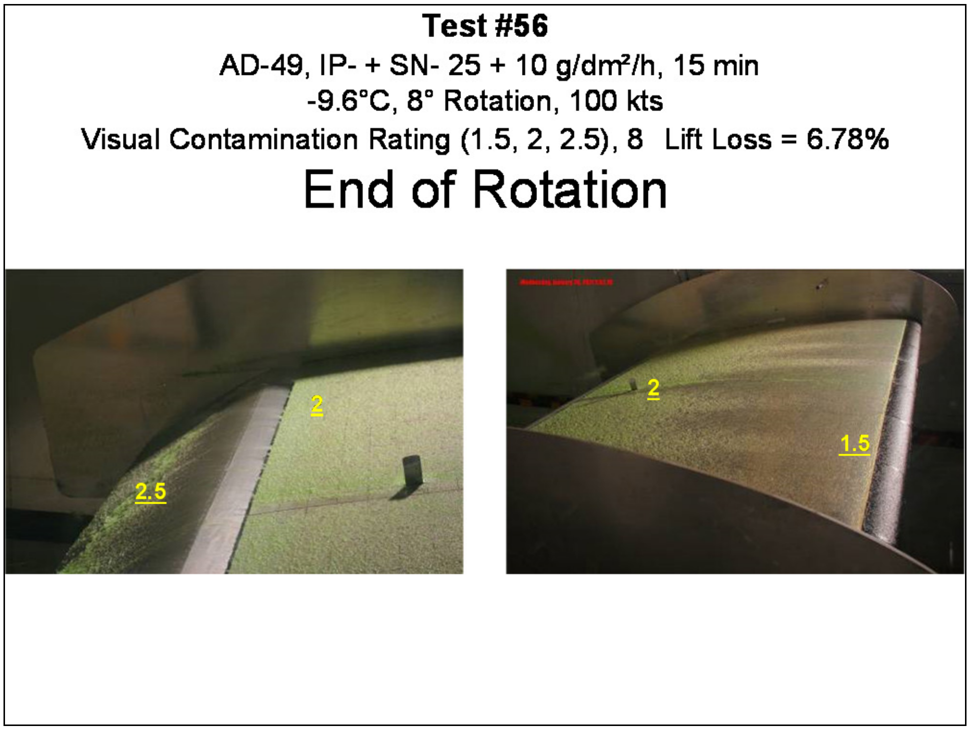
AD-49, IP- + SN- 25 + 10 g/dm²/h, 15 min

-9.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.5, 2, 2.5), 8 Lift Loss = 6.78%

Before Rotation

Photo 10.19: Test #56 – End of Rotation



Test #56

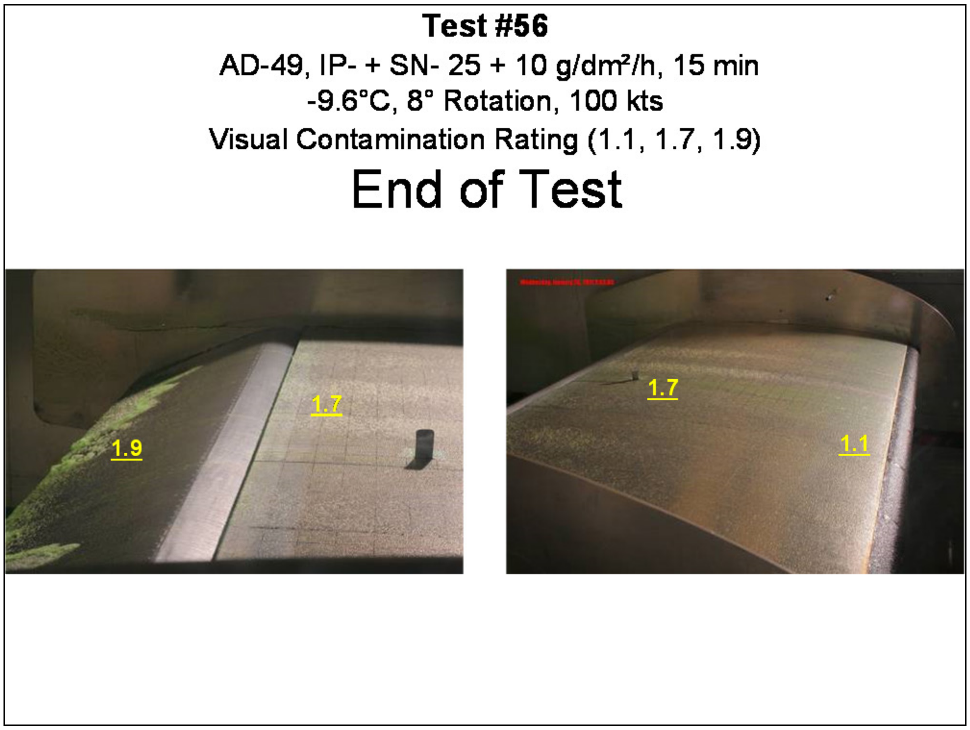
AD-49, IP- + SN- 25 + 10 g/dm²/h, 15 min

-9.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.5, 2, 2.5), 8 Lift Loss = 6.78%

End of Rotation

Photo 10.20: Test #56 – End of Test



Test #56

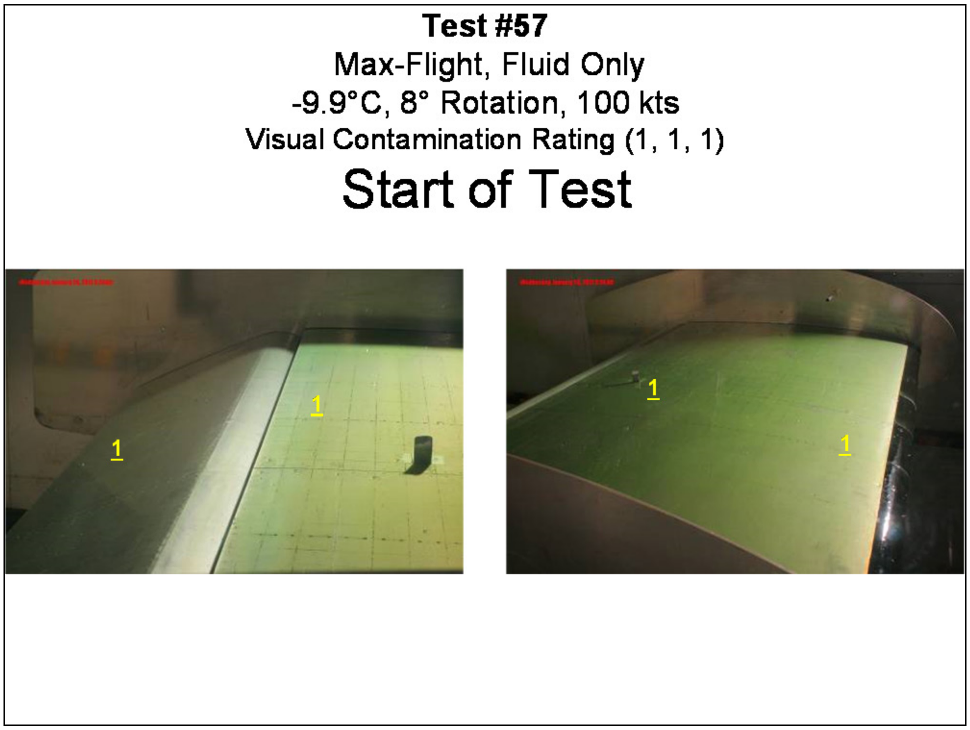
AD-49, IP- + SN- 25 + 10 g/dm²/h, 15 min

-9.6°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.7, 1.9)

End of Test

Photo 10.21: Test #57 – Start of Test



Test #57

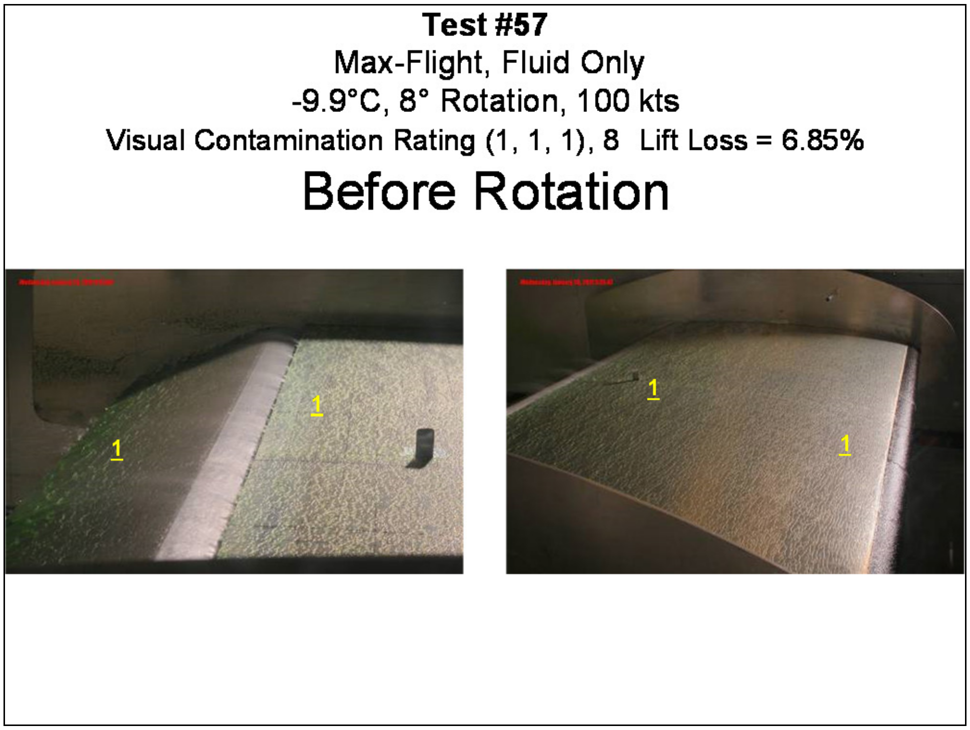
Max-Flight, Fluid Only

-9.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 10.22: Test #57 – Before Rotation



Test #57

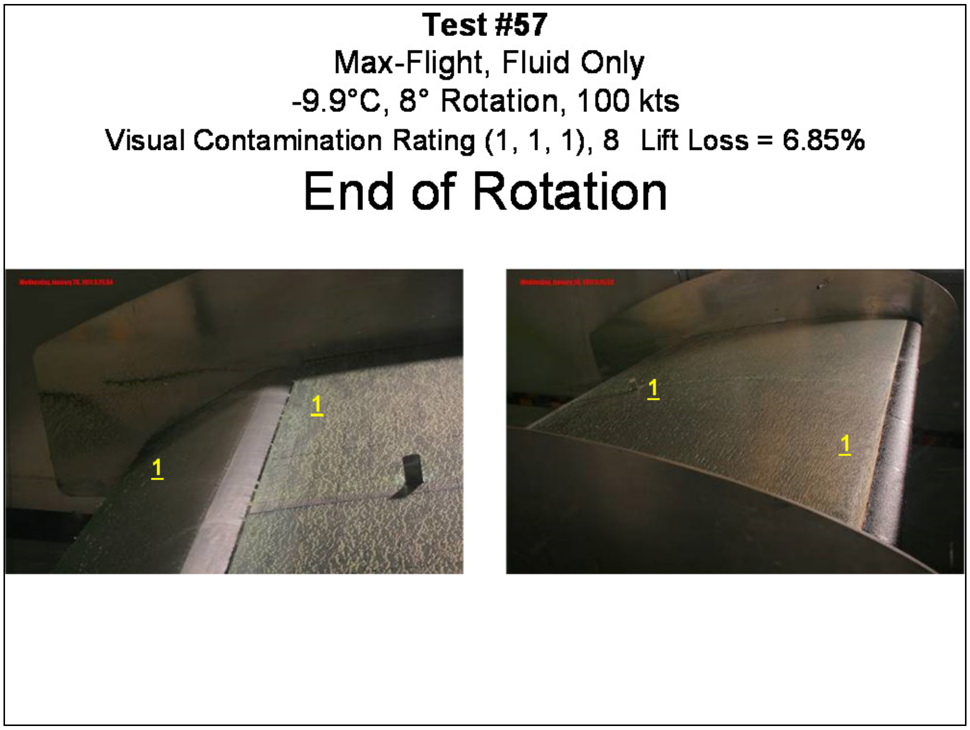
Max-Flight, Fluid Only

-9.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.85%

Before Rotation

Photo 10.23: Test #57 – End of Rotation



Test #57

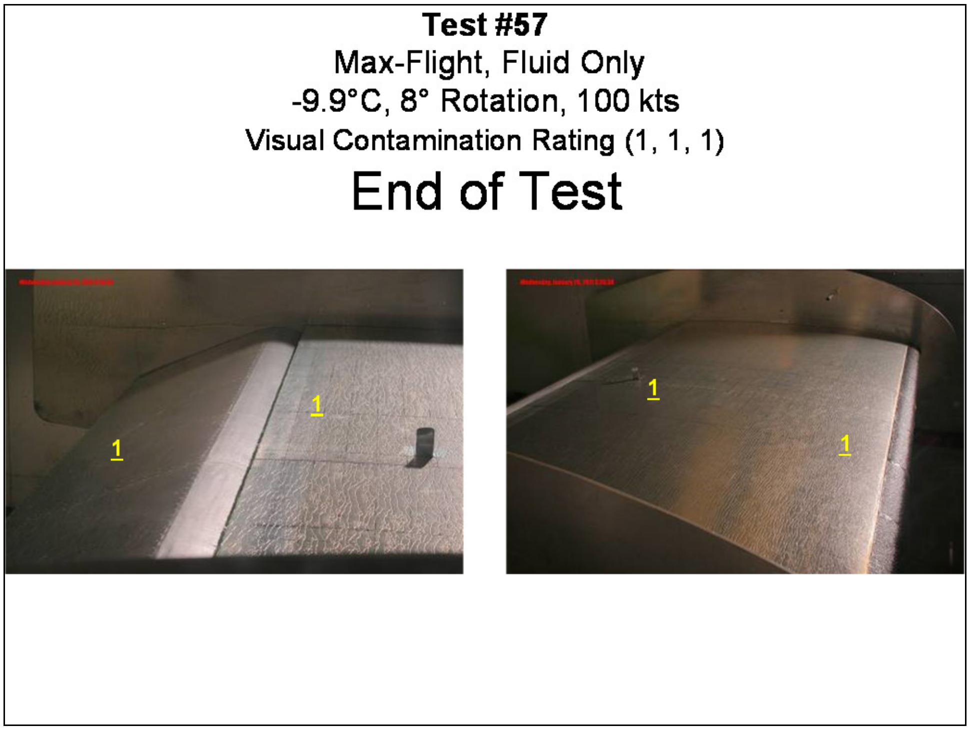
Max-Flight, Fluid Only

-9.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.85%

End of Rotation

Photo 10.24: Test #57 – End of Test



Test #57

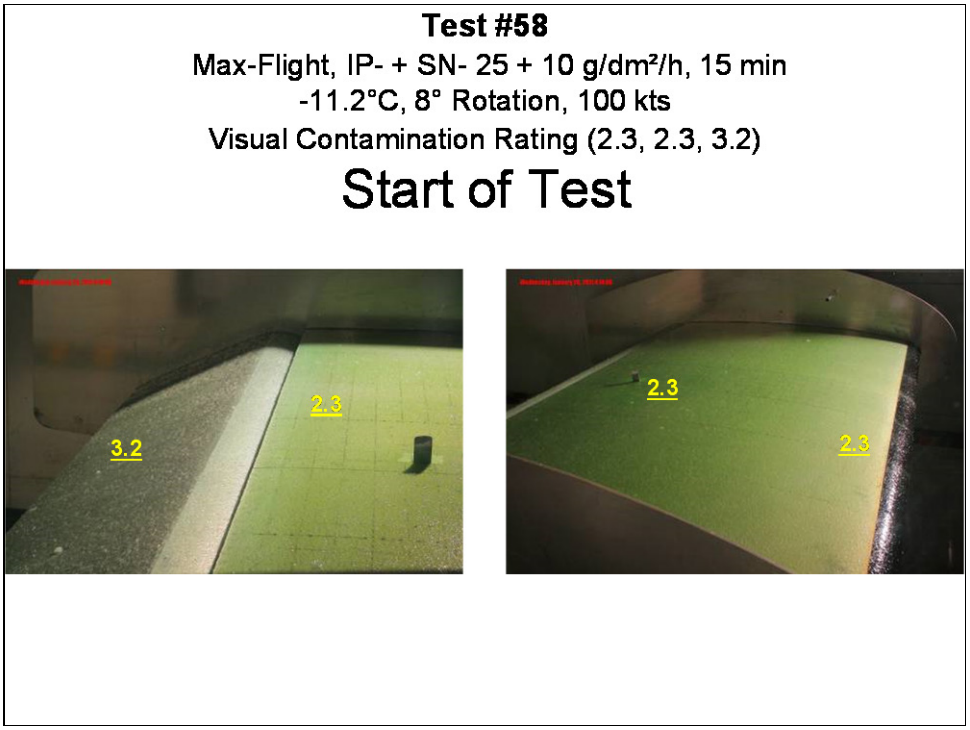
Max-Flight, Fluid Only

-9.9°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 10.25: Test #58 – Start of Test



Test #58

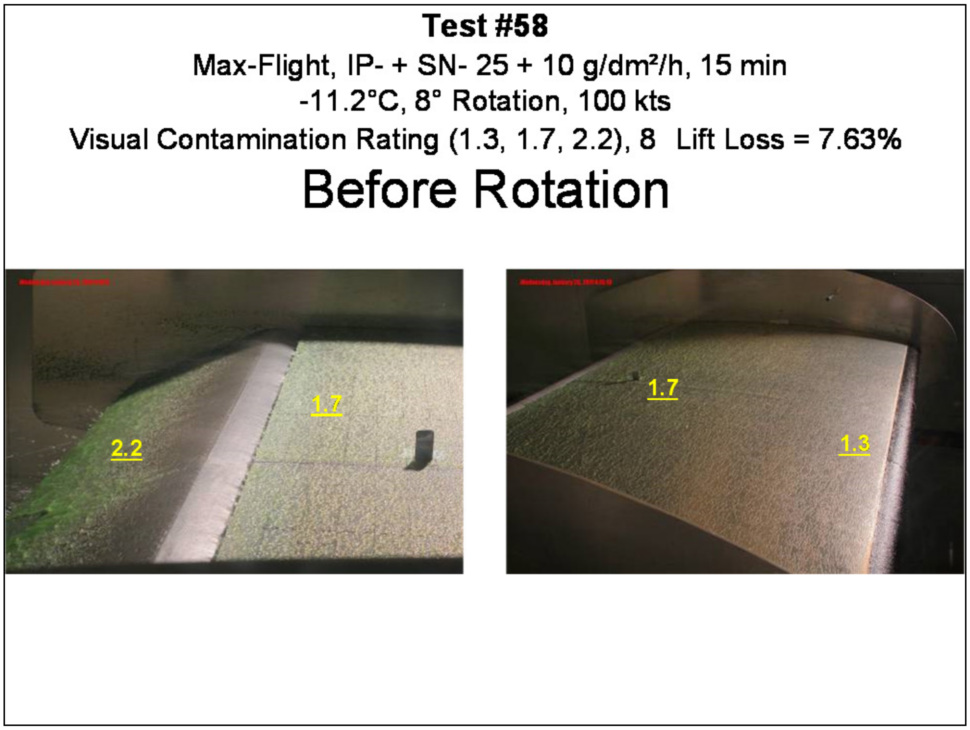
Max-Flight, IP- + SN- 25 + 10 g/dm²/h, 15 min

-11.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.3, 2.3, 3.2)

Start of Test

Photo 10.26: Test #58 – Before Rotation



Test #58

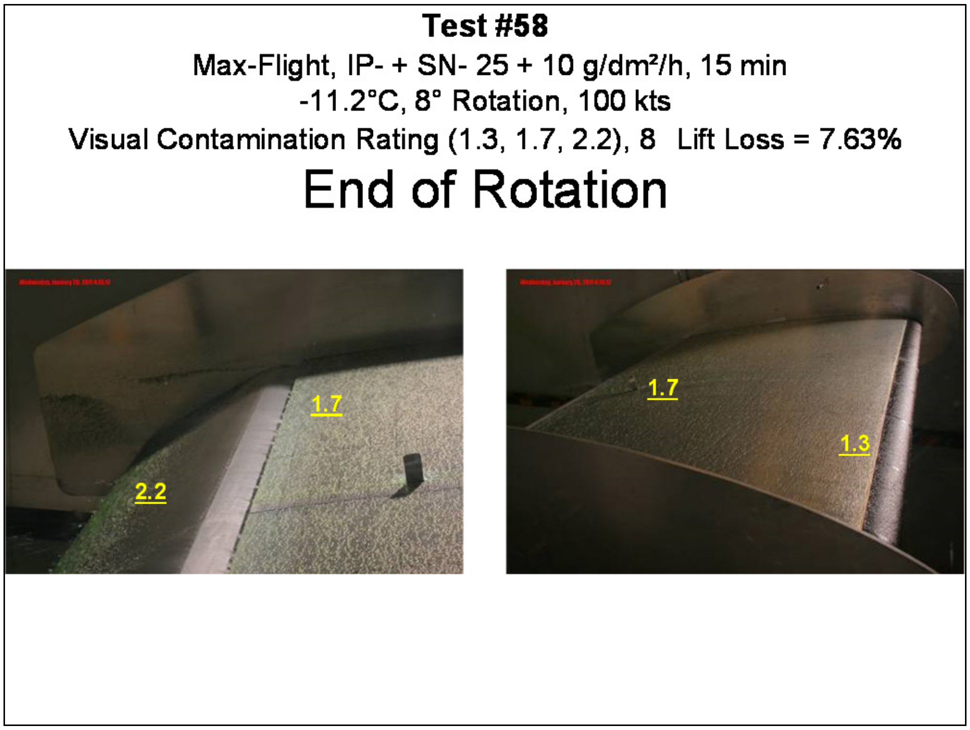
Max-Flight, IP- + SN- 25 + 10 g/dm²/h, 15 min

-11.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.3, 1.7, 2.2), 8 Lift Loss = 7.63%

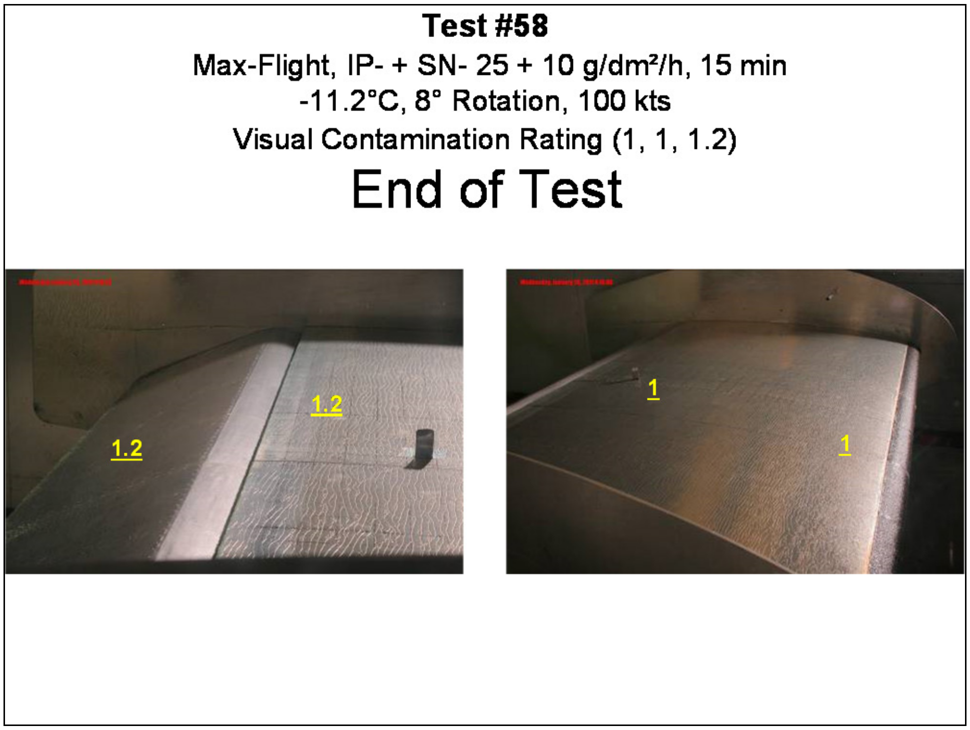
Before Rotation

Photo 10.27: Test #58 – End of Rotation



Test #58
Max-Flight, IP- + SN- 25 + 10 g/dm²/h, 15 min
-11.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1.3, 1.7, 2.2), 8 Lift Loss = 7.63%
End of Rotation

Photo 10.28: Test #58 – End of Test



Test #58
Max-Flight, IP- + SN- 25 + 10 g/dm²/h, 15 min
-11.2°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1.2)
End of Test

Photo 10.29: Test #70 (09-10) – Start of Test

Test #70
Launch, Fluid Only
-18°C, 8° Rotation
Visual Contamination Rating (1,1,1)
Start of Test

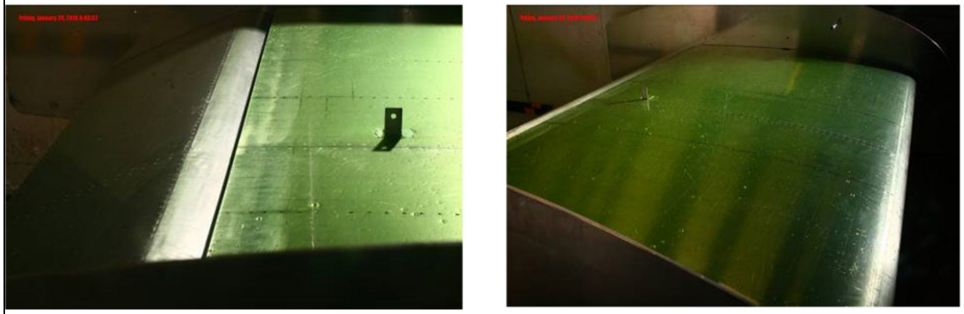


Photo 10.30: Test #70 (09-10) – Before Rotation

Test #70
Launch, Fluid Only
-18°C, 8° Rotation
Visual Contamination Rating (1,1,1)
Before Rotation

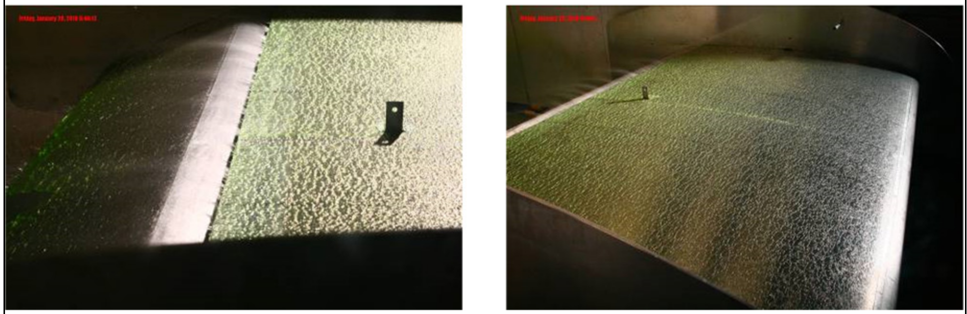
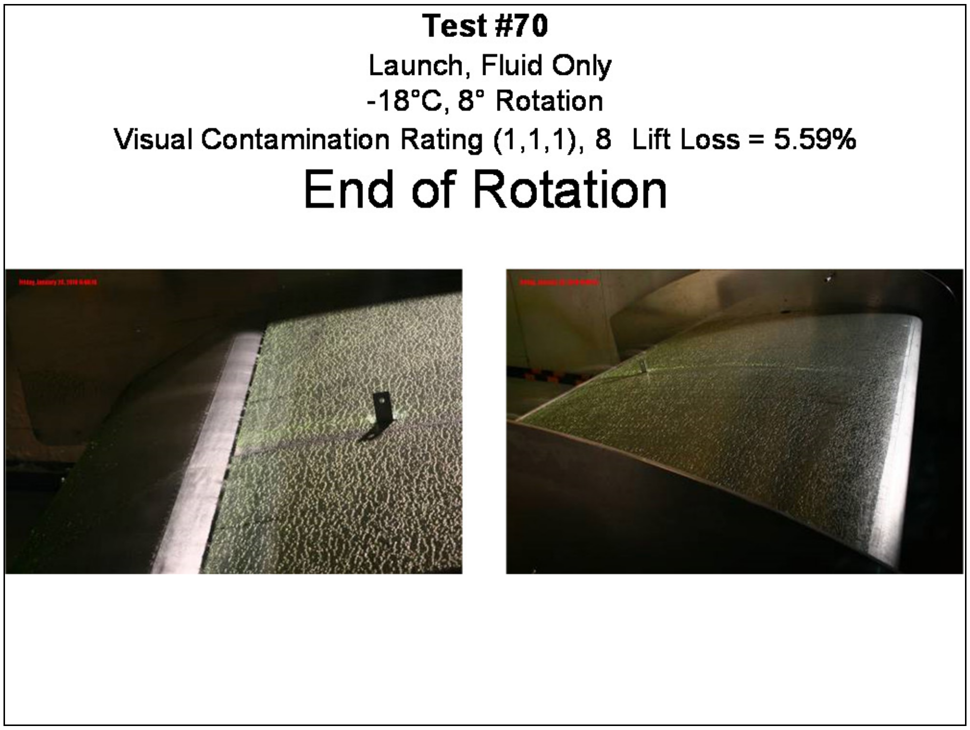


Photo 10.31: Test #70 (09-10) – End of Rotation



Test #70

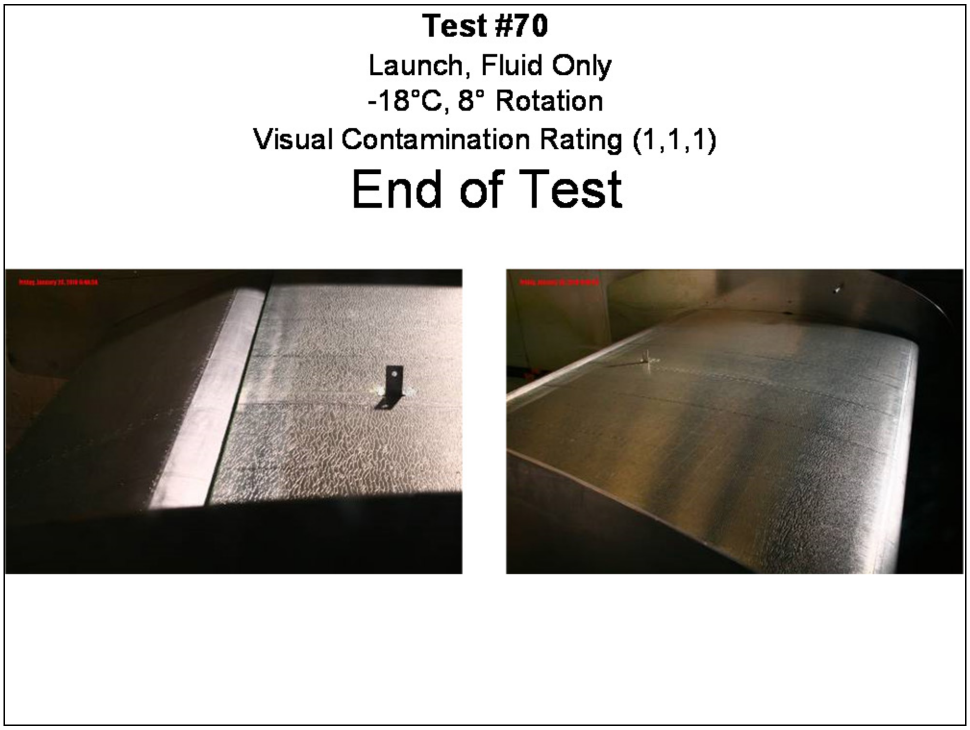
Launch, Fluid Only

-18°C, 8° Rotation

Visual Contamination Rating (1,1,1), 8 Lift Loss = 5.59%

End of Rotation

Photo 10.32: Test #70 (09-10) – End of Test



Test #70

Launch, Fluid Only

-18°C, 8° Rotation

Visual Contamination Rating (1,1,1)

End of Test

Photo 10.33: Test #74 – Start of Test

Test #74

Max-Flight, IP- + SN- 25 + 10 g/dm^2/h, 25 min

-4.8°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (2.5, 2.3, 3)

Start of Test

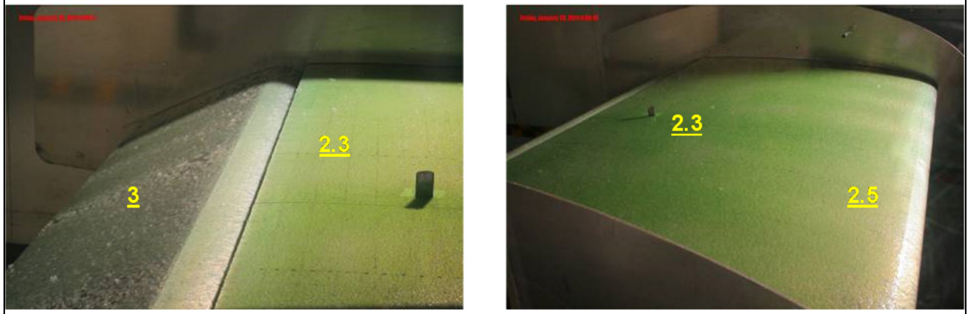


Photo 10.34: Test #74 – Before Rotation

Test #74

Max-Flight, IP- + SN- 25 + 10 g/dm^2/h, 25 min

-4.8°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1.5, 1.6), 8 Lift Loss = 6.75%

Before Rotation

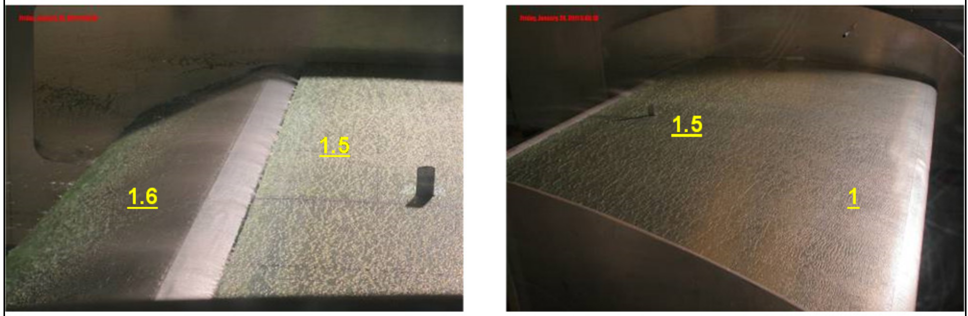
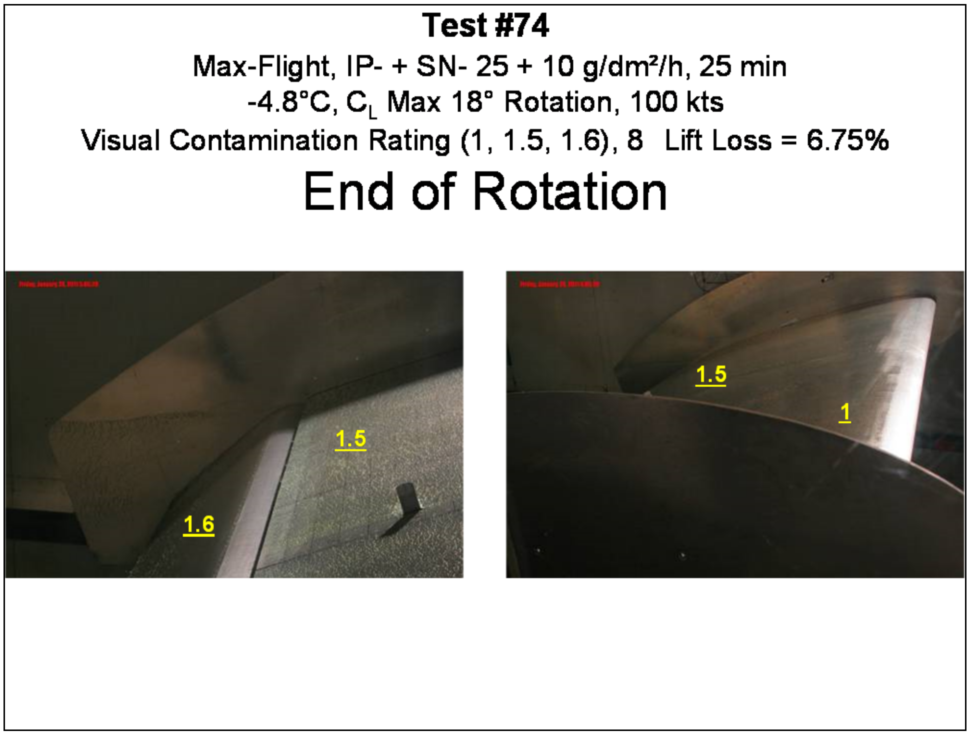


Photo 10.35: Test #74 – End of Rotation



Test #74

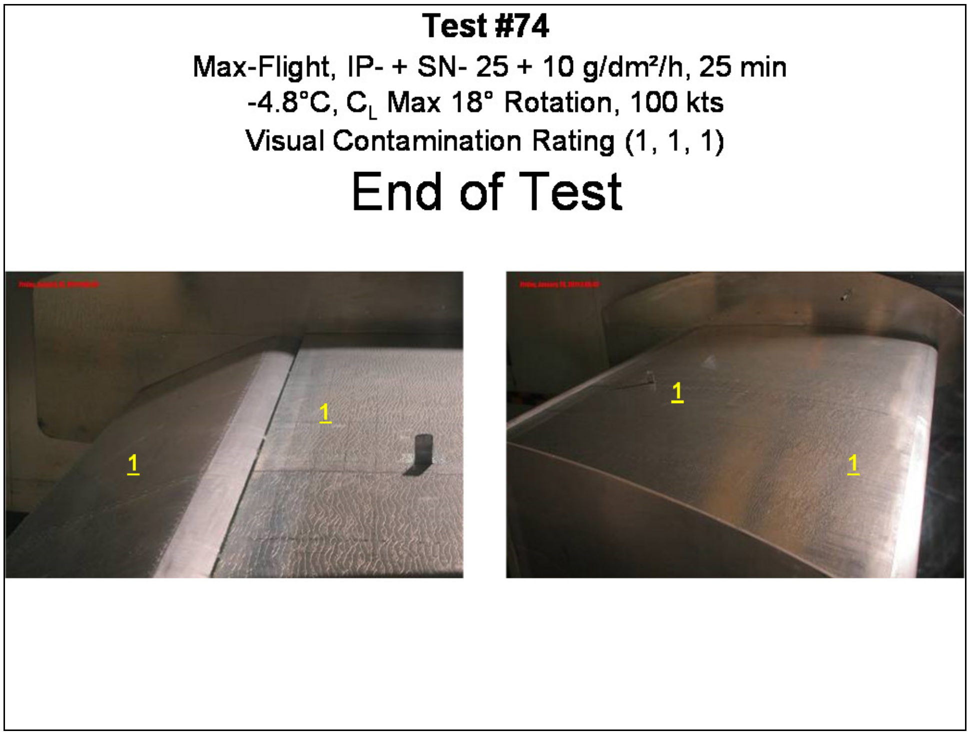
Max-Flight, IP- + SN- 25 + 10 g/dm²/h, 25 min

-4.8°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1.5, 1.6), 8 Lift Loss = 6.75%

End of Rotation

Photo 10.36: Test #74 – End of Test



Test #74

Max-Flight, IP- + SN- 25 + 10 g/dm²/h, 25 min

-4.8°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 10.37: Test #76 – Start of Test

Test #76
Max-Flight, Fluid Only
-5.5°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

Start of Test

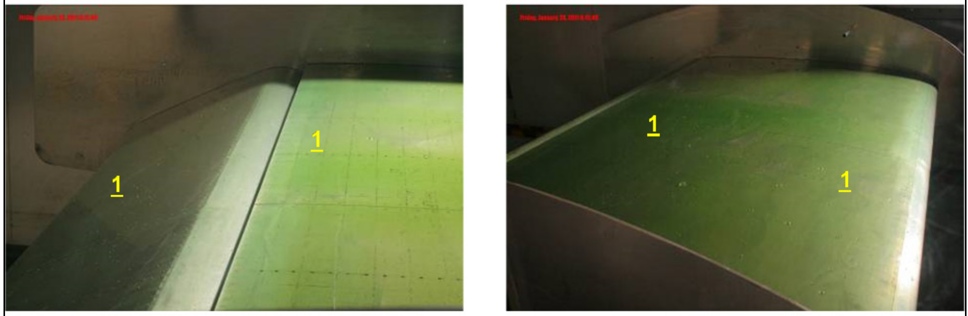


Photo 10.38: Test #76 – Before Rotation

Test #76
Max-Flight, Fluid Only
-5.5°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.61%

Before Rotation

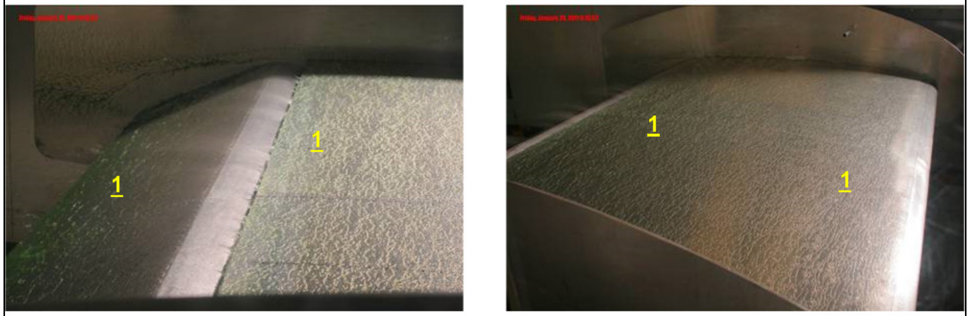
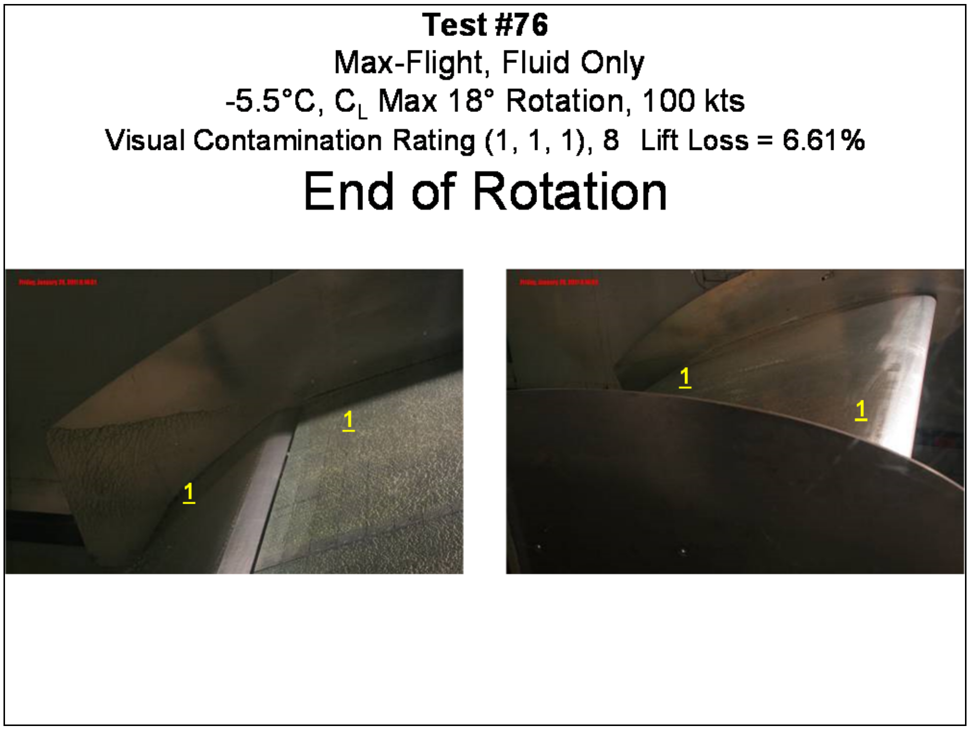
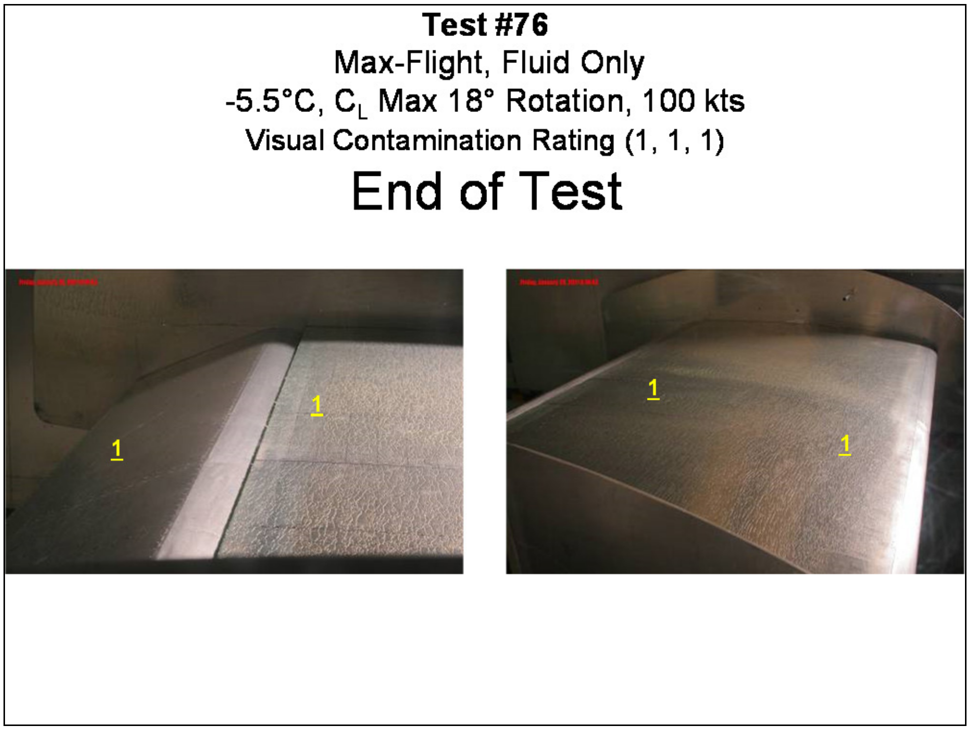


Photo 10.39: Test #76 – End of Rotation



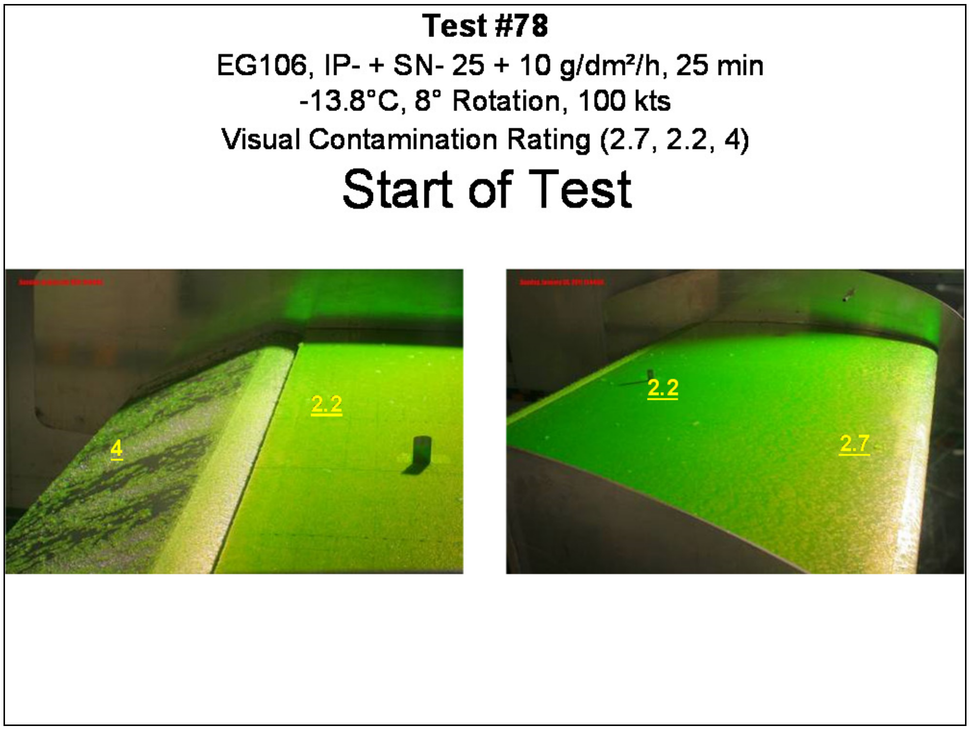
Test #76
Max-Flight, Fluid Only
-5.5°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.61%
End of Rotation

Photo 10.40: Test #76 – End of Test



Test #76
Max-Flight, Fluid Only
-5.5°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 10.41: Test #78 – Start of Test



Test #78

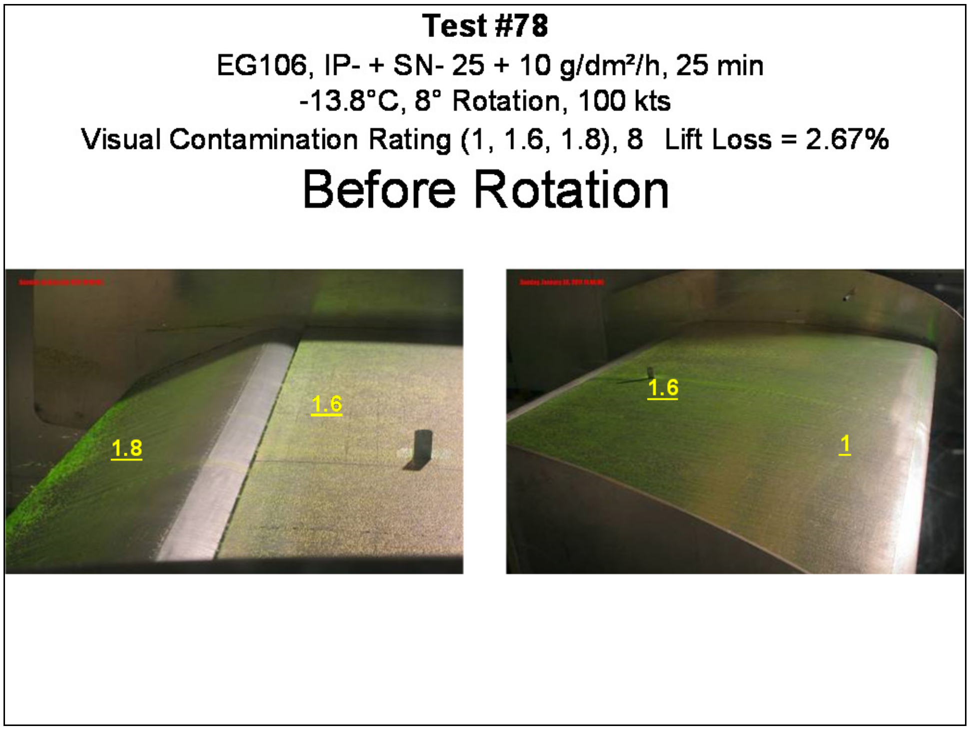
EG106, IP- + SN- 25 + 10 g/dm²/h, 25 min

-13.8°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.7, 2.2, 4)

Start of Test

Photo 10.42: Test #78 – Before Rotation



Test #78

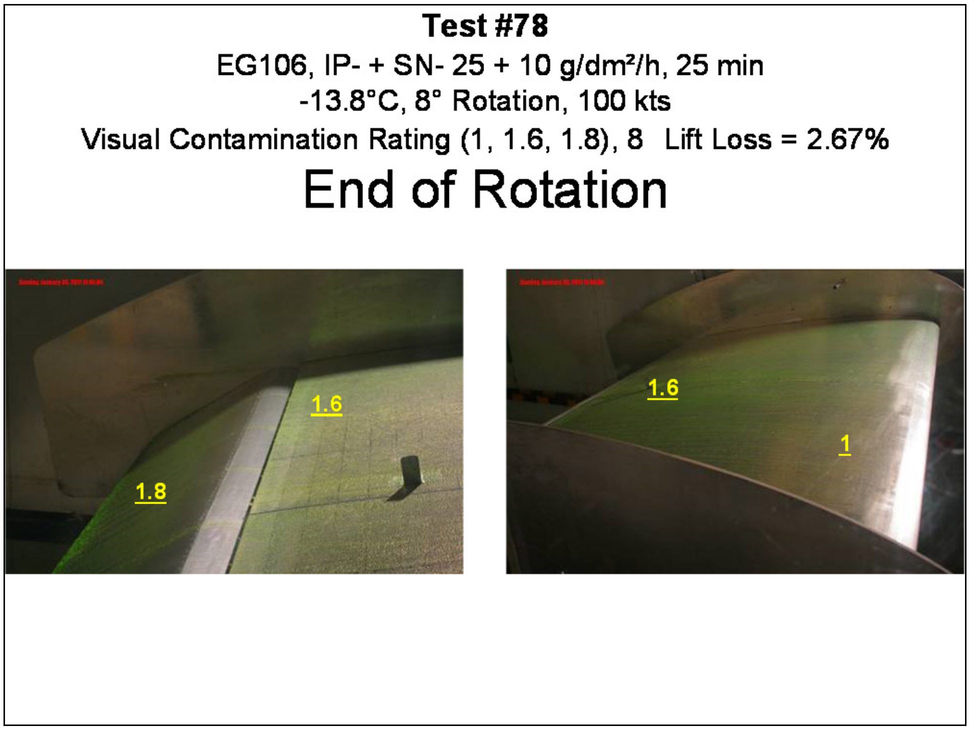
EG106, IP- + SN- 25 + 10 g/dm²/h, 25 min

-13.8°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.6, 1.8), 8 Lift Loss = 2.67%

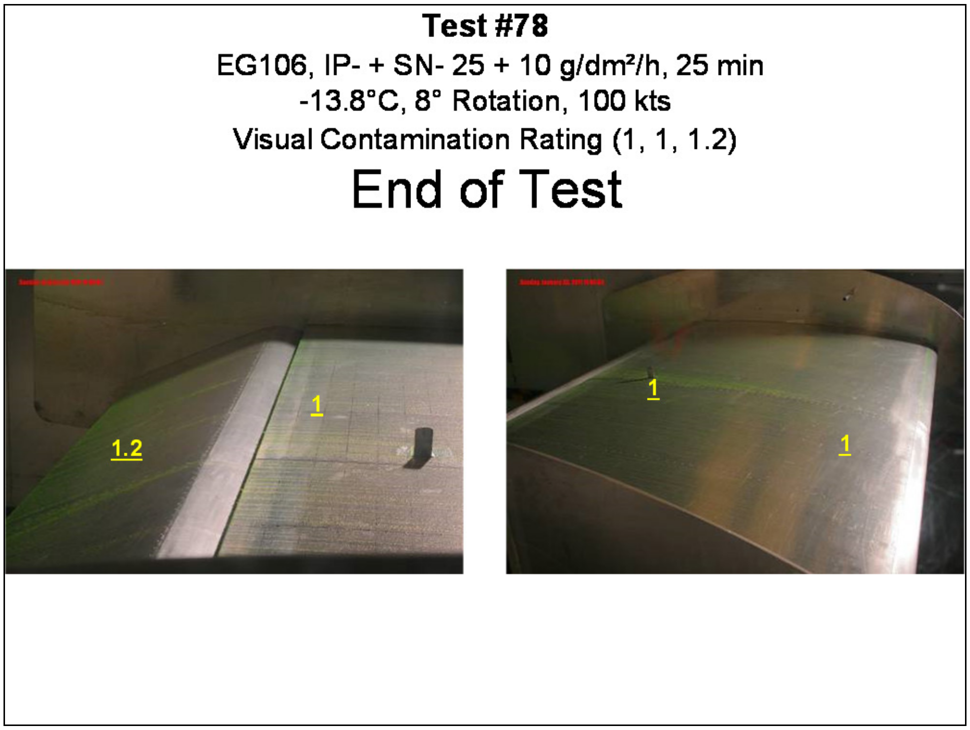
Before Rotation

Photo 10.43: Test #78 – End of Rotation



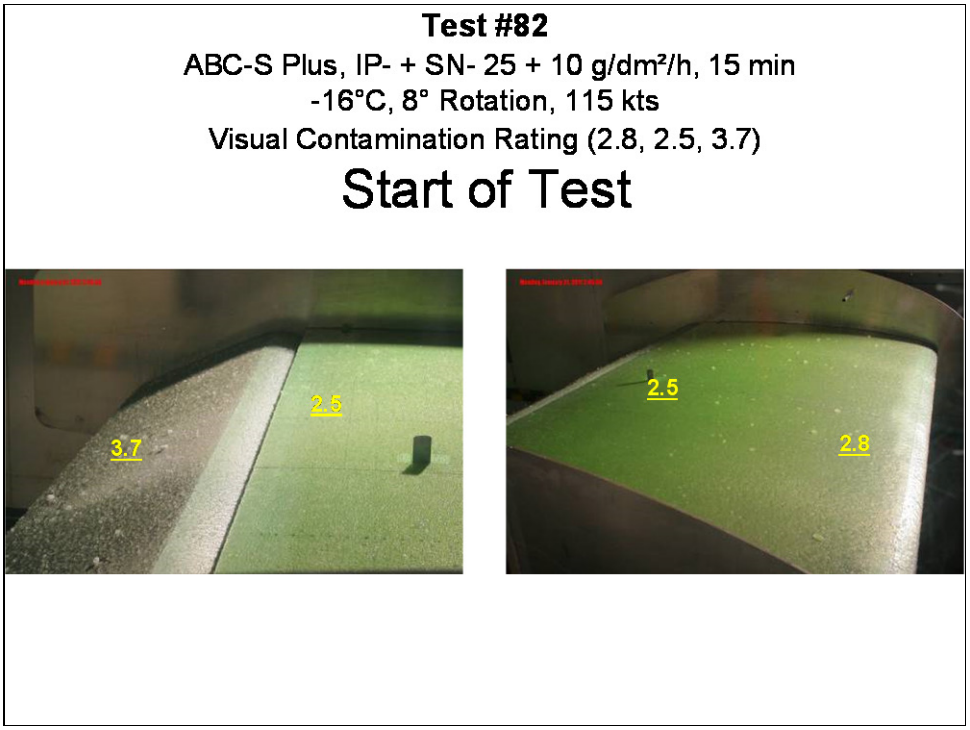
Test #78
EG106, IP- + SN- 25 + 10 g/dm²/h, 25 min
-13.8°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1.6, 1.8), 8 Lift Loss = 2.67%
End of Rotation

Photo 10.44: Test #78 – End of Test



Test #78
EG106, IP- + SN- 25 + 10 g/dm²/h, 25 min
-13.8°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1.2)
End of Test

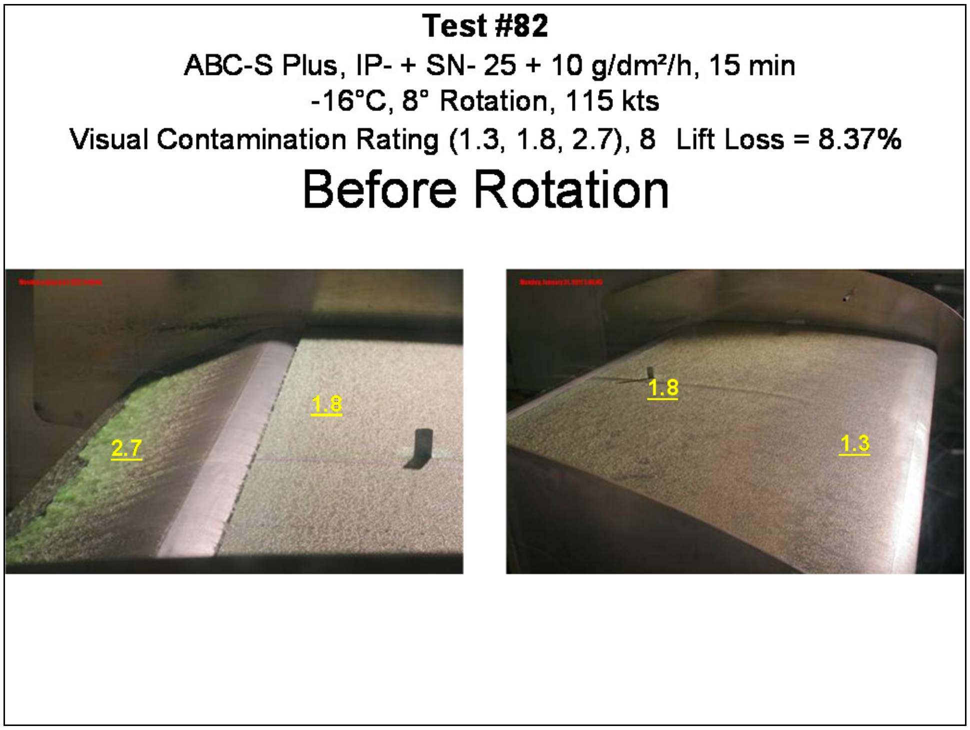
Photo 10.45: Test #82 – Start of Test



Test #82
ABC-S Plus, IP- + SN- 25 + 10 g/dm²/h, 15 min
-16°C, 8° Rotation, 115 kts
Visual Contamination Rating (2.8, 2.5, 3.7)

Start of Test

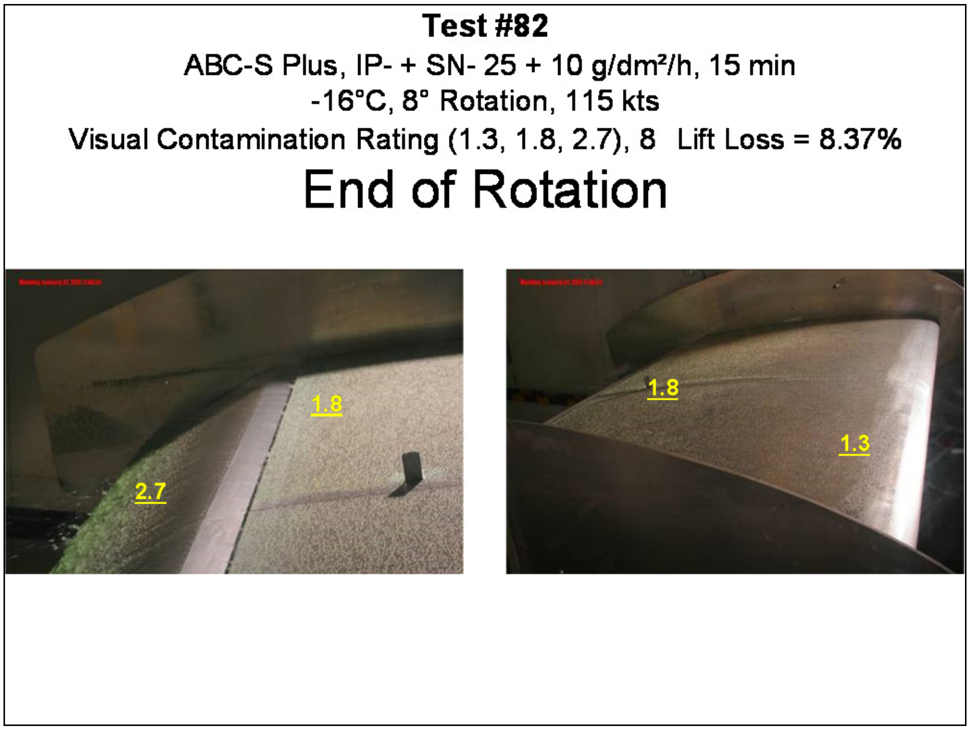
Photo 10.46: Test #82 – Before Rotation



Test #82
ABC-S Plus, IP- + SN- 25 + 10 g/dm²/h, 15 min
-16°C, 8° Rotation, 115 kts
Visual Contamination Rating (1.3, 1.8, 2.7), 8 Lift Loss = 8.37%

Before Rotation

Photo 10.47: Test #82 – End of Rotation



Test #82

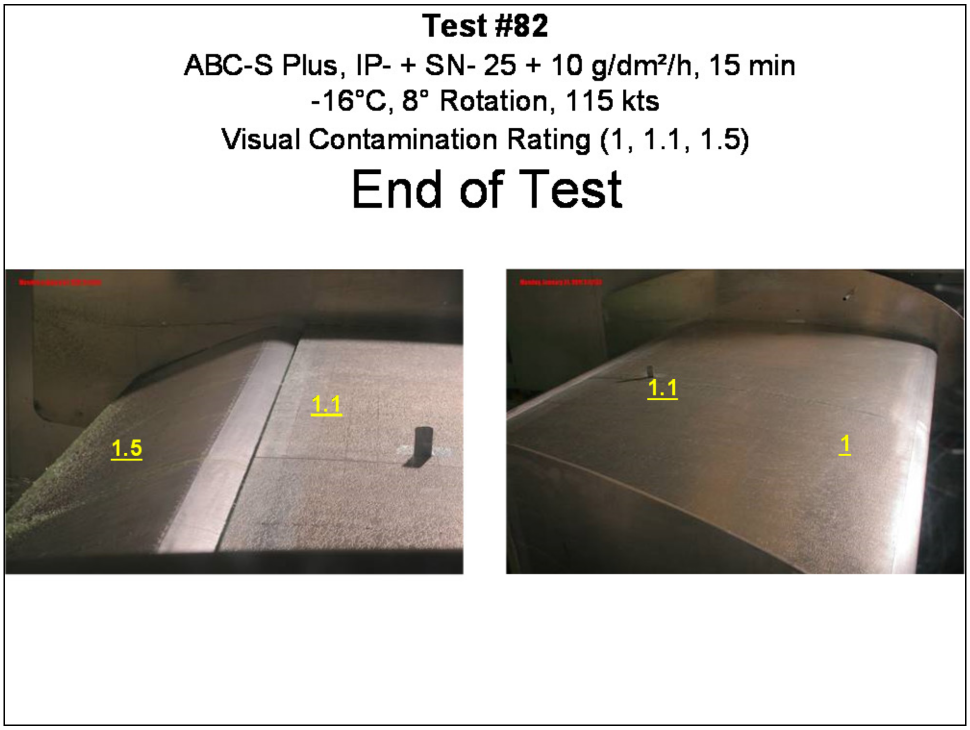
ABC-S Plus, IP- + SN- 25 + 10 g/dm²/h, 15 min

-16°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.3, 1.8, 2.7), 8 Lift Loss = 8.37%

End of Rotation

Photo 10.48: Test #82 – End of Test



Test #82

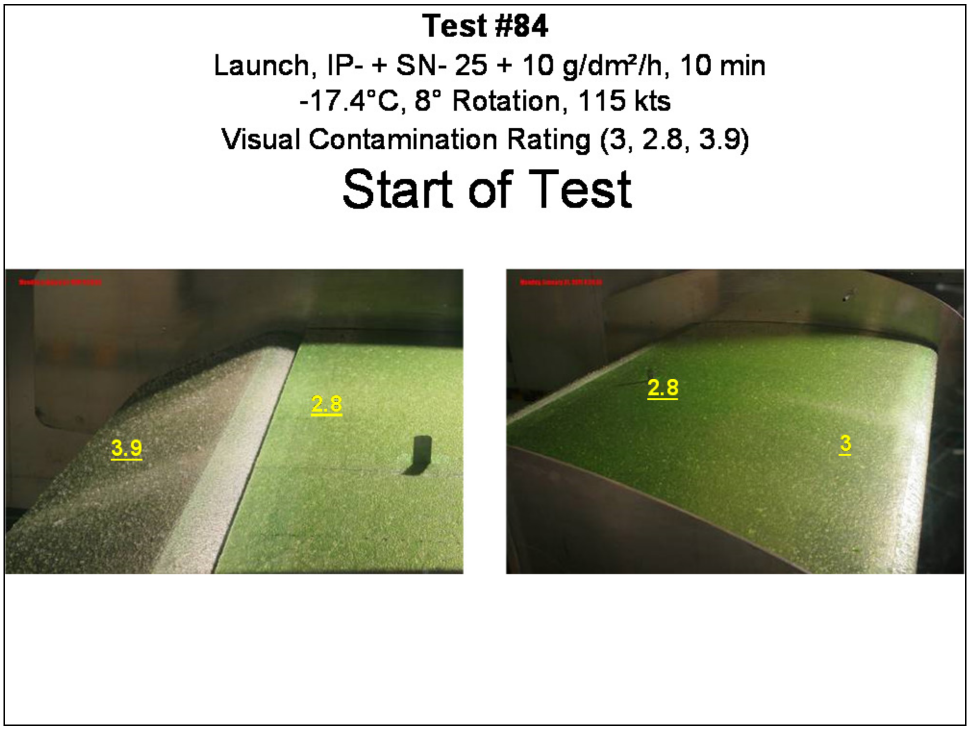
ABC-S Plus, IP- + SN- 25 + 10 g/dm²/h, 15 min

-16°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.1, 1.5)

End of Test

Photo 10.49: Test #84 – Start of Test



Test #84

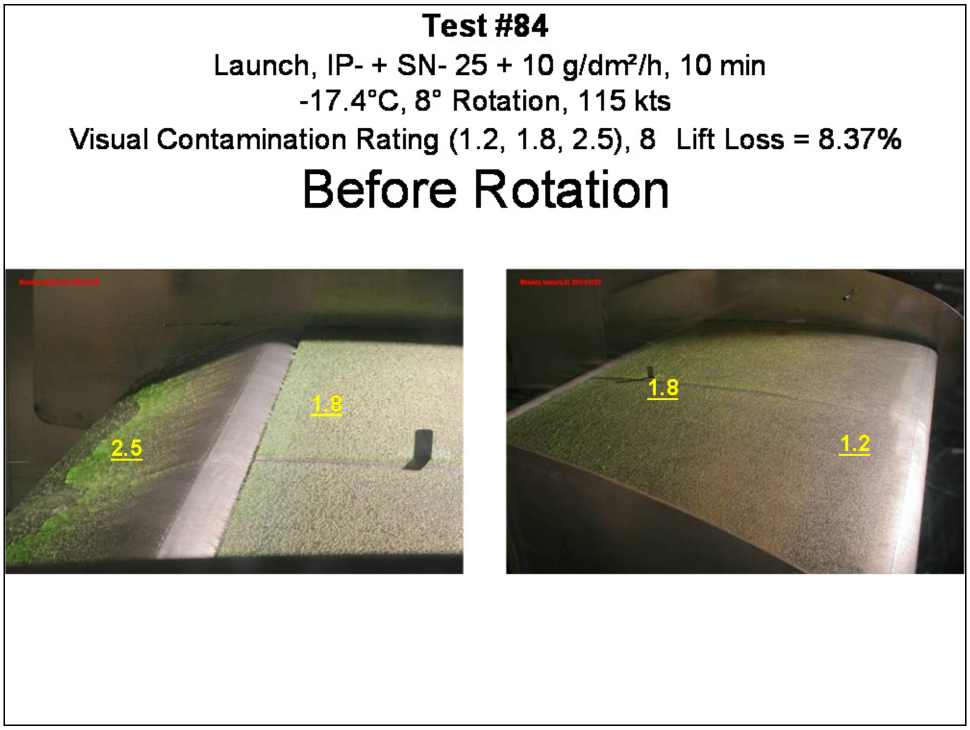
Launch, IP- + SN- 25 + 10 g/dm²/h, 10 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (3, 2.8, 3.9)

Start of Test

Photo 10.50: Test #84 – Before Rotation



Test #84

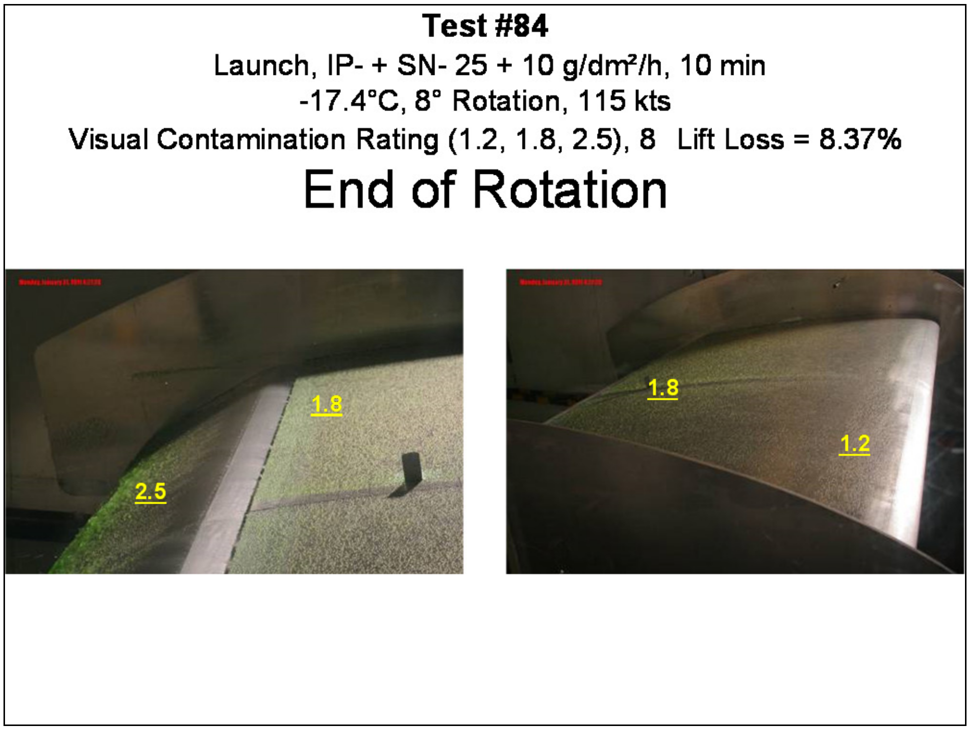
Launch, IP- + SN- 25 + 10 g/dm²/h, 10 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.2, 1.8, 2.5), 8 Lift Loss = 8.37%

Before Rotation

Photo 10.51: Test #84 – End of Rotation



Test #84

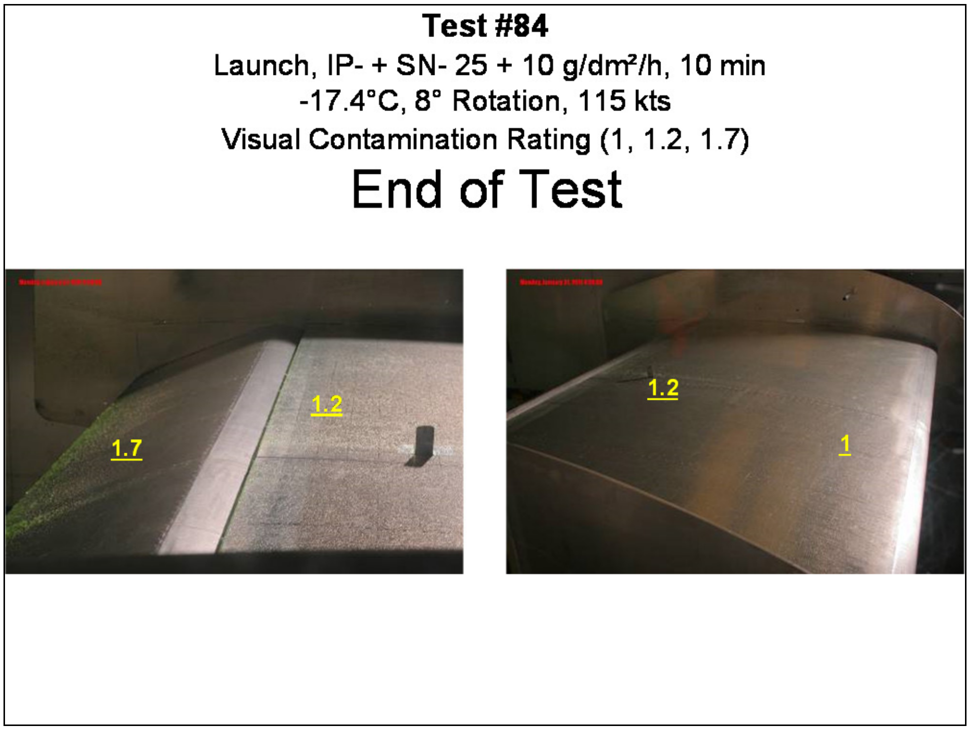
Launch, IP- + SN- 25 + 10 g/dm²/h, 10 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.2, 1.8, 2.5), 8 Lift Loss = 8.37%

End of Rotation

Photo 10.52: Test #84 – End of Test



Test #84

Launch, IP- + SN- 25 + 10 g/dm²/h, 10 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.2, 1.7)

End of Test

11. LIGHT ICE PELLETS MIXED WITH MODERATE SNOW ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Previous testing in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Light Freezing Rain;
- Section 9: Light Ice Pellets and Moderate Rain;
- Section 10: Light Ice Pellets and Light Snow;
- Section 11: Light Ice Pellets and Moderate Snow; and
- Section 12: Light Ice Pellets and Light Rain.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellet Mixed with Moderate Snow conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

11.1 Overview of Tests

A summary of the Light Ice Pellet Mixed with Moderate Snow tests conducted in the wind tunnel is shown in Table 11.1. The table provides relevant information for each of the tests, as well as the final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1. The following is a brief description of the column headings for Table 11.1:

Test #:	Exclusive number identifying each test.
Date:	Date when the test was conducted.

Fluid:	Aircraft deicing fluid specified by product name; all fluids were in the "neat" 100/0 dilution.
Condition:	Simulated precipitation condition.
Precipitation Rate (g/dm²/h):	Simulated freezing precipitation rate (or combination of different precipitation rates). "N/A" indicates that no precipitation was applied.
Precip. Time (min.):	Total time of exposure to simulated precipitation.
Tunnel Temp. at Start of Test (ºC):	The tunnel air temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Flap Angle (º):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended).
Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present.

	3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
CL at 8° During Rotation:	Calculated lift coefficient at the 8° wing rotation angle position; data provided by the NRC.
% Lift Loss:	% Lift Loss calculated based on the comparison of the 8° lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).
Associated Baseline Run:	The associated fluid only baseline run based on fluid selection.

Table 11.1: Summary of 2010-11 Light Ice Pellets Mixed with Moderate Snow Testing

Test No.	Date	Fluid	Associated Fluid Only Test	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
44	*25-Jan-11*	*EG 106*	52	*IP- / SN*	IP:25 , SN:25	*10*	*-13.2*	*-15.4*	*20*	*100*	2.25 , 2 , 3.5	1.15 , 1.35 , 1.1	*1.362*	*2.85*
47**	*25-Jan-11*	*Launch*	-	*IP- / SN*	IP:25 , SN:25	*5*	*-13.3*	*-14.9*	*20*	*100*	2.25 , 2 , 3.5	1.3 , 1.75 , 2.25	*1.287*	*8.20*
73**	*28-Jan-11*	*Max-Flight*	71**	*IP- / SN*	IP:25 , SN:25	*10*	*-4.2*	*N/A*	*20*	*100*	2.7 , 2.3 , 3.1	1 , 1.6 , 1.7	*1.33*	*6.47*
79	*31-Jan-11*	*EG 106*	43	*IP- / SN*	IP:25 , SN:25	*15*	*-15.1*	*-12.9*	*20*	*100*	2.8 , 2.6 , 4	1.1 , 1.4 , 1.8	*1.379*	*3.02*
83*	*31-Jan-11*	*ABC-S+*	-	*IP- / SN*	IP:25 , SN:25	*10*	*-15.2*	*-13.3*	*20*	*115*	3 , 2.5 , 4	1.4 , 1.8 , 2.6	*1.283*	*9.77*
85*	*31-Jan-11*	*Launch*	-	*IP- / SN*	IP:25 , SN:25	*5*	*-17.4*	*-15.3*	*20*	*115*	2.6 , 2.5 , 3.5	1.1 , 1.7 , 2.3	*1.307*	*8.09*
104	*2-Feb-11*	*Launch*	101 (09-10)	*IP- / SN*	IP:25 , SN:25	*7*	*-7.5*	*-8.7*	*20*	*100*	2.8 , 2.5 , 3.1	1.1 , 1.6 , 1.9	*1.33*	*6.47*
105**	*3-Feb-11*	*ABC-S+*	97**	*IP- / SN*	IP:25 , SN:25	*7*	*-9.3*	*-9.6*	*20*	*100*	2.3 , 2.2 , 2.8	1.1 , 1.6 , 2	*1.301*	*8.51*
106	*3-Feb-11*	*AD-49*	5A	*IP- / SN*	IP:25 , SN:25	*7*	*-9.4*	*-9.2*	*20*	*100*	1.4 , 2.2 , 3.1	1.2 , 1.8 , 2.3	*1.319*	*7.24*
5A	*19-Jan-11*	*AD-49*	-	*Fluid Only*	-	-	*-10.4*	*-8.2*	*20*	*100*	1 , 1 , 1	1 , 1 , 1	*1.367*	*3.87*
43	*25-Jan-11*	*EG 106*	-	*Fluid Only*	-	-	*-15*	*-16*	*20*	*100*	1 , 1 , 1	1 , 1 , 1	*1.359*	*3.07*
52	*25-Jan-11*	*EG 106*	-	*Fluid Only*	-	-	*-13.4*	*-12.6*	*20*	*100*	1 , 1 , 1	1 , 1 , 1	*1.363*	*2.78*
71**	*28-Jan-11*	*Max-Flight*	-	*Fluid Only*	-	-	*-3.7*	*-2.3*	*20*	*100*	1 , 1 , 1	1 , 1 , 1	*1.332*	*6.33*
97**	*2-Feb-11*	*ABC-S+*	-	*Fluid Only*	-	-	*-11.9*	*-10.4*	*20*	*100*	1 , 1 , 1	1 , 1 , 1	*1.338*	*5.91*
101 (09-10)	*3-Feb-10*	*Launch*	-	*Fluid Only*	-	-	*-7.6*	*-8.4*	*20*	*100*	1 , 1 , 1	1 , 1 , 1	*1.636*	*4.96*

****115 kt Test,** CL Max Test,*** Special Test***

11.2 Data Collected

11.2.1 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.2. Fluid thickness measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix G shows the fluid thickness measurements collected during the contaminated fluid tests.

11.2.2 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.3. Skin temperature measurements were recorded at the following intervals:

- Before fluid application;
- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix H shows the wing temperature measurements recorded during the contaminated fluid tests.

11.2.3 Fluid Brix Data

Fluid Brix measurements were recorded at the following intervals by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.4.

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Appendix I shows the fluid Brix measurements collected during the contaminated fluid tests.

11.3 Photos

High-speed digital photographs of each test were taken; wide-angle photos were taken of the leading edge, and close-up photos were taken of the trailing edge. For each test, photo summaries have been compiled comprising four stages

- Start of test;
- Before Rotation (just before the wing began to pitch);
- End of Rotation (end of the rotation cycle when the wing position is returned to 4 degrees); and
- End of test.

The photos taken during the Light Ice Pellets and [or: Mixed with Moderate Snow testing have been presented along with the fluid only (baseline) tests for comparison purposes. In each case, the fluid only photo is presented first, followed by the contaminated fluid photo. Photos 11.1 to 11.60 show the photo summaries of the tests conducted. A complete set of photos will be provided to the TDC in electronic format.

11.4 Summary of Results

11.4.1 OAT -5°C and Above

One test (#73) was conducted with exposure times of 10 minutes in this cell. See Table 11.2 for a summary of the tests.

Test #73, conducted at a temperature of -4.2°C with a PG fluid, demonstrated good results. The visual ratings at the start of test and at rotation were deemed good. The lift loss at 8° was 6.47 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test, however, do not suggest a need to change the current allowance time of 10 minutes. See Table 11.3 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that the current allowance time of 10 minutes for this cell is acceptable and validated. There is a potential to expand to 20 minutes for PG and EG fluids based on supporting data from 2009-10; however, more data and analysis are necessary.

Table 11.2: Light Ice Pellets Mixed with Moderate Snow Allowance Time Tests Winter 2010-11

LightIce Pellets Mixed with Moderate Snow	**OAT -5°C and Above**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	10 minutes **Test # 73**	**Caution: No allowance times currently exist**	**Caution: No allowance times currently exist**
		5 minutes **Test # (47),**	5 minutes **Test # 47**
		7 minutes **Test # 104, 105, 106**	10 minutes **Test # 44**
		10 minutes **Test # (47),**	15 minutes **Test # 79**
115 kts	10 minutes	**Caution: No allowance times currently exist**	**Caution: No allowance times currently exist**
			5 minutes **Test # 85**
			10 minutes **Test # 83**

Table 11.3: Summary of Light Ice Pellets Mixed With Moderate Snow Allowance Time Test Results

OAT -5°C AND ABOVE (10 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
73	*Max-Flight*	*-4.2*	IP:25 , SN:25	*10*	2.7 , 2.3 , 3.1	GOOD	1 , 1.6 , 1.7	GOOD	*6.47*	REVIEW	REVIEW
Notes:											
CONCLUSION: ALLOWANCE TIME AT 10 MINUTES IS GOOD, COULD EXPAND TO 20 MINUTES BASED ON DATA FROM 2009-10											

OAT LESS THAN -5°C TO -10°C (No allowance times currently exist)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
44	*EG 106*	*-13.2*	IP:25 , SN:25	*10*	2.25 , 2 , 3.5	GOOD	1.15 , 1.35 , 1.1	REVIEW	*2.85*	GOOD	REVIEW
47	*Launch*	*-13.3*	IP:25 , SN:25	*5*	2.25 , 2 , 3.5	GOOD	1.3 , 1.75 , 2.25	REVIEW	*8.20*	REVIEW	REVIEW
104	*Launch*	*-7.5*	IP:25 , SN:25	*7*	2.8 , 2.5 , 3.1	GOOD	1.1 , 1.6 , 1.9	REVIEW	*6.47*	REVIEW	REVIEW
105	*ABC-S+*	*-9.3*	IP:25 , SN:25	*7*	2.3 , 2.2 , 2.8	GOOD	1.1 , 1.6 , 2	REVIEW	*8.51*	REVIEW	REVIEW
106	*AD-49*	*-9.4*	IP:25 , SN:25	*7*	1.4 , 2.2 , 3.1	GOOD	1.2 , 1.8 , 2.3	REVIEW	*7.24*	REVIEW	REVIEW
Notes:											
CONCLUSION: ALLOWANCE TIME AT 7 MINUTES IS FEASIBLE											

Table 11.3: Summary of Light Ice Pellets Mixed With Moderate Snow Allowance Time Test Results (cont'd)

OAT LESS THAN -10°C (No allowance times currently exist)											
Run #	**Fluid**	**Tunnel Temp. Before Test (ºC)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
79	*EG 106*	*-15.1*	IP:25 , SN:25	*15*	2.8 , 2.6 , 4	GOOD	1.1 , 1.4 , 1.8	REVIEW	*3.02*	GOOD	REVIEW
115 kts											
83	*ABC-S+*	*-15.2*	IP:25 , SN:25	*10*	3 , 2.5 , 4	GOOD	1.4 , 1.8 , 2.6	REVIEW	*9.77*	*BAD*	*BAD*
85	*Launch*	*-17.4*	IP:25 , SN:25	*5*	2.6 , 2.5 , 3.5	GOOD	1.1 , 1.7 , 2.3	REVIEW	*8.09*	REVIEW	REVIEW
Notes:											
CONCLUSION: AN ALLOWANCE TIME OF 15 MINUTES FOR EG FLUIDS AND AN ALLOWANCE TIME OF 5 MINUTES FOR PG FLUIDS IS FEASIBLE											

11.4.2 OAT Less than -5°C to -10°C

Although no allowance time currently exists in this cell, three tests (Tests #104, #105, and #106) were conducted with 7-minute exposure times. See Table 11.2 for a summary of the tests.

Test #104, conducted at an exposure time of 7 minutes and at a temperature of -7.5°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory. The lift loss at 8° was 6.47 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test suggest a potential allowance time of 7 minutes; however, further review of the data is required. See Table 11.3 for the details of this test.

Test #105, conducted at an exposure time of 7 minutes and at a temperature of -9.3°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory. The lift loss at 8° was 8.51 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test suggest a potential allowance time of 7 minutes; however, further review of the data is required. See Table 11.3 for the details of this test.

Test #106, conducted at an exposure time of 7 minutes and at a temperature of -9.4°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory. The lift loss at 8° was 7.24 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test suggest a potential allowance time of 7 minutes; however, further review of the data is required. See Table 11.3 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that an allowance time of 7 minutes could be developed. Further review of the data is required in order to develop an allowance time.

11.4.3 OAT Less than -10°C

Although no allowance time currently exists in this cell, Tests #47, #44, and #79 were conducted with 5- and 10-minute exposure times. Two other tests, #85 and #83, were 115 knots tests conducted with exposure times of 5 minutes and 10 minutes, respectively. See Table 11.2 for a summary of the tests.

Test #44, conducted at an exposure time of 10 minutes and at a temperature of -13.2°C with an EG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory. The lift loss at 8° was 2.85 percent, which is well below the 5.4 percent lower limit. The results of this test suggest a potential allowance time of 10 minutes for EG fluids. See Table 11.3 for the details of this test.

Test #47, conducted at an exposure time of 7 minutes and at a temperature of -13.3°C with a PG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory. The lift loss at 8° was 8.20 percent, which is above the 5.4 percent but below the 9.2 percent lower limit. The results of this test suggest a potential allowance time of 5 minutes for PG fluids; however, further review of the data is required. See Table 11.3 for the details of this test.

Test #79, conducted at an exposure time of 15 minutes and at a temperature of -15.1°C with a EG fluid, demonstrated satisfactory results. The visual rating at the start of test was good; however, the results at rotation were deemed satisfactory. The lift loss at 8° was 3.02 percent, which is above the 5.4 percent lower limit. The results of this test suggest a potential allowance time of 15 minutes for EG fluids may be possible, but further review of the data is required. See Table 11.3 for the details of this test.

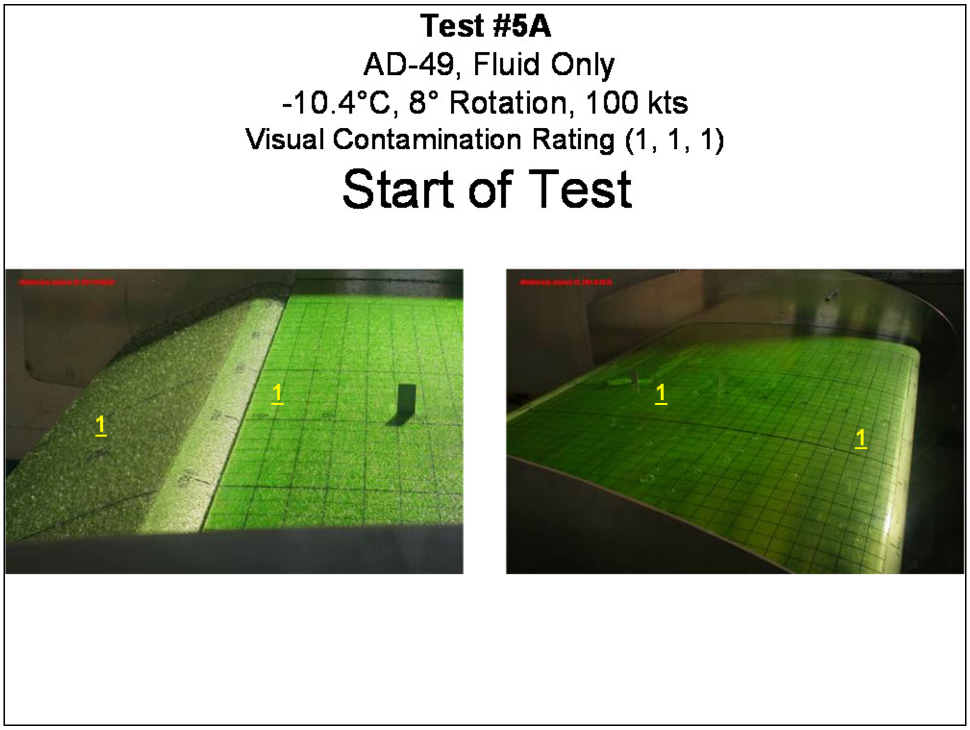
Test #83, conducted at an exposure time of 10 minutes and at a temperature of -17.4°C with a PG fluid, demonstrated good results. This test was conducted at a speed of 115 knots. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 9.77 percent, which is well above the 9.2 percent upper limit. The results of this test indicate that an allowance time of 10 minutes for PG fluids may be too severe and not appropriate. See Table 11.3 for the details of this test.

Test #85, conducted at an exposure time of 5 minutes and at a temperature of -17.4°C with a PG fluid, demonstrated good results. This test was conducted at a speed of 115 knots. The visual rating at the start of test was good, and the results at rotation were deemed satisfactory. The lift loss at 8° was 8.09 percent, which is above the 5.4 percent lower limit but below the 9.2 percent upper limit. The results of this test suggest a potential allowance time of 5 minutes for PG fluids; however, further review of the data is required. See Table 11.3 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that an allowance time could be developed. More specifically, an allowance time up to 15 minutes for EG fluids may be possible; however, 5 minutes may be the limit for PG fluids based on the preliminary data.

This page intentionally left blank.

Photo 11.1: Test 5A – Start of Test



Test #5A

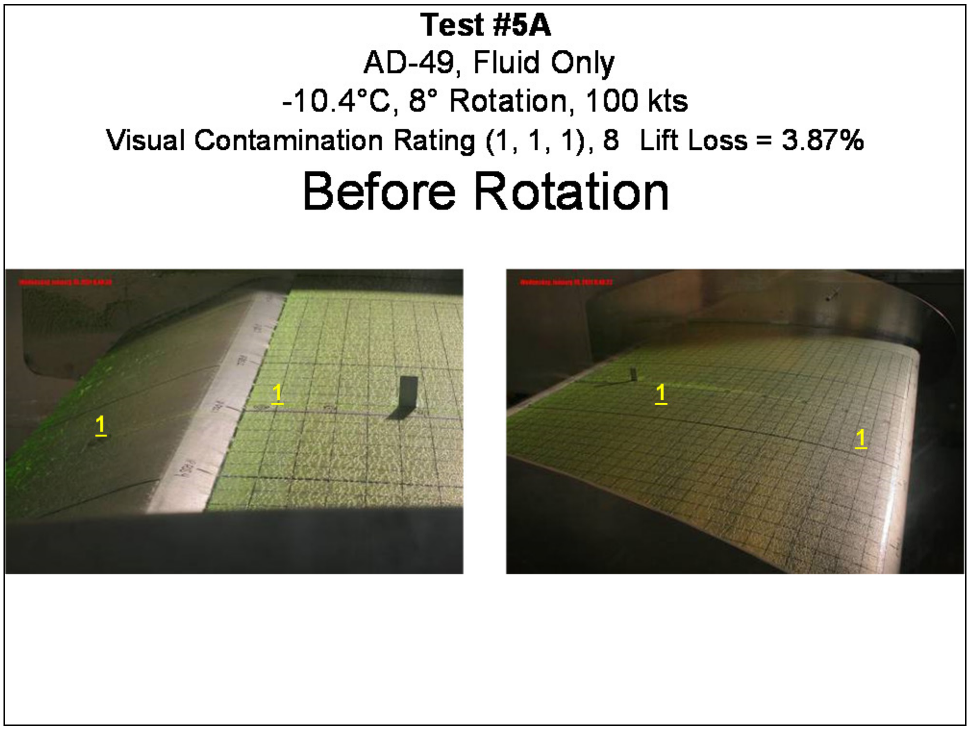
AD-49, Fluid Only

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 11.2: Test #5A – Before Rotation



Test #5A

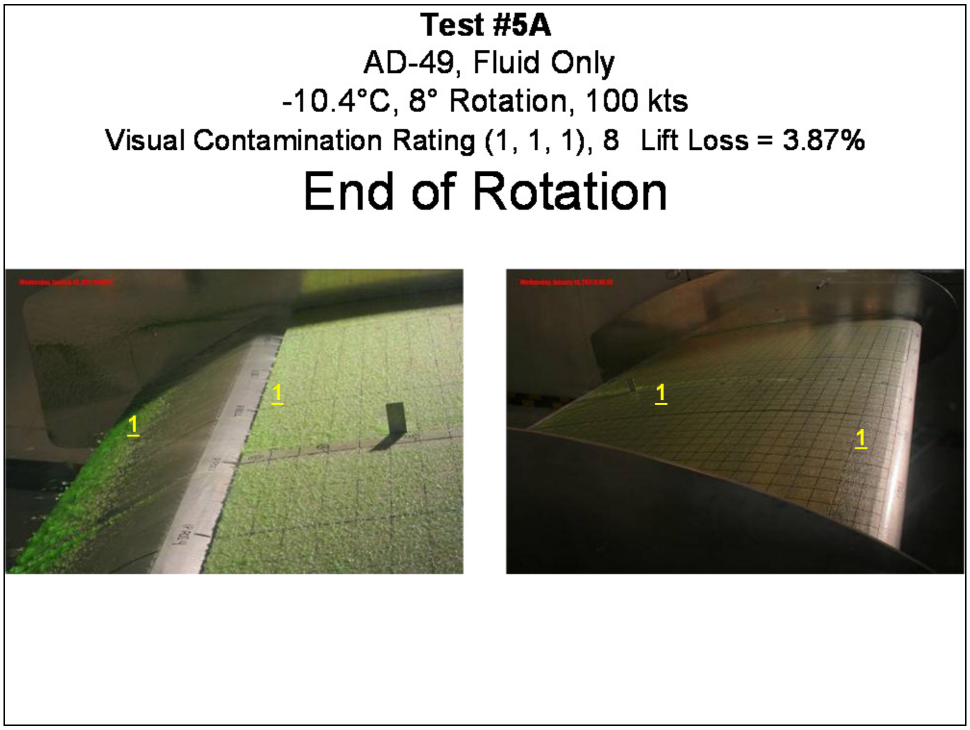
AD-49, Fluid Only

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.87%

Before Rotation

Photo 11.3: Test #5A – End of Rotation



Test #5A

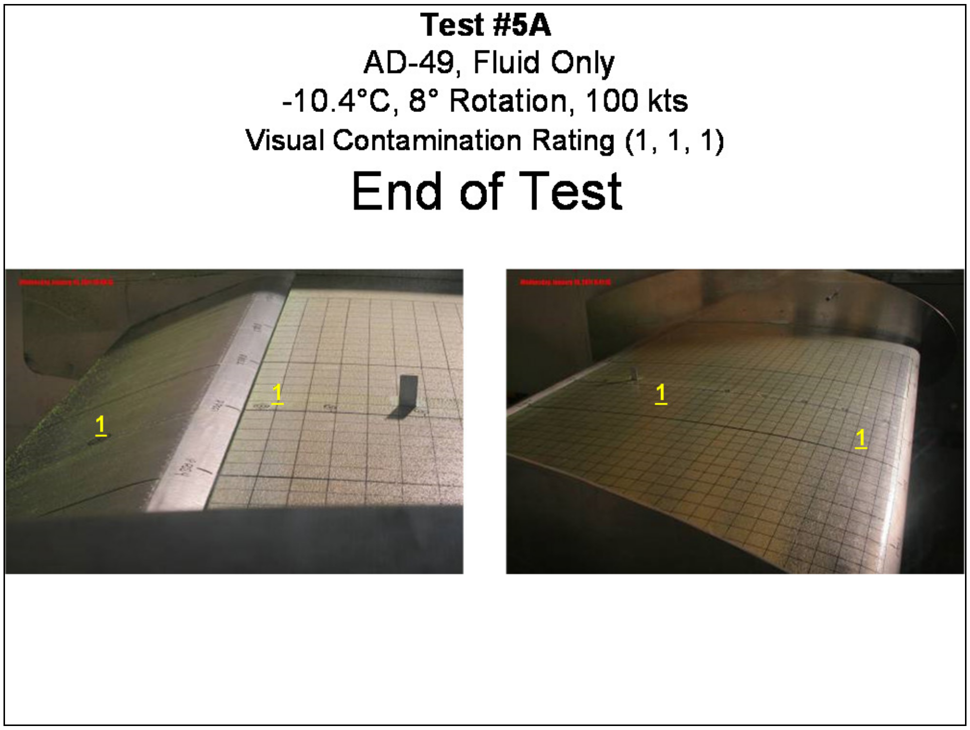
AD-49, Fluid Only

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.87%

End of Rotation

Photo 11.4: Test #5A – End of Test



Test #5A

AD-49, Fluid Only

-10.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 11.5: Test #43 – Start of Test

Test #43
EG106, Fluid Only
-15°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

Start of Test

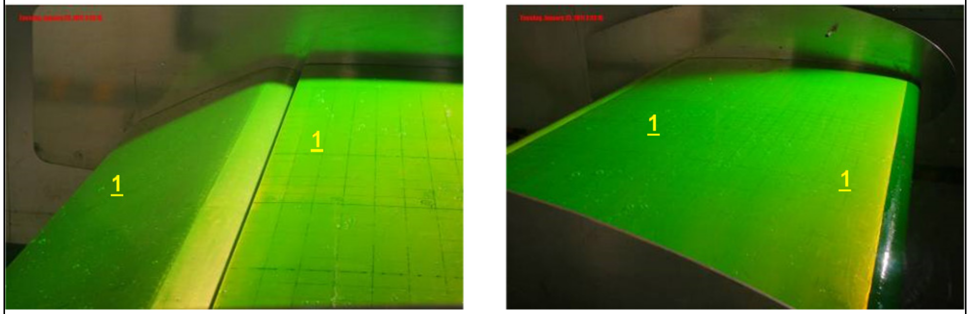


Photo 11.6: Test #43 – Before Rotation

Test #43
EG106, Fluid Only
-15°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.07%

Before Rotation

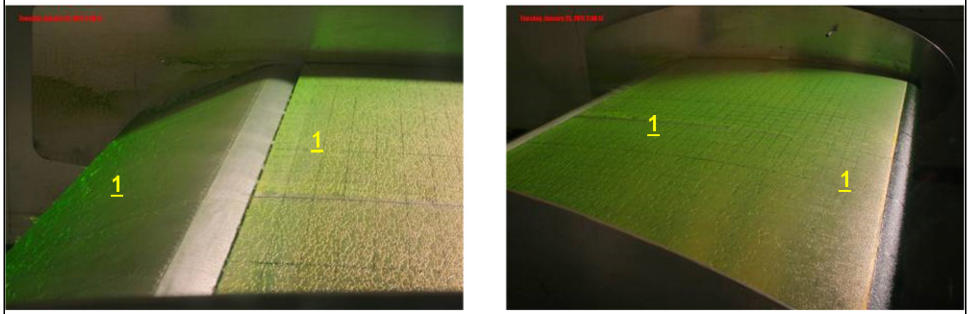
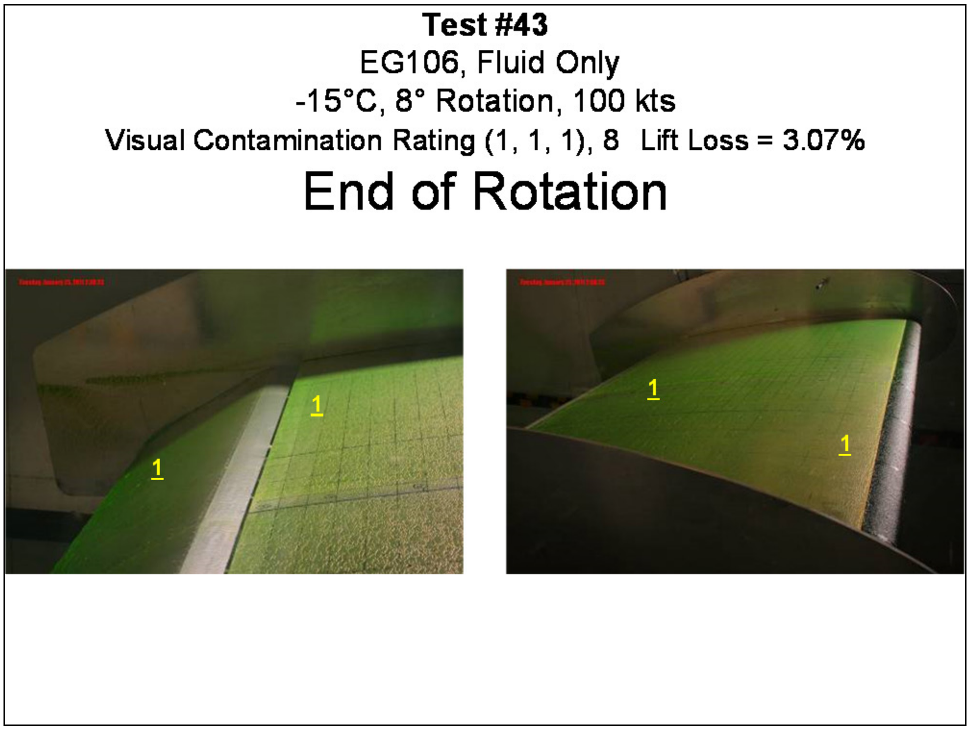


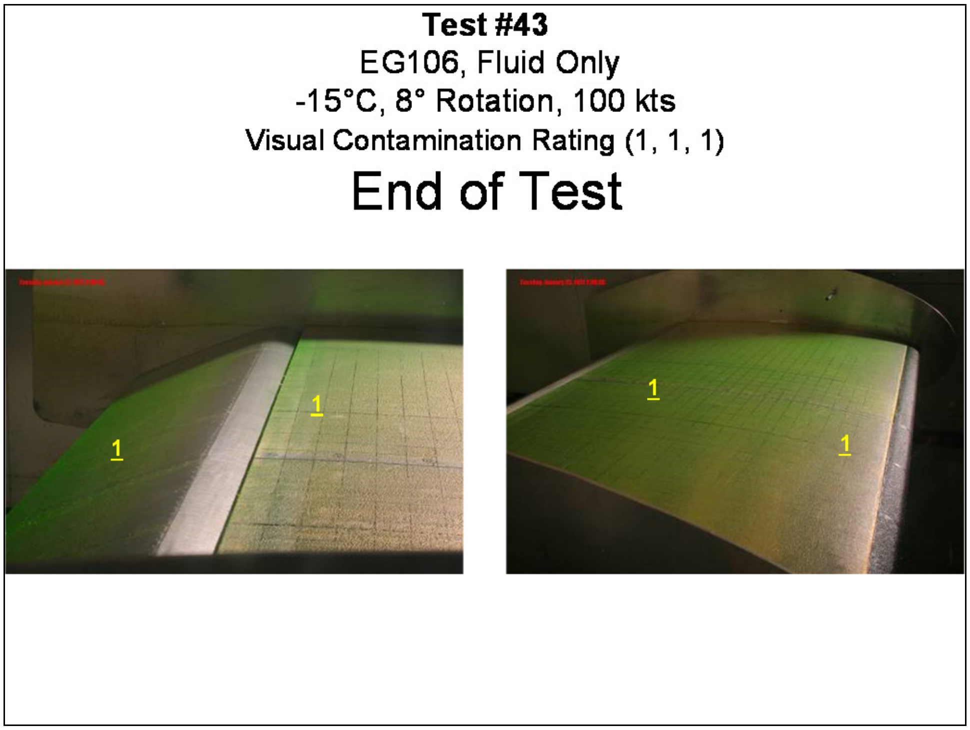
Photo 11.7: Test #43 – End of Rotation



Test #43
EG106, Fluid Only
-15°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 3.07%

End of Rotation

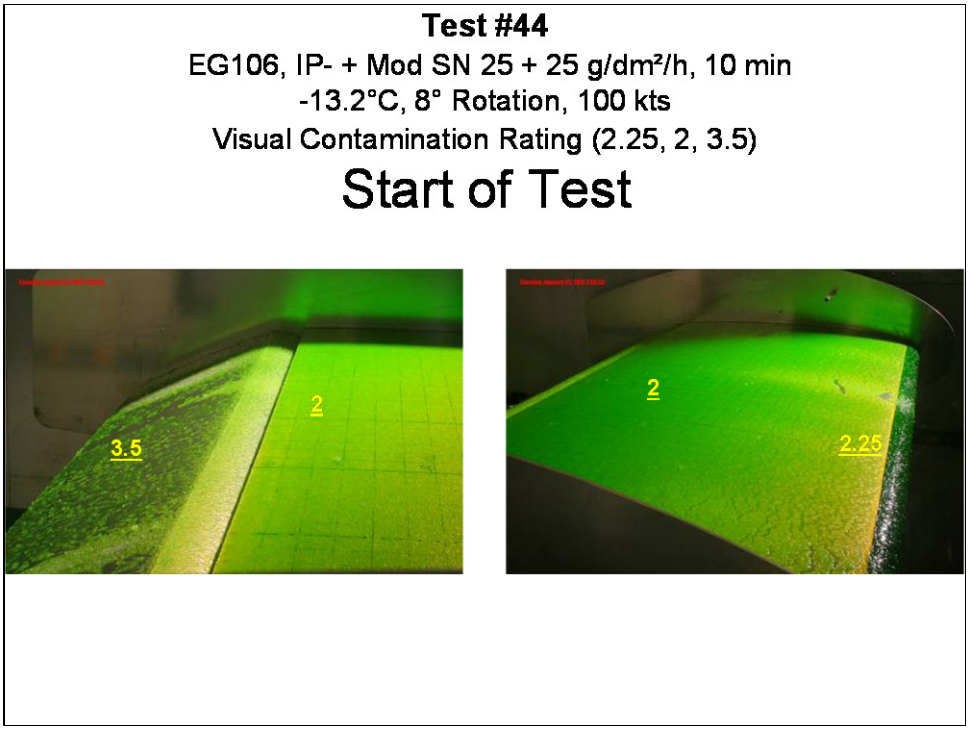
Photo 11.8: Test #43 – End of Test



Test #43
EG106, Fluid Only
-15°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

Photo 11.9: Test #44 – Start of Test



Test #44

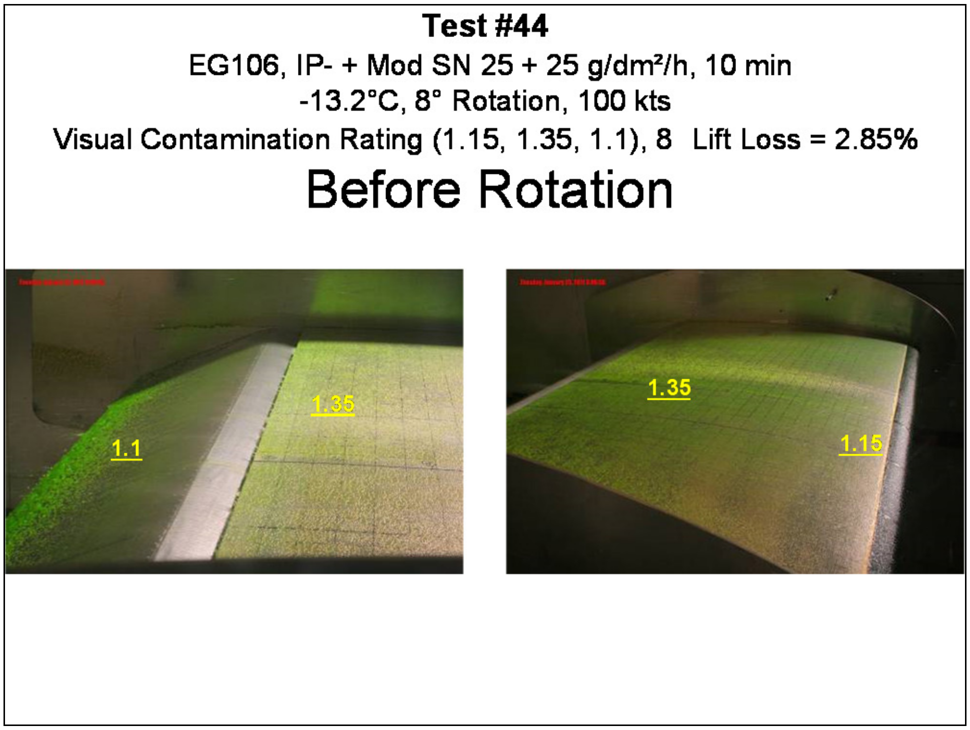
EG106, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-13.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.25, 2, 3.5)

Start of Test

Photo 11.10: Test #44 – Before Rotation



Test #44

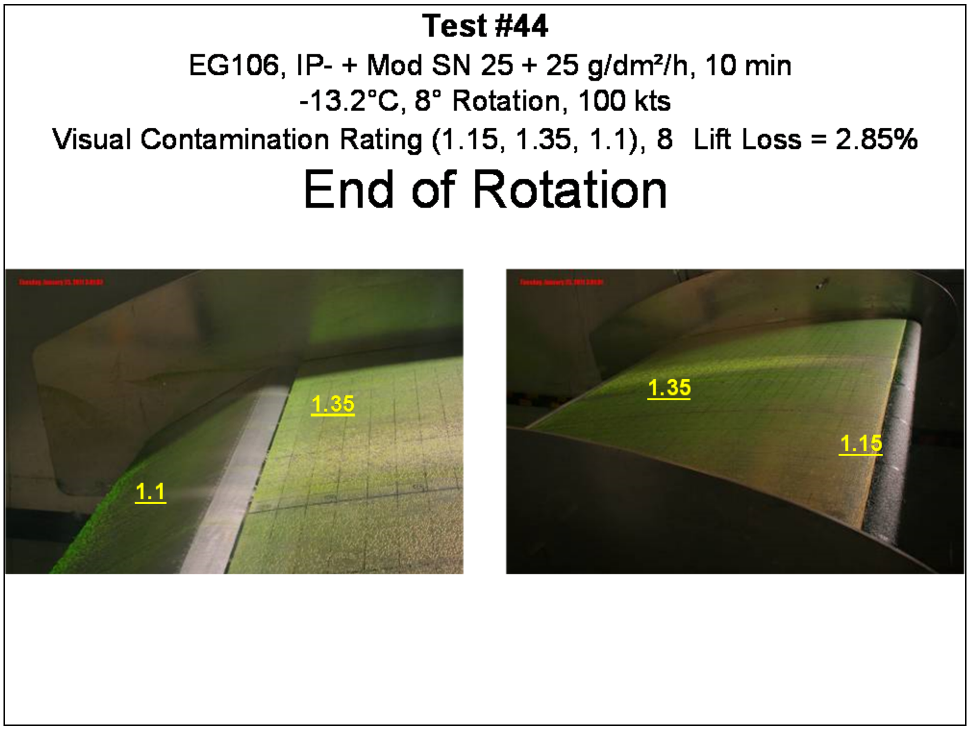
EG106, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-13.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.15, 1.35, 1.1), 8 Lift Loss = 2.85%

Before Rotation

Photo 11.11: Test #44 – End of Rotation



Test #44

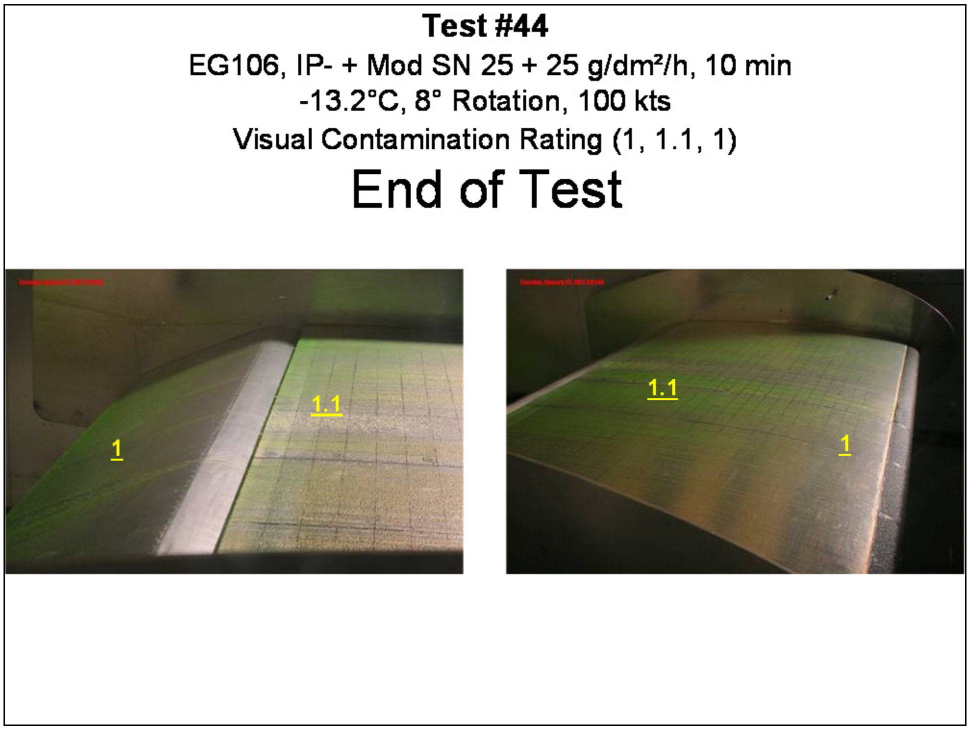
EG106, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-13.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.15, 1.35, 1.1), 8 Lift Loss = 2.85%

End of Rotation

Photo 11.12: Test #44 – End of Test



Test #44

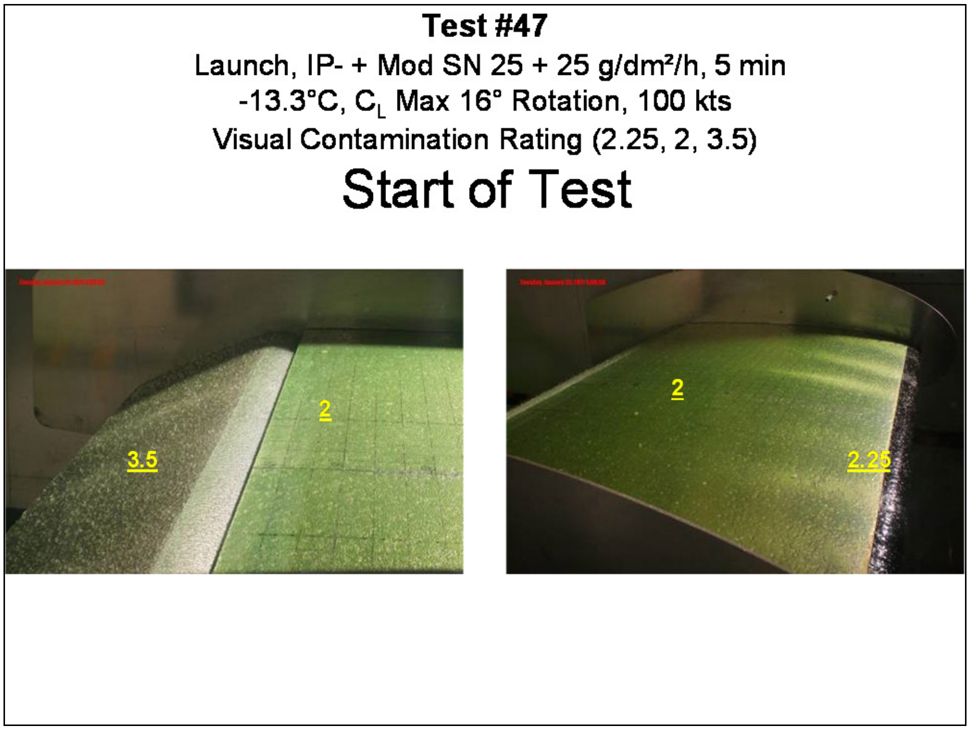
EG106, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-13.2°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.1, 1)

End of Test

Photo 11.13: Test #47 – Start of Test



Test #47

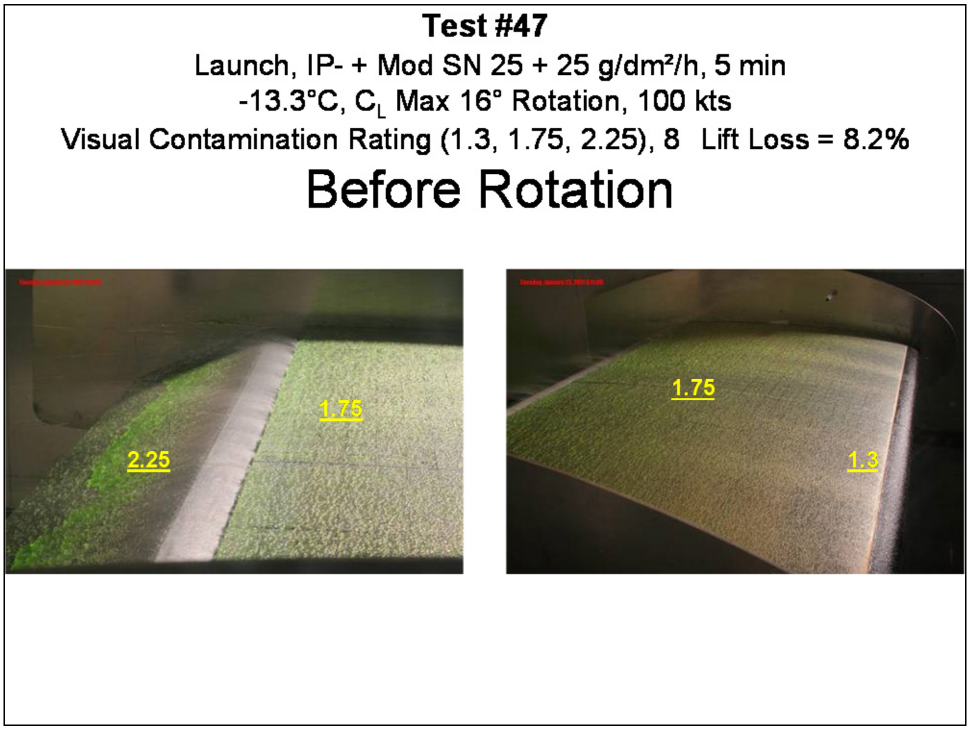
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-13.3°C, C_L Max 16° Rotation, 100 kts

Visual Contamination Rating (2.25, 2, 3.5)

Start of Test

Photo 11.14: Test #47 – Before Rotation



Test #47

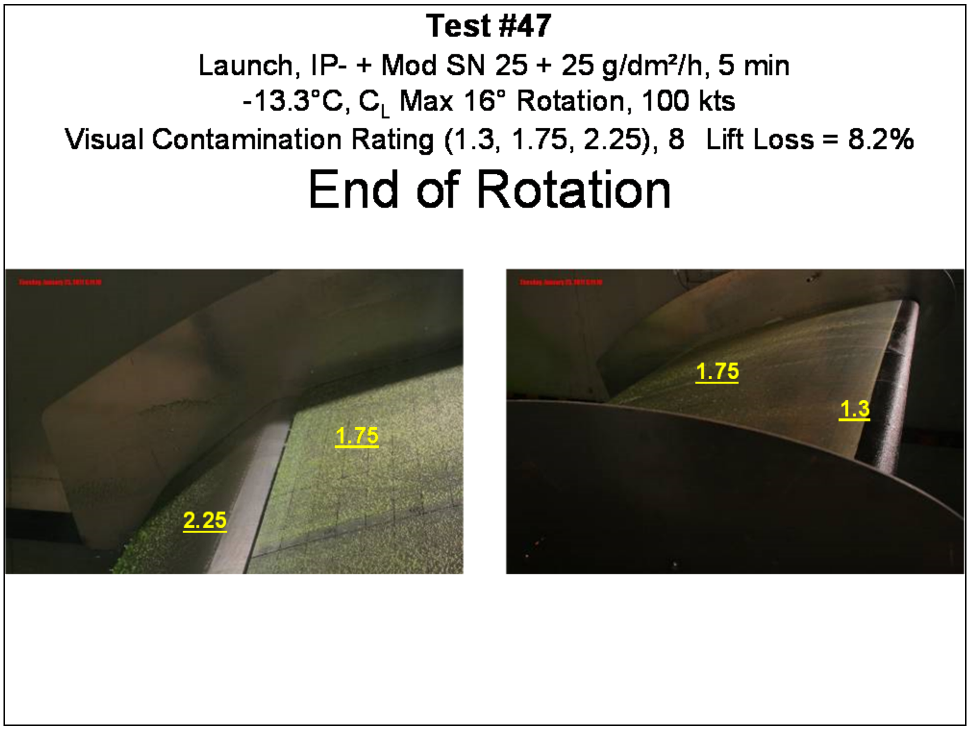
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-13.3°C, C_L Max 16° Rotation, 100 kts

Visual Contamination Rating (1.3, 1.75, 2.25), 8 Lift Loss = 8.2%

Before Rotation

Photo 11.15: Test #47 – End of Rotation



Test #47

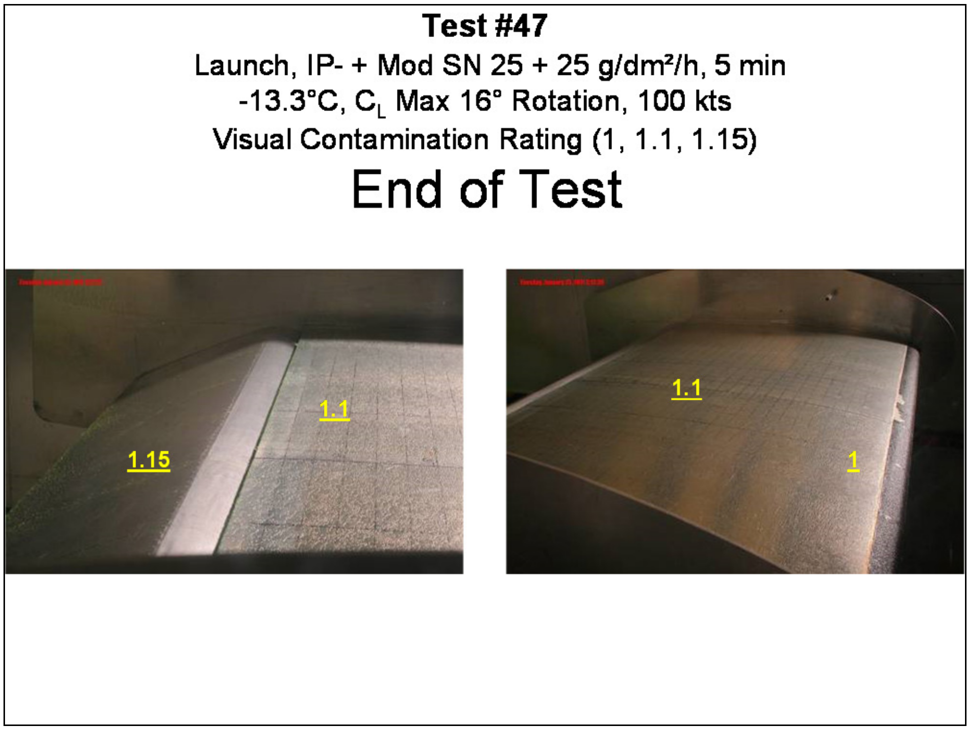
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-13.3°C, C_L Max 16° Rotation, 100 kts

Visual Contamination Rating (1.3, 1.75, 2.25), 8 Lift Loss = 8.2%

End of Rotation

Photo 11.16: Test #47 – End of Test



Test #47

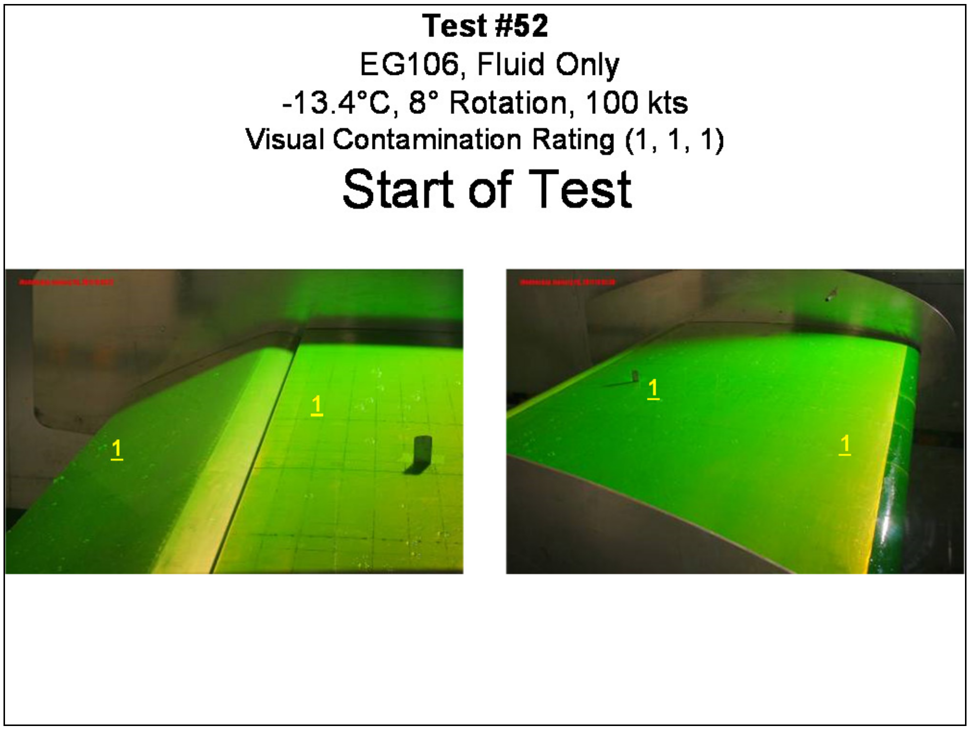
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-13.3°C, C_L Max 16° Rotation, 100 kts

Visual Contamination Rating (1, 1.1, 1.15)

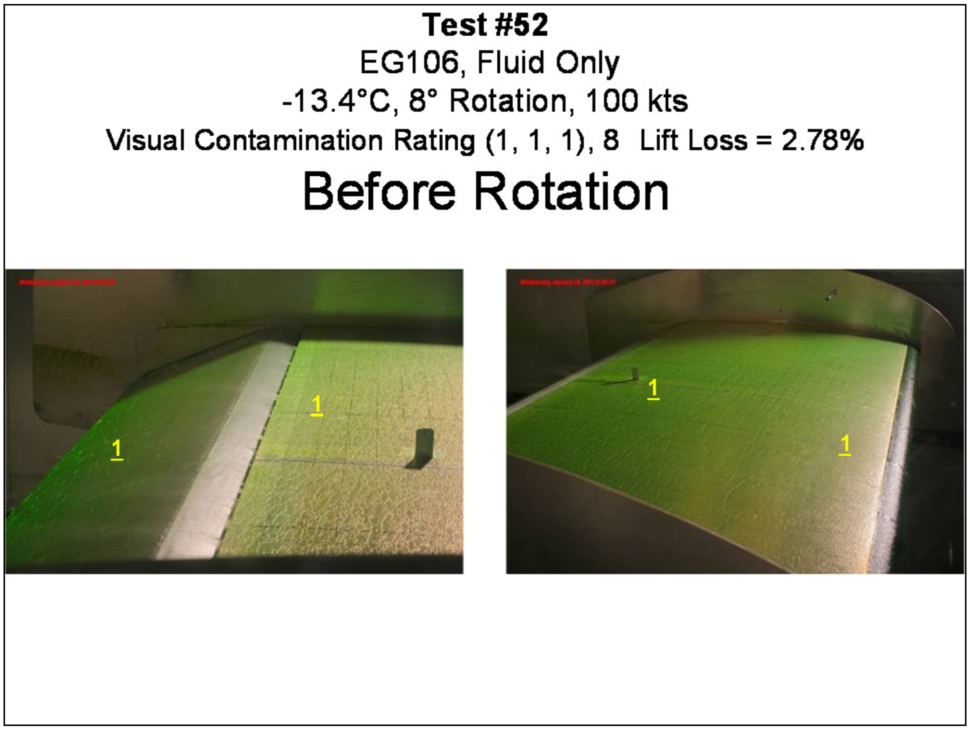
End of Test

Photo 11.17: Test #52 – Start of Test



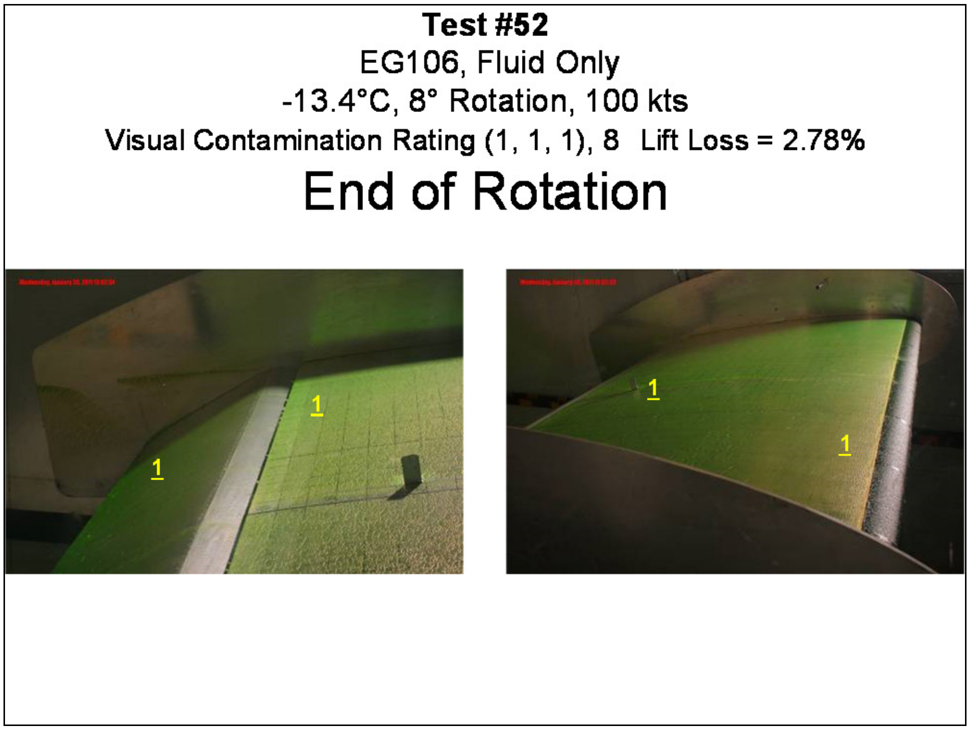
Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 11.18: Test #52 – Before Rotation



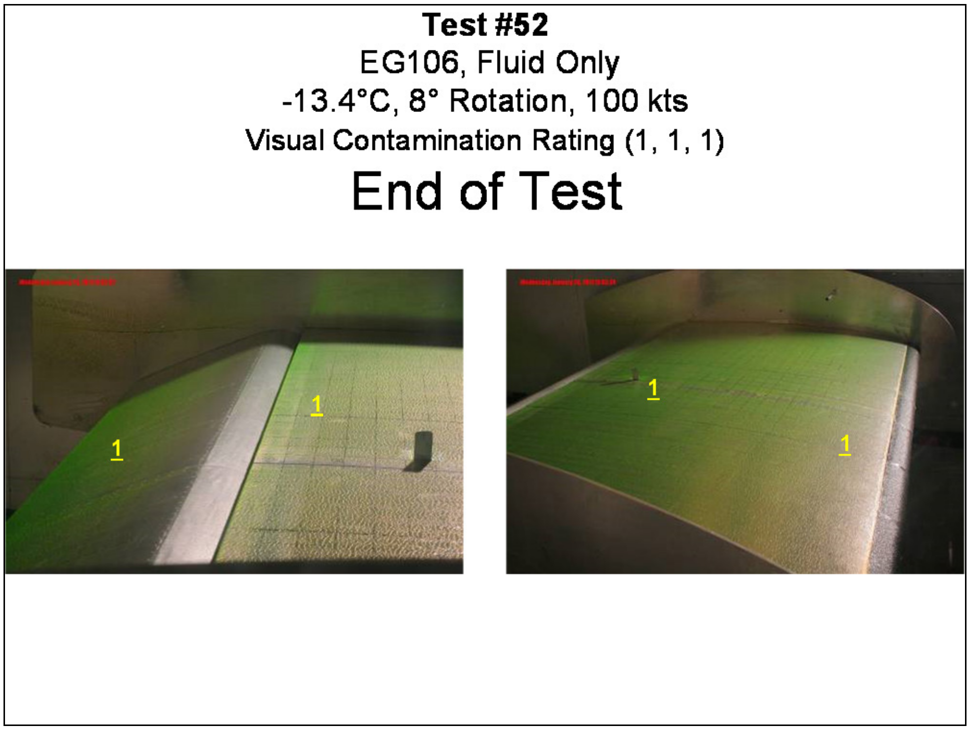
Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%
Before Rotation

Photo 11.19: Test #52 – End of Rotation



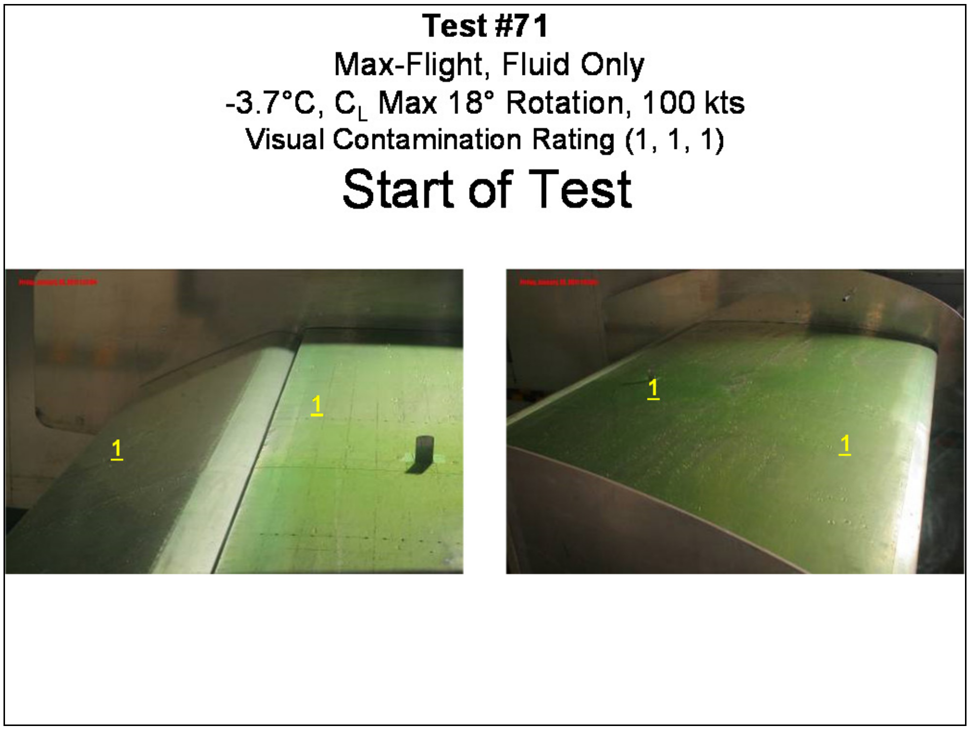
Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.78%
End of Rotation

Photo 11.20: Test #52 – End of Test



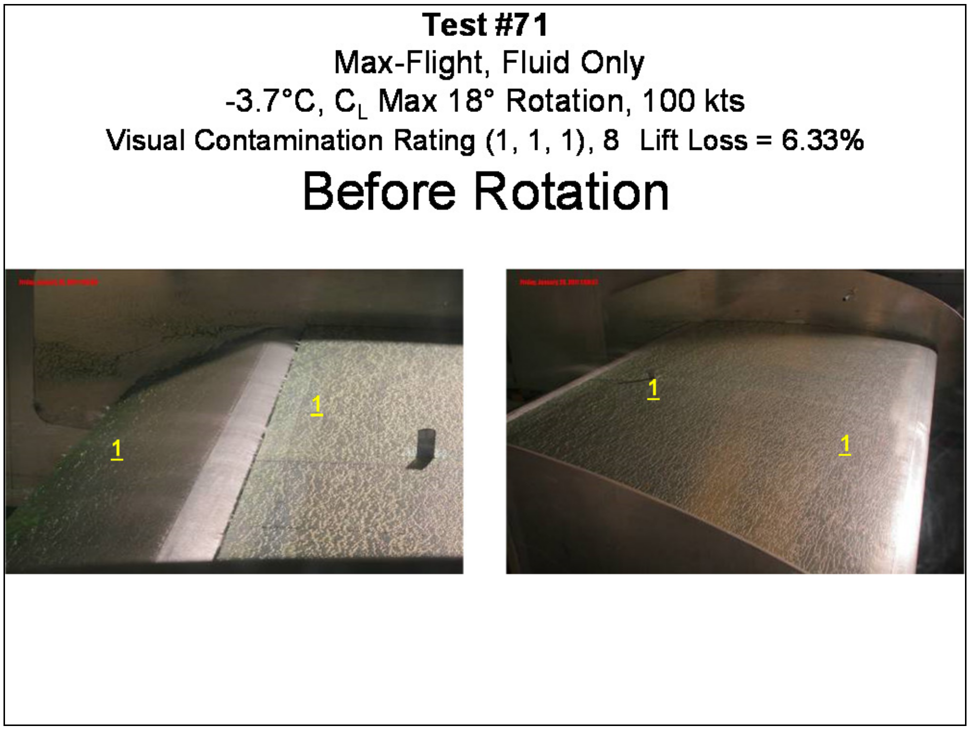
Test #52
EG106, Fluid Only
-13.4°C, 8° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
End of Test

Photo 11.21: Test #71 – Start of Test



Test #71
Max-Flight, Fluid Only
-3.7°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)
Start of Test

Photo 11.22: Test #71 – Before Rotation



Test #71
Max-Flight, Fluid Only
-3.7°C, C_L Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.33%
Before Rotation

Photo 11.23: Test #71 – End of Rotation

Test #71

Max-Flight, Fluid Only

-3.7°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 6.33%

End of Rotation

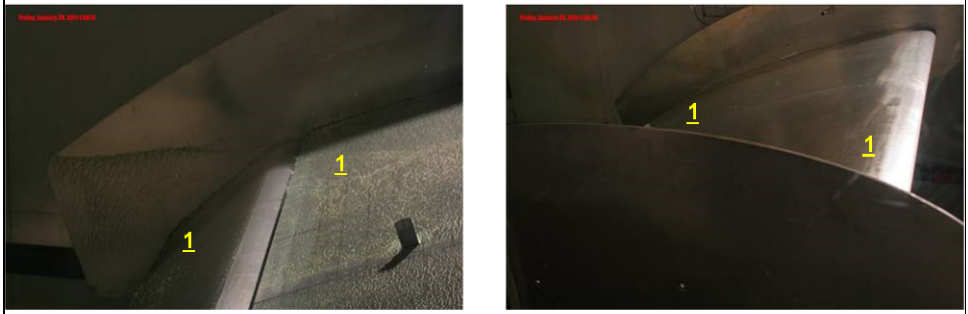


Photo 11.24: Test #71 – End of Test

Test #71

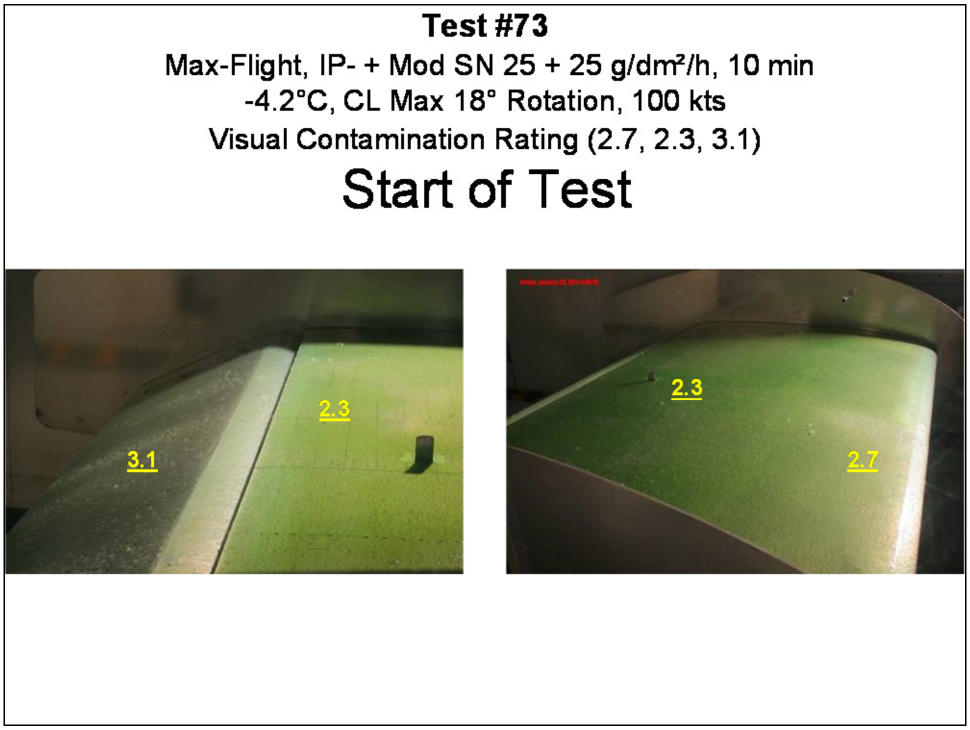
Max-Flight, Fluid Only

-3.7°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 11.25: Test #73 – Start of Test



Test #73

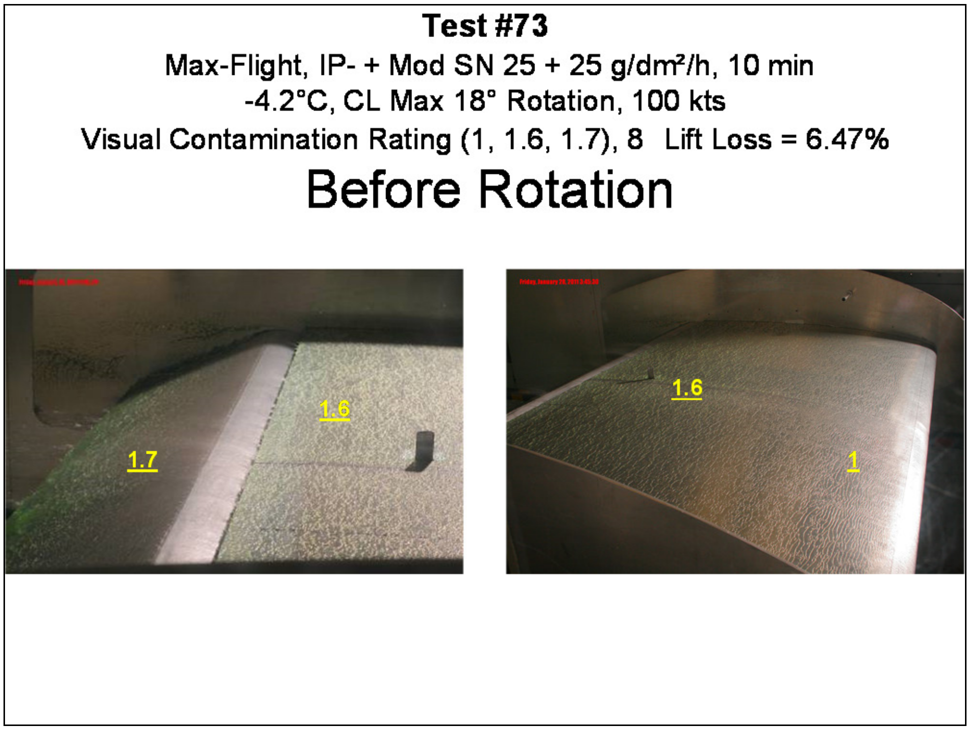
Max-Flight, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-4.2°C, CL Max 18° Rotation, 100 kts

Visual Contamination Rating (2.7, 2.3, 3.1)

Start of Test

Photo 11.26: Test #73 – Before Rotation



Test #73

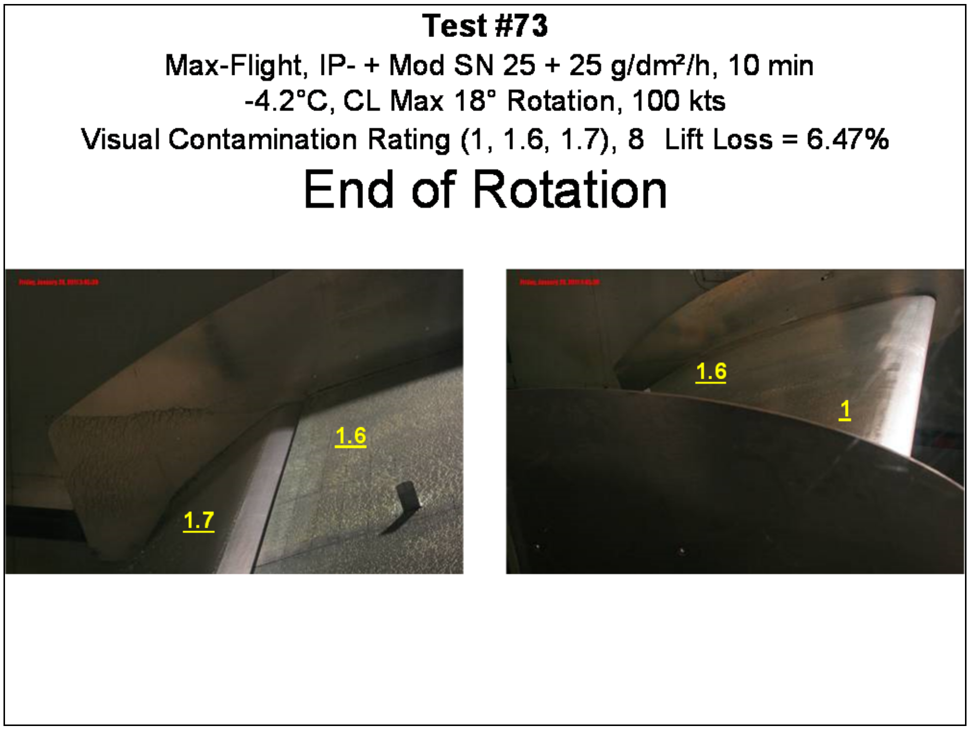
Max-Flight, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-4.2°C, CL Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1.6, 1.7), 8 Lift Loss = 6.47%

Before Rotation

Photo 11.27: Test #73 – End of Rotation

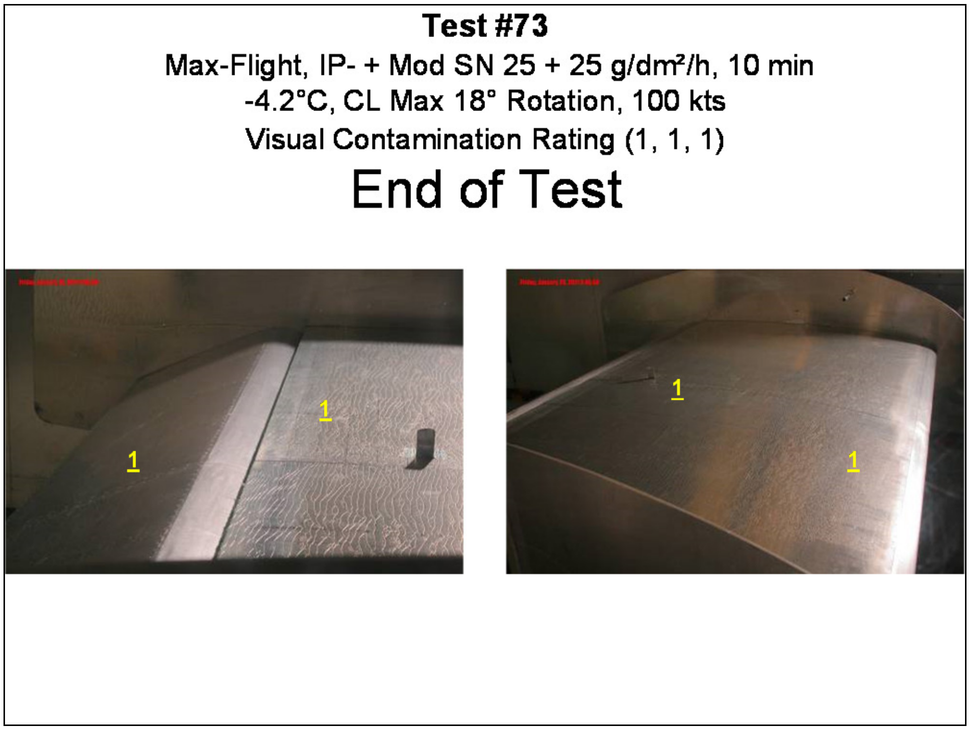


Test #73

Max-Flight, IP- + Mod SN 25 + 25 g/dm²/h, 10 min
-4.2°C, CL Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1.6, 1.7), 8 Lift Loss = 6.47%

End of Rotation

Photo 11.28: Test #73 – End of Test

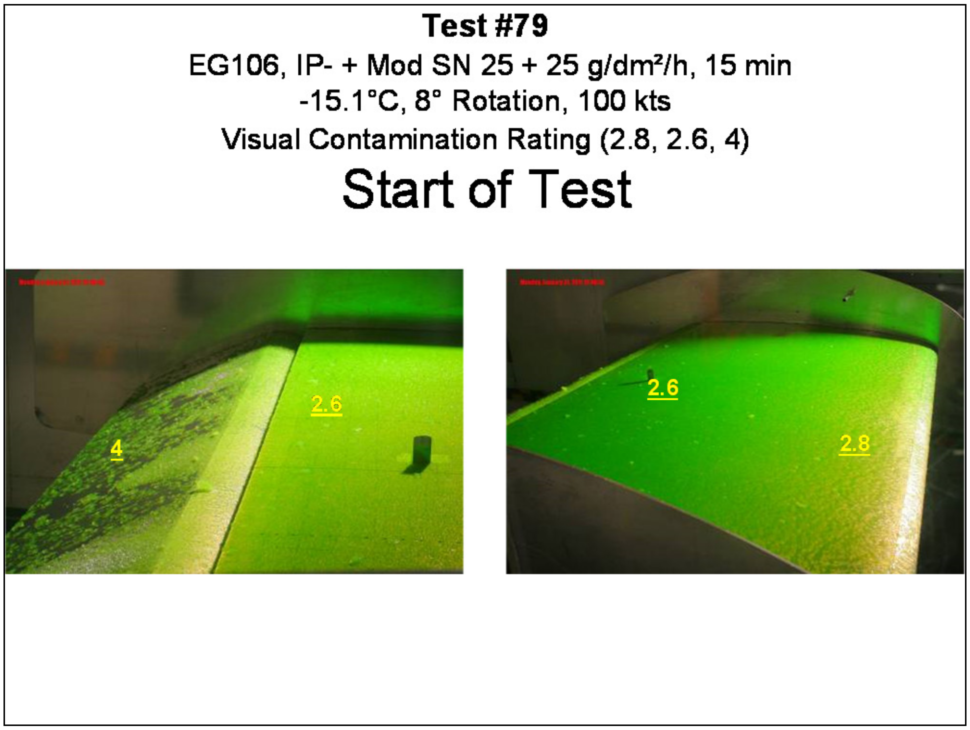


Test #73

Max-Flight, IP- + Mod SN 25 + 25 g/dm²/h, 10 min
-4.2°C, CL Max 18° Rotation, 100 kts
Visual Contamination Rating (1, 1, 1)

End of Test

Photo 11.29: Test #79 – Start of Test



Test #79

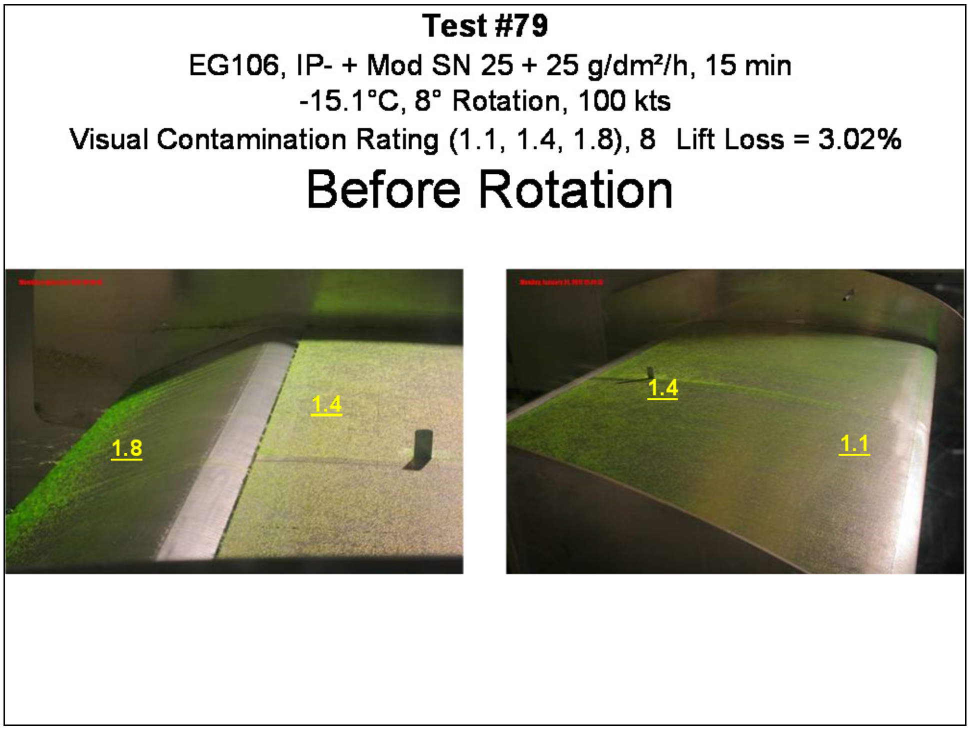
EG106, IP- + Mod SN 25 + 25 g/dm²/h, 15 min

-15.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.8, 2.6, 4)

Start of Test

Photo 11.30: Test #79 – Before Rotation



Test #79

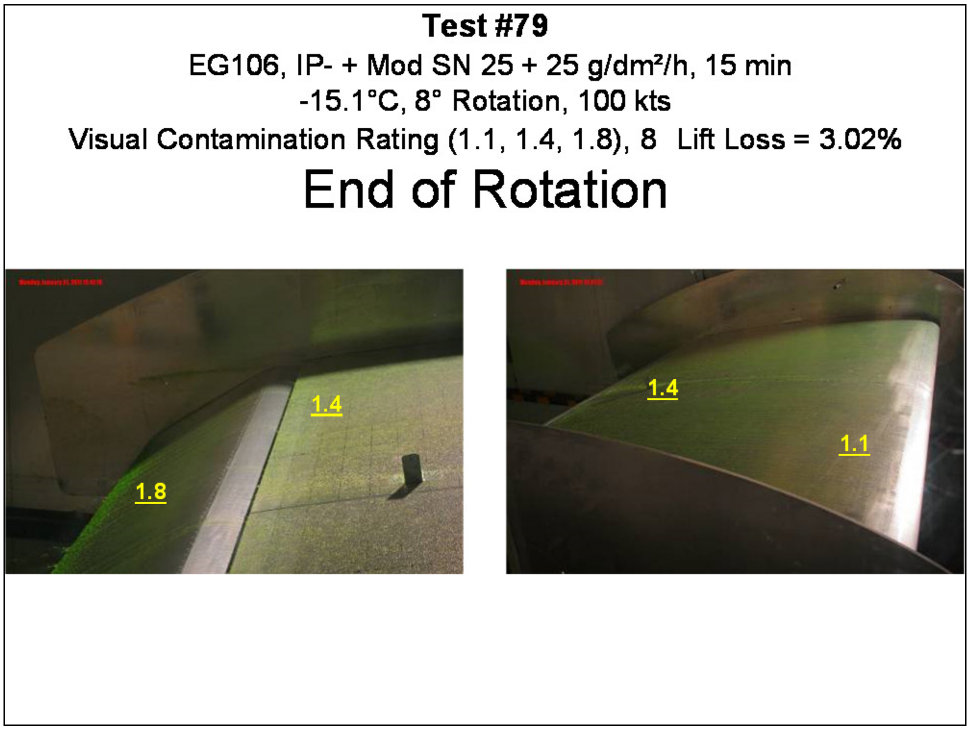
EG106, IP- + Mod SN 25 + 25 g/dm²/h, 15 min

-15.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.4, 1.8), 8 Lift Loss = 3.02%

Before Rotation

Photo 11.31: Test #79 – End of Rotation



Test #79

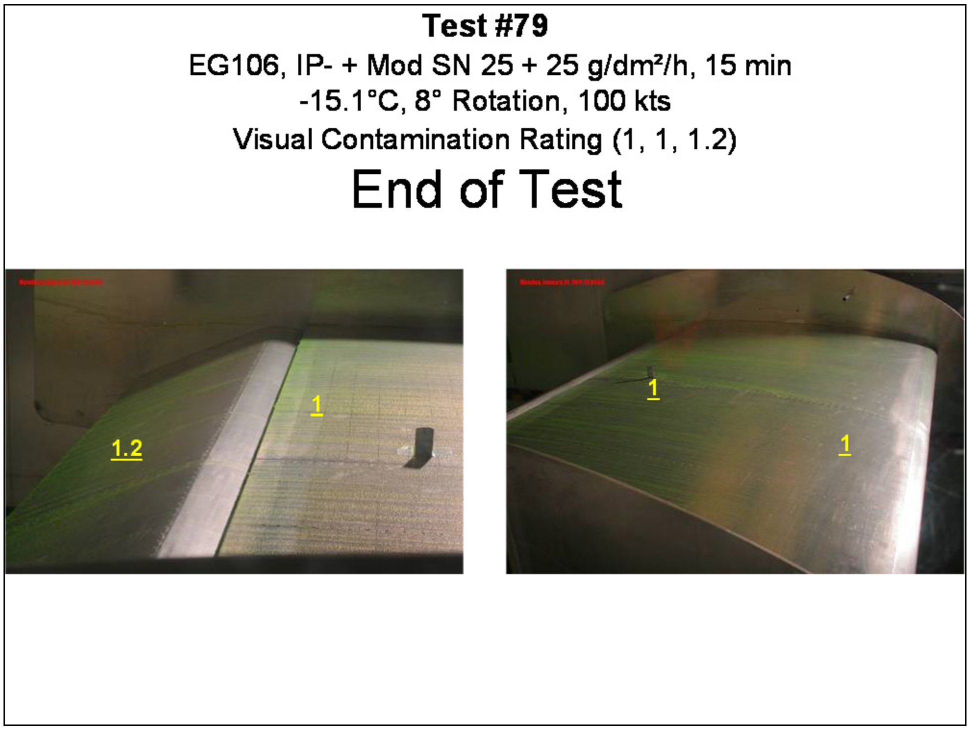
EG106, IP- + Mod SN 25 + 25 $g/dm^2/h$, 15 min

-15.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.4, 1.8), 8 Lift Loss = 3.02%

End of Rotation

Photo 11.32: Test #79 – End of Test



Test #79

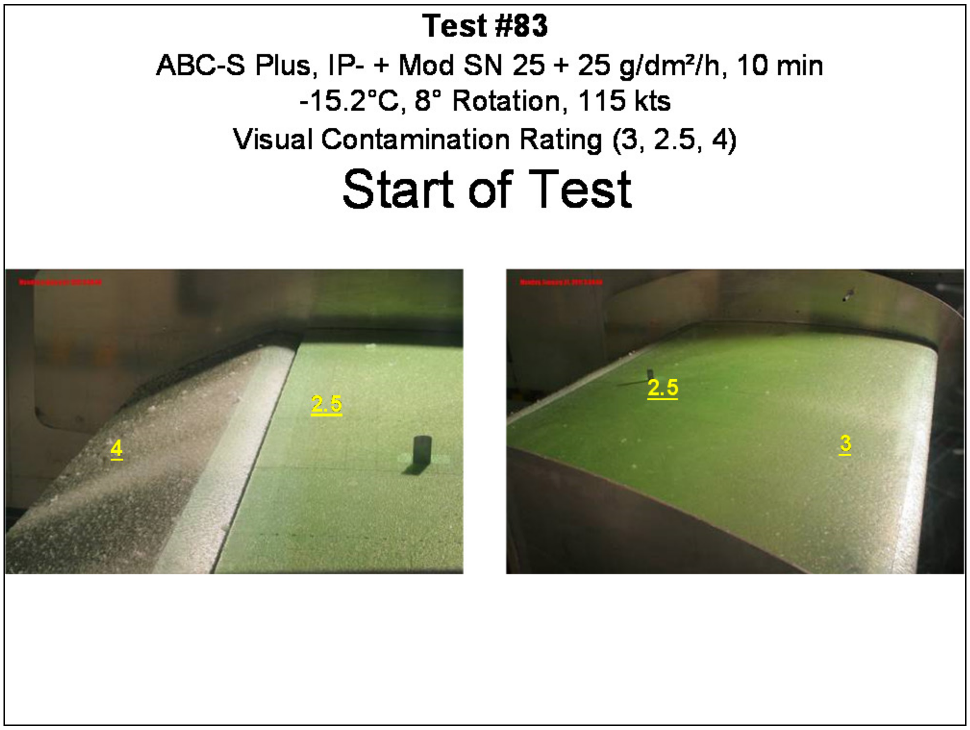
EG106, IP- + Mod SN 25 + 25 $g/dm^2/h$, 15 min

-15.1°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1.2)

End of Test

Photo 11.33: Test #83 – Start of Test



Test #83

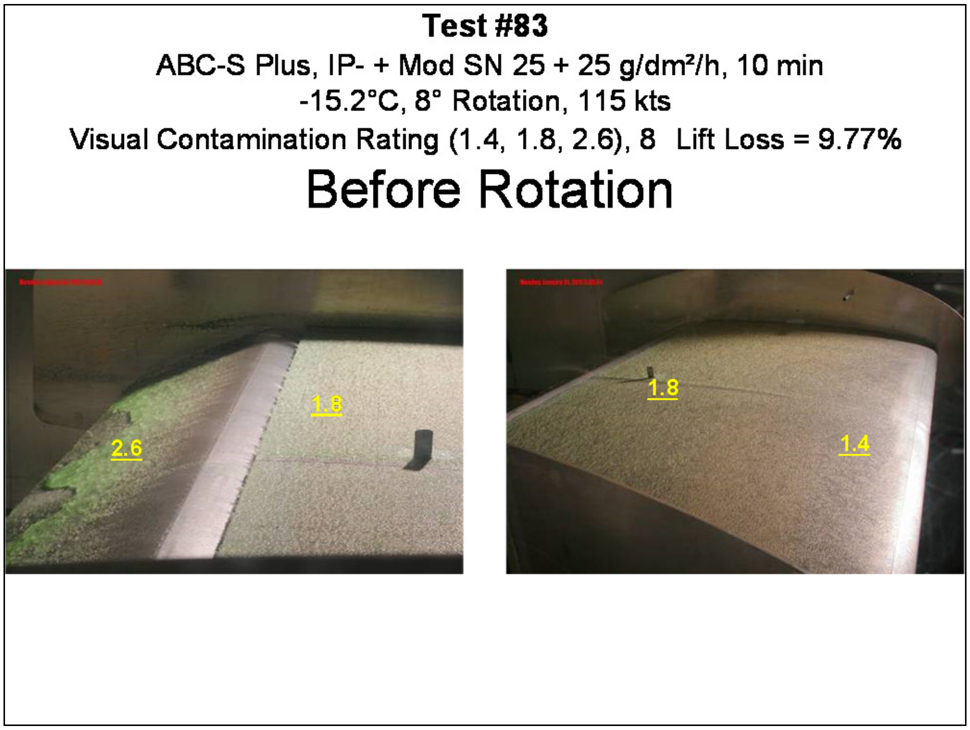
ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-15.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (3, 2.5, 4)

Start of Test

Photo 11.34: Test #83 – Before Rotation



Test #83

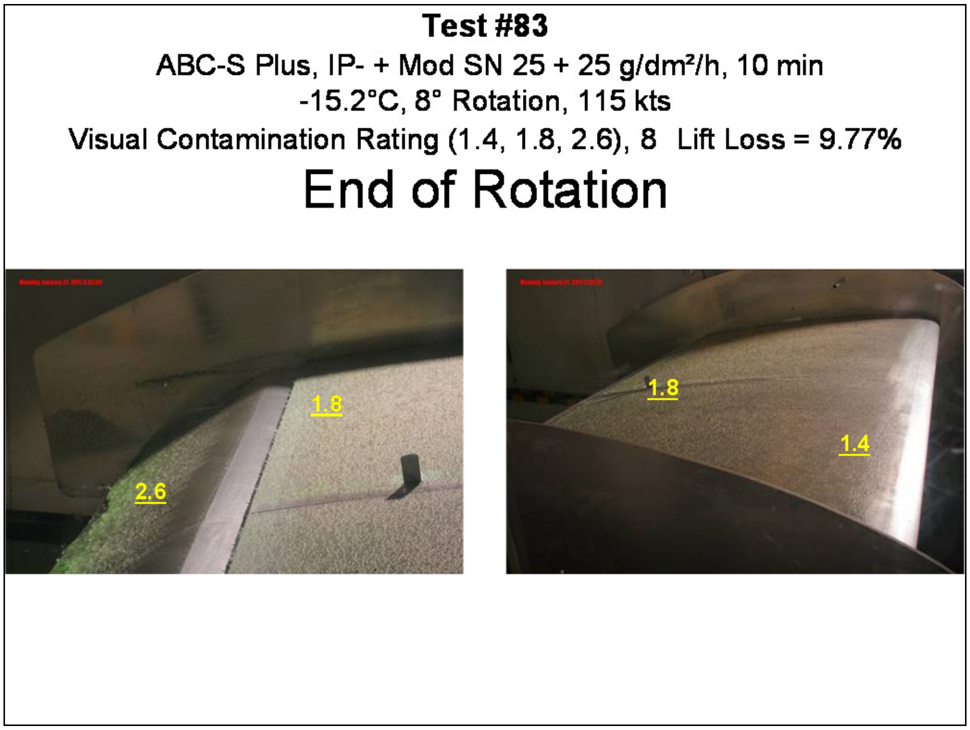
ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-15.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.4, 1.8, 2.6), 8 Lift Loss = 9.77%

Before Rotation

Photo 11.35: Test #83 – End of Rotation



Test #83

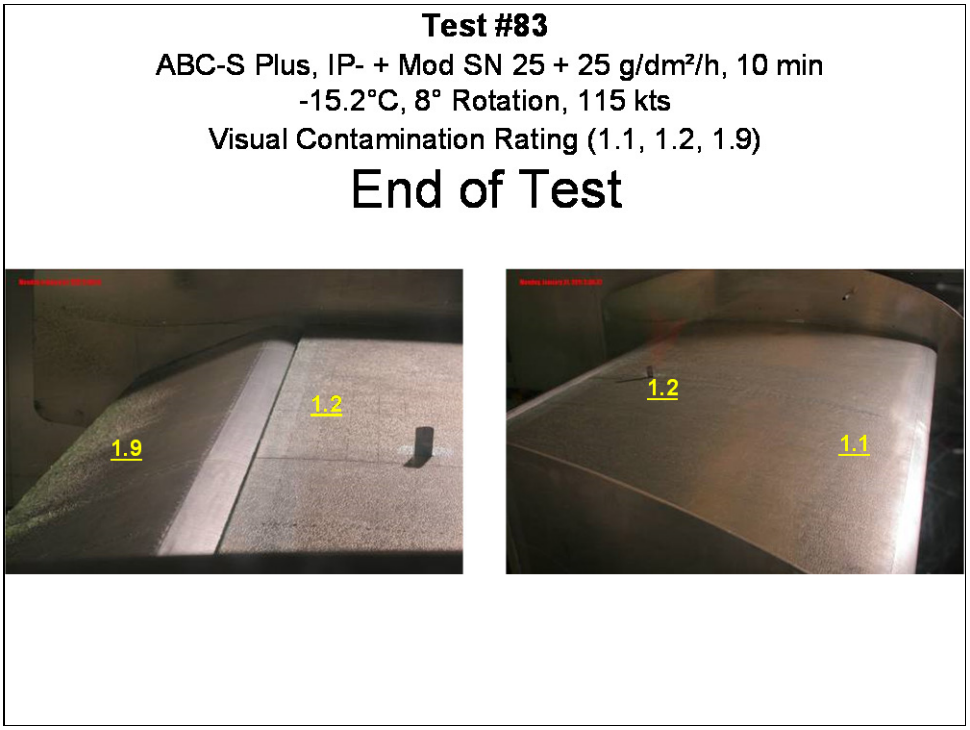
ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-15.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.4, 1.8, 2.6), 8 Lift Loss = 9.77%

End of Rotation

Photo 11.36: Test #83 – End of Test



Test #83

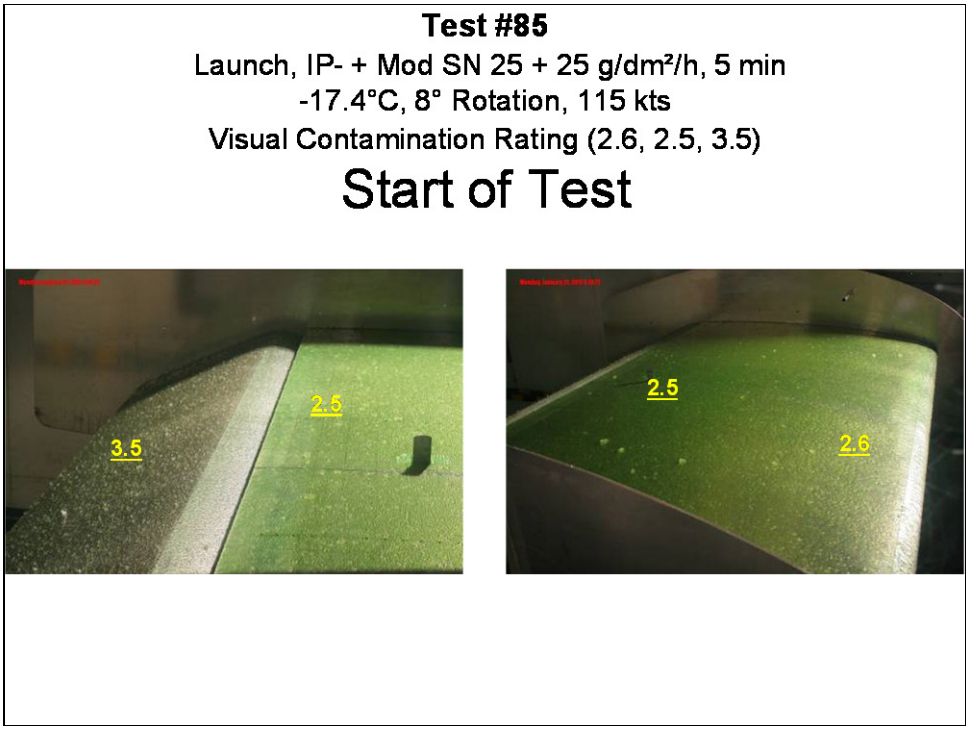
ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 10 min

-15.2°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.1, 1.2, 1.9)

End of Test

Photo 11.37: Test #85 – Start of Test



Test #85

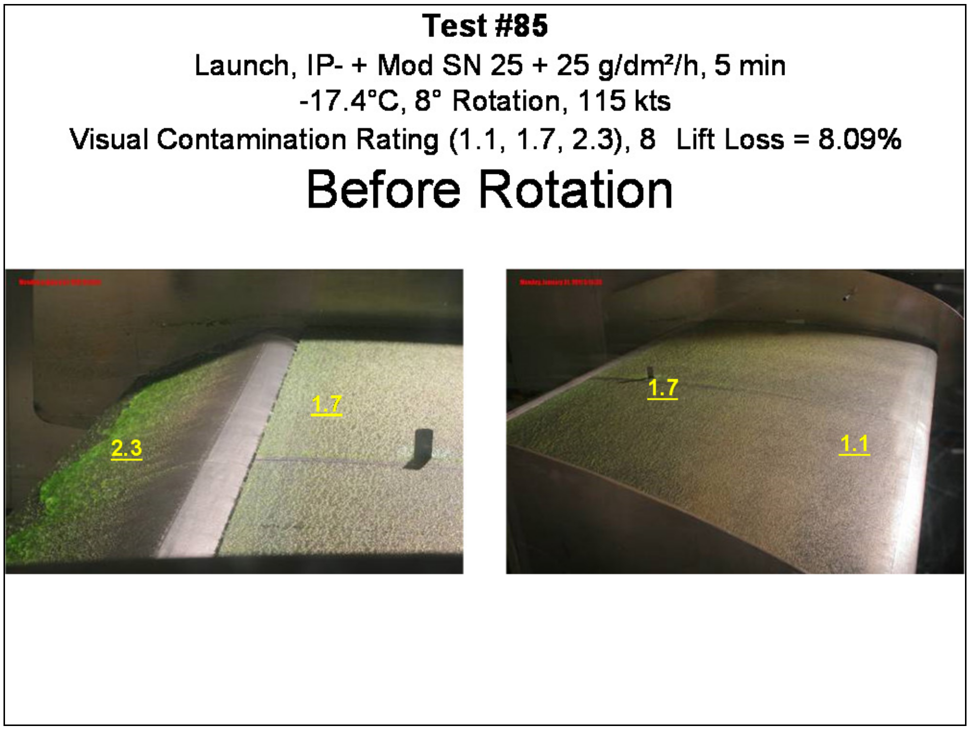
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (2.6, 2.5, 3.5)

Start of Test

Photo 11.38: Test #85 – Before Rotation



Test #85

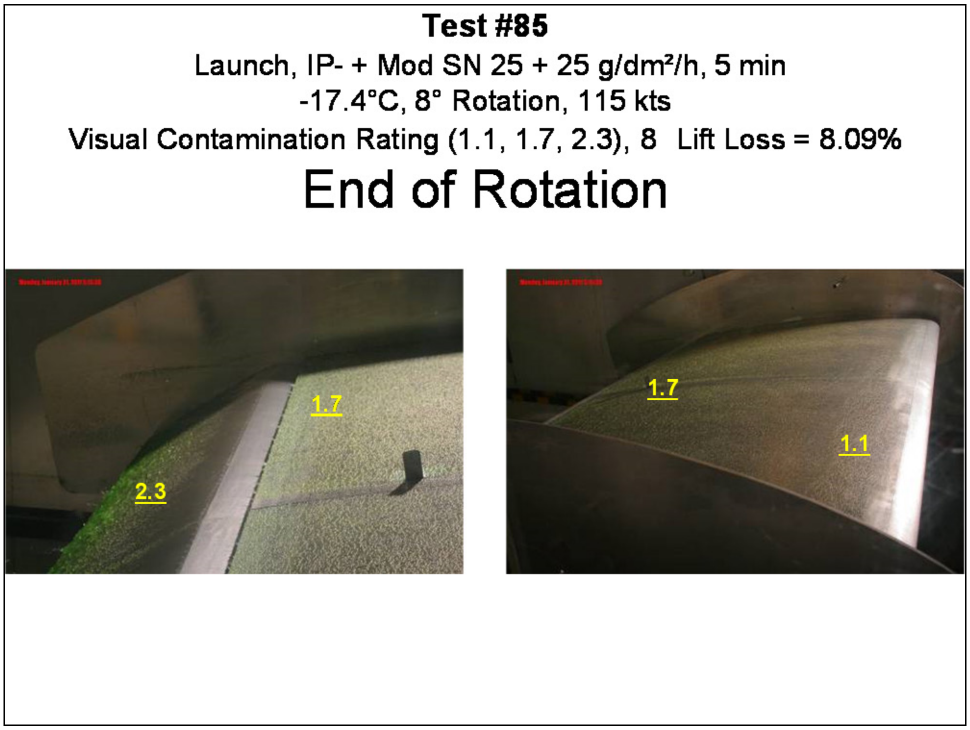
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.1, 1.7, 2.3), 8 Lift Loss = 8.09%

Before Rotation

Photo 11.39: Test #85 – End of Rotation



Test #85

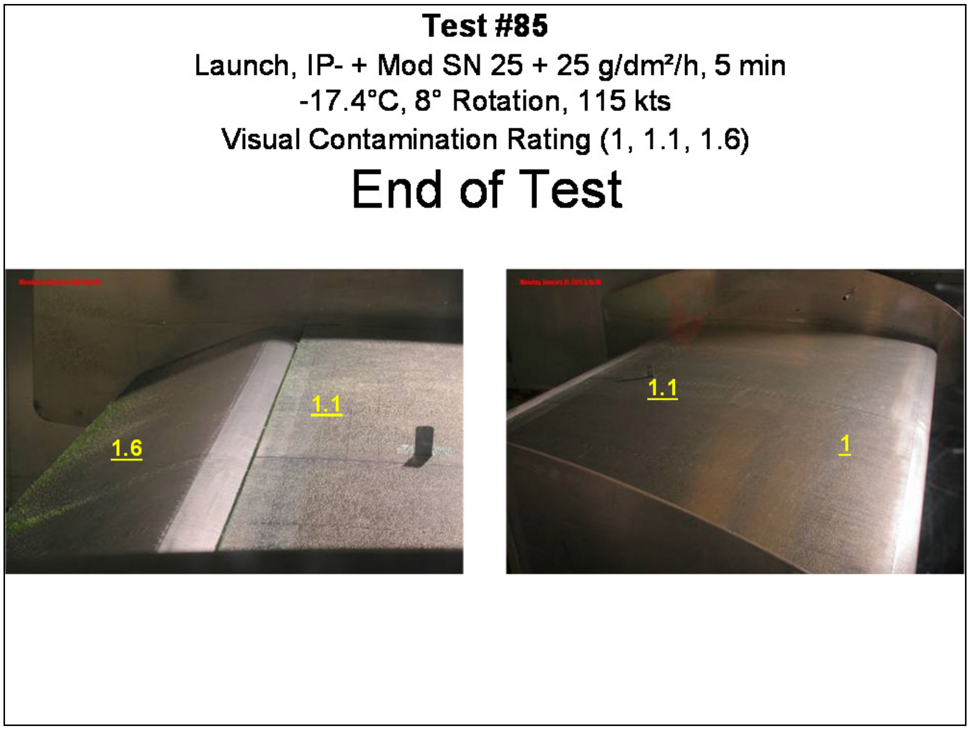
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1.1, 1.7, 2.3), 8 Lift Loss = 8.09%

End of Rotation

Photo 11.40: Test #85 – End of Test



Test #85

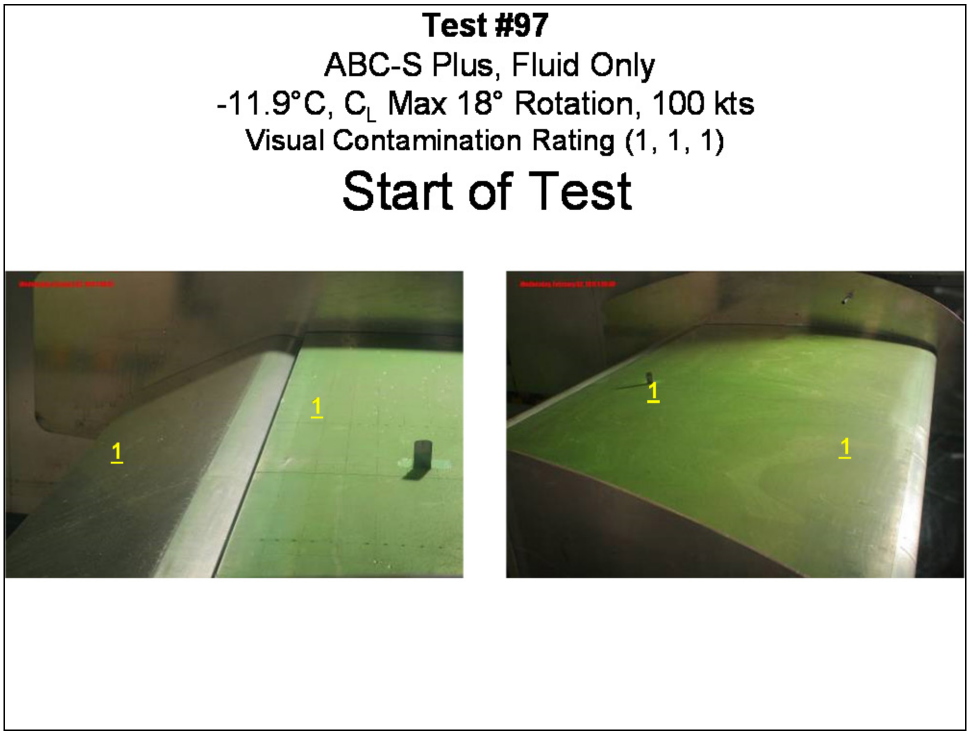
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 5 min

-17.4°C, 8° Rotation, 115 kts

Visual Contamination Rating (1, 1.1, 1.6)

End of Test

Photo 11.41: Test #97 – Start of Test



Test #97

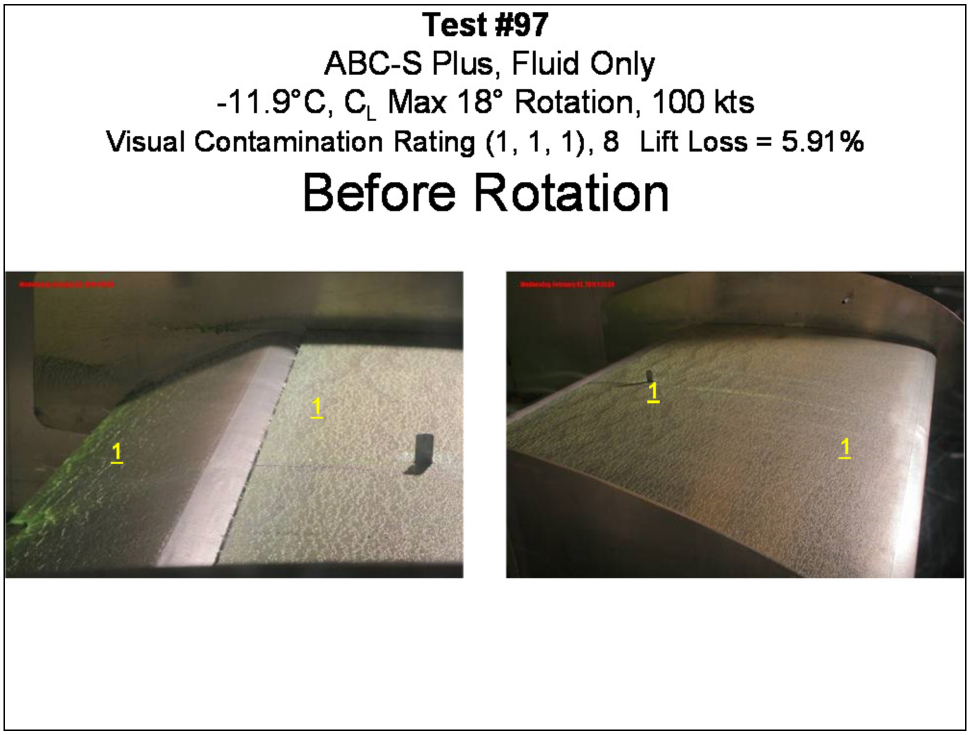
ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

Start of Test

Photo 11.42: Test #97 – Before Rotation



Test #97

ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.91%

Before Rotation

Photo 11.43: Test #97 – End of Rotation

Test #97

ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 5.91%

End of Rotation

Photo 11.44: Test #97 – End of Test

Test #97

ABC-S Plus, Fluid Only

-11.9°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

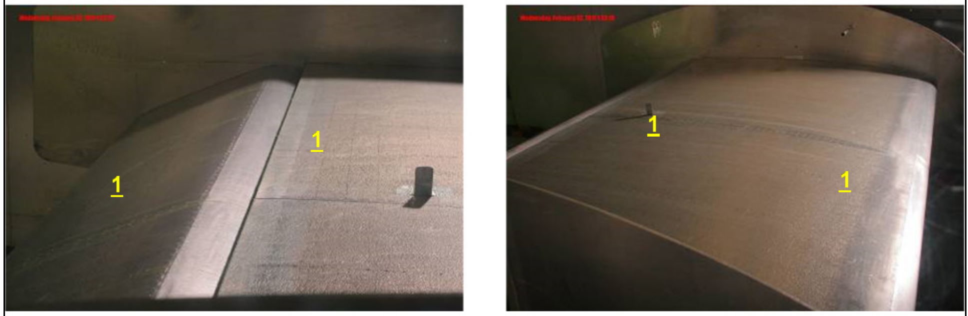


Photo 11.45: Test #101 (09-10) – Start of Test

(PHOTO NOT AVAILABLE)

Photo 11.46: Test #101 (09-10) – Before Rotation

(PHOTO NOT AVAILABLE)

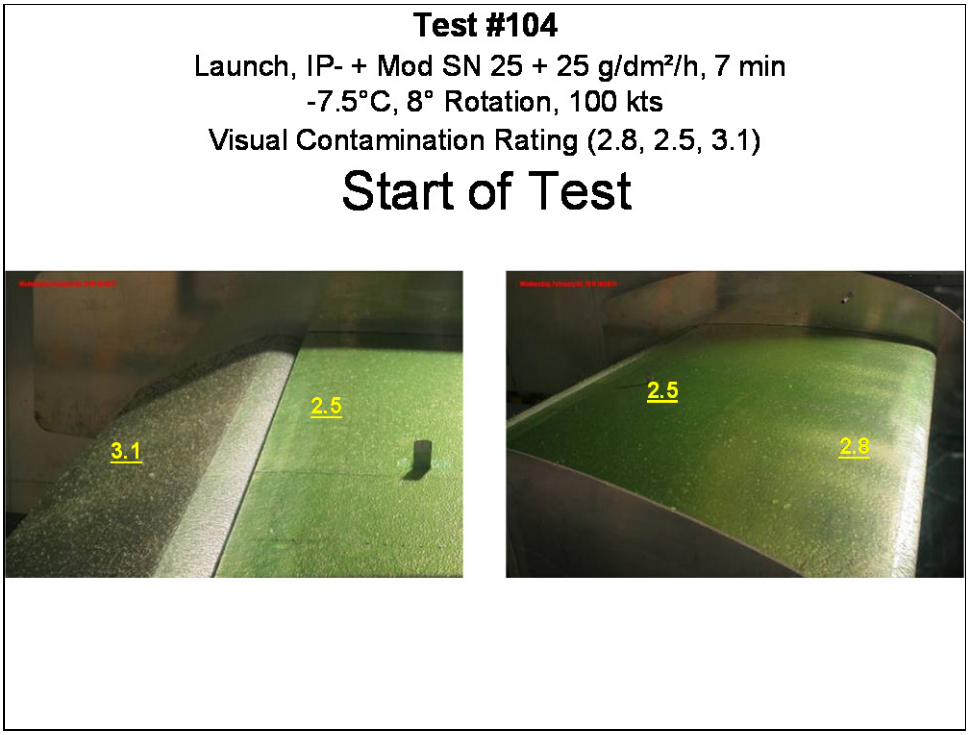
Photo 11.47: Test #101 (09-10) – End of Rotation

(PHOTO NOT AVAILABLE)

Photo 11.48: Test #101 (09-10) – End of Test

(PHOTO NOT AVAILABLE)

Photo 11.49: Test #104 – Start of Test



Test #104

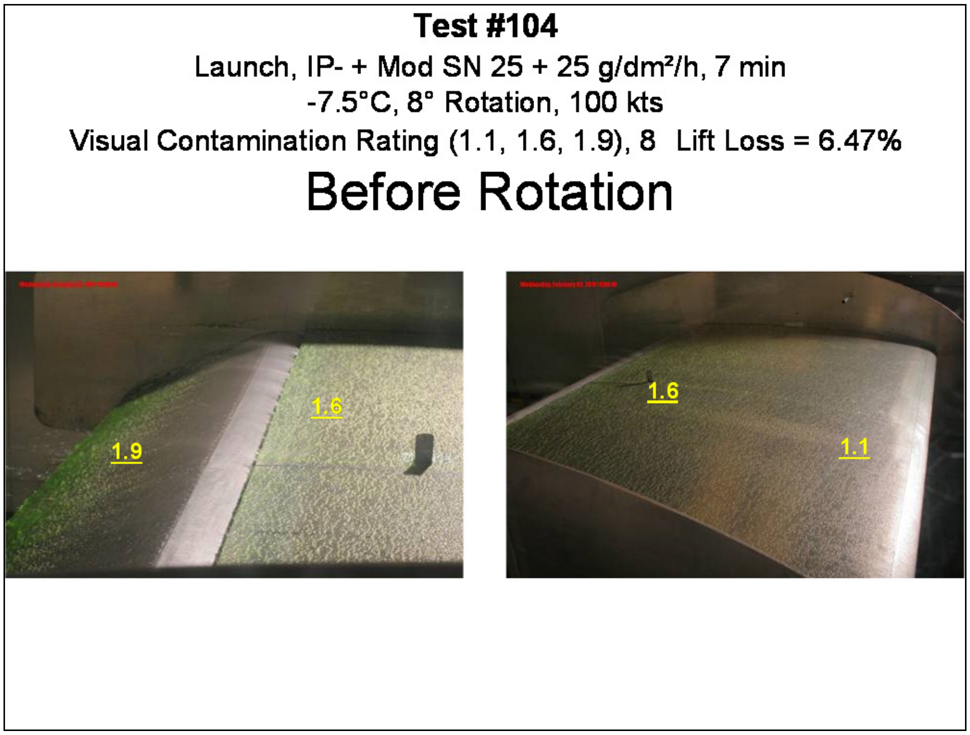
Launch, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-7.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (2.8, 2.5, 3.1)

Start of Test

Photo 11.50: Test #104 – Before Rotation



Test #104

Launch, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-7.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.6, 1.9), 8 Lift Loss = 6.47%

Before Rotation

Photo 11.51: Test #104 – End of Rotation

Test #104

Launch, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-7.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.6, 1.9), 8 Lift Loss = 6.47%

End of Rotation

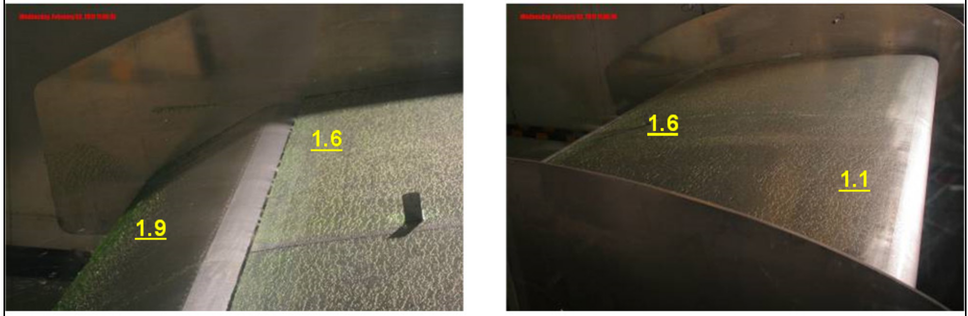


Photo 11.52: Test #104 – End of Test

Test #104

Launch, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-7.5°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

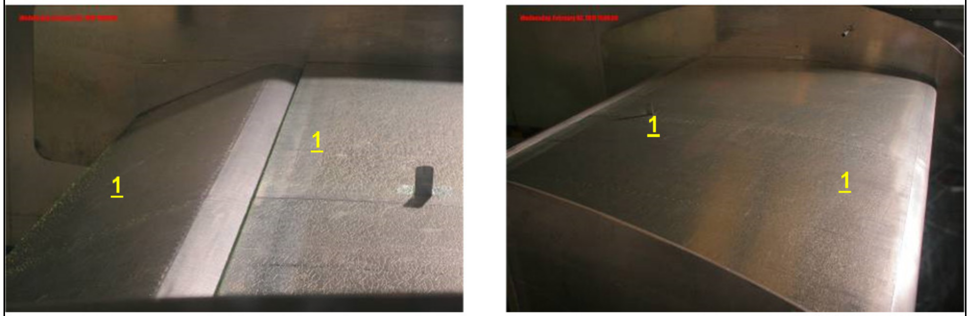


Photo 11.53: Test #105 – Start of Test

Test #105

ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.3°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (2.3, 2.2, 2.8)

Start of Test

Photo 11.54: Test #105 – Before Rotation

Test #105

ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.3°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.6, 2), 8 Lift Loss = 8.51%

Before Rotation

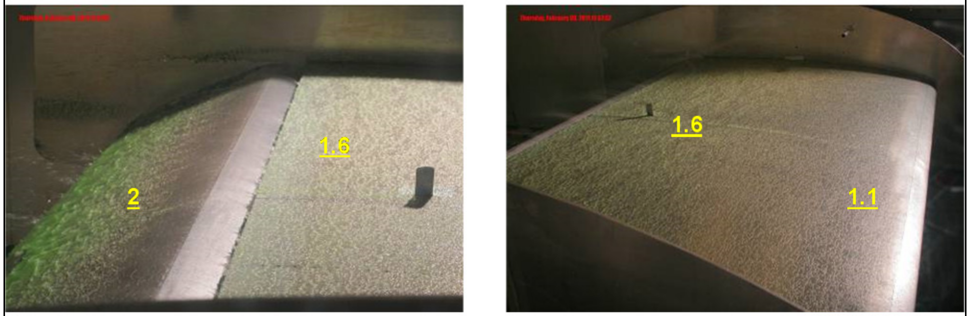
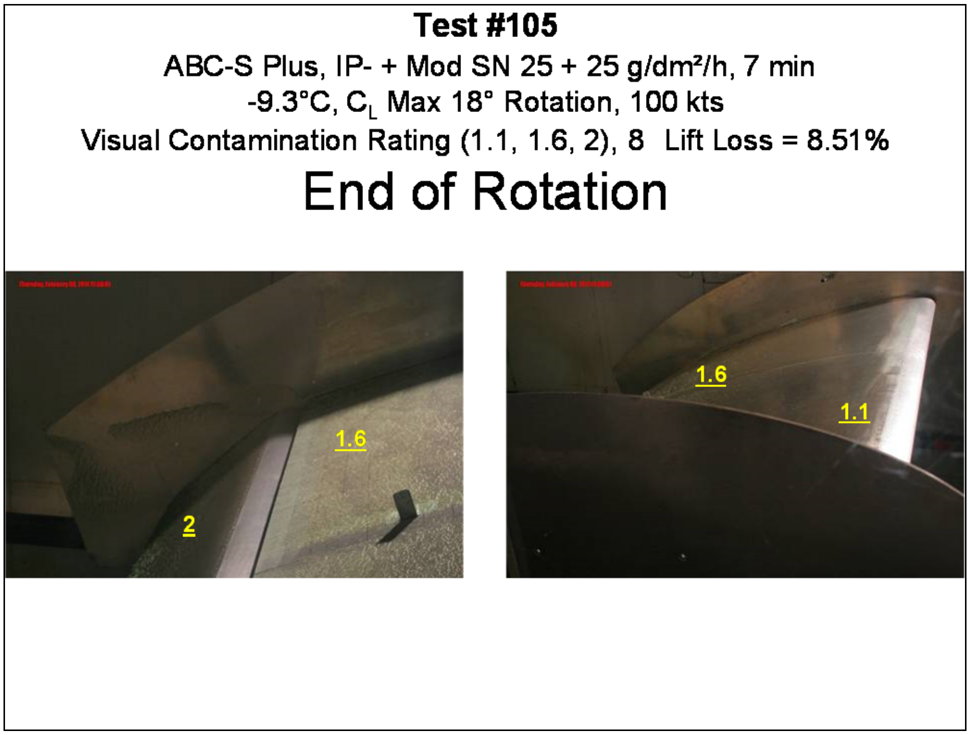


Photo 11.55: Test #105 – End of Rotation



Test #105

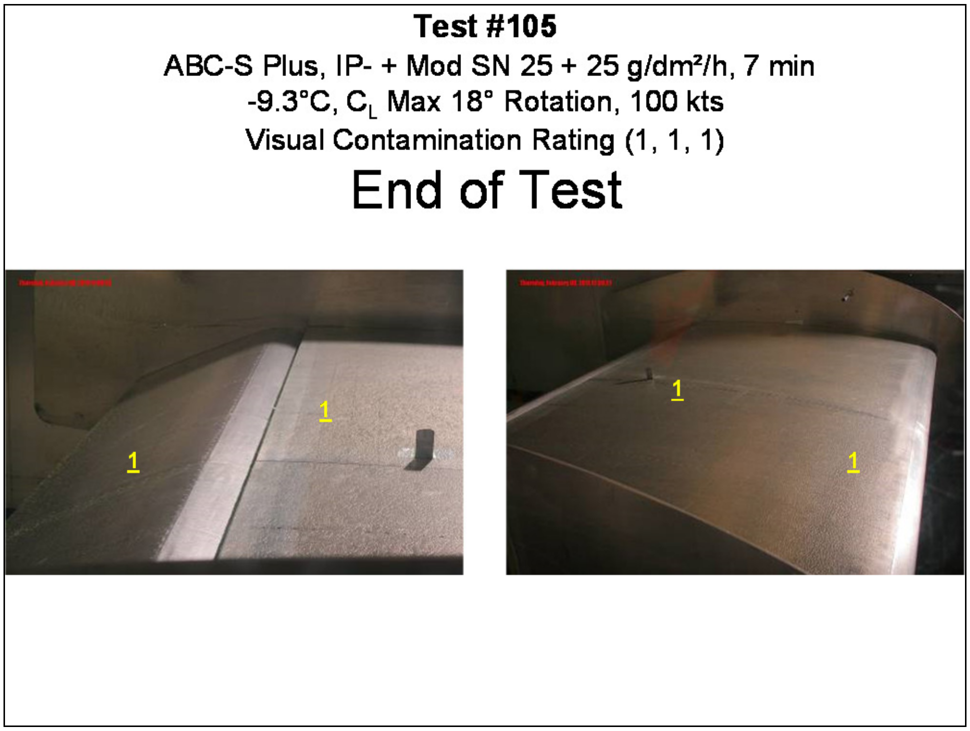
ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.3°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1.1, 1.6, 2), 8 Lift Loss = 8.51%

End of Rotation

Photo 11.56: Test #105 – End of Test



Test #105

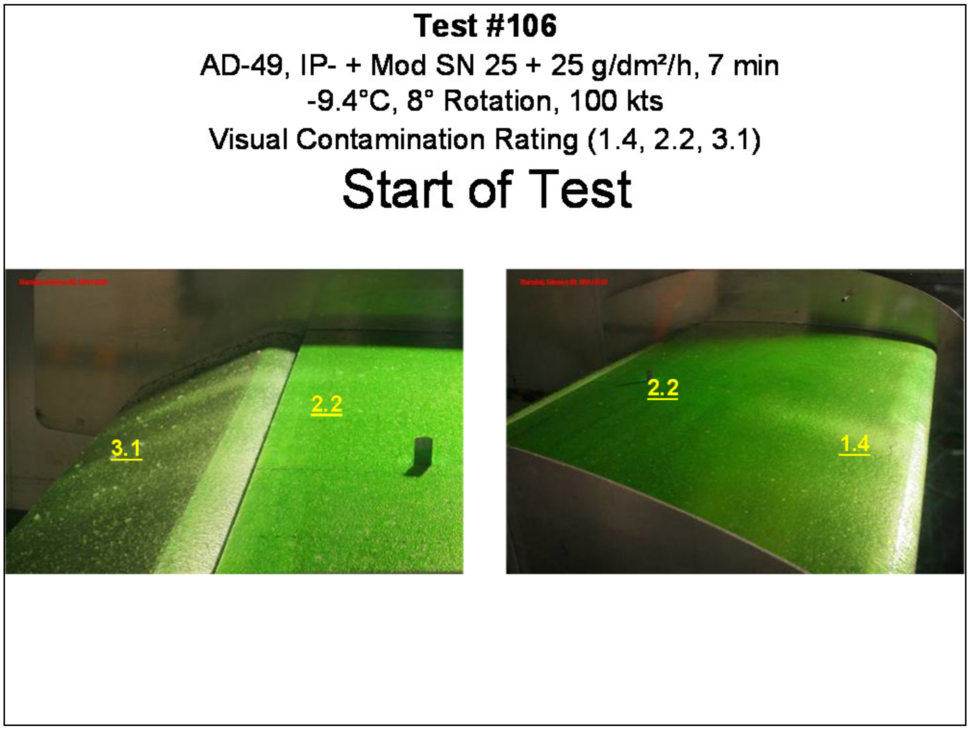
ABC-S Plus, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.3°C, C_L Max 18° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

Photo 11.57: Test #106 – Start of Test



Test #106

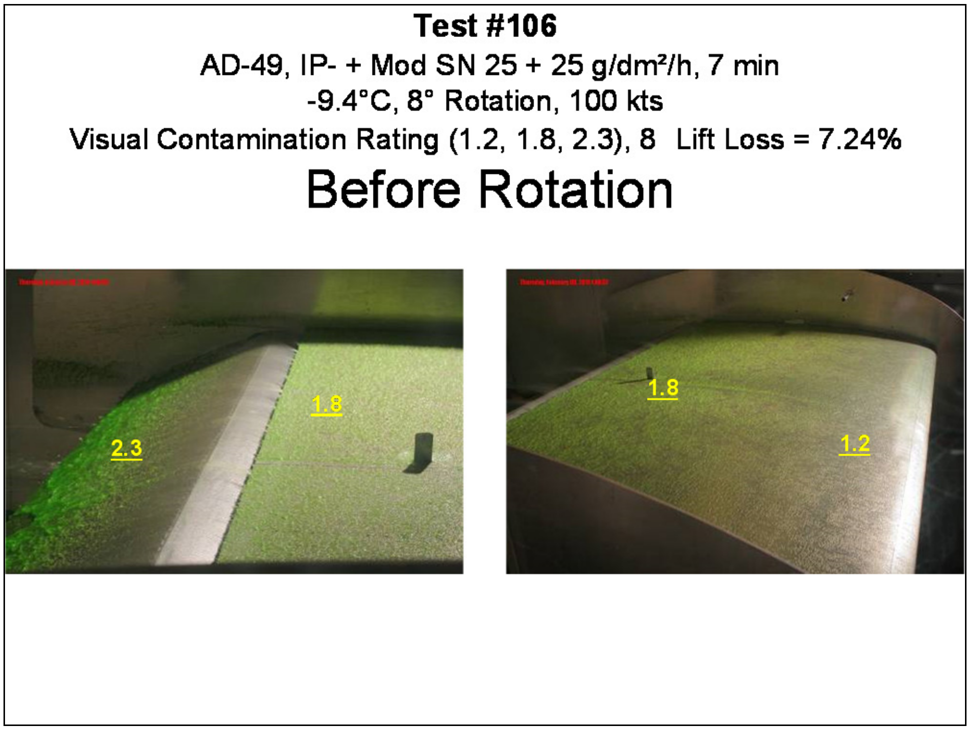
AD-49, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.4, 2.2, 3.1)

Start of Test

Photo 11.58: Test #106 – Before Rotation



Test #106

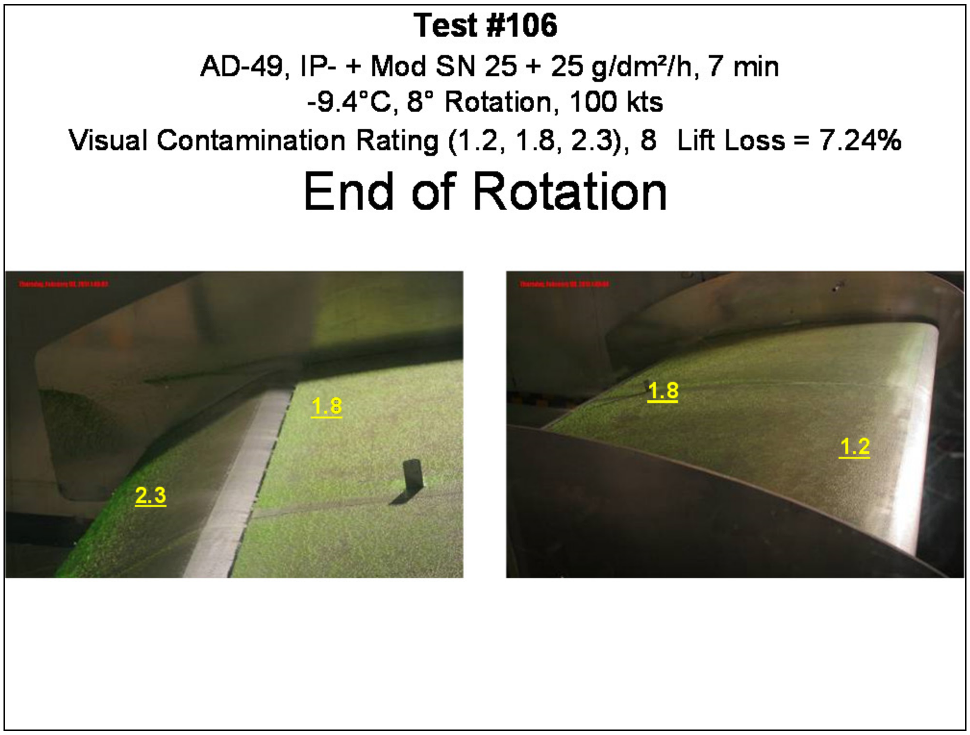
AD-49, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.8, 2.3), 8 Lift Loss = 7.24%

Before Rotation

Photo 11.59: Test #106 – End of Rotation



Test #106

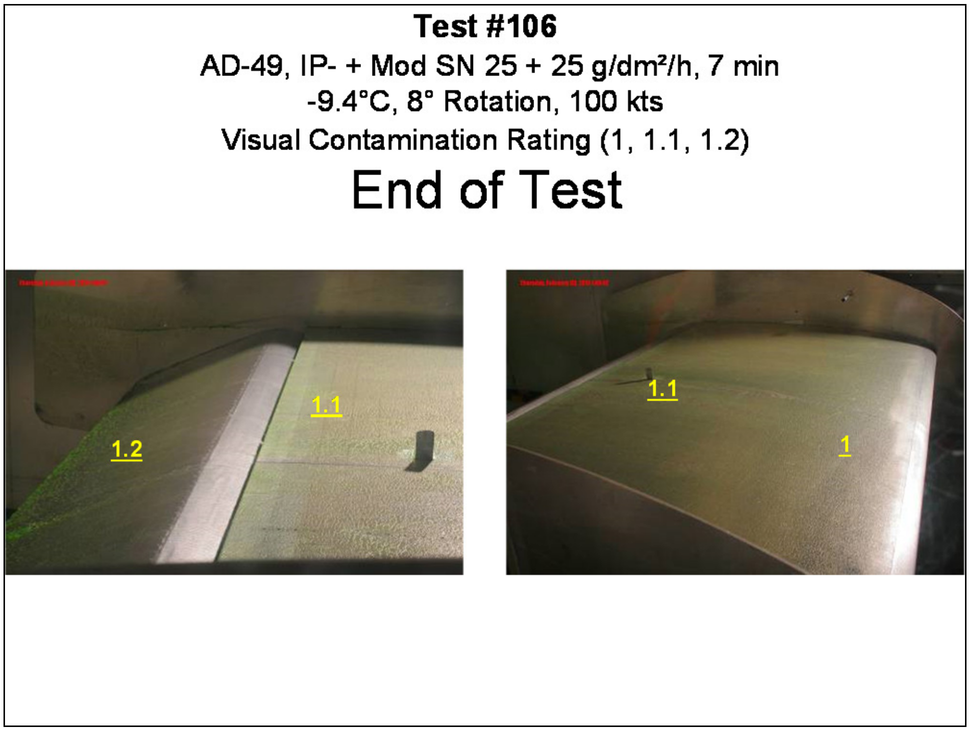
AD-49, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.2, 1.8, 2.3), 8 Lift Loss = 7.24%

End of Rotation

Photo 11.60: Test #106 – End of Test



Test #106

AD-49, IP- + Mod SN 25 + 25 g/dm²/h, 7 min

-9.4°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1.1, 1.2)

End of Test

12. LIGHT ICE PELLET MIXED WITH LIGHT RAIN ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Previous testing in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Light Freezing Rain;
- Section 9: Light Ice Pellets and Moderate Rain;
- Section 10: Light Ice Pellets and Light Snow;
- Section 11: Light Ice Pellets and Moderate Snow; and
- Section 12: Light Ice Pellets and Light Rain.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellet Mixed with Light Rain conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

12.1 Overview of Tests

A summary of the Light Ice Pellets Mixed with Light Rain tests conducted in the wind tunnel is shown in Table 12.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1. The following is a brief description of the column headings for Table 12.1:

Test #: Exclusive number identifying each test.

Date: Date when the test was conducted.

Fluid:	Aircraft deicing fluid specified by product name; all fluids were in the "neat" 100/0 dilution.
Condition:	Simulated precipitation condition.
Precipitation Rate (g/dm²/h):	Simulated freezing precipitation rate (or combination of different precipitation rates). "N/A" indicates that no precipitation was applied.
Precip. Time (min.):	Total time of exposure to simulated precipitation.
Tunnel Temp. at Start of Test (ºC):	The tunnel air temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Flap Angle (º):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended).
Visual Contamination Rating Before Takeoff (LE, TE, Flap):	Visual contamination rating determined before the start of the simulated takeoff: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present. 3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
Visual Contamination Rating at Rotation (LE, TE, Flap):	Visual contamination rating determined at the time of rotation: 1 - Contamination not very visible, fluid still clean. 2 - Contamination is visible, but lots of fluid still present.

	3 - Contamination visible, spots of bridging contamination. 4 - Contamination visible, lots of dry bridging present. 5 - Contamination visible, adherence of contamination.
CL at 8º During Rotation:	Calculated lift coefficient at the 8º wing rotation angle position; data provided by the NRC.
% Lift Loss:	% Lift Loss calculated based on the comparison of the 8º lift coefficient during the test run versus the dry wing average lift coefficient (calculated to be 1.402 for Tests 17 to 61 and 1.420 for all other tests).
Associated Fluid Only Run:	The associated fluid only baseline run based on fluid selection.

Table 12.1: Summary of 2010-11 Light Ice Pellet Mixed with Light Rain Testing

Test No.	Speed (kts)	Condition	Fluid	Flap Angle (°)	Date	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)	Associated Fluid Only Test
117	100	*IP- / R-*	*Launch*	*20*	*7-Feb-11*	*2.3*	*0.2*	IP:25 , R:25	*25*	1.3 , 1.3 , 1.3	1 , 1 , 1	*1.381*	*2.88*	*54 (09-10)*
54 (09-10)	100	*Fluid Only*	*Launch*	*20*	*27-Jan-10*	*-3.6*	*-2.2*	-	-	1 , 1 , 1	1 , 1 , 1	*1.282*	3.56	-

12.2 Data Collected

12.2.1 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.2. Fluid thickness measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Tables 12.2 to 12.9 show the fluid thickness measurements collected during the contaminated fluid tests.

Table 12.2: Test #26 Fluid Thickness Data

Test 26: EG106, IP-/ZR-, Tunnel OAT -1.9°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
1	1.7	0.6	0.0
2	2.2	1.7	0.0
3	2.2	2.5	0.1
4	3.5	3.7	0.1
5	3.5	3.9	0.1
6	4.5	5.7	0.0
7	4.5	4.5	0.0
8	3.5	3.5	0
Flap	1.0	slush	0.1

Table 12.3: Test #26A Fluid Thickness Data

Test 26A: EG106, IP-/ZR-, Tunnel OAT -3.3°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
1	1.6	1.1	0.0
2	2.5	1.5	0.0
3	2.7	3.1	0.0
4	3.3	3.7	0.0
5	4.5	4.5	0.0
6	4.0	4.5	0.0
7	3.5	4.5	0.0
8	3.5	2.7	0.0
Flap	3.3	3.1	0.1

Table 12.4: Test #28 Fluid Thickness Data

Test 28: Launch, IP-, Tunnel OAT -4.2°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
1	1.3	2.2	0.0
2	1.8	3.9	0.1
3	2.2	4.5	0.1
4	2.7	4.5	0.2
5	2.9	4.5	0.3
6	3.1	5.7	0.2
7	2.7	4.5	0.2
8	2.2	4.5	0.2
Flap	0.7	slush	0.2

Table 12.5: Test #28A Fluid Thickness Data

Test 28A: Launch, IP-, Tunnel OAT -5.5°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
1	1.0	slush	0.0
2	1.6	1.8	0.0
3	1.8	3.3	0.0
4	2.2	4.5	0.1
5	2.2	4.5	0.1
6	2.2	4.5	0.2
7	1.8	4.5	0.2
8	1.5	3.7	0.2
Flap	2.2	3.5	0.1

Table 12.6: Test #56 Fluid Thickness Data

Test 56: EG106, IP/R Mod, Tunnel OAT -1.1°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Test
1	1.8	0.6	0.0
2	3.1	0.8	0.0
3	3.3	1.0	0.0
4	4.5	1.5	0.0
5	4.5	2.2	0.0
6	4.5	2.5	0.0
7	4.5	1.3	0.0
8	4.5	1.0	0.0
Flap	0.8	slush	N/A

Table 12.7: Test #56A Fluid Thickness Data

Test 56A: EG106, IP/R Mod, Tunnel OAT -1.4°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
1	1.7	0.4	0.0
2	2.5	0.8	0.0
3	3.3	1.0	0.0
4	4.5	1.1	0.0
5	4.5	1.8	0.0
6	3.7	1.3	0.0
7	4.5	1.0	0.0
8	2.7	1.0	0.0
Flap	1.0	0.4	N/A

Table 12.8: Test #57 Fluid Thickness Data

Test 57: Launch, IP-/SN-, Tunnel OAT -3.6°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
1	0.7	2.5	0.1
2	1.8	2.7	0.1
3	2.2	3.3	0.1
4	2.5	3.9	0.1
5	2.7	3.9	0.1
6	2.7	4.5	0.1
7	2.5	4.5	0.1
8	2.2	3.7	0.1
Flap	0.5	slush	0.2

Table 12.9: Test #57A Fluid Thickness Data

Test 57A: Launch, IP-/SN-, Tunnel OAT -4.2°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
1	1.0	2.2	0.0
2	1.8	3.5	0.1
3	2.2	4.5	0.1
4	2.7	4.5	0.1
5	3.1	4.5	0.2
6	3.1	5.7	0.1
7	2.7	4.5	0.2
8	2.2	4.5	0.2
Flap	2.2	4.5	0.1

12.2.2 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.3. Skin temperature measurements were recorded at the following intervals:

- Before fluid application;
- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Tables 12.10 to 12.17 show the wing temperature measurements recorded during the contaminated fluid tests.

Table 12.10: Test #26 Wing Skin Temperature Data

Test 26: EG106, IP-/ZR-, Tunnel OAT -1.9°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Test
T2	-2.8	-3.0	-7.6	-3.6
T5	-2.8	-2.9	-6.6	-2.3
TU	-3.8	-3.5	-4.4	-3.5

Table 12.11: Test #26A Wing Skin Temperature Data

Test 26A: EG106, IP-/ZR-, Tunnel OAT -3.3°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip. Application	After Takeoff Test
T2	-2.8	-3.3	-7.7	-4.1
T5	-2.2	-3.2	-6.6	-3.2
TU	-3.5	-3.5	-4.3	-4.5

Table 12.12: Test #28 Wing Skin Temperature Data

Test 28: Launch, IP-, Tunnel OAT -4.2°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip. Application	After Takeoff Test
T2	-1.2	-1.6	-7.3	-5.0
T5	-0.4	-1.6	-7.6	-4.4
TU	-1.6	-1.6	-3.9	-5.7

Table 12.13: Test #28A Wing Skin Temperature Data

Test 28A: Launch, IP-, Tunnel OAT -5.5°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip. Application	After Takeoff Test
T2	-3.4	-3.3	-8.5	-7.4
T5	-2.8	-3.4	-8.3	-7.3
TU	-5.1	-4.6	-5.4	-7.8

Table 12.14: Test #56 Wing Skin Temperature Data

Test 56: EG106, IP/R Mod, Tunnel OAT -1.1°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Test
T2	-1.2	-1.5	-5.3	-4.3
T5	-1.3	-1.7	-5.1	-4.0
TU	-1.5	-2.1	-2.6	-4.4

Table 12.15: Test #56A Wing Skin Temperature Data

Test 56A: EG106, IP/R Mod, Tunnel OAT -1.4°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip. Application	After Takeoff Test
T2	-3.4	-1.7	-3.3	-3.5
T5	-2.7	-1.6	-3.0	-2.7
TU	-3.6	-3.1	-0.9	-3.4

Table 12.16: Test #57 Wing Skin Temperature Data

Test 57: Launch, IP-/SN-, Tunnel OAT -3.6°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Test
T2	-3.4	-2.5	-6.9	-4.6
T5	-3.3	-2.4	-6.8	-4.2
TU	-3.0	-3.1	-2.6	-4.9

Table 12.17: Test #57A Wing Skin Temperature Data

Test 57A: Launch, IP-/SN-, Tunnel OAT -4.2°C				
WING TEMPERATURE (°C)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Test
T2	-3.9	-3.0	-7.1	-5.1
T5	-3.3	-3.0	-7.2	-4.8
TU	-4.6	-4.3	-2.7	-5.3

12.2.3 Fluid Brix Data

Fluid Brix measurements were recorded at the following intervals by APS personnel. The wing positions used for the wind tunnel tests are described in Subsection 2.15.4. Fluid Brix measurements were recorded at the following intervals:

- After fluid application;
- After application of contamination; and
- After the simulated takeoff test.

Tables 12.18 to 12.25 show the fluid Brix measurements collected during the contaminated fluid tests.

Table 12.18: Test #26 Fluid Brix Data

Test 26: EG106, IP-/ZR-, Tunnel OAT -1.9°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Test
2	32.00	20.25	29.50
8	32.00	14.50	28.00

Table 12.19: Test #26A Fluid Brix Data

Test 26A: EG106, IP-/ZR-, Tunnel OAT -3.3°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
2	31.75	17.50	25.25
8	32.00	21.50	25.00

Table 12.20: Test #28 Fluid Brix Data

Test 28: Launch, IP-, Tunnel OAT -4.2°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
2	35.75	15.75	23.00
8	36.50	14.75	24.00

Table 12.21: Test #28A Fluid Brix Data

Test 28A: Launch, IP-, Tunnel OAT -5.5°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
2	37.25	18.50	29.25
8	37.00	19.00	21.00

Table 12.22: Test #56 Fluid Brix Data

Test 56: EG106, IP/R Mod, Tunnel OAT -1.1°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
2	32.00	13.50	31.25
8	32.50	12.00	30.75

Table 12.23: Test #57 Fluid Brix Data

Test 57: Launch, IP-/SN-, Tunnel OAT -3.6°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
2	36.25	15.00	26.25
8	36.75	14.50	26.00

Table 12.24: Test #56A Fluid Brix Data

Test 56A: EG106, IP/R Mod, Tunnel OAT -1.4°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
2	32.25	12.00	N/A
8	32.00	10.50	29.00

Table 12.25: Test #57A Fluid Brix Data

Test 57A: Launch, IP-/SN-, Tunnel OAT -4.2°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Test
2	37.50	13.50	24.25
8	36.75	7.50	27.50

12.3 Photos

High-speed digital photographs of each test were taken; wide-angle photos were taken of the leading edge, and close-up photos were taken of the trailing edge. For each test, photo summaries have been compiled comprising four stages:

- Start of test;
- Before Rotation (just before the wing began to pitch);

- End of Rotation (end of the rotation cycle when the wing position is returned to 4 degrees); and
- End of test.

The photos taken during the Light Ice Pellet Mixed with Light Rain testing have been presented. Photo 12.1 to Photo 12.8 show the photo summaries of the tests conducted and are organized for easy comparison. A complete set of photos will be provided to the TDC in electronic format.

12.4 Summary of Results

12.4.1 OAT -5°C and Above

One test (#117) was conducted with exposure times of 25 minutes in this cell. Tabble 12.26 for a summary of the tests.

Test #117, conducted with an EG fluid, demonstrated very good results. The temperature during this test run was 0°C. The lift coefficient and the visual rating results were deemed good. The 8° lift loss was 2.88 percent, below the 5.4 percent safety criteria. The ramp-up time from 40 knots to rotation was 21 seconds in this run, slightly greater than the 17-second average. Due to the positive results that were displayed, there is a potential to further expand the current allowance time for EG fluids. See Table 12.27 for the details of this test.

In conclusion, this test demonstrated positive results, indicating that the current allowance time of 25 minutes for this cell is acceptable and validated.

12.4.2 OAT Less than -5°C to -10°C

No allowance times currently exist in this cell.

12.4.3 OAT Less than -10°C

No allowance times currently exist in this cell.

Table 12.26: Light Ice Pellets Mixed with Light Rain Allowance Time Tests Winter 2010-11

Light Ice Pellets Mixed with Light Rain	OAT -5°C and Above (No allowance times below 0°C)	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts	25 minutes **Test # 117**	**Caution: No allowance times currently exist**	

Table 12.27: Summary of Light Ice Pellets Mixed with Light Rain Allowance Time Test Results

OAT -5°C AND ABOVE (25 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
117	*Launch*	*-3.6*	IP:25 , R:25	*25*	1.3 , 1.3 , 1.3	GOOD	1 , 1 , 1	GOOD	*2.88*	GOOD	

Notes:

CONCLUSION: ALLOWANCE TIME AT 25 MINUTES IS GOOD

OAT LESS THAN -5°C TO -10°C

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status

Notes:

CONCLUSION: No Allowance Times Currently Exist

OAT LESS THAN -10°C

Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status

Notes:

CONCLUSION: No Allowance Times Currently Exist

This page intentionally left blank.

Photo 12.1: Test #54 (09-10) – Start of Test

Test #54

Launch, Fluid Only

-2°C, 8° Rotation

Visual Contamination Rating (1,1,1)

Start of Test

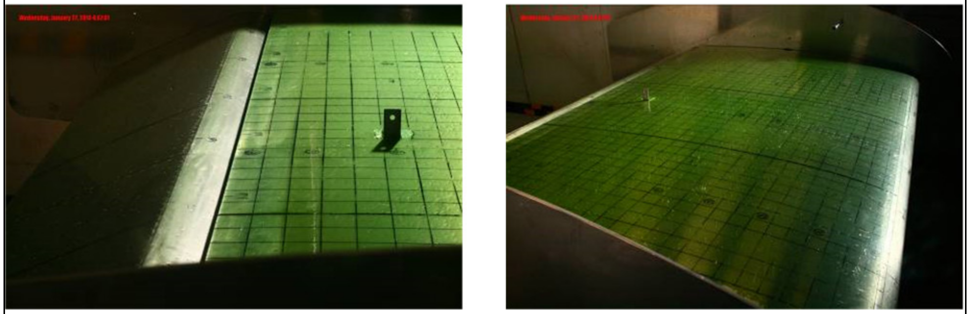


Photo 12.2: Test #54 (09-10) – Before Rotation

Test #54

Launch, Fluid Only

-2°C, 8° Rotation

Visual Contamination Rating (1,1,1)

Before Rotation

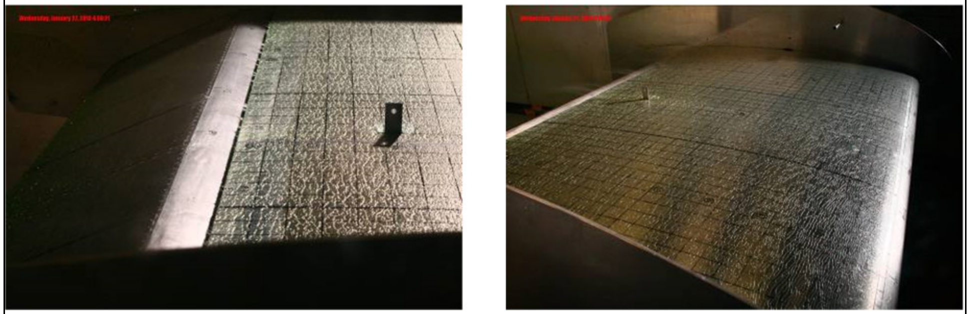
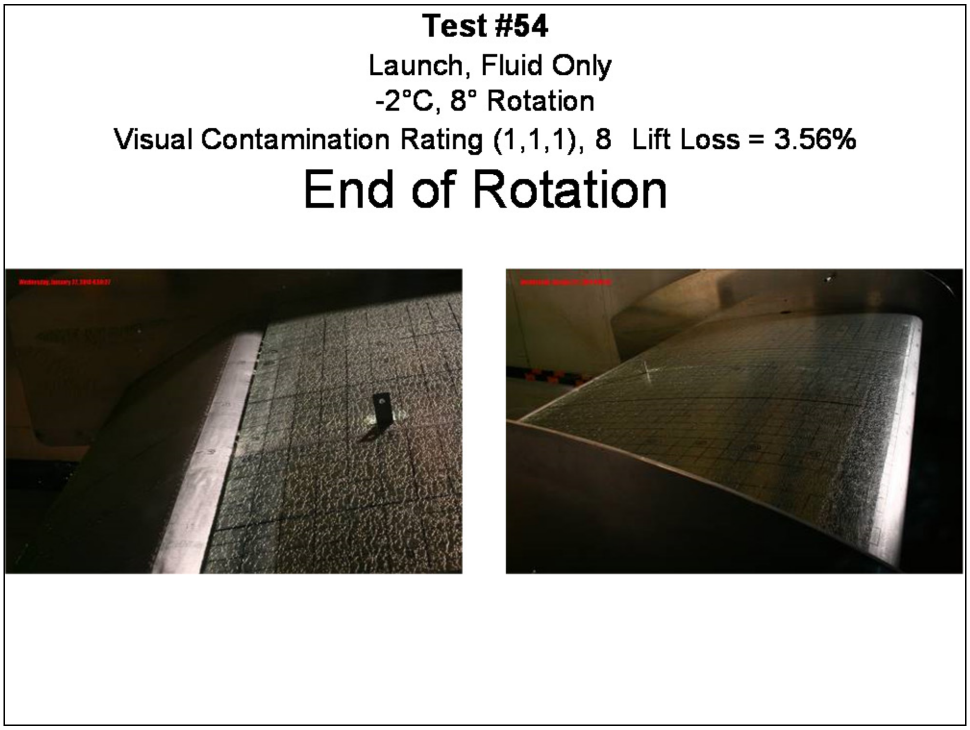


Photo 12.3: Test #54 (09-10) – End of Rotation



Test #54

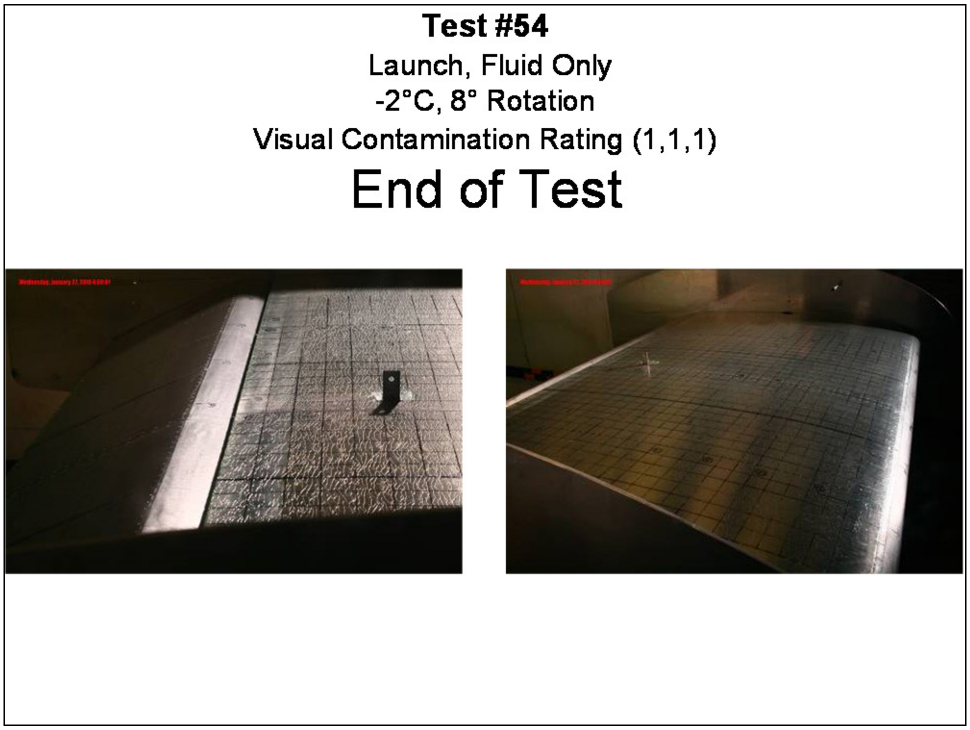
Launch, Fluid Only

-2°C, 8° Rotation

Visual Contamination Rating (1,1,1), 8 Lift Loss = 3.56%

End of Rotation

Photo 12.4: Test #54 (09-10) – End of Test



Test #54

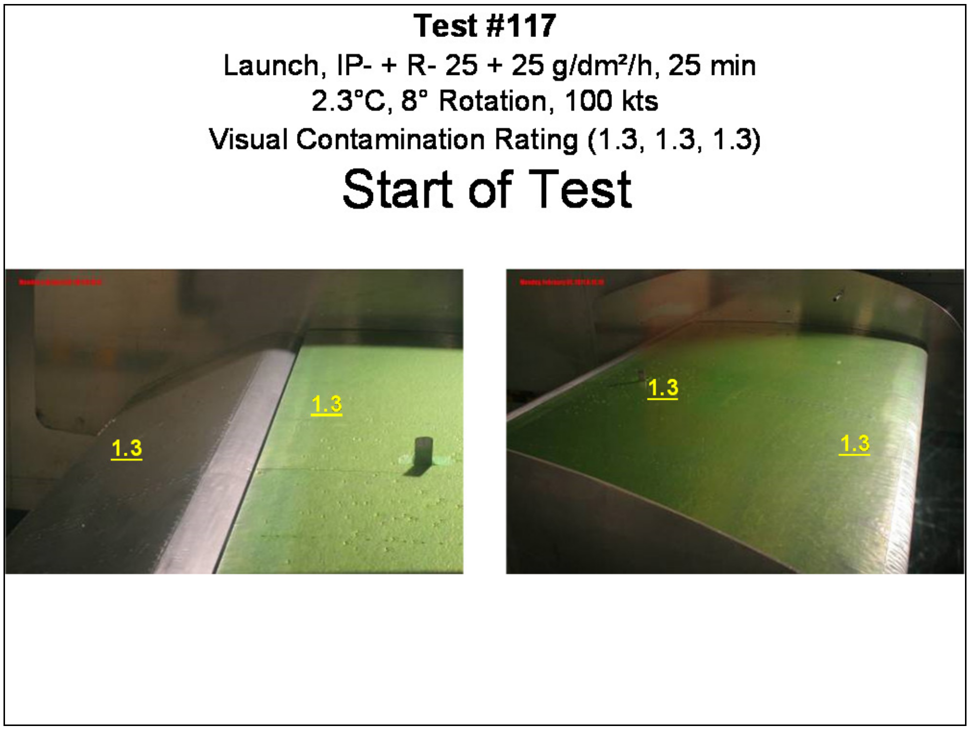
Launch, Fluid Only

-2°C, 8° Rotation

Visual Contamination Rating (1,1,1)

End of Test

Photo 12.5: Test #117 – Start of Test



Test #117

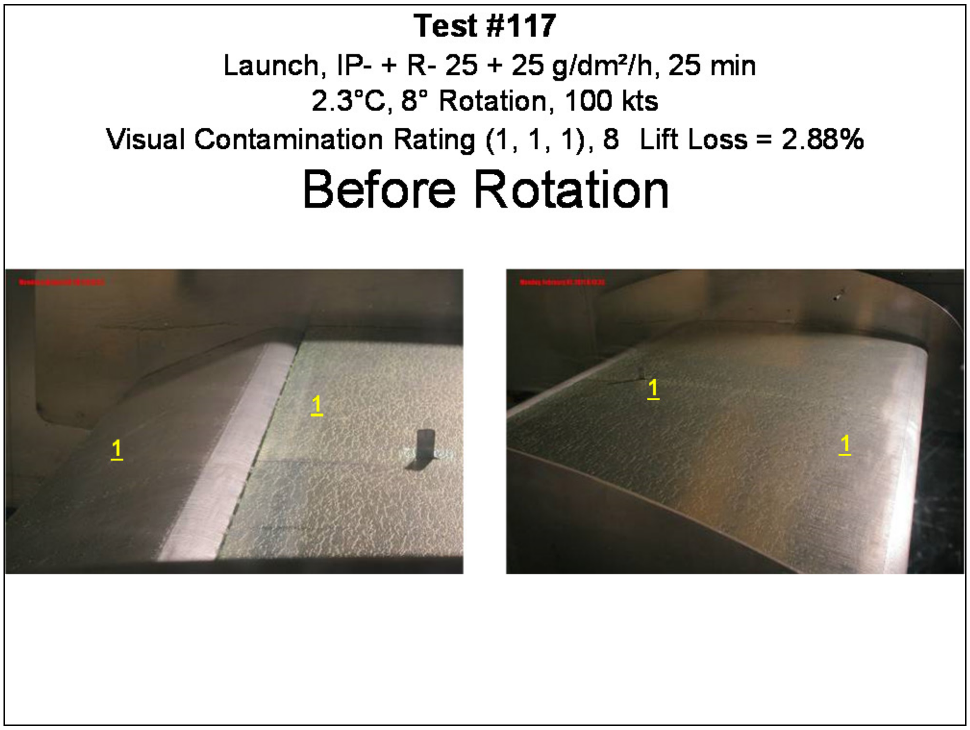
Launch, IP- + R- 25 + 25 g/dm²/h, 25 min

2.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1.3, 1.3, 1.3)

Start of Test

Photo 12.6: Test #117 - Before Rotation



Test #117

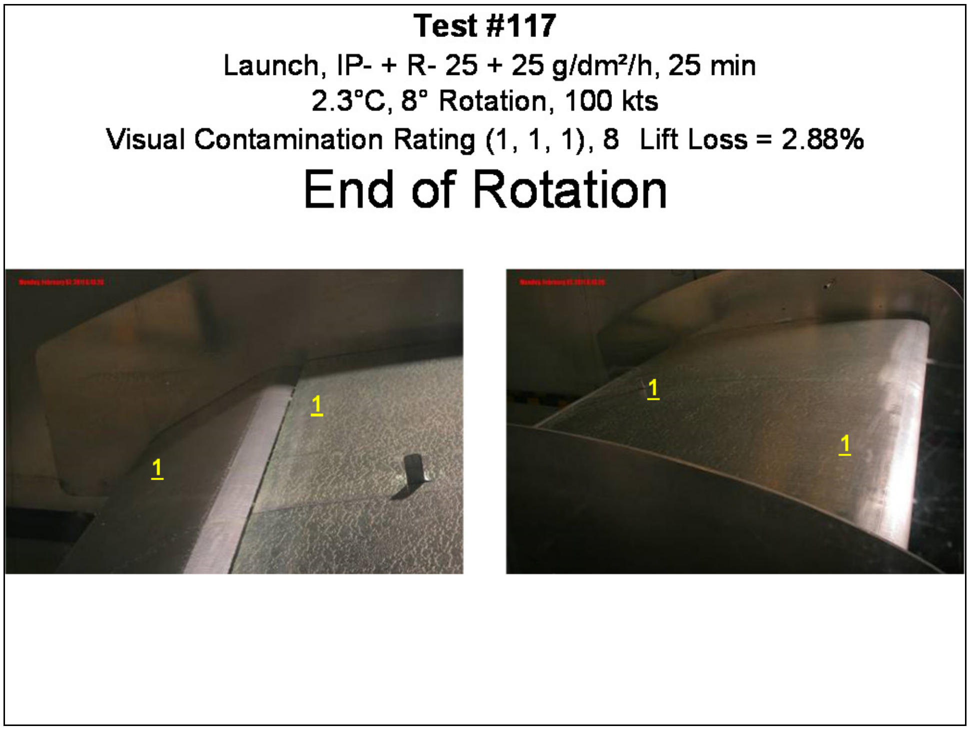
Launch, IP- + R- 25 + 25 g/dm²/h, 25 min

2.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.88%

Before Rotation

Photo 12.7: Test #117 – End of Rotation



Test #117

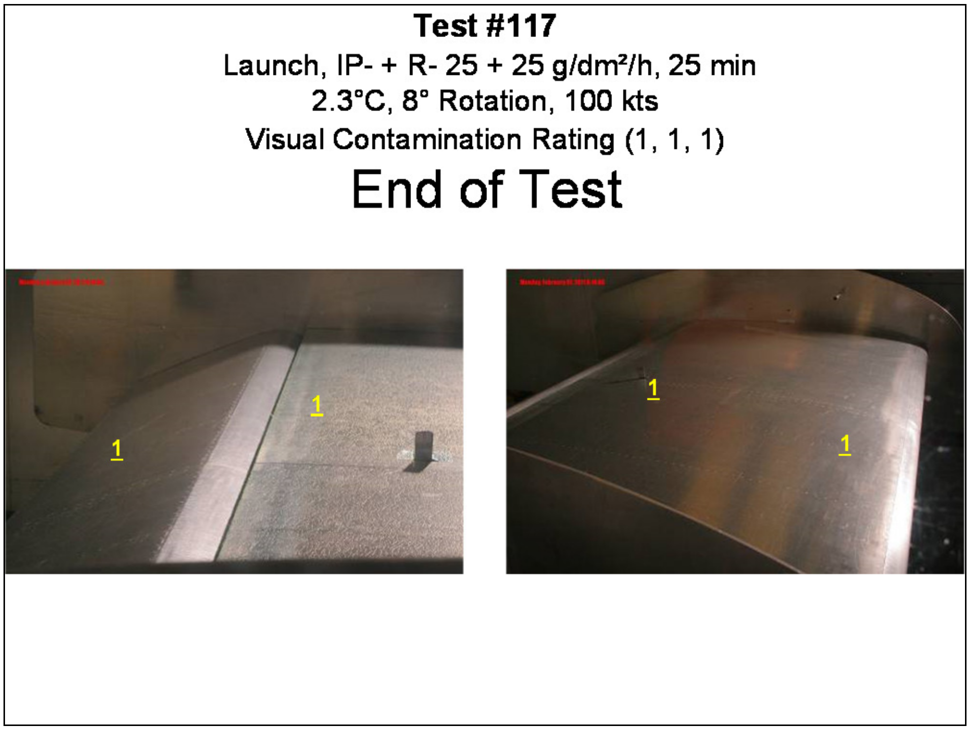
Launch, IP- + R- 25 + 25 g/dm²/h, 25 min

2.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1), 8 Lift Loss = 2.88%

End of Rotation

Photo 12.8: Test #117 – End of Test



Test #117

Launch, IP- + R- 25 + 25 g/dm²/h, 25 min

2.3°C, 8° Rotation, 100 kts

Visual Contamination Rating (1, 1, 1)

End of Test

13. CONCLUSIONS AND OBSERVATIONS

These observations and conclusions were derived from the testing conducted during the winter of 2010-11.

13.1 Type IV High-Speed Allowance Times

Results from the 2010-11 testing demonstrated results similar to the 2009-10 testing in that the results indicated fluid flow-off issues with the supercritical wing when using PG fluids at the lower temperatures. During the winter of 2009-10, greater lift losses on the 2D model were recorded during light ice pellet and moderate ice pellet conditions below -10ºC, and changes to the guidance material were made to address this.

During the winter of 2010-11, similar results were obtained, and the data collected indicated that the footnote in the guidance material restricting the use of PG fluids to aircraft with rotation greater than 115 knots during light ice pellet and moderate ice pellet conditions below -10ºC was still relevant and should remain in the allowance time table for the winter of 2011-12.

It should be noted that three moderate ice pellet tests conducted at 115 knots and at the very low end of the temperature range demonstrated lift loss results that were marginally above the upper acceptable limit of 9.2 percent; however, the visual observations demonstrated satisfactory results. It was agreed that changes would not be made until some additional testing could be conducted to support this work and until the lift loss limits were further investigated.

The testing conducted during the winters of 2009-10 and 2010-11 supported the potential expansion of the light ice pellets mixed with light or moderate snow cells. More specifically, the results indicated that for light ice pellets mixed with light snow in above -5ºC conditions, the allowance time could potentially be increased from 25 minutes to 40 minutes; for light ice pellets mixed with moderate snow in above -5ºC conditions, the allowance time could potentially be increased from 10 minutes to 20 minutes; and a new allowance time of 7 minutes could potentially be added for light ice pellets mixed with moderate snow in the -5ºC to -10ºC condition. It was agreed that changes would not be made until some additional testing could be conducted to support this work and until the lift loss limits were further investigated.

Additional analysis paired with wind tunnel testing is recommended to further develop a correlation between the lift losses observed in the wind tunnel and those used as the basis of the AAT. It is anticipated that this testing will be conducted during the winter of 2011-12. It is recommended that the entire 2009-10 and 2010-11 data sets be revisited following the testing in 2011-12 and that changes to the guidance material be made in accordance.

13.2 Correlation of Fluid Certification BLDT Results with NRC Wind Tunnel Lift Loss Results

Based on the work that was conducted by NASA and APS, it was determined that a maximum lift loss of 5.24 percent on the B737-200ADV airplane is equivalent to a lift loss of 7.29 percent on the PIWT model. Due to the scatter in the data, the standard error of the estimate determined an upper limit of lift loss on the PIWT model of 9.17 percent and a lower limit of 5.41 percent.

Currently, the scatter in the "review" range is still large and causes complications when analysing the data collected. It is anticipated that as future testing progresses and as more data is collected, a single-value pass/fail cut-off will be developed similar to the AAT and B737-200ADV airplane tests.

13.3 Probability of Ice Pellet Occurrences for Use with Allowance Times

Ice pellet precipitation data was acquired from instruments located at six stations in Quebec, Canada, from the MSC. This data was collected as part of an ongoing study to evaluate the suitability of the current format of the HOT tables (see TP 15051E, *Winter Weather Impact on Holdover Time Table Format (1995-2010)* (14). The results were translated into the likelihood of ice pellet occurrence in each cell of the allowance time table. The outcome is shown in Table 13.1

Values in italics in Table 13.1 indicate conditions where no allowance times currently exist. Based on this limited data, it appears a significant portion of precipitation can occur below -10°C in light ice pellets mixed with light snow, where no allowance times currently exist. Similarly, light ice pellets mixed with moderate snow can also occur at temperatures less than -5°C to -10°C and OAT less than -10°C; no ice pellet allowance times currently exist. It is recommended that future research target these conditions in order to allow greater flexibility to operators in conditions of mixed ice pellets with light or moderate snow.

Table 13.1: Likelihood of Occurrence for Use with Ice Pellet Allowance Times

Condition	Possible Rate	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C	Total
Light Ice Pellets	(0 to 25 g/dm^2/h)	87.1%	10.3%	0%	**100%**
Moderate Ice Pellets	(25 to 75 g/dm^2/h)	2.6%	0%	0%	
***Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle**	(0 to 38 g/dm^2/h)	92.4%	7.6%	*0%*	**100%**
***Light Ice Pellets Mixed with Light Freezing Rain**	(0 to 50 g/dm^2/h)				
***Light Ice Pellets Mixed with Light Rain**	(0 to 50 g/dm^2/h)	98.9% (1)	*0%*	*0%*	
***Light Ice Pellets Mixed with Moderate Rain**	(25 to 100 g/dm^2/h)	11.1%(2)	*0%*	*0%*	
***Light Ice Pellets Mixed with Light Snow**	(0 to 35 g/dm^2/h)	68.2%	16.7%(3)	*12.3%*	
***Light Ice Pellets Mixed with Moderate Snow**	(10 to 50 g/dm^2/h)	16.3%(4)	*6.7%*	*1%*	

Values in italics indicate conditions where no allowance times currently exist.
*Analysis based upon a cumulative rate of both precipitation types and assumes ice pellet intensity does not exceed "light" or 25 g/dm^2/h

FOOTNOTES

(1) If the weather report is ice pellets mixed with rain, there is a 98.9 percent likelihood of light ice pellets mixed with light rain with a possible rate from 0 to 50 g/dm^2/h (at OAT -5°C and above).

(2) If the weather report is ice pellets mixed with rain, there is a 11.1 percent likelihood of light ice pellets mixed with moderate rain with a possible rate from 25 to 100 g/dm^2/h (at OAT -5°C and above).

(3) If the weather report is ice pellets mixed with snow, there is a 16.7 percent likelihood of light ice pellets mixed with light snow with a possible rate from 0 to 35 g/dm^2/h (at OAT -5°C to -10°C).

(4) If the weather report is ice pellets mixed with snow, there is a 16.3 percent likelihood of light ice pellets mixed with moderate snow with a possible rate from 10 to 50 g/dm^2/h (at OAT -5°C and above).

This page intentionally left blank.

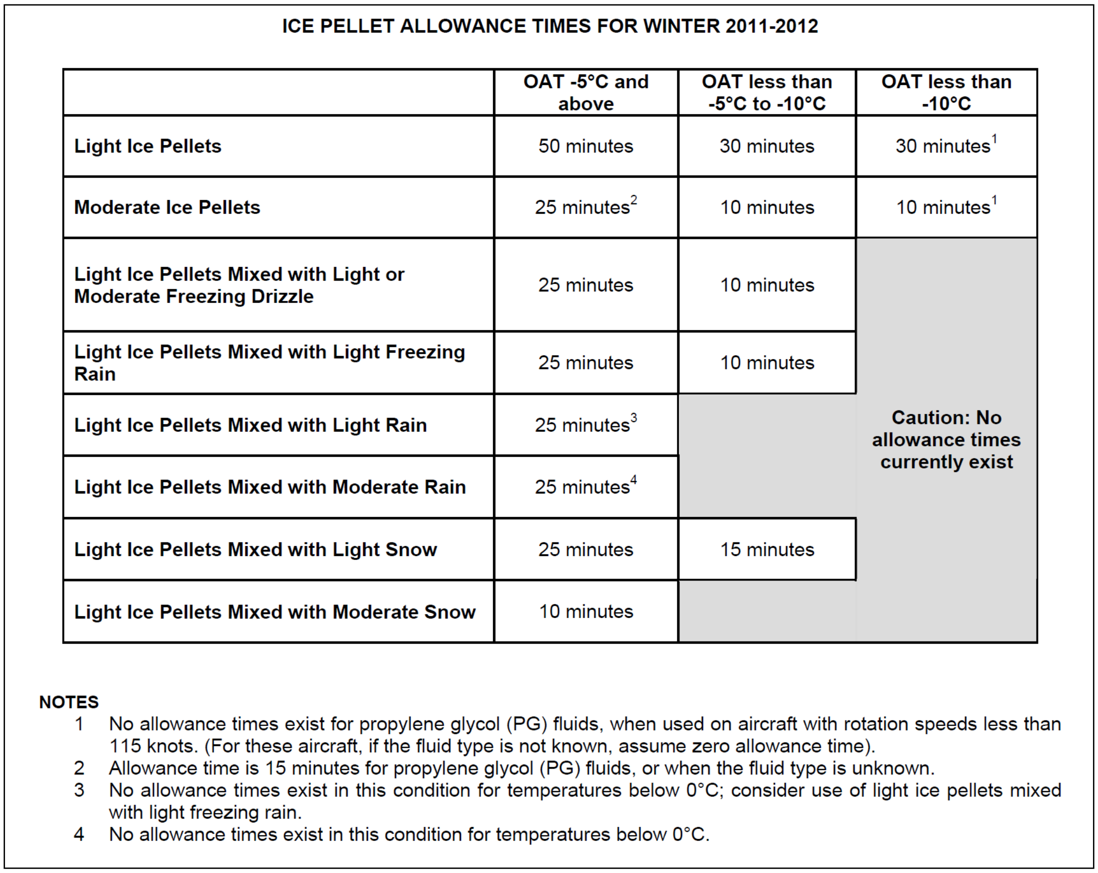
14. RECOMMENDATIONS

The following recommendations were compiled based on the work conducted during the winter of 2010-11.

14.1 Type IV High-Speed Allowance Time Table

Based on the 2010-11 wind tunnel test results, no changes were made to the values in the Type IV allowance time table; however, additional guidance was included to explicitly indicate that guidance material does not exist for light ice pellets mixed with light or moderate rain below 0°C (see newly added Notes 3 and 4). This work was presented at the SAE G-12 meeting in San Francisco in May 2011 and in Montreal in November 2011; a copy of the presentations is included in TC report, TP 15158E, *Aircraft Ground Icing General Research Activities During the 2010-11 Winter (16)*. The updated allowance time table is shown in Table 14.1.

Table 14.1: 2011-12 Type IV Ice Pellet Allowance Time Table



ICE PELLET ALLOWANCE TIMES FOR WINTER 2011-2012

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets	50 minutes	30 minutes	30 minutes[1]
Moderate Ice Pellets	25 minutes[2]	10 minutes	10 minutes[1]
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	**Caution: No allowance times currently exist**
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes	
Light Ice Pellets Mixed with Light Rain	25 minutes[3]		
Light Ice Pellets Mixed with Moderate Rain	25 minutes[4]		
Light Ice Pellets Mixed with Light Snow	25 minutes	15 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes		

NOTES

1 No allowance times exist for propylene glycol (PG) fluids, when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time).

2 Allowance time is 15 minutes for propylene glycol (PG) fluids, or when the fluid type is unknown.

3 No allowance times exist in this condition for temperatures below 0°C; consider use of light ice pellets mixed with light freezing rain.

4 No allowance times exist in this condition for temperatures below 0°C.

14.2 Future Research

14.2.1 Type IV High-Speed Allowance Times

Historical winter weather data has indicated that a significant portion of light ice pellets mixed with light snow precipitation occurs below -10°C and light ice pellets mixed with moderate snow precipitation occurs below -5 to -10°C where no allowance times currently exist. It is recommended that future research target these conditions in order to allow greater flexibility to operators in conditions of mixed ice pellets with light or moderate snow, as initial results from the 2010-11 testing have indicated a potential for new, longer allowance times.

Additional testing is also recommended in moderate ice pellets close to the lower end of the -10ºC to -25ºC range where the higher lift losses were observed during the winter of 2010-11. The additional testing is recommended in order to better understand the impact of the higher lift losses and if changes to the guidance material are required in the future.

14.2.2 Additional Testing and Analysis to Further Investigate Supercritical Wing Lift Losses

Additional analysis paired with wind tunnel testing is recommended to develop a correlation between the lift losses observed in the wind tunnel and the AAT, which is the basis for the fluid certification process. Currently, the scatter in the data is still large and causes complications when analysing the data collected. It is anticipated that as future testing progresses and as more data is collected, a single-value pass/fail cut-off will be developed similar to the AAT and B737-200ADV airplane tests.

14.2.3 Testing to Investigate Repeatability and Calibration of the PIWT

A large portion of the work planned for the winter of 2011-12 will focus on the repeatability and calibration of the PIWT. An extensive series of tests are being planned that will included angle of attack sweeps, stall runs, oil flow visualization, boundary layer tripping, and pristine and contaminated fluid testing. This testing will be conducted in cooperation with NASA aerodynamicists to obtain a better understanding of the PIWT characteristics and their effects on the fluid testing, which is the basis of the ice pellet allowance times.

REFERENCES

1. Ruggi, M., *Preliminary Endurance Time Testing in Simulated Ice Pellet Conditions,* APS Aviation Inc., Transportation Development Centre, Montreal, January 2006, TP 14718E, 42.

2. Balaban, G., *Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets,* APS Aviation Inc., Transportation Development Centre, Montreal, December 2006, TP 14716E, XX (to be published).

3. Ruggi, M., *Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets*, APS Aviation Inc., Transportation Development Centre, Montreal, January 2008, TP 14779E, XX (to be published).

4. Ruggi, M., *Research for Further Development of Ice Pellet Allowance Times: Aircraft Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2007-08*, APS Aviation Inc., Transportation Development Centre, Montreal, March 2009, TP 14871E, XX (to be published).

5. Chaput, M., Dawson, P., Hanna, M., *Contaminated Aircraft Takeoff Test for the 1997/98 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 1998, TP 13316E, 54.

6. Dawson, P., Hanna, M., *Contaminated Aircraft Takeoff Tests for the 1998-99 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1999, TP 13479E, 157.

7. Dawson, P., *Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures*, APS Aviation Inc., Transportation Development Centre, Montreal, August 2000, TP 13666E, 18.

8. Campbell, R., Chaput, M., *Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2002, TP 13995E, 92.

9. Chaput, M., *Aircraft Takeoff Test Program for Winter 2002-03: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2003, TP 14147E, 92.

10. Balaban, G., *Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report*, APS Aviation Inc., Transportation Development Centre, Montreal, January 2008, TP 14778E, XX (to be published).

11. Myron, O., Penna, P., *Air-Flap Performance with De-Anti-Icing Fluids and Freezing Precipitation,* National Research Council Canada, Transportation Development Centre, Ottawa, May 1999, TP 13426E, 14.

12. Ruggi, M., *Research for Further Development of Ice Pellet Allowance Times: Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2009, TP 14935E, 252.

13. Ruggi, M., *Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winters 2009-10 to 2012-13,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2013, TP 15232E, XX (to be published).

14. Ruggi, M., *Exploratory Wind Tunnel Aerodynamic Research: Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2010-11,* APS Aviation Inc., Transportation Development Centre, Montreal, March 2012, TP 15160E, XX (to be published).

15. Broeren, A., P., Riley, J., T., *Review of the Aerodynamic Acceptance Test and Application to Anti-Icing Fluids Testing in the NRC Propulsion and Icing Wind Tunnel*, FAA, August 2012, DOT/FAA/TC-12/32, 34. Retrieved from https://ntrs.nasa.gov/citations/20120016397

16. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2010-11 Winter,* APS Aviation Inc., Transportation Development Centre, Montreal, January 2012, TP 15158E, XX (to be published).

APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2010-11

TRANSPORTATION DEVLOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2010-11

6.3 Aircraft Performance Research

6.3.1 Wind Tunnel Testing to Refine Allowance Times

a) Meet with NRC personnel to arrange for access to the Propulsion Wind Tunnel (PWT) in M46 at the NRC Montreal Road facility in Ottawa;

Note: The NRC facility costs associated with testing at M46 are not included in this task and are dealt with directly with TC through a M.O.U. agreement with NRC;

b) Participate in the modification of the recently constructed super-critical airfoil model to be used for testing (modifications may include moveable flap, leading edge devices etc.);

c) Develop a procedure and test plan and discuss the plan with TC, FAA, and the NRC staff that operates the PWT. It is anticipated that one day of setup will be required, followed by a three week test period. It is anticipated that much of the testing will be conducted during overnight hours;

d) Perform wind tunnel tests to possibly expand current allowance times published by TC and FAA and to validate the results for super-critical airfoils. Testing may also be conducted to potentially develop an allowance time table for use with Type III fluid;

e) Perform wind tunnel tests with an ethylene glycol and a propylene glycol anti-icing fluid at low temperatures;

f) Perform wind tunnel tests to simulate low speed and high speed takeoffs in accordance with the speed and angle of attack profiles provided by TDC and airframe manufacturers. The simulated take-off profile will target the clean wing stall angle as the maximum angle of attack in order to obtain CLmax data. The analysis will evaluate the lift results at an angle approximately halfway between the typical angle of attack at rotation and the stall angle. In addition, fluid only data points will be collected close to the BLDT limits in order to develop a correlation between the lift losses observed in the NRC wind tunnel and the fluid certification tests (consider feasibility of using BLDT measurement device for wind tunnel tests);

g) During contaminated test runs, a baseline fluid only case will be run immediately before, or after the contaminated test run to provide a direct correlation of the results;

h) Collect the following data during the tests:
    i. Type and amount of fluid applied;
    ii. Type and rate of contamination applied; and
    iii. Extent of fluid contamination prior to the test run.

i) Take a series of high resolution photos of the fluid motion at the leading and trailing edges of the wing at a rate of about 3 frames per second, with lighting adequate to see the fluid waves and ripples of about 1mm in height, even when the wing is at the peak angle of attack;

j) Document the appearance of fluid on the wing during the simulated takeoff run and climb of the aircraft by analyzing the photographic records;

k) Continue analysis of 5-8% lift losses observed during previous testing with the super-critical wing, evaluate the effects of using a ground plane on the testing results (reference Boeing report), and develop correlation to operational aircraft; and

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

APPENDIX B

PROCEDURE:
WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

CM2169.003

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

Winter 2010-11

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

APS
Aviation Inc.

January 14, 2011
Final Version 1.0

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

1. BACKGROUND

Prior to the winter of 2006-07, Holdover Time (HOT) guidance material did not exist for ice pellet conditions, however aircraft could still depart during ice pellet conditions following aircraft deicing and a pre take off contamination check. This protocol was feasible for common air carrier aircraft that provided access to emergency exit windows overlooking the leading edge of the aircraft wings; however, it posed a significant problem for cargo aircraft that have limited visibility of the wings from the cabin.

On December 22, 2004, United Parcel Service (UPS) aircraft in Louisville were grounded for several hours due to extended ice pellet conditions. Due to cargo aircraft configuration, pre-take off contamination checks by the on-board crew were not possible. FedEx had been faced with similar problems in Memphis. Following this event, in October 2005, the FAA issued two notices restricting take offs in ice pellet conditions.

As a result of this costly incident, UPS set out to obtain experimental data to provide guidance and allow operations to continue in ice pellet conditions. During the winter of 2004-05, aerodynamic and endurance time testing were conducted in simulated ice pellet conditions. APS also conducted some preliminary flat plate research (see TP 14718E). Based on the preliminary data, an allowance of 20 minutes in light ice pellet conditions was proposed, however no changes to the HOT guidelines were made.

During the following winter of 2006-07, the FAA provided a 25 minute allowance as a preliminary guideline; TC issued a note indicating that no changes would be made to the HOT guidelines. This allowance was based on the previous research conducted during the winter of 2005-06, primarily as a result of Falcon 20 aerodynamic research (see TP 14716E); these results were presented at the Society of Automotive Engineers (SAE) meeting in Lisbon in May 2006. To address the option of a pre-take off contamination check, the 20 minute targeted allowance was extended to 25 minutes; pre-take off contamination checks would no longer apply. This allowance was followed by a list of conditions; one restriction was that operations would be limited to ice pellets alone (no mixed conditions).

Due to the high occurrence of ice pellets combined with freezing rain or snow, the industry requested additional guidance material for operations in mixed ice pellet conditions. Additional endurance time testing and aerodynamic research were conducted in simulated ice pellet conditions during the winter of 2006-07.

During the winter of 2007-08, the TC and FAA provided allowance time guidance material for operations in mixed conditions with ice pellets guideline. These allowance times were based on the research conducted during the winter of 2006-07 (see TP 14779E). The recommended allowance times were based on aerodynamic research conducted using the 3 m x 6 m Open Circuit Propulsion and Icing Wind Tunnel (PIWT) and the NRC Falcon 20 aircraft; these results were presented at the SAE meeting in San Diego in May 2007. These allowance time guidelines were followed by a list of restrictions based on the results obtained through the research conducted, and the lack of data in specific conditions.

During the winter of 2008-09, additional endurance time testing and aerodynamic research was conducted to support and further expand the ice pellet allowance times (see TP 14935E). Full-scale testing with the NRC PIWT was conducted in mixed conditions with ice pellets and in non precipitation conditions. Testing was geared towards validating the current ice pellet allowance times, and potentially expanding the guidance material to include different conditions, fluids, and acceleration profiles. A revised version of the ice pellet allowance times was published for the winter of 2009-10; changes were made to the high speed table allowance times only.

During the winter of 2009-10, additional aerodynamic research using a generic super-critical wing model was conducted at the NRC PIWT to support and further expand the ice pellet allowance times for use with newer generation aircraft. During the testing, fluid flow-off issues with the supercritical wing were observed with PG fluids at the lower temperatures; more specifically during light ice pellets and moderate ice pellet conditions below -10°C. In addition fluid failure issues with the supercritical wing were observed with PG fluids during moderate ice pellets above -5°C; the relatively flat surface of the wing had less fluid flow off during contamination and resulted in an earlier fluid failure for PG fluids. In general, higher lift losses were observed with the supercritical wing as compared to previous wings tested. A revised version of the ice pellet allowance times was published for the winter of 2009-10.

It was recommended that testing continue with the supercritical wing in the PIWT during the winter of 2010-11. The objective of the testing is to validate the current allowance times for aircraft with supercritical airfoils, to correlate the lift losses observed the fluid aerodynamic acceptance test, to validate the analysis methodologies developed following the winter 2009-10 testing, and to potentially expand the results to include different conditions, fluids, and acceleration profiles.

2. OBJECTIVES

The objective of this testing is to conduct aerodynamic testing with a super critical airfoil to:

- Validate the current allowance times (using new fluids) for newer generation aircraft (with super critical wings);
- Validate the analysis methodologies developed following the Winter 2009-10 testing (i.e. extrapolation of data to 115 knots);
- To correlate the lift losses observed in the NRC PIWT with the fluid aerodynamic acceptance test protocol (5.24% LL);

As lower priority objectives, testing will be conducted to investigate the following:

- Potentially expand the current allowance times for the following conditions:
    - IP-/SN-;
    - IP-/SN;
    - Type III Fluid in all conditions, heated and un-heated.
- Heavily contaminated fluid during heavy snow conditions;
- Effect of CL Max on recorded lift losses;
- Surface roughness as a result of adhered contamination;
- Effect of wing geometry on fluid failure and aerodynamic performance;
- Low speed testing for Aero Certification Test (67 vs. 80 knots);
- Snow on an Un-Protected Wing;
- Feasibility of conducting horizontal stabilizer testing;
- Rain on an un-protected wing;
- Effect of ice phobic coatings on contaminated airfoil aerodynamic performance ;
- Degraded Anti-icing Fluid Performance Following Contamination with Runway Deicing Fluid; and
- Heavily contaminated vertical stabilizer;

- Frost CSW Spot Deicing;
- Light Freezing Rain and Snow;
- Ice pellet allowance times for low speed aircraft using Type IV fluid;
- Ice pellet allowance times for Type II fluid.

Testing will objectively determine the level of contamination of anti-icing fluid at which the aerodynamic shear forces during takeoff ground roll, rotation and lift off fail to remove the resultant slush.

To satisfy these objectives, a super-critical wing section (Figure 2.1) will be subjected to a series of tests in the NRC wind tunnel. The dimensions indicated are in inches. This wing section was constructed by NRC specifically for the conduct of these tests following extensive consultations with an airframe manufacturer to ensure a representative super-critical design.

Three weeks of testing (over a four week period) have been scheduled for the conduct of these tests. The start date for testing is currently scheduled for January 18th and testing will continue until February 11th (see table 2.1).

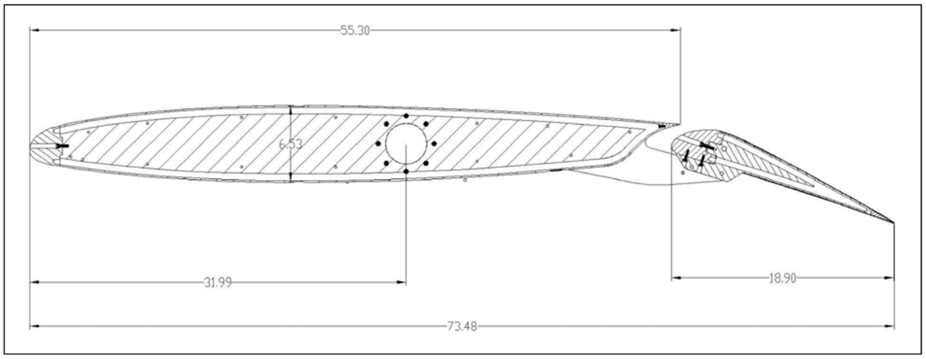


Figure 2.1: Super-Critical Wing Section

Table 2.1: Test Calendar

JANUARY 2011

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
16	17 **TRAVEL DAY** -Pack Truck -Leave for YOW	18 **MORNING** -Setup -Calibration -Training -Briefing **AFTERNOON** -Official Start of Tests (Using 2.5 hr Credit from 09/10)	19 **TEST DAY 1** (Using 7.5 hr Credit from 09/10)	20 **TEST DAY 2**	21 **TEST DAY 3**	22
23	24 **TEST DAY 4**	25 **TEST DAY 5**	26 **TEST DAY 6**	27 **TEST DAY 7**	28 **TEST DAY 8**	29
30	31 **TEST DAY 9**					

FEBRUARY 2011

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1 **TEST DAY 10**	2 **TEST DAY 11**	3 **TEST DAY 12**	4 **TEST DAY 13**	5
6	7 **TEST DAY 14**	8 **TEST DAY 15** -Pack & Leave at End of Day	9 **ALTERNATE DAY 1**	10 **ALTERNATE DAY 2**	11 **ALTERNATE DAY 3**	12

** Anticipate Mon-Fri Testing, However, Weekend May be Needed Due to Temperature.*
*** Testing will Likely be Conducted During Overnight Periods (i.e. 8PM - 6AM), Unless Temperatures are Suitable for Day, Evening Testing. Typical Test Day is 8hrs for APS Staff.*

3. TEST PLAN

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

Representative Type I/III/IV propylene and ethylene fluids in Neat form (standard mix for Type I) shall be evaluated against their uncontaminated performance; Attachments I to VIII present the generic holdover time guidelines for Type I and III fluids and the fluid-specific holdover time guidelines for the representative Type II, III, and IV fluids that will be tested. The current Ice Pellet Allowance Time table has been included in VII.

A preliminary list of test objectives is shown in Table 3.1. It should be noted that the order in which the tests will be carried out will be depend on weather conditions and TC/FAA directive. A detailed preliminary test matrix is shown in Table 3.2.

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

Each test shall be comprised of one fluid at one temperature and one contamination scenario. A test series will be comprised of one fluid at one temperature, using one form of contamination, with varying levels of exposure to the contamination. Baseline fluid-only tests are to be conducted following each contaminated test (or series of sequential tests conducted during similar conditions).

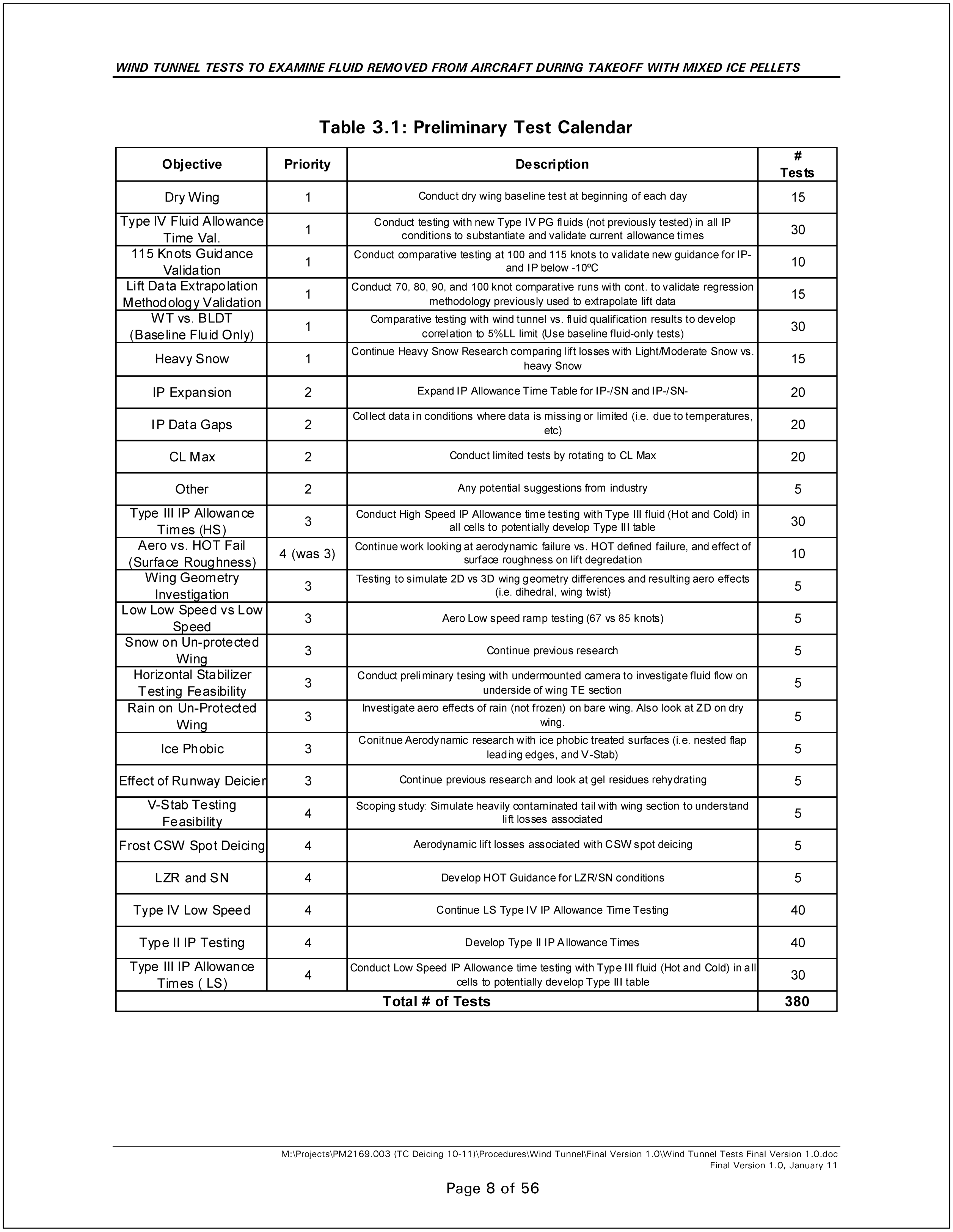


Table 3.1: Preliminary Test Calendar

Objective	Priority	Description	# Tests
Dry Wing	1	Conduct dry wing baseline test at beginning of each day	15
Type IV Fluid Allowance Time Val.	1	Conduct testing with new Type IV PG fluids (not previously tested) in all IP conditions to substantiate and validate current allowance times	30
115 Knots Guidance Validation	1	Conduct comparative testing at 100 and 115 knots to validate new guidance for IP- and IP below -10ºC	10
Lift Data Extrapolation Methodology Validation	1	Conduct 70, 80, 90, and 100 knot comparative runs with cont. to validate regression methodology previously used to extrapolate lift data	15
WT vs. BLDT (Baseline Fluid Only)	1	Comparative testing with wind tunnel vs. fluid qualification results to develop correlation to 5%LL limit (Use baseline fluid-only tests)	30
Heavy Snow	1	Continue Heavy Snow Research comparing lift losses with Light/Moderate Snow vs. heavy Snow	15
IP Expansion	2	Expand IP Allowance Time Table for IP-/SN and IP-/SN-	20
IP Data Gaps	2	Collect data in conditions where data is missing or limited (i.e. due to temperatures, etc)	20
CL Max	2	Conduct limited tests by rotating to CL Max	20
Other	2	Any potential suggestions from industry	5
Type III IP Allowance Times (HS)	3	Conduct High Speed IP Allowance time testing with Type III fluid (Hot and Cold) in all cells to potentially develop Type III table	30
Aero vs. HOT Fail (Surface Roughness)	4 (was 3)	Continue work looking at aerodynamic failure vs. HOT defined failure, and effect of surface roughness on lift degredation	10
Wing Geometry Investigation	3	Testing to simulate 2D vs 3D wing geometry differences and resulting aero effects (i.e. dihedral, wing twist)	5
Low Low Speed vs Low Speed	3	Aero Low speed ramp testing (67 vs 85 knots)	5
Snow on Un-protected Wing	3	Continue previous research	5
Horizontal Stabilizer Testing Feasibility	3	Conduct preliminary tesing with undermounted camera to investigate fluid flow on underside of wing TE section	5
Rain on Un-Protected Wing	3	Investigate aero effects of rain (not frozen) on bare wing. Also look at ZD on dry wing.	5
Ice Phobic	3	Conitnue Aerodynamic research with ice phobic treated surfaces (i.e. nested flap leading edges, and V-Stab)	5
Effect of Runway Deicier	3	Continue previous research and look at gel residues rehydrating	5
V-Stab Testing Feasibility	4	Scoping study: Simulate heavily contaminated tail with wing section to understand lift losses associated	5
Frost CSW Spot Deicing	4	Aerodynamic lift losses associated with CSW spot deicing	5
LZR and SN	4	Develop HOT Guidance for LZR/SN conditions	5
Type IV Low Speed	4	Continue LS Type IV IP Allowance Time Testing	40
Type II IP Testing	4	Develop Type II IP Allowance Times	40
Type III IP Allowance Times (LS)	4	Conduct Low Speed IP Allowance time testing with Type III fluid (Hot and Cold) in all cells to potentially develop Type III table	30
Total # of Tests			**380**

Table 3.2: Proposed Test Plan

Test Plan #	Objective	Priority	Test Condition	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time	Target OAT (ºC)	Ramp (s/kts)
P001	Dry Wing	1	None	None	-	-	-	-	-	0	100
P002	Dry Wing	1	None	None	-	-	-	-	-	-5	100
P003	Dry Wing	1	None	None	-	-	-	-	-	-10	100
P004	Dry Wing	1	None	None	-	-	-	-	-	-25	100
P005	Type IV Fluid Val.	1	IP-	AD-49	25	-	-	-	50	-5	100
P006	Type IV Fluid Val.	1	IP-	Max-Flight	25	-	-	-	50	-5	100
P007	Type IV Fluid Val.	1	IP Mod	AD-49	75	-	-	-	25	-5	100
P008	Type IV Fluid Val.	1	IP Mod	Max-Flight	75	-	-	-	25	-5	100
P009	Type IV Fluid Val.	1	IP- / ZR-	AD-49	25	-	25	-	25	-5	100
P010	Type IV Fluid Val.	1	IP- / ZR-	Max-Flight	25	-	25	-	25	-5	100
P011	Type IV Fluid Val.	1	IP- / SN-	AD-49	25	10	-	-	25	-5	100
P012	Type IV Fluid Val.	1	IP- / SN-	Max-Flight	25	10	-	-	25	-5	100
P013	Type IV Fluid Val.	1	IP- / SN	AD-49	25	25	-	-	10	-5	100
P014	Type IV Fluid Val.	1	IP- / SN	Max-Flight	25	25	-	-	10	-5	100
P015	Type IV Fluid Val.	1	IP-	AD-49	25	-	-	-	30	-10	100
P016	Type IV Fluid Val.	1	IP-	Max-Flight	25	-	-	-	30	-10	100
P017	Type IV Fluid Val.	1	IP Mod	AD-49	75	-	-	-	10	-10	100
P018	Type IV Fluid Val.	1	IP Mod	Max-Flight	75	-	-	-	10	-10	100
P019	Type IV Fluid Val.	1	IP- / ZR-	AD-49	25	-	25	-	10	-10	100
P020	Type IV Fluid Val.	1	IP- / ZR-	Max-Flight	25	-	25	-	10	-10	100
P021	Type IV Fluid Val.	1	IP- / SN-	AD-49	25	10	-	-	15	-10	100
P022	Type IV Fluid Val.	1	IP- / SN-	Max-Flight	25	10	-	-	15	-10	100
P023	Type IV Fluid Val.	1	IP-	AD-49	25	-	-	-	30	-25	100
P024	Type IV Fluid Val.	1	IP-	Max-Flight	25	-	-	-	30	-25	100
P025	Type IV Fluid Val.	1	IP Mod	AD-49	75	-	-	-	10	-25	100
P026	Type IV Fluid Val.	1	IP Mod	Max-Flight	75	-	-	-	10	-25	100
P027	115 Knots Val.	1	IP-	ABC-S+	25	-	-	-	50	-5	115
P028	115 Knots Val.	1	IP-	Launch	25	-	-	-	50	-5	115
P029	115 Knots Val.	1	IP Mod	ABC-S+	75	-	-	-	25	-5	115
P030	115 Knots Val.	1	IP Mod	Launch	75	-	-	-	25	-5	115
P031	115 Knots Val.	2	IP-	ABC-S+	25	-	-	-	50	-5	100
P032	115 Knots Val.	2	IP-	Launch	25	-	-	-	50	-5	100
P033	115 Knots Val.	2	IP Mod	ABC-S+	75	-	-	-	25	-5	100
P034	115 Knots Val.	2	IP Mod	Launch	75	-	-	-	25	-5	100
P035	Extrapolation Val.	2	IP-	ABC-S+	25	-	-	-	50	-5	70
P036	Extrapolation Val.	2	IP-	Launch	25	-	-	-	50	-5	70
P037	Extrapolation Val.	1	IP Mod	ABC-S+	75	-	-	-	25	-5	70
P038	Extrapolation Val.	1	IP Mod	Launch	75	-	-	-	25	-5	70
P039	Extrapolation Val.	2	IP-	ABC-S+	25	-	-	-	50	-5	80
P040	Extrapolation Val.	2	IP-	Launch	25	-	-	-	50	-5	80
P041	Extrapolation Val.	1	IP Mod	ABC-S+	75	-	-	-	25	-5	80
P042	Extrapolation Val.	1	IP Mod	Launch	75	-	-	-	25	-5	80
P043	Extrapolation Val.	2	IP-	ABC-S+	25	-	-	-	50	-5	90
P044	Extrapolation Val.	2	IP-	Launch	25	-	-	-	50	-5	90
P045	Extrapolation Val.	1	IP Mod	ABC-S+	75	-	-	-	25	-5	90
P046	Extrapolation Val.	1	IP Mod	Launch	75	-	-	-	25	-5	90
P047	Extrapolation Val.	2	IP-	ABC-S+	25	-	-	-	50	-5	100
P048	Extrapolation Val.	2	IP-	Launch	25	-	-	-	50	-5	100
P049	Extrapolation Val.	1	IP Mod	ABC-S+	75	-	-	-	25	-5	100
P050	Extrapolation Val.	1	IP Mod	Launch	75	-	-	-	25	-5	100
P051	Baseline (BLDT)	1	None	EG 106	-	-	-	-	-	0	100
P052	Baseline (BLDT)	1	None	ABC-S+	-	-	-	-	-	0	100
P053	Baseline (BLDT)	1	None	Launch	-	-	-	-	-	0	100
P054	Baseline (BLDT)	1	None	AD-49	-	-	-	-	-	0	100
P055	Baseline (BLDT)	1	None	Max-Flight	-	-	-	-	-	0	100
P056	Baseline (BLDT)	1	None	2031	-	-	-	-	-	0	100
P057	Baseline (BLDT)	1	None	EG 106	-	-	-	-	-	-10	100
P058	Baseline (BLDT)	1	None	ABC-S+	-	-	-	-	-	-10	100
P059	Baseline (BLDT)	1	None	Launch	-	-	-	-	-	-10	100
P060	Baseline (BLDT)	1	None	AD-49	-	-	-	-	-	-10	100
P061	Baseline (BLDT)	1	None	Max-Flight	-	-	-	-	-	-10	100
P062	Baseline (BLDT)	1	None	2031	-	-	-	-	-	-10	100
P063	Baseline (BLDT)	2	None	EG 106	-	-	-	-	-	-15	100
P064	Baseline (BLDT)	2	None	ABC-S+	-	-	-	-	-	-15	100
P065	Baseline (BLDT)	2	None	Launch	-	-	-	-	-	-15	100

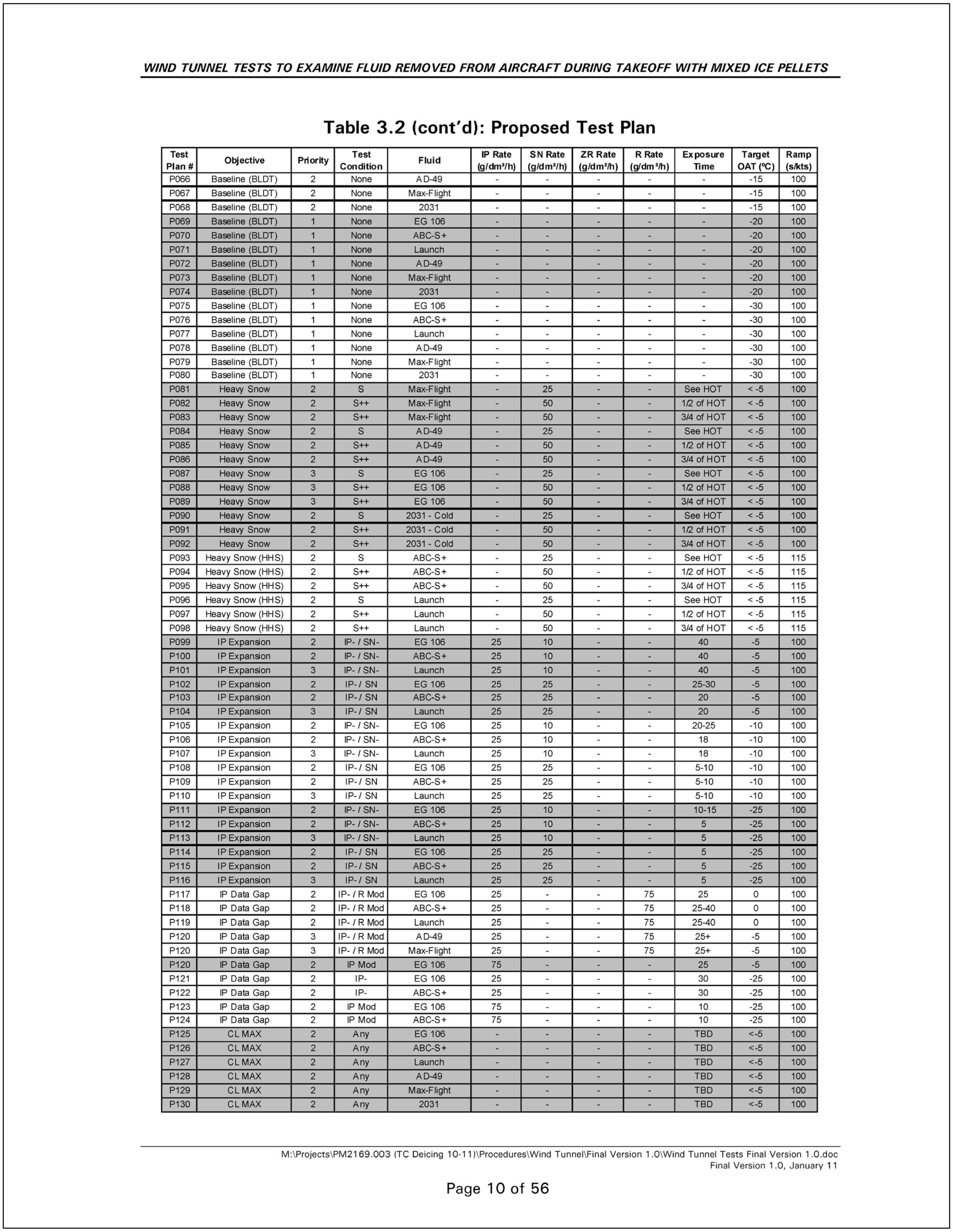


Table 3.2 (cont'd): Proposed Test Plan

Test Plan #	Objective	Priority	Test Condition	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Target OAT (ºC)	Ramp (s/kts)
P066	Baseline (BLDT)	2	None	AD-49	-	-	-	-	-	-15	100
P067	Baseline (BLDT)	2	None	Max-Flight	-	-	-	-	-	-15	100
P068	Baseline (BLDT)	2	None	2031	-	-	-	-	-	-15	100
P069	Baseline (BLDT)	1	None	EG 106	-	-	-	-	-	-20	100
P070	Baseline (BLDT)	1	None	ABC-S+	-	-	-	-	-	-20	100
P071	Baseline (BLDT)	1	None	Launch	-	-	-	-	-	-20	100
P072	Baseline (BLDT)	1	None	AD-49	-	-	-	-	-	-20	100
P073	Baseline (BLDT)	1	None	Max-Flight	-	-	-	-	-	-20	100
P074	Baseline (BLDT)	1	None	2031	-	-	-	-	-	-20	100
P075	Baseline (BLDT)	1	None	EG 106	-	-	-	-	-	-30	100
P076	Baseline (BLDT)	1	None	ABC-S+	-	-	-	-	-	-30	100
P077	Baseline (BLDT)	1	None	Launch	-	-	-	-	-	-30	100
P078	Baseline (BLDT)	1	None	AD-49	-	-	-	-	-	-30	100
P079	Baseline (BLDT)	1	None	Max-Flight	-	-	-	-	-	-30	100
P080	Baseline (BLDT)	1	None	2031	-	-	-	-	-	-30	100
P081	Heavy Snow	2	S	Max-Flight	-	25	-	-	See HOT	< -5	100
P082	Heavy Snow	2	S++	Max-Flight	-	50	-	-	1/2 of HOT	< -5	100
P083	Heavy Snow	2	S++	Max-Flight	-	50	-	-	3/4 of HOT	< -5	100
P084	Heavy Snow	2	S	AD-49	-	25	-	-	See HOT	< -5	100
P085	Heavy Snow	2	S++	AD-49	-	50	-	-	1/2 of HOT	< -5	100
P086	Heavy Snow	2	S++	AD-49	-	50	-	-	3/4 of HOT	< -5	100
P087	Heavy Snow	3	S	EG 106	-	25	-	-	See HOT	< -5	100
P088	Heavy Snow	3	S++	EG 106	-	50	-	-	1/2 of HOT	< -5	100
P089	Heavy Snow	3	S++	EG 106	-	50	-	-	3/4 of HOT	< -5	100
P090	Heavy Snow	2	S	2031 - Cold	-	25	-	-	See HOT	< -5	100
P091	Heavy Snow	2	S++	2031 - Cold	-	50	-	-	1/2 of HOT	< -5	100
P092	Heavy Snow	2	S++	2031 - Cold	-	50	-	-	3/4 of HOT	< -5	100
P093	Heavy Snow (HHS)	2	S	ABC-S+	-	25	-	-	See HOT	< -5	115
P094	Heavy Snow (HHS)	2	S++	ABC-S+	-	50	-	-	1/2 of HOT	< -5	115
P095	Heavy Snow (HHS)	2	S++	ABC-S+	-	50	-	-	3/4 of HOT	< -5	115
P096	Heavy Snow (HHS)	2	S	Launch	-	25	-	-	See HOT	< -5	115
P097	Heavy Snow (HHS)	2	S++	Launch	-	50	-	-	1/2 of HOT	< -5	115
P098	Heavy Snow (HHS)	2	S++	Launch	-	50	-	-	3/4 of HOT	< -5	115
P099	IP Expansion	2	IP- / SN-	EG 106	25	10	-	-	40	-5	100
P100	IP Expansion	2	IP- / SN-	ABC-S+	25	10	-	-	40	-5	100
P101	IP Expansion	3	IP- / SN-	Launch	25	10	-	-	40	-5	100
P102	IP Expansion	2	IP- / SN	EG 106	25	25	-	-	25-30	-5	100
P103	IP Expansion	2	IP- / SN	ABC-S+	25	25	-	-	20	-5	100
P104	IP Expansion	3	IP- / SN	Launch	25	25	-	-	20	-5	100
P105	IP Expansion	2	IP- / SN-	EG 106	25	10	-	-	20-25	-10	100
P106	IP Expansion	2	IP- / SN-	ABC-S+	25	10	-	-	18	-10	100
P107	IP Expansion	3	IP- / SN-	Launch	25	10	-	-	18	-10	100
P108	IP Expansion	2	IP- / SN	EG 106	25	25	-	-	5-10	-10	100
P109	IP Expansion	2	IP- / SN	ABC-S+	25	25	-	-	5-10	-10	100
P110	IP Expansion	3	IP- / SN	Launch	25	25	-	-	5-10	-10	100
P111	IP Expansion	2	IP- / SN-	EG 106	25	10	-	-	10-15	-25	100
P112	IP Expansion	2	IP- / SN-	ABC-S+	25	10	-	-	5	-25	100
P113	IP Expansion	3	IP- / SN-	Launch	25	10	-	-	5	-25	100
P114	IP Expansion	2	IP- / SN	EG 106	25	25	-	-	5	-25	100
P115	IP Expansion	2	IP- / SN	ABC-S+	25	25	-	-	5	-25	100
P116	IP Expansion	3	IP- / SN	Launch	25	25	-	-	5	-25	100
P117	IP Data Gap	2	IP- / R Mod	EG 106	25	-	-	75	25	0	100
P118	IP Data Gap	2	IP- / R Mod	ABC-S+	25	-	-	75	25-40	0	100
P119	IP Data Gap	2	IP- / R Mod	Launch	25	-	-	75	25-40	0	100
P120	IP Data Gap	3	IP- / R Mod	AD-49	25	-	-	75	25+	-5	100
P120	IP Data Gap	3	IP- / R Mod	Max-Flight	25	-	-	75	25+	-5	100
P120	IP Data Gap	2	IP Mod	EG 106	75	-	-	-	25	-5	100
P121	IP Data Gap	2	IP-	EG 106	25	-	-	-	30	-25	100
P122	IP Data Gap	2	IP-	ABC-S+	25	-	-	-	30	-25	100
P123	IP Data Gap	2	IP Mod	EG 106	75	-	-	-	10	-25	100
P124	IP Data Gap	2	IP Mod	ABC-S+	75	-	-	-	10	-25	100
P125	CL MAX	2	Any	EG 106	-	-	-	-	TBD	<-5	100
P126	CL MAX	2	Any	ABC-S+	-	-	-	-	TBD	<-5	100
P127	CL MAX	2	Any	Launch	-	-	-	-	TBD	<-5	100
P128	CL MAX	2	Any	AD-49	-	-	-	-	TBD	<-5	100
P129	CL MAX	2	Any	Max-Flight	-	-	-	-	TBD	<-5	100
P130	CL MAX	2	Any	2031	-	-	-	-	TBD	<-5	100

Table 3.2 (cont'd): Proposed Test Plan

Test Plan #	Objective	Priority	Test Condition	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time	Target OAT (ºC)	Ramp (s/kts)
P131	Industry Request	2	TBD	TBD	-	-	-	-	-	TBD	100
P132	Type III HS (HOT)	3	IP-	2031 - Hot	25	-	-	-	10	-5	100
P133	Type III HS (HOT)	3	IP Mod	2031 - Hot	75	-	-	-	5	-5	100
P134	Type III HS (HOT)	3	IP- / ZR-	2031 - Hot	25	-	25	-	7	-5	100
P135	Type III HS (HOT)	3	IP- / SN-	2031 - Hot	25	10	-	-	10	-5	100
P136	Type III HS (HOT)	3	IP- / SN	2031 - Hot	25	25	-	-	10	-5	100
P137	Type III HS (HOT)	3	IP-	2031 - Hot	25	-	-	-	10	-10	100
P138	Type III HS (HOT)	3	IP Mod	2031 - Hot	75	-	-	-	5	-10	100
P139	Type III HS (HOT)	3	IP- / ZR-	2031 - Hot	25	-	25	-	5	-10	100
P140	Type III HS (HOT)	3	IP- / SN-	2031 - Hot	25	10	-	-	10	-10	100
P141	Type III HS (HOT)	3	IP- / SN	2031 - Hot	25	25	-	-	5	-10	100
P142	Type III HS (HOT)	3	IP-	2031 - Hot	25	-	-	-	10	-25	100
P143	Type III HS (HOT)	3	IP Mod	2031 - Hot	75	-	-	-	5	-25	100
P144	Type III HS (COLD)	3	IP-	2031 - Cold	25	-	-	-	10	-5	100
P145	Type III HS (COLD)	3	IP Mod	2031 - Cold	75	-	-	-	5	-5	100
P146	Type III HS (COLD)	3	IP- / ZR-	2031 - Cold	25	-	25	-	7	-5	100
P147	Type III HS (COLD)	3	IP- / SN-	2031 - Cold	25	10	-	-	10	-5	100
P148	Type III HS (COLD)	3	IP- / SN	2031 - Cold	25	25	-	-	10	-5	100
P149	Type III HS (COLD)	3	IP-	2031 - Cold	25	-	-	-	10	-10	100
P150	Type III HS (COLD)	3	IP Mod	2031 - Cold	75	-	-	-	5	-10	100
P151	Type III HS (COLD)	3	IP- / ZR-	2031 - Cold	25	-	25	-	5	-10	100
P152	Type III HS (COLD)	3	IP- / SN-	2031 - Cold	25	10	-	-	10	-10	100
P153	Type III HS (COLD)	3	IP- / SN	2031 - Cold	25	25	-	-	5	-10	100
P154	Type III HS (COLD)	3	IP-	2031 - Cold	25	-	-	-	10	-25	100
P155	Type III HS (COLD)	3	IP Mod	2031 - Cold	75	-	-	-	5	-25	100
P156	Roughness	4 (was 3)	ZR/IP/SN	Dry	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	-	< -5	100
P157	Wing Geometry	3	None	Type IV	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	See HOT	< -5	100
P158	67 vs 80	3	None	Type IV	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	-	< -5	100
P159	SN w/ No Fluid	3	None	Dry - Cold Wing	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	-	< -5	100
P160	SN w/ No Fluid	3	None	Dry - Warm Wing	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	-	< -5	100
P161	H-Stab Feasability	3	None	Any	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	-	< -5	100
P162	Rain No Fluid	3	R	None	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	-	< -5	100
P163	Ice Phobic	3	ZR	Type IV	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	See HOT	< -5	100
P164	Runway Deicier	3	ZR	Safeway +Any	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	See HOT	< -5	100
P165	V-Stab	4	S++	Type IV	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	See HOT	< -5	100
P166	Frost Spot Deicing	4	Frost	Any	See Details in Procedure	See Details in Procedure	See Details in Procedure	See Details in Procedure	until Failure	<-5	100
P167	LZR / SN	4	LZR / SN	Type IV	-	25	25	-	See HOT	< -5	100
P168	LS Type IV IP	4	IP-	Type IV	Extra tests in separate log	Extra tests in separate log	Extra tests in separate log	Extra tests in separate log	-	< -5	80
P169	Type II IP	4	All	Type IV	Need T II fluid to conduct tests	Need T II fluid to conduct tests	Need T II fluid to conduct tests	Need T II fluid to conduct tests	-	< -5	100
P170	Type III LS (HOT)	4	IP-	2031 - Hot	25	-	-	-	10	-5	80
P171	Type III LS (HOT)	4	IP Mod	2031 - Hot	75	-	-	-	5	-5	80
P172	Type III LS (HOT)	4	IP- / ZR-	2031 - Hot	25	-	25	-	7	-5	80
P173	Type III LS (HOT)	4	IP- / SN-	2031 - Hot	25	10	-	-	10	-5	80
P174	Type III LS (HOT)	4	IP- / SN	2031 - Hot	25	25	-	-	10	-5	80
P175	Type III LS (HOT)	4	IP-	2031 - Hot	25	-	-	-	10	-10	80
P176	Type III LS (HOT)	4	IP Mod	2031 - Hot	75	-	-	-	5	-10	80
P177	Type III LS (HOT)	4	IP- / ZR-	2031 - Hot	25	-	25	-	5	-10	80
P178	Type III LS (HOT)	4	IP- / SN-	2031 - Hot	25	10	-	-	10	-10	80
P179	Type III LS (HOT)	4	IP- / SN	2031 - Hot	25	25	-	-	5	-10	80
P180	Type III LS (HOT)	4	IP-	2031 - Hot	25	-	-	-	10	-25	80
P181	Type III LS (HOT)	4	IP Mod	2031 - Hot	75	-	-	-	5	-25	80
P182	Type III LS (COLD)	4	IP-	2031 - Cold	25	-	-	-	10	-5	80
P183	Type III LS (COLD)	4	IP Mod	2031 - Cold	75	-	-	-	5	-5	80
P184	Type III LS (COLD)	4	IP- / ZR-	2031 - Cold	25	-	25	-	7	-5	80
P185	Type III LS (COLD)	4	IP- / SN-	2031 - Cold	25	10	-	-	10	-5	80
P186	Type III LS (COLD)	4	IP- / SN	2031 - Cold	25	25	-	-	10	-5	80
P187	Type III LS (COLD)	4	IP-	2031 - Cold	25	-	-	-	10	-10	80
P188	Type III LS (COLD)	4	IP Mod	2031 - Cold	75	-	-	-	5	-10	80
P189	Type III LS (COLD)	4	IP- / ZR-	2031 - Cold	25	-	25	-	5	-10	80
P190	Type III LS (COLD)	4	IP- / SN-	2031 - Cold	25	10	-	-	10	-10	80
P191	Type III LS (COLD)	4	IP- / SN	2031 - Cold	25	25	-	-	5	-10	80
P192	Type III LS (COLD)	4	IP-	2031 - Cold	25	-	-	-	10	-25	80
P193	Type III LS (COLD)	4	IP Mod	2031 - Cold	75	-	-	-	5	-25	80

A rating system has been developed and will be filled out by the onsite experts (Attachment XIV). The overall rating will provide insight into the severity of the conditions observed. A test failure (failure to shed the fluid at time of rotation) shall be determined by the on-site experts based on residual contamination. The first test in each series will closely emulate expected holdover time or allowance time. The second test will effectively double or halve the first time depending on whether failure to clear has occurred. The third test will double or halve the previous time or halve the interval to the previous test depending on the failure history. This decision matrix is shown in Figure 3.1 with a beginning exposure time of 60 minutes.

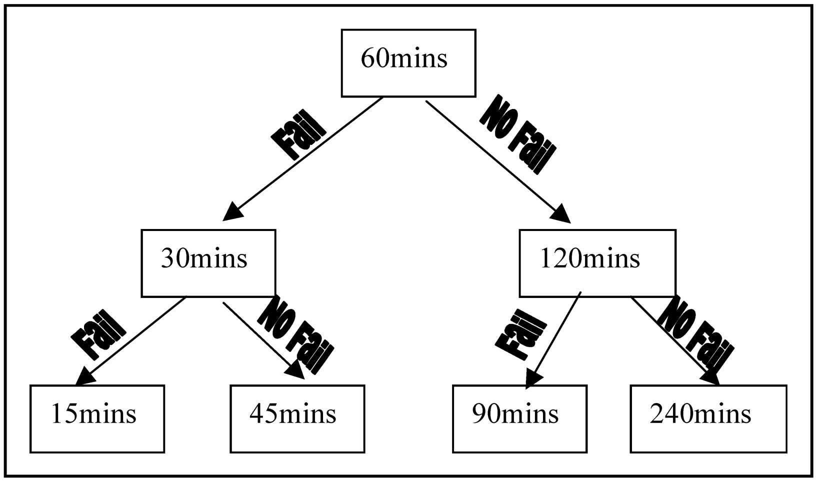


Figure 3.1: Decision Matrix for Each Test Series

4. PRE-TEST SETUP

The following describes the activities to be performed prior to the conduct of any tests:

- Co-ordinate with NRC wind tunnel personnel;
- Co-ordinate with APS photographer;
- Conduct dry photography test of old vs. new camera positioning;
- Document new final camera and flash locations;
- Arrange for hotel accommodations for APS personnel;
- Ensure availability of de/anti-icing fluid (shipped directly to NRC);
- Conduct falling ball tests on received fluids;

- Collect fluid samples for viscosity verification at APS office;
- Arrange personnel travel to Ottawa;
- Ensure proper functioning of ice pellet dispenser equipment;
- Ensure proper functioning of freezing rain sprayer equipment;
- Mark wing data collection locations and draw grid on the wing (refer to Feasibility report for diagrams);
- Prepare and arrange for transport of equipment to Ottawa;
- Co-ordinate fabrication of ice pellets/snow/snow pellets; and
- Arrange for storage of ice pellets/snow/snow pellets.

The task list for setup and testing is included as Attachment VIII.

5. DATA FORMS

The following data forms are required for the January – February 2010 wind tunnel tests:

- Attachment IX – General Form;
- Attachment X – Wing Temperature, Fluid Thickness and Fluid Brix Form;
- Attachment XI & XII – Ice Pellet and Snow Dispensing Forms;
- Attachment XIII– Sprayer Calibration Form;
- Attachment XIV – Visual Evaluation Rating Form
- Attachment XV– Condition of Wing and Plate Form; and
- Attachment XVI – Fluid Receipt Form (Generic form used by APS; will be used for this project as appropriate);
- Attachment XVII – Log of Fluid Sample Bottles.

When and how the data forms will be used is described throughout Section 6.

6. PROCEDURE

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

6.1 Initial Test Conditions Survey

- Record ambient conditions of the test (Attachment IX); and
- Record wing temperature (Attachment X).

6.2 Fluid Application (Pour)

- Hand pour 20L of anti-icing fluid over the test area (fluid can be poured directly out of pales or transferred into smaller 3L jugs);
- Record fluid application times (Attachment IX);
- Record fluid application quantities (Attachment IX);
- Let fluid settle for 5 minutes (as the wing section is relatively flat, last winter it required tilting the wing for 1-minute to enable fluid to be uniform);
- Measure fluid thickness at pre-determined locations on the wing (Attachment X);
- Record wing temperature (Attachment X).
- Measure fluid Brix value (Attachment X); and
- Photograph and videotape the appearance of the fluid on the wing;

Note: At the request of TC/FAA, a standard aluminum test plate will be positioned on the wing in order to run a simultaneous endurance time test.

6.3 Application of Contamination

6.3.1 Ice Pellet/Snow Dispenser Calibration and Set-Up

Calibration work was performed during the winter of 2007-08 on the modified ice pellet/snow dispensers prior to testing with the Falcon 20. The purpose of this calibration work was to attain the dispenser's distribution footprint for both ice pellets and snow. A series of tests were performed in various conditions:

1. Ice Pellets, Low Winds (0 to 5 km/h);
2. Ice Pellets, Moderate Winds (10 km/h);
3. Snow, Low Wind (0 to 5 km/h); and
4. Snow, Moderate Wind (10 km/h).

These tests were conducted using 121 collection pans, each measuring 6 x 6 inches, over an area 11 x 11 feet. Pre-measured amounts of ice pellets/snow were dispersed over this area and the amount collected by each pan was recorded. A distribution footprint of the dispenser was attained and efficiency for the dispenser was computed.

6.3.2 Dispensing Ice Pellets/Snow for Wind Tunnel Tests

Using the results from these calibration tests, a decision was made to use two dispensers on each of the leading and trailing edges of wing; each of the four dispensers are moved to four different positions along each edge during the dispensing process. Attachments XIII and XIV display the data sheets that will be used during testing in the wind tunnel. These data sheets will provide all the necessary information related to the amount of ice pellets/snow needed, effective rates and dispenser positions. During the winter of 2009-10, snow was also dispensed manually using sieves. This technique was used when higher rates of precipitation were required (for heavy snow) or when winds in the tunnel made dispensing difficult. The efficiency of this technique was estimated at 90% and a form to be used for this dispensing process along with dispensing instructions is included in Attachment XV.

Note: Dispensing forms should be filled out and saved for each run and included and pertinent information shall be included in the general form (Attachment XI). Any comments regarding dispensing activities should be documented directly on the form.

6.3.3 Application of Freezing Rain/Drizzle

- Ensure correct rate of precipitation is being generated by NRC freezing precipitation sprayer (see Attachment XVI);
- Record rate of precipitation dispersed (Attachment XI);
- Record application times (Attachment XI); and
- Photograph and videotape the appearance of the fluid on the wing.

6.4 Prior to Engines-On Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment XII);
- Measure fluid Brix value (Attachment XII);
- Record wing temperatures (Attachment XII);
- Record start time of test (Attachment XI); and
- Fill out visual evaluation rating form (Attachment XVII).

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

6.5 During Wind Tunnel Test:

- Take still pictures/videotape the behavior of the fluid on the wing during the takeoff run, capturing any movement of fluid/contamination;
- Fill out visual evaluation rating form at the time of rotation (Attachment XVII); and
- Record wind tunnel operation start and stop times.

6.6 After the Wind Tunnel Test:

- Measure fluid thickness at the pre-determined locations on the wing (Attachment XII);
- Measure fluid Brix value (Attachment XII);
- Record wing temperatures (Attachment XII);
- Observe and record the status of the fluid/contamination (Attachment XII);
- Fill out visual evaluation rating form (Attachment XVII);
- Obtain lift data (excel file) from NRC; and
- Update APS test log with pertinent information.

6.7 Fluid Sample Collection for Viscosity Testing

Two litres of each fluid to be tested are to be collected on the first day of testing. The fluid receipt form (Attachment XVIII) should be completed indicating quantity of fluid and date received. Any samples extracted for viscosity purposes should be documented in the log of fluid samples data form (Attachment XIX). A falling ball viscosity test should be performed on site to confirm that fluid viscosity is appropriate before testing.

6.8 At the End of Each Test Session

If required, APS personnel will collect the waste solution. At the end of the testing period, the services of Safety-Kleen (or other glycol recovery service) will be employed to safely dispose of the waste glycol fluid.

6.9 Camera Setup

It is anticipated that the camera setup will be similar to the setup used during the winter of 2008-09. Modifications may be necessary to account for the different airfoil. The flashes will be positioned on the control-room side of the tunnel, and the cameras will be positioned on the opposite side. The final positioning of the cameras and flashes should be documented to identify any deviation from the previous year's setup.

6.10 Demonstration of a Typical Wind Tunnel Test Sequence

Table 6.1 demonstrates a typical Wind Tunnel test sequence of activities, assuming the test starts at 08:00:00. Figure 6.1 demonstrates a typical wind tunnel run timeline.

Table 6.1: Typical Wind Tunnel Test

TIME	TASK
8:00:00	START OF TEST. ALL EQUIPMENT READY.
8:00:00	- Record test conditions.
8:05:00	- Prepare wing for fluid application (clean wing, etc).
8:15:00	- Measure wing temperature. - Ensure clean wing for fluid application
8:20:00	- Pour fluid over test area.
8:30:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
8:35:00	- Apply contamination over test area. (i.e. 30 min)
9:05:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
9:10:00	- Clear area and start wind tunnel
9:25:00	- Wind tunnel stopped
9:35:00	- Measure Brix, thickness, wing temperature. - Photograph test area. - Record test observations
9:45:00	END OF TEST

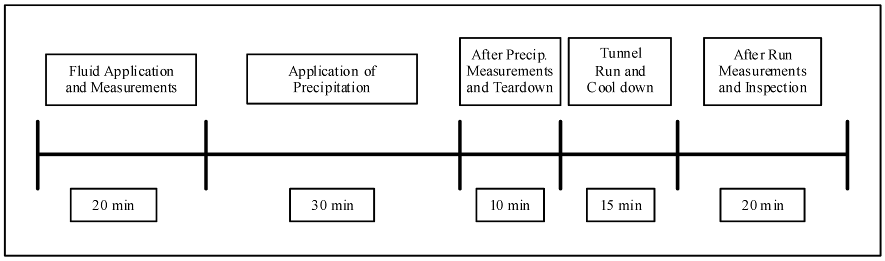


Figure 6.1: Typical Wind Tunnel Run Timeline

6.11 Procedure for Application of Heated Type III Fluid for Wind Tunnel Tests

Testing with Type III fluid will require testing with both fluid at ambient temperature, and heated fluid. A procedure has been developed to describe the heating and application methods for the Type III heated tests and is included in Attachment XX.

6.12 Procedures for R&D Activities

It is anticipated that testing will be conducted to support several research and development (R&D) activities. The objectives of these lower priority activities are as follows:

- Heavily contaminated fluid during heavy snow conditions (Attachment XXI);
- Effect of CL Max on recorded lift losses (Attachment XXII);
- Surface roughness as a result of adhered contamination (Attachment XXIII);
- Effect of wing geometry on fluid failure and aerodynamic performance (Attachment XXIV);
- Low speed testing for Aero Certification Test: 67 vs. 80 knots (Attachment XXV);
- Snow on an Un-Protected Wing (Attachment XXVI);;
- Feasibility of conducting horizontal stabilizer testing (Attachment XXVII);
- Rain on an un-protected wing (Attachment XXVIII);
- Effect of ice phobic coatings on contaminated airfoil aerodynamic performance (Attachment XXIX);
- Degraded Anti-icing Fluid Performance Following Contamination with Runway Deicing Fluid (Attachment XXX);
- Heavily contaminated vertical stabilizer (Attachment XXXI);
- Frost CSW Spot Deicing (Attachment XXXII);
- Light Freezing Rain and Snow (Attachment XXXIII);
- Ice pellet allowance times for low speed aircraft using Type IV fluid (Attachment XXXIIV); and
- Ice pellet allowance times for Type II fluid (Attachment XXXV).

As these full-scale R&D activities have in general not been previously attempted, brief summaries of the anticipated procedures have been prepared to provide guidance at the time of testing. These procedures are attached to this document as indicated in parentheses above. The procedures are preliminary and may change based on the quality of the results obtained in the wind tunnel.

7. EQUIPMENT

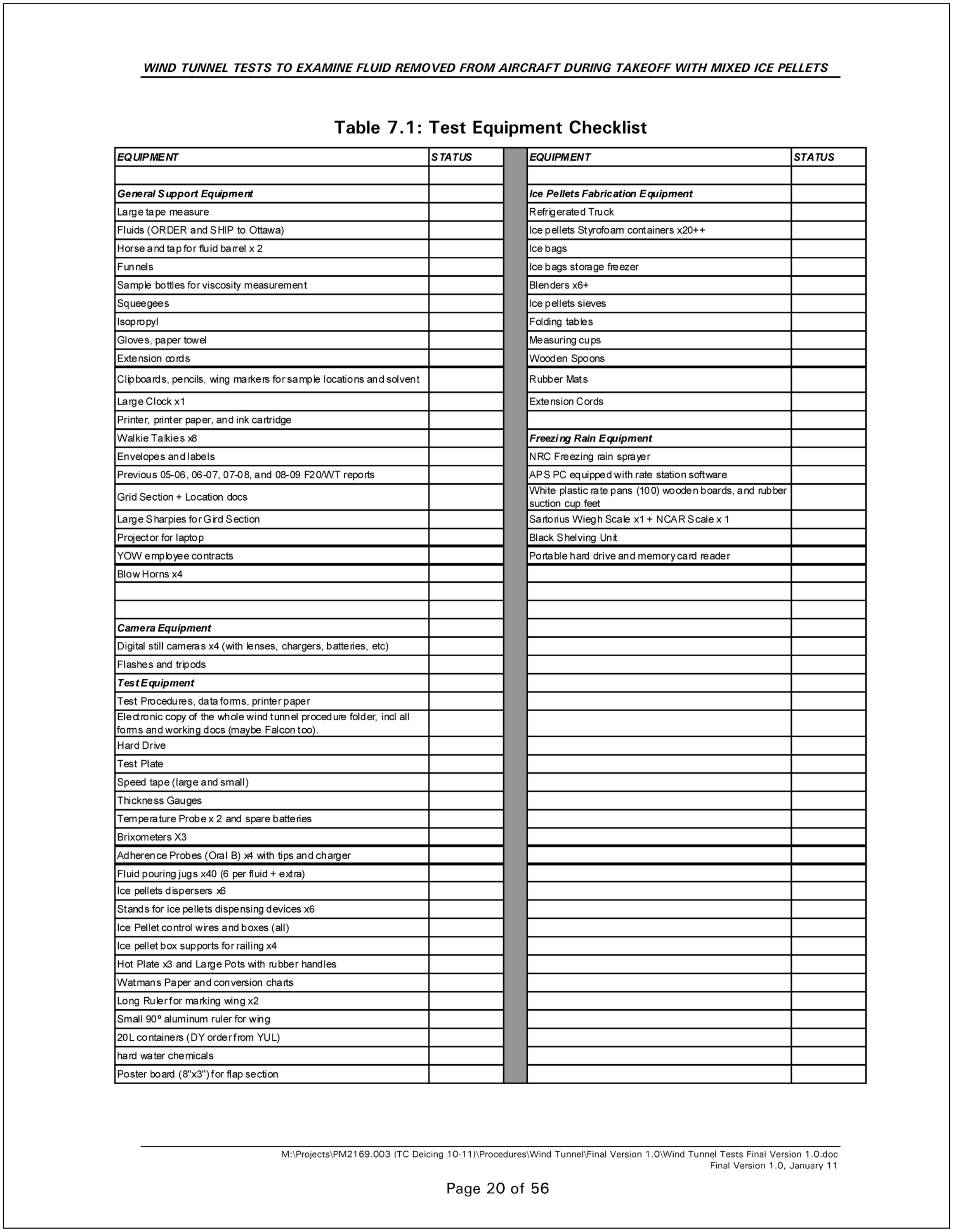
Equipment to be employed is shown in Table 7.1.

8. FLUIDS

Mid-viscosity samples of ethylene glycol and propylene glycol III and IV fluids will be used in the wind tunnel tests. Although the number off tests conducted will be determined based on the results obtained, the fluid quantities available are estimated and are shown in Table 8.1. Fluid application will be performed by pouring the fluid (rather than spraying) to reduce any shearing to the fluid.

Table 8.1: Fluid Available for Wind Tunnel Tests

Fluid Manufacturer	Fluid Name	Type	2010-11 Quantity Leftover From 2009-10 (L)	2010-11 Quantity Ordered (L)
Dow Checmical Company	EG106	IV	400	600
Kilfrost Limited	ABC-S PLUS	IV	-	1000
Clariant Produkte	Launch	IV	475	-
Clariant Produkte	2031	III	-	400
Dow Checmical Company	AD-49	IV	-	600
Octagon Process Inc.	Max-Flight 04	IV	-	600
Octagon Process Inc.	Octaflo EF (Conc.)	I	100	-



WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

Table 7.1: Test Equipment Checklist

EQUIPMENT	*STATUS*	*EQUIPMENT*	*STATUS*
General Support Equipment		***Ice Pellets Fabrication Equipment***	
Large tape measure		Refrigerated Truck	
Fluids (ORDER and SHIP to Ottawa)		Ice pellets Styrofoam containers x20++	
Horse and tap for fluid barrel x 2		Ice bags	
Funnels		Ice bags storage freezer	
Sample bottles for viscosity measurement		Blenders x6+	
Squeegees		Ice pellets sieves	
Isopropyl		Folding tables	
Gloves, paper towel		Measuring cups	
Extension cords		Wooden Spoons	
Clipboards, pencils, wing markers for sample locations and solvent		Rubber Mats	
Large Clock x1		Extension Cords	
Printer, printer paper, and ink cartridge			
Walkie Talkies x8		***Freezing Rain Equipment***	
Envelopes and labels		NRC Freezing rain sprayer	
Previous 05-06, 06-07, 07-08, and 08-09 F20/WT reports		APS PC equipped with rate station software	
Grid Section + Location docs		White plastic rate pans (100) wooden boards, and rubber suction cup feet	
Large Sharpies for Gird Section		Sartorius Wiegh Scale x1 + NCAR Scale x 1	
Projector for laptop		Black Shelving Unit	
YOW employee contracts		Portable hard drive and memory card reader	
Blow Horns x4			
Camera Equipment			
Digital still cameras x4 (with lenses, chargers, batteries, etc)			
Flashes and tripods			
Test Equipment			
Test Procedures, data forms, printer paper			
Electronic copy of the whole wind tunnel procedure folder, incl all forms and working docs (maybe Falcon too).			
Hard Drive			
Test Plate			
Speed tape (large and small)			
Thickness Gauges			
Temperature Probe x 2 and spare batteries			
Brixometers X3			
Adherence Probes (Oral B) x4 with tips and charger			
Fluid pouring jugs x40 (6 per fluid + extra)			
Ice pellets dispersers x6			
Stands for ice pellets dispensing devices x6			
Ice Pellet control wires and boxes (all)			
Ice pellet box supports for railing x4			
Hot Plate x3 and Large Pots with rubber handles			
Watmans Paper and conversion charts			
Long Ruler for marking wing x2			
Small 90º aluminum ruler for wing			
20L containers (DY order from YUL)			
hard water chemicals			
Poster board (8"x3") for flap section			

9. PERSONNEL

Five APS staff members are required for the tests at the NRC wind tunnel. Four additional persons will be required from Ottawa for making and dispensing the ice pellets and snow. One additional person from Ottawa will be required to photograph the testing. Table 9.1 demonstrates the personnel required and their associated tasks.

Fluid and ice pellets applications will be performed by APS/YOW personnel at the NRC wind tunnel. NRC personnel will operate the NRC wind tunnel and operate the freezing rain/drizzle sprayer.

Table 9.1: Personnel List

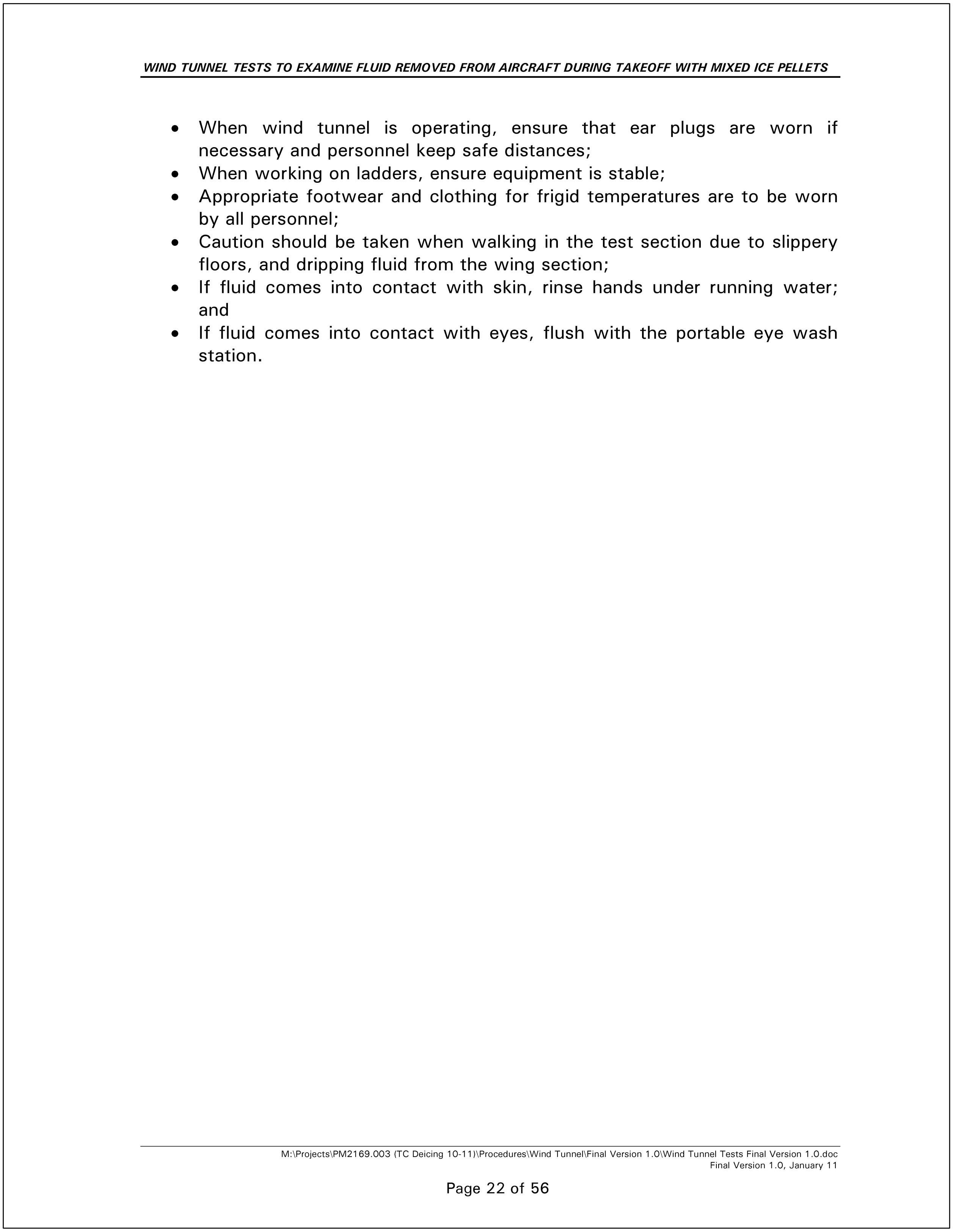
Wind Tunnel 10-11 - Tentative	
Person	**Responsibility**
John	Overall Co-ordinator
Marco	Co-ordinator / General
Victoria	IP Manager / Camera Documentation / Fluid Manager
Michelle	Forms & Data Collection Manager / YOW Pers. Manager
Dave	Data Collection /IP Support / Fluid Application
YOW Personnel	
Ben/Jesse	Photography
James	Fluids / IP / Dispensing
YOW 1	Fluids / IP / Dispensing
YOW 2	Fluids / IP / Dispensing
YOW 3	Fluids / IP / Dispensing

NRC Institute of Aerospace Research

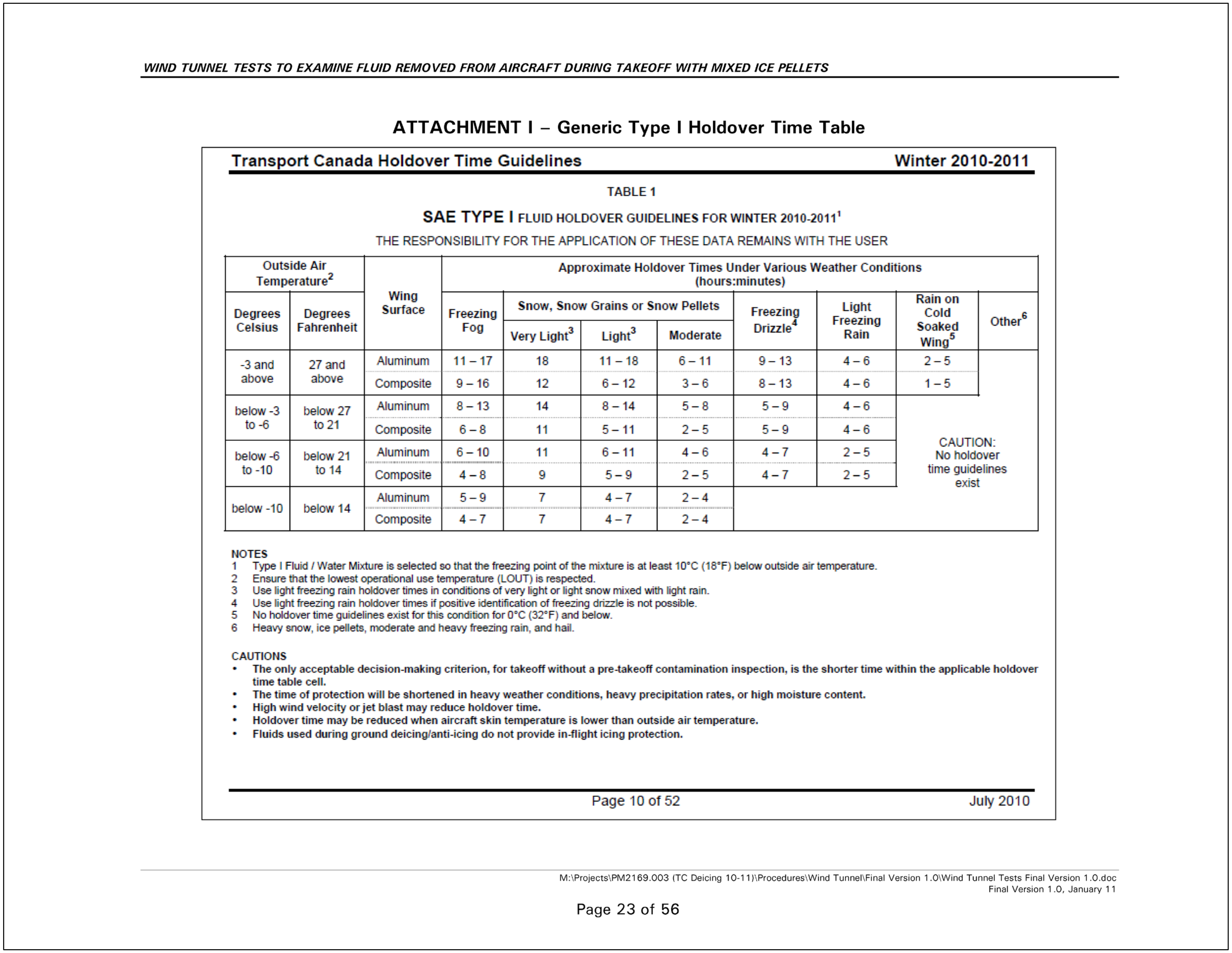
- Eric Perron: (613) 229-2058
- Catherine Clark: (613) 998-6932

10. SAFETY

- A safety briefing will be done on the first day of testing;
- All personnel must be familiar with the Material Safety Data Sheets (MSDS) for fluids;
- Prior to operating the wind tunnel, loose objects should be removed from the vicinity;



- When wind tunnel is operating, ensure that ear plugs are worn if necessary and personnel keep safe distances;
- When working on ladders, ensure equipment is stable;
- Appropriate footwear and clothing for frigid temperatures are to be worn by all personnel;
- Caution should be taken when walking in the test section due to slippery floors, and dripping fluid from the wing section;
- If fluid comes into contact with skin, rinse hands under running water; and
- If fluid comes into contact with eyes, flush with the portable eye wash station.



ATTACHMENT I – Generic Type I Holdover Time Table

TABLE 1

SAE TYPE I FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

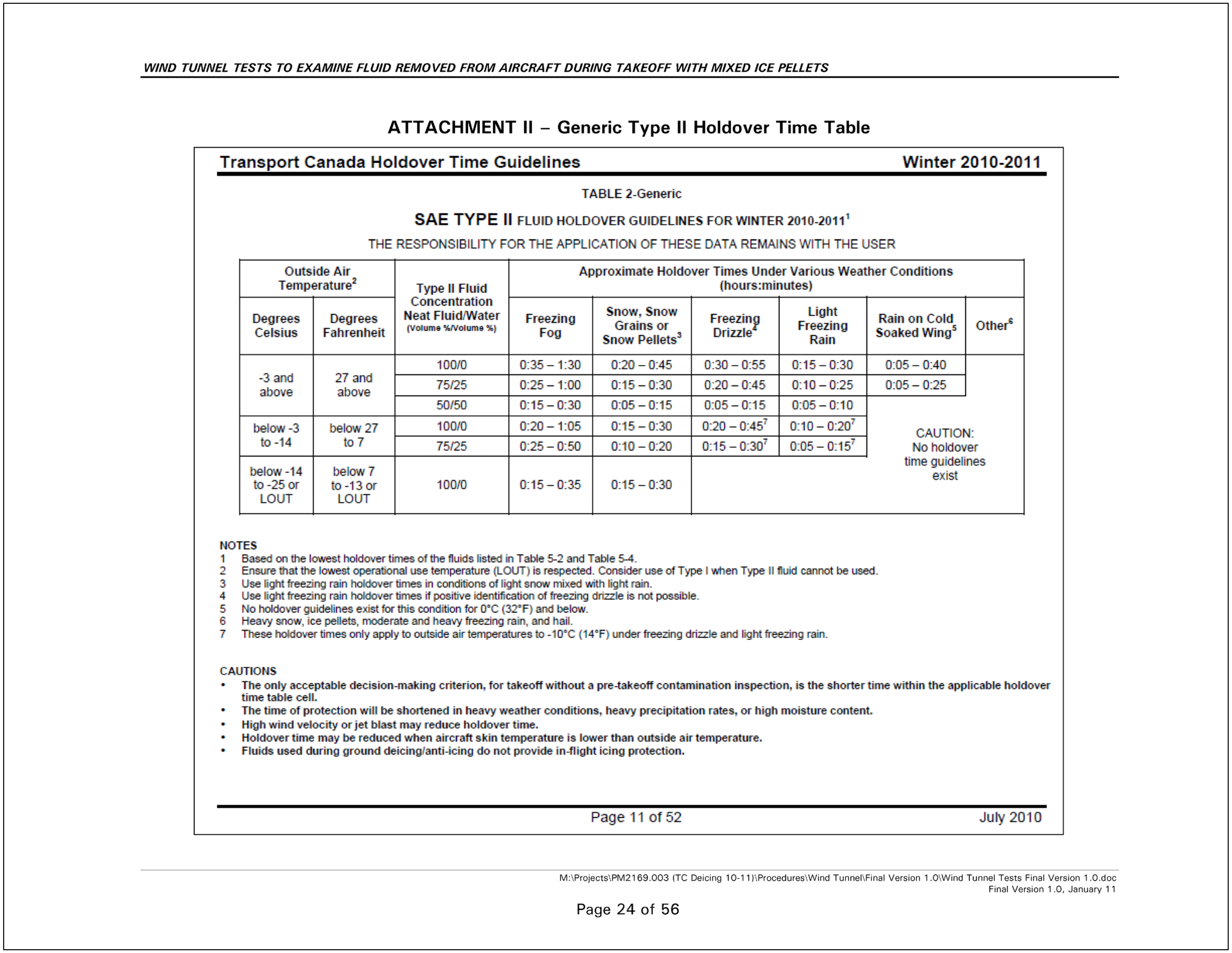
Outside Air Temperature[2]		Wing Surface	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	Aluminum	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
		Composite	9 – 16	12	6 – 12	3 – 6	8 – 13	4 – 6	1 – 5	
below -3 to -6	below 27 to 21	Aluminum	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6		
		Composite	6 – 8	11	5 – 11	2 – 5	5 – 9	4 – 6		
below -6 to -10	below 21 to 14	Aluminum	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
		Composite	4 – 8	9	5 – 9	2 – 5	4 – 7	2 – 5		
below -10	below 14	Aluminum	5 – 9	7	4 – 7	2 – 4				
		Composite	4 – 7	7	4 – 7	2 – 4				

NOTES

1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**



ATTACHMENT II – Generic Type II Holdover Time Table

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 2-Generic

SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	CAUTION: No holdover time guidelines exist
		75/25	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	0:20 – 1:05	0:15 – 0:30	0:20 – 0:45[7]	0:10 – 0:20[7]		
		75/25	0:25 – 0:50	0:10 – 0:20	0:15 – 0:30[7]	0:05 – 0:15[7]		
below -14 to -25 or LOUT	below 7 to -13 or LOUT	100/0	0:15 – 0:35	0:15 – 0:30				

NOTES

1 Based on the lowest holdover times of the fluids listed in Table 5-2 and Table 5-4.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type II fluid cannot be used.
3 Use light freezing rain holdover times in conditions of light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

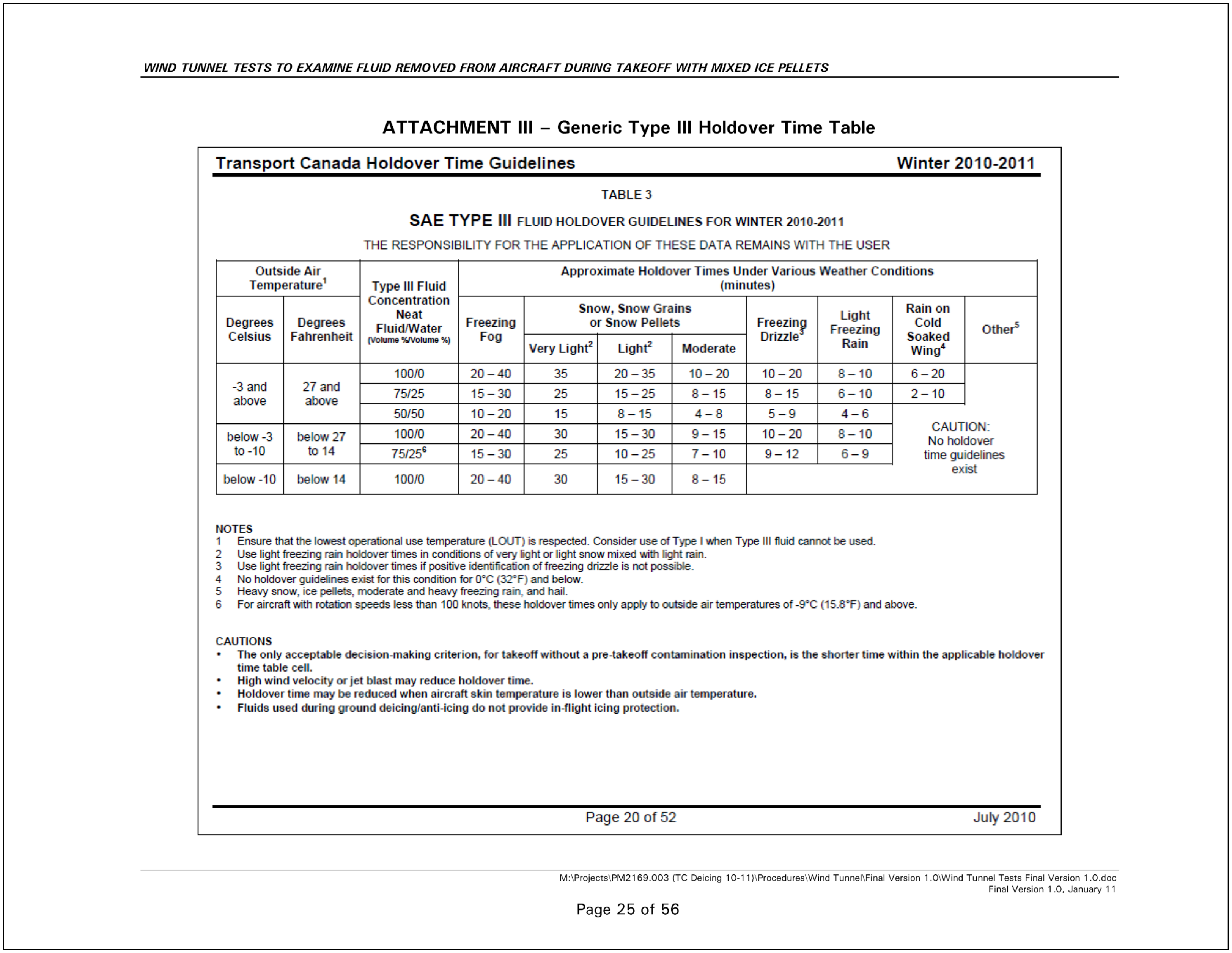
CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 11 of 52 July 2010

M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Tests Final Version 1.0.doc
Final Version 1.0, January 11

Page 24 of 56



WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

ATTACHMENT III – Generic Type III Holdover Time Table

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[1]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets			Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing[4]	Other[5]
				Very Light[2]	Light[2]	Moderate				
-3 and above	27 and above	100/0	20 – 40	35	20 – 35	10 – 20	10 – 20	8 – 10	6 – 20	CAUTION: No holdover time guidelines exist
		75/25	15 – 30	25	15 – 25	8 – 15	8 – 15	6 – 10	2 – 10	
		50/50	10 – 20	15	8 – 15	4 – 8	5 – 9	4 – 6		
below -3 to -10	below 27 to 14	100/0	20 – 40	30	15 – 30	9 – 15	10 – 20	8 – 10		
		75/25[6]	15 – 30	25	10 – 25	7 – 10	9 – 12	6 – 9		
below -10	below 14	100/0	20 – 40	30	15 – 30	8 – 15				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type III fluid cannot be used.
2 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 No holdover guidelines exist for this condition for 0°C (32°F) and below.
5 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
6 For aircraft with rotation speeds less than 100 knots, these holdover times only apply to outside air temperatures of -9°C (15.8°F) and above.

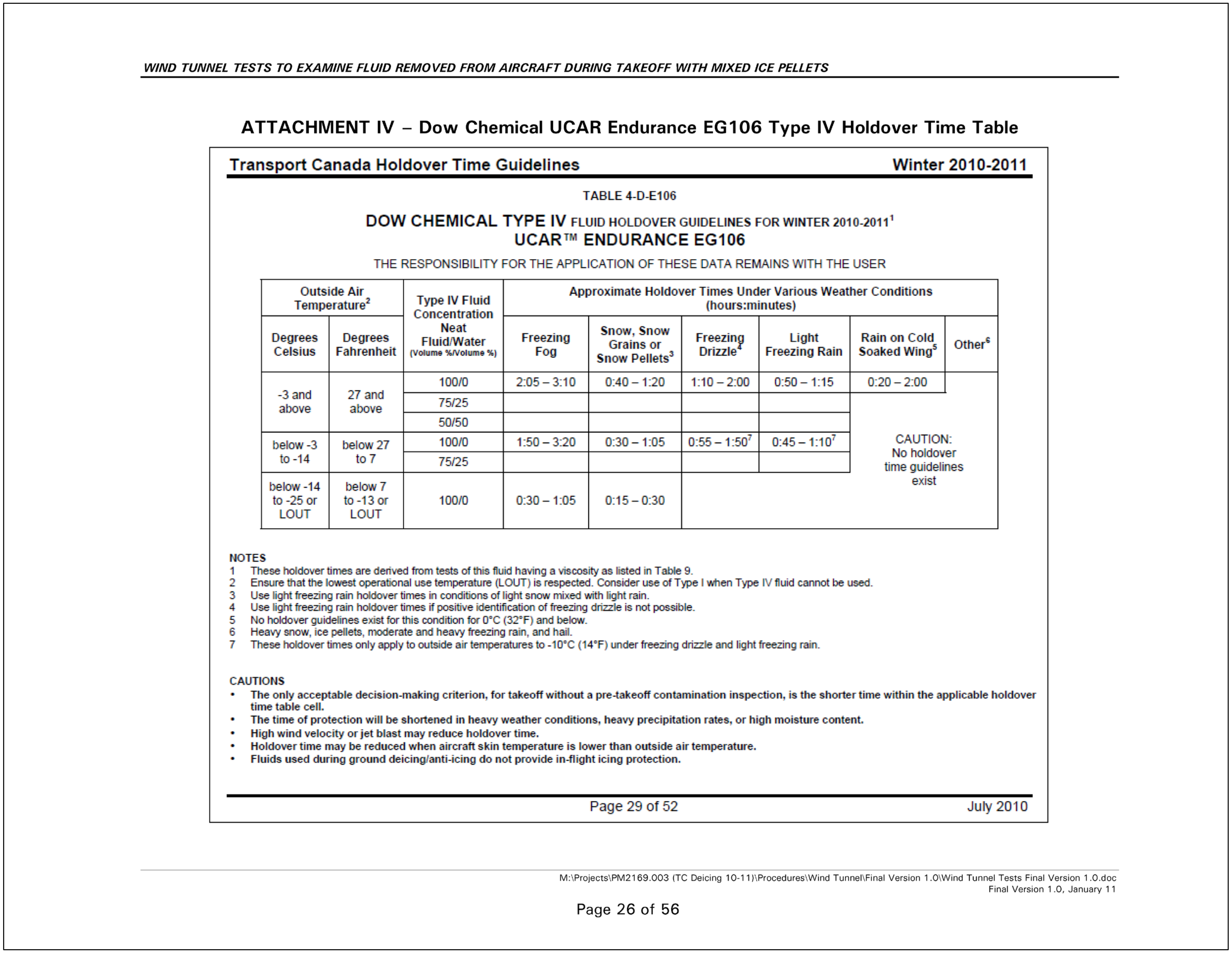
CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 20 of 52 July 2010

M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Tests Final Version 1.0.doc
Final Version 1.0, January 11

Page 25 of 56



ATTACHMENT IV – Dow Chemical UCAR Endurance EG106 Type IV Holdover Time Table

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 4-D-E106

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]
UCAR™ ENDURANCE EG106

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:05 – 3:10	0:40 – 1:20	1:10 – 2:00	0:50 – 1:15	0:20 – 2:00	
		75/25					CAUTION: No holdover time guidelines exist	
		50/50						
below -3 to -14	below 27 to 7	100/0	1:50 – 3:20	0:30 – 1:05	0:55 – 1:50[7]	0:45 – 1:10[7]		
		75/25						
below -14 to -25 or LOUT	below 7 to -13 or LOUT	100/0	0:30 – 1:05	0:15 – 0:30				

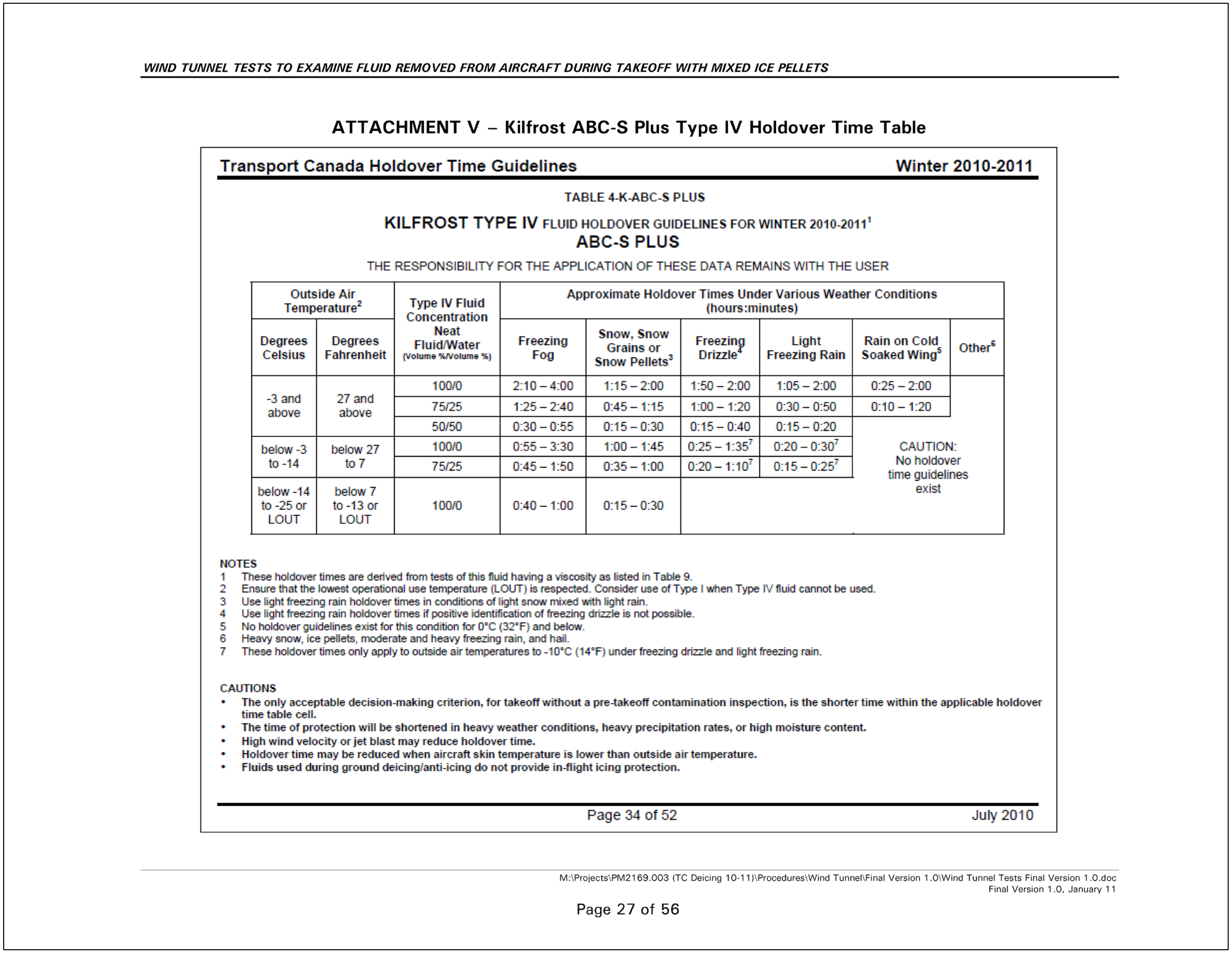
NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 29 of 52 July 2010



ATTACHMENT V – Kilfrost ABC-S Plus Type IV Holdover Time Table

TABLE 4-K-ABC-S PLUS

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]
ABC-S PLUS

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

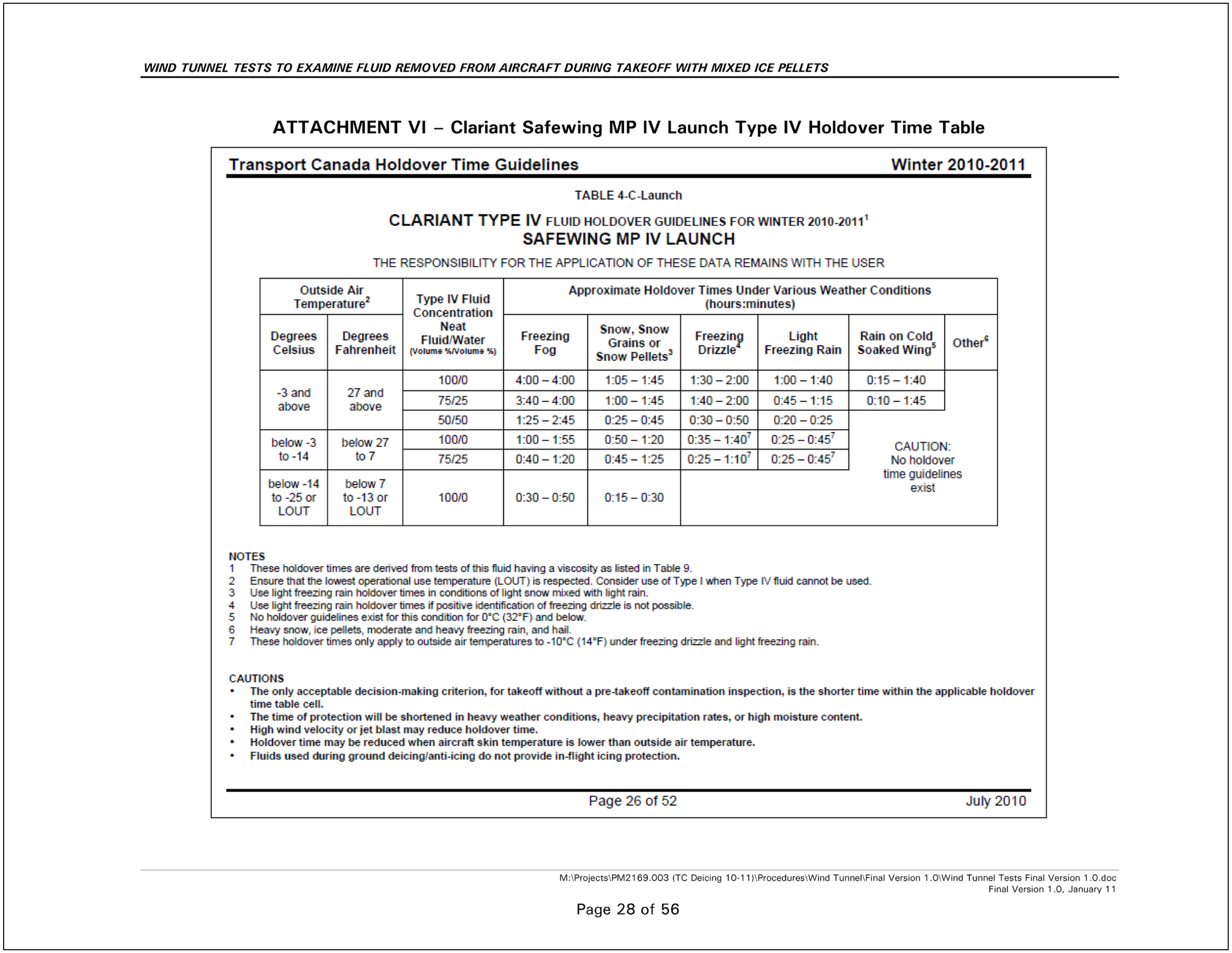
Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:10 – 4:00	1:15 – 2:00	1:50 – 2:00	1:05 – 2:00	0:25 – 2:00	
		75/25	1:25 – 2:40	0:45 – 1:15	1:00 – 1:20	0:30 – 0:50	0:10 – 1:20	
		50/50	0:30 – 0:55	0:15 – 0:30	0:15 – 0:40	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55 – 3:30	1:00 – 1:45	0:25 – 1:35[7]	0:20 – 0:30[7]		
		75/25	0:45 – 1:50	0:35 – 1:00	0:20 – 1:10[7]	0:15 – 0:25[7]		
below -14 to -25 or LOUT	below 7 to -13 or LOUT	100/0	0:40 – 1:00	0:15 – 0:30				

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**



WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

ATTACHMENT VI – Clariant Safewing MP IV Launch Type IV Holdover Time Table

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 4-C-Launch

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]
SAFEWING MP IV LAUNCH

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	4:00 – 4:00	1:05 – 1:45	1:30 – 2:00	1:00 – 1:40	0:15 – 1:40	CAUTION: No holdover time guidelines exist
		75/25	3:40 – 4:00	1:00 – 1:45	1:40 – 2:00	0:45 – 1:15	0:10 – 1:45	
		50/50	1:25 – 2:45	0:25 – 0:45	0:30 – 0:50	0:20 – 0:25		
below -3 to -14	below 27 to 7	100/0	1:00 – 1:55	0:50 – 1:20	0:35 – 1:40[7]	0:25 – 0:45[7]		
		75/25	0:40 – 1:20	0:45 – 1:25	0:25 – 1:10[7]	0:25 – 0:45[7]		
below -14 to -25 or LOUT	below 7 to -13 or LOUT	100/0	0:30 – 0:50	0:15 – 0:30				

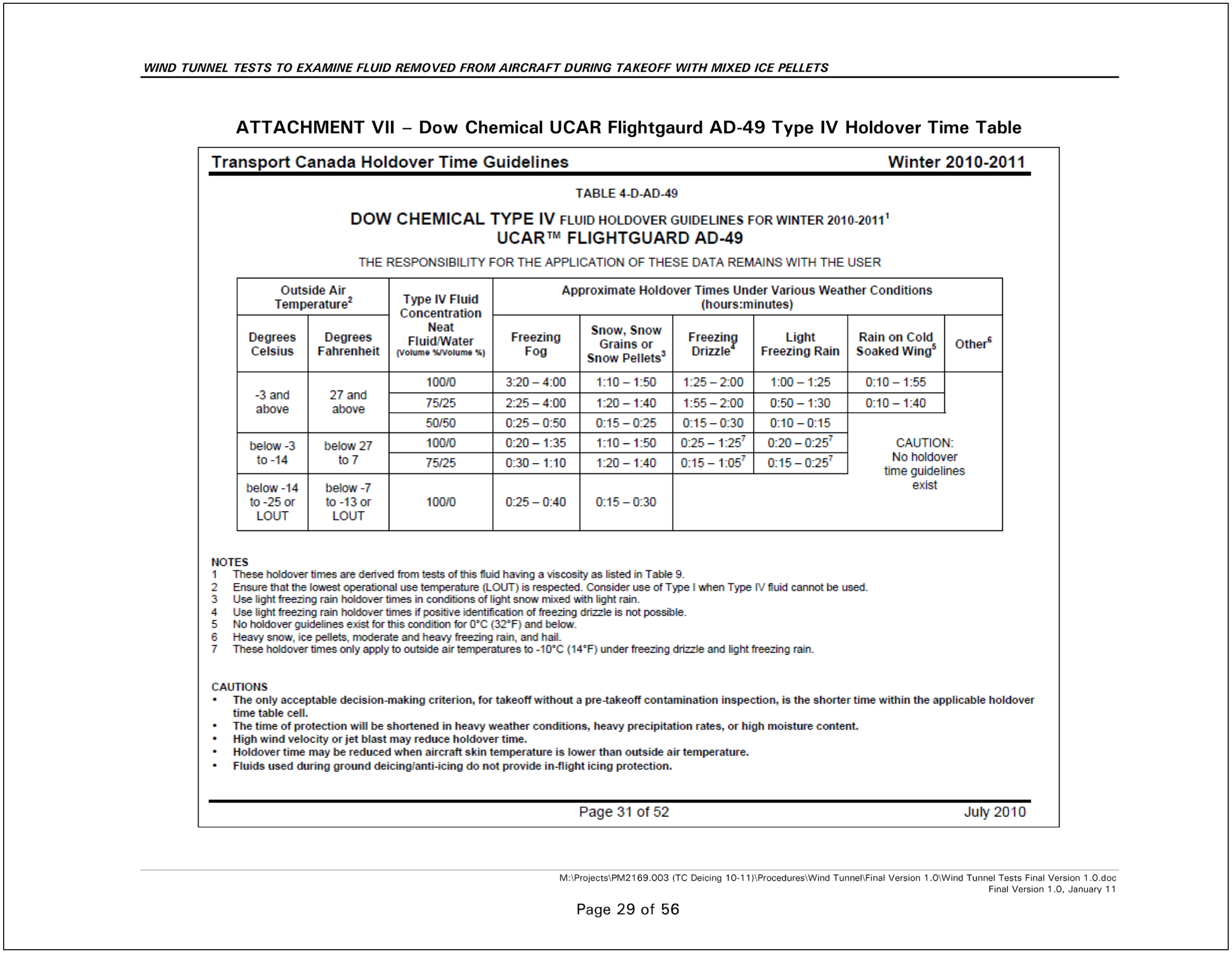
NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 26 of 52 July 2010

M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Tests Final Version 1.0.doc
Final Version 1.0, January 11

Page 28 of 56



WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

ATTACHMENT VII – Dow Chemical UCAR Flightgaurd AD-49 Type IV Holdover Time Table

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 4-D-AD-49

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]
UCAR™ FLIGHTGUARD AD-49

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	3:20 – 4:00	1:10 – 1:50	1:25 – 2:00	1:00 – 1:25	0:10 – 1:55	
		75/25	2:25 – 4:00	1:20 – 1:40	1:55 – 2:00	0:50 – 1:30	0:10 – 1:40	
		50/50	0:25 – 0:50	0:15 – 0:25	0:15 – 0:30	0:10 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20 – 1:35	1:10 – 1:50	0:25 – 1:25[7]	0:20 – 0:25[7]		
		75/25	0:30 – 1:10	1:20 – 1:40	0:15 – 1:05[7]	0:15 – 0:25[7]		
below -14 to -25 or LOUT	below -7 to -13 or LOUT	100/0	0:25 – 0:40	0:15 – 0:30				

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

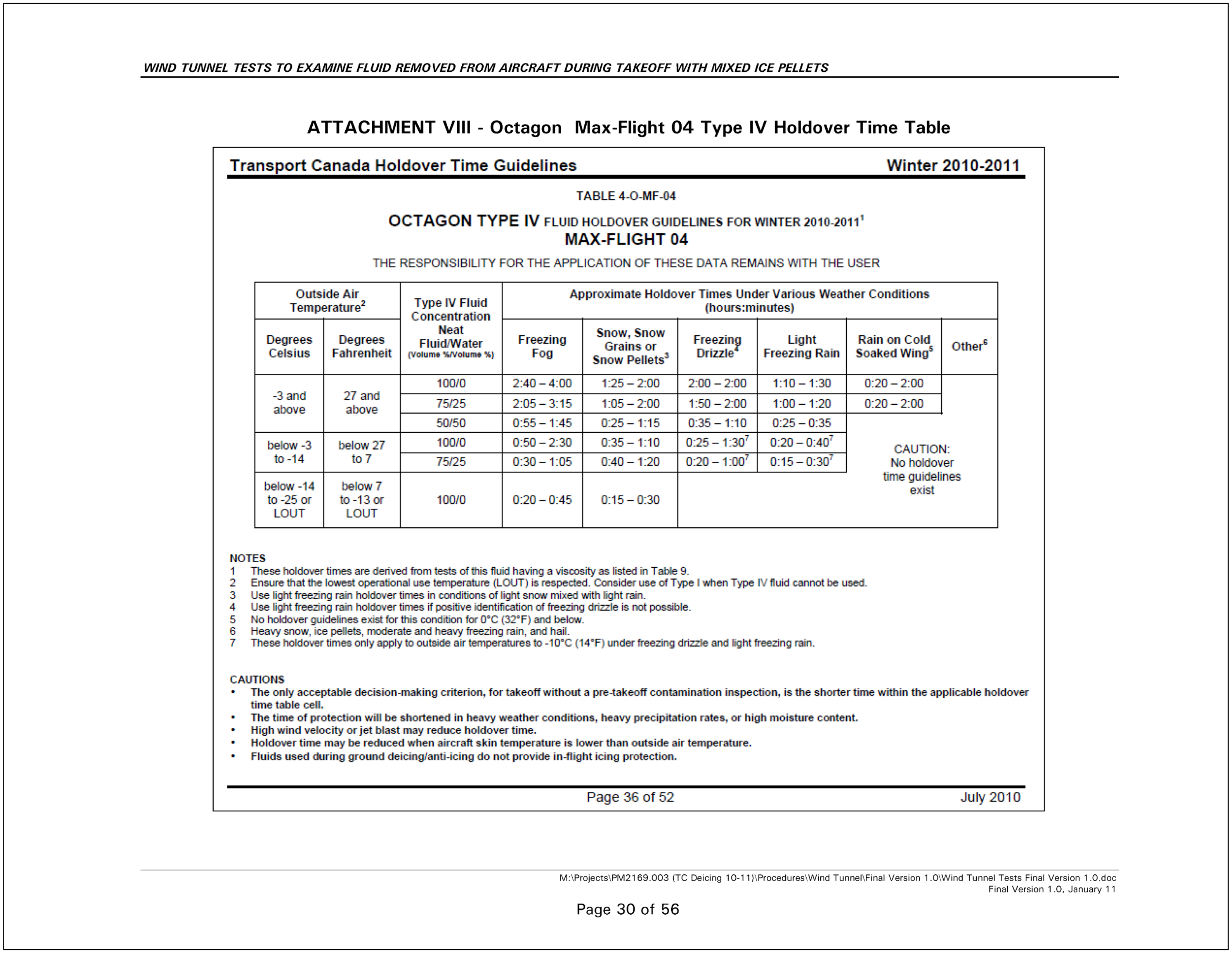
CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 31 of 52 July 2010

M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Tests Final Version 1.0.doc
Final Version 1.0, January 11

Page 29 of 56



ATTACHMENT VIII - Octagon Max-Flight 04 Type IV Holdover Time Table

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 4-O-MF-04

OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]
MAX-FLIGHT 04

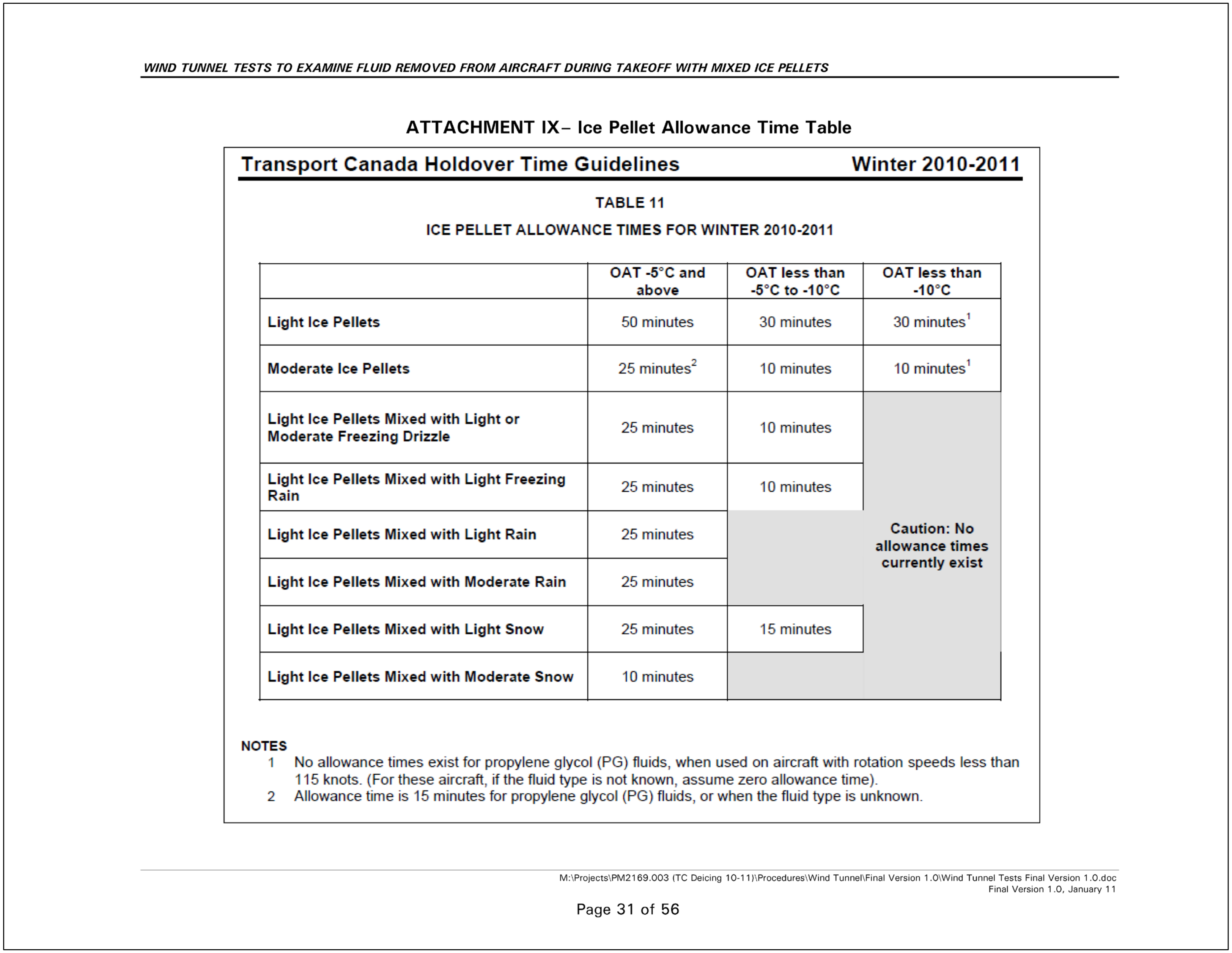
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:40 – 4:00	1:25 – 2:00	2:00 – 2:00	1:10 – 1:30	0:20 – 2:00	
		75/25	2:05 – 3:15	1:05 – 2:00	1:50 – 2:00	1:00 – 1:20	0:20 – 2:00	
		50/50	0:55 – 1:45	0:25 – 1:15	0:35 – 1:10	0:25 – 0:35	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:50 – 2:30	0:35 – 1:10	0:25 – 1:30[7]	0:20 – 0:40[7]		
		75/25	0:30 – 1:05	0:40 – 1:20	0:20 – 1:00[7]	0:15 – 0:30[7]		
below -14 to -25 or LOUT	below 7 to -13 or LOUT	100/0	0:20 – 0:45	0:15 – 0:30				

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 36 of 52 July 2010



ATTACHMENT IX– Ice Pellet Allowance Time Table

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 11

ICE PELLET ALLOWANCE TIMES FOR WINTER 2010-2011

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets	50 minutes	30 minutes	30 minutes[1]
Moderate Ice Pellets	25 minutes[2]	10 minutes	10 minutes[1]
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	**Caution: No allowance times currently exist**
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes	
Light Ice Pellets Mixed with Light Rain	25 minutes		
Light Ice Pellets Mixed with Moderate Rain	25 minutes		
Light Ice Pellets Mixed with Light Snow	25 minutes	15 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes		

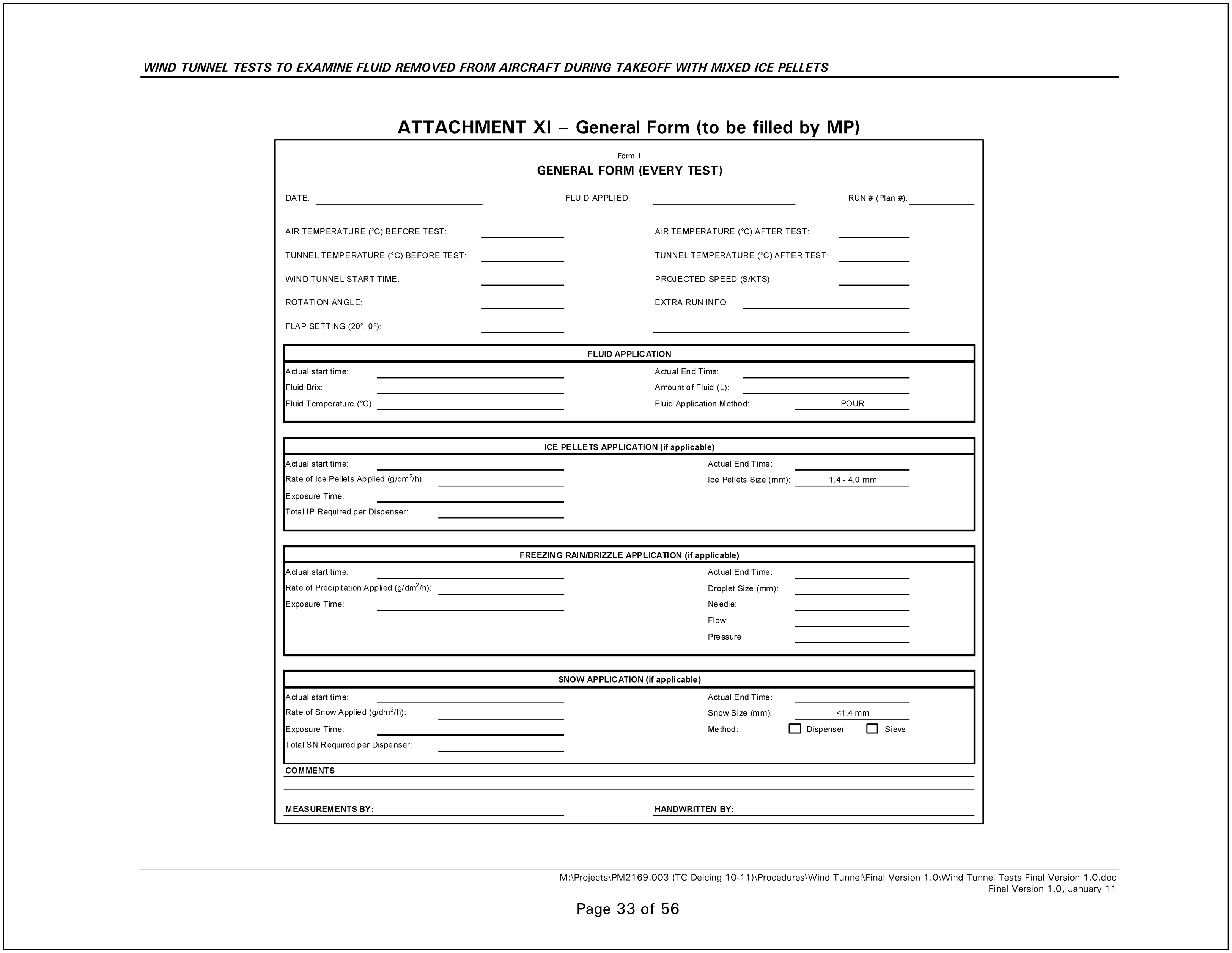
NOTES

1 No allowance times exist for propylene glycol (PG) fluids, when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time).

2 Allowance time is 15 minutes for propylene glycol (PG) fluids, or when the fluid type is unknown.

ATTACHMENT X – Task List for Setup and Actual Tests

No.	Task	Person	Status
	Planning and Preparation		
1	Co-ordinate with NRC wind tunnel personnel	MR/JD	
2	Ensure fluid is received and is stored outdoors	MR/JD	
3	Co-ordinate with APS photographer	MR	
4	Arrange for hotel accommodations for APS personnel	MP	
5	Arrange personnel travel to Ottawa;	MP/VZ	
6	Hire YOW personnel	DY/MP	
7	Complete contract for YOW personnel	MP/YOW	
8	Ensure proper functioning of ice pellet dispenser equipment;	MR/VZ	
9	Ensure availability of freezing rain sprayer equipment;	MR	
10	Prepare and Arrange Office Materials to YOW	MP	
11	Prepare and Arrange Site Equipment to YOW	DY/VZ	
12	Prepare Data forms and procedure	MP	
13	Prepare Test Log (See JD with it)	MP	
14	Finalize and complete list of equipment/materials required	DY/MR	
15	Arrange for freezer storage of ice pellets/snow/snow pellets.	DY	
16	Investigate IP/ZR/SN dispersal techniques and location	VZ/MR	
17	Update IP Rate File	VZ/MR	
18	Check with NRC the status of the testing site, tunnel etc	MR	
19	Check weather prior to establishing test dates	MR	
20	Arrange for pallets to lift up 1000L totes	MR	
21	Purchase new 20 L containers (as necessary)	DY	
	Monday Jan 17		
22	Pack and leave YUL for YOW on Jan 17th	APS	
23	Unload Truck	APS	
24	Organize all Equipment in Lower Level of Wind Tunnel	APS	
25	Verify fluids received		
26	Ice and freezer delivery	DY	
27	Setup general office and testing equipment (time permitting)	APS	
	Tuesday Jan 18		
28	Safety Briefing & Training (APS/YOW)	MR	
29	Setup rate station	DY	
30	Setup Projector	MP	
31	Setup printer	MP	
32	Setup IP/SN manufacturing material	VZ	
33	Test and prepare IP dispensing equipment	VZ	
34	Organize Fluid Outside (labels and fluid receipt forms)	MP/DY/YOW	
35	Transfer Fluids from 1000 L Totes to 20 L containers.	MP/DY/YOW	
36	Verify ZR sprayer installation	MR	
37	Train IP making personnel	VZ/YOW	James will help train others
38	Conduct dry photography test of old vs. new camera positioning;	BG/MR	Jessie
39	Document new final camera and flash locations	VZ/BG	
40	Conduct falling ball tests on received fluids;	MP/DY	
41	Collect fluid samples for viscosity verification at APS office;	MP/DY	
42	Mark wing data collection locations and draw grid on the wing (refer to Feasibility report for diagrams);	VZ/DY	
43	Co-ordinate fabrication of ice pellets/snow/snow pellets	VZ	
44	ZR Calibration	DY/MP	
45	IP/SN Calibration (confirm rates with spot check with rate pan)	DY/VZ	
46	IP manufacturing	YOW's	
47	General safety briefing and update on testing	APS/NRC/YOW	
48	Dry Run of tests (APS / NRC)	APS/NRC	
	Each Testing Day		
49	Check with NRC the status of the testing site, tunnel etc	MR	
50	Check weather prior to establishing test dates	MR	
51	Prepare equipment and fluid to be used for test	DY	
52	Manufacture ice pellets	VZ/YOW	
53	Arrange for photo doc. of the test	MR	
54	Prepare data forms for test	MP	
55	Conduct tests based on test plan	APS	
56	Modify test plan based on results obtained	WU/JD/MR	
57	Update IP/S Inventory	VZ/YOW	
58	Update Ice Quantity	VZ/YOW	
59	Update Fluid Quantity	MP/DY	
60	Update Test Plan	MP	



ATTACHMENT XI – General Form (to be filled by MP)

Form 1

GENERAL FORM (EVERY TEST)

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

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

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

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

ROTATION ANGLE: EXTRA RUN INFO:

FLAP SETTING (20°, 0°):

FLUID APPLICATION

Actual start time: Actual End Time:

Fluid Brix: Amount of Fluid (L):

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

ICE PELLETS APPLICATION (if applicable)

Actual start time: Actual End Time:

Rate of Ice Pellets Applied (g/dm^2/h): Ice Pellets Size (mm): 1.4 - 4.0 mm

Exposure Time:

Total IP Required per Dispenser:

FREEZING RAIN/DRIZZLE APPLICATION (if applicable)

Actual start time: Actual End Time:

Rate of Precipitation Applied (g/dm^2/h): Droplet Size (mm):

Exposure Time: Needle:

Flow:

Pressure

SNOW APPLICATION (if applicable)

Actual start time: Actual End Time:

Rate of Snow Applied (g/dm^2/h): Snow Size (mm): <1.4 mm

Exposure Time: Method: ☐ Dispenser ☐ Sieve

Total SN Required per Dispenser:

COMMENTS

MEASUREMENTS BY: **HANDWRITTEN BY:**

ATTACHMENT XII – Wing Temperature, Fluid Thickness and Fluid Brix Form (to be filled by MP)

Date: ______________________

Run: ______________

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2				
T5				
TU				
Time:				

FLUID BRIX

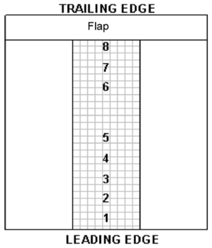
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2			
8	▨		
Flap	▨		
Time:			

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2			
3	▨	▨	▨
4	▨	▨	▨
5			
6	▨	▨	▨
7	▨	▨	▨
8			
Flap			
Time:			

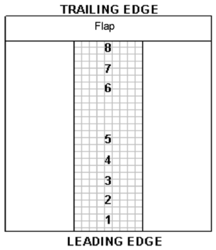
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: __________

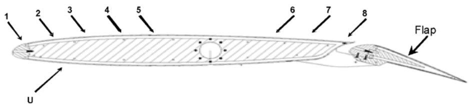


Comments:____________________
____
____
____
____

Wing and Plate Condition
Before the Takeoff Run
Time: __________



Comments:____________________
____
____
____
____



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;

Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;

Wing Position 6: Approximately 30 cm from trailing edge;

Wing Position 7: Approximately 15 cm from trailing edge;

Wing Position 8: Approximately 2.5 cm from trailing edge; and

Wing Position 9: Midway up the flap

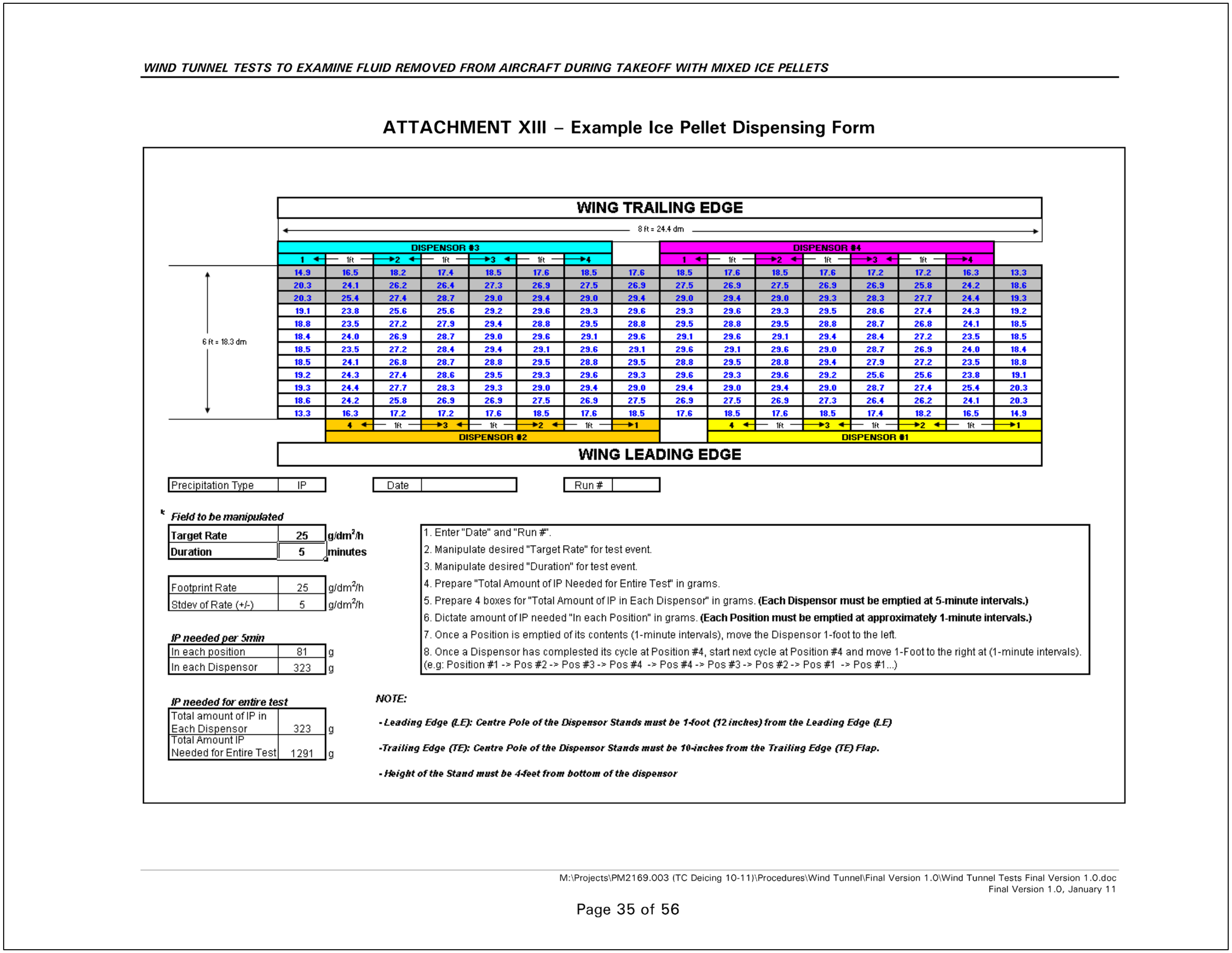
Underside: Approximately 40 cm up from the leading edge stagnation point.

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

General Comments:
____
____
____

OBSERVER: ______________________

ASSISTED BY: ______________________



WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

ATTACHMENT XIII – Example Ice Pellet Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm

6 ft = 18.3 dm

DISPENSOR #3								DISPENSOR #4							
1 ←	1ft	→ 2 ←	1ft	→ 3 ←	1ft	→ 4		1 ←	1ft	→ 2 ←	1ft	→ 3 ←	1ft	→ 4	
14.9	16.5	18.2	17.4	18.5	17.6	18.5	17.6	18.5	17.6	18.5	17.6	17.2	17.2	16.3	13.3
20.3	24.1	26.2	26.4	27.3	26.9	27.5	26.9	27.5	26.9	27.5	26.9	26.9	25.8	24.2	18.6
20.3	25.4	27.4	28.7	29.0	29.4	29.0	29.4	29.0	29.4	29.0	29.3	28.3	27.7	24.4	19.3
19.1	23.8	25.6	25.6	29.2	29.6	29.3	29.6	29.3	29.6	29.3	29.5	28.6	27.4	24.3	19.2
18.8	23.5	27.2	27.9	29.4	28.8	29.5	28.8	29.5	28.8	29.5	28.8	28.7	26.8	24.1	18.5
18.4	24.0	26.9	28.7	29.0	29.6	29.1	29.6	29.1	29.6	29.1	29.4	28.4	27.2	23.5	18.5
18.5	23.5	27.2	28.4	29.4	29.1	29.6	29.1	29.6	29.1	29.6	29.0	28.7	26.9	24.0	18.4
18.5	24.1	26.8	28.7	28.8	29.5	28.8	29.5	28.8	29.5	28.8	29.4	27.9	27.2	23.5	18.8
19.2	24.3	27.4	28.6	29.5	29.3	29.6	29.3	29.6	29.3	29.6	29.2	25.6	25.6	23.8	19.1
19.3	24.4	27.7	28.3	29.3	29.0	29.4	29.0	29.4	29.0	29.4	29.0	28.7	27.4	25.4	20.3
18.6	24.2	25.8	26.9	26.9	27.5	26.9	27.5	26.9	27.5	26.9	27.3	26.4	26.2	24.1	20.3
13.3	16.3	17.2	17.2	17.6	18.5	17.6	18.5	17.6	18.5	17.6	18.5	17.4	18.2	16.5	14.9
	4 ←	1ft	→ 3 ←	1ft	→ 2 ←	1ft	→ 1		4 ←	1ft	→ 3 ←	1ft	→ 2 ←	1ft	→ 1
	DISPENSOR #2								DISPENSOR #1						

WING LEADING EDGE

Precipitation Type	IP	Date		Run #	

Field to be manipulated

Target Rate	**25**	**g/dm²/h**
Duration	**5**	**minutes**

Footprint Rate	25	g/dm²/h
Stdev of Rate (+/-)	5	g/dm²/h

IP needed per 5min

In each position	81	g
In each Dispensor	323	g

IP needed for entire test

Total amount of IP in Each Dispensor	323	g
Total Amount IP Needed for Entire Test	1291	g

1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of IP Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of IP in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of IP needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispensor 1-foot to the left.
8. Once a Dispensor has completed its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals). (e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

- Leading Edge (LE): Centre Pole of the Dispensor Stands must be 1-foot (12 inches) from the Leading Edge (LE)

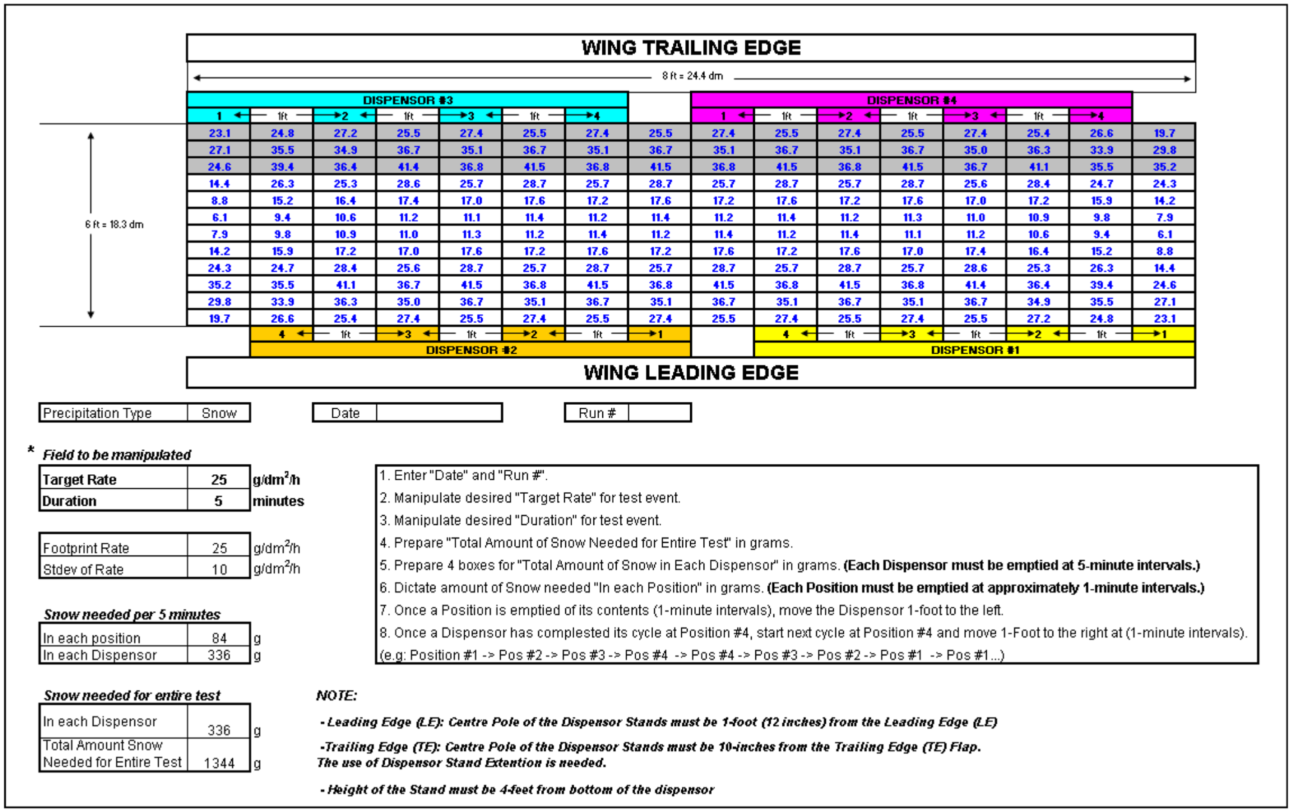
-Trailing Edge (TE): Centre Pole of the Dispensor Stands must be 10-inches from the Trailing Edge (TE) Flap.

- Height of the Stand must be 4-feet from bottom of the dispensor

M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Tests Final Version 1.0.doc
Final Version 1.0, January 11

Page 35 of 56

ATTACHMENT XIV – Example Snow Dispensing Form



WING TRAILING EDGE

8 ft = 24.4 dm

6 ft = 18.3 dm

DISPENSOR #3								DISPENSOR #4							
1 ←	1ft	→ 2 ←	1ft	→ 3 ←	1ft	→ 4		1 ←	1ft	→ 2 ←	1ft	→ 3 ←	1ft	→ 4	
23.1	24.8	27.2	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.4	26.6	19.7
27.1	35.5	34.9	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.0	36.3	33.9	29.8
24.6	39.4	36.4	41.4	36.8	41.5	36.8	41.5	36.8	41.5	36.8	41.5	36.7	41.1	35.5	35.2
14.4	26.3	25.3	28.6	25.7	28.7	25.7	28.7	25.7	28.7	25.7	28.7	25.6	28.4	24.7	24.3
8.8	15.2	16.4	17.4	17.0	17.6	17.2	17.6	17.2	17.6	17.2	17.6	17.0	17.2	15.9	14.2
6.1	9.4	10.6	11.2	11.1	11.4	11.2	11.4	11.2	11.4	11.2	11.3	11.0	10.9	9.8	7.9
7.9	9.8	10.9	11.0	11.3	11.2	11.4	11.2	11.4	11.2	11.4	11.1	11.2	10.6	9.4	6.1
14.2	15.9	17.2	17.0	17.6	17.2	17.6	17.2	17.6	17.2	17.6	17.0	17.4	16.4	15.2	8.8
24.3	24.7	28.4	25.6	28.7	25.7	28.7	25.7	28.7	25.7	28.7	25.7	28.6	25.3	26.3	14.4
35.2	35.5	41.1	36.7	41.5	36.8	41.5	36.8	41.5	36.8	41.5	36.8	41.4	36.4	39.4	24.6
29.8	33.9	36.3	35.0	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.1	36.7	34.9	35.5	27.1
19.7	26.6	25.4	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.2	24.8	23.1
	4 ←	1ft	→ 3 ←	1ft	→ 2 ←	1ft	→ 1		4 ←	1ft	→ 3 ←	1ft	→ 2 ←	1ft	→ 1
	DISPENSOR #2								DISPENSOR #1						

WING LEADING EDGE

Precipitation Type	Snow

Date	

Run #	

* *Field to be manipulated*

Target Rate	**25**	**$g/dm^2/h$**
Duration	**5**	**minutes**

Footprint Rate	25	$g/dm^2/h$
Stdev of Rate	10	$g/dm^2/h$

Snow needed per 5 minutes

In each position	84	g
In each Dispensor	336	g

Snow needed for entire test

In each Dispensor	336	g
Total Amount Snow Needed for Entire Test	1344	g

1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Snow Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of Snow in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of Snow needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispensor 1-foot to the left.
8. Once a Dispensor has complested its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals).

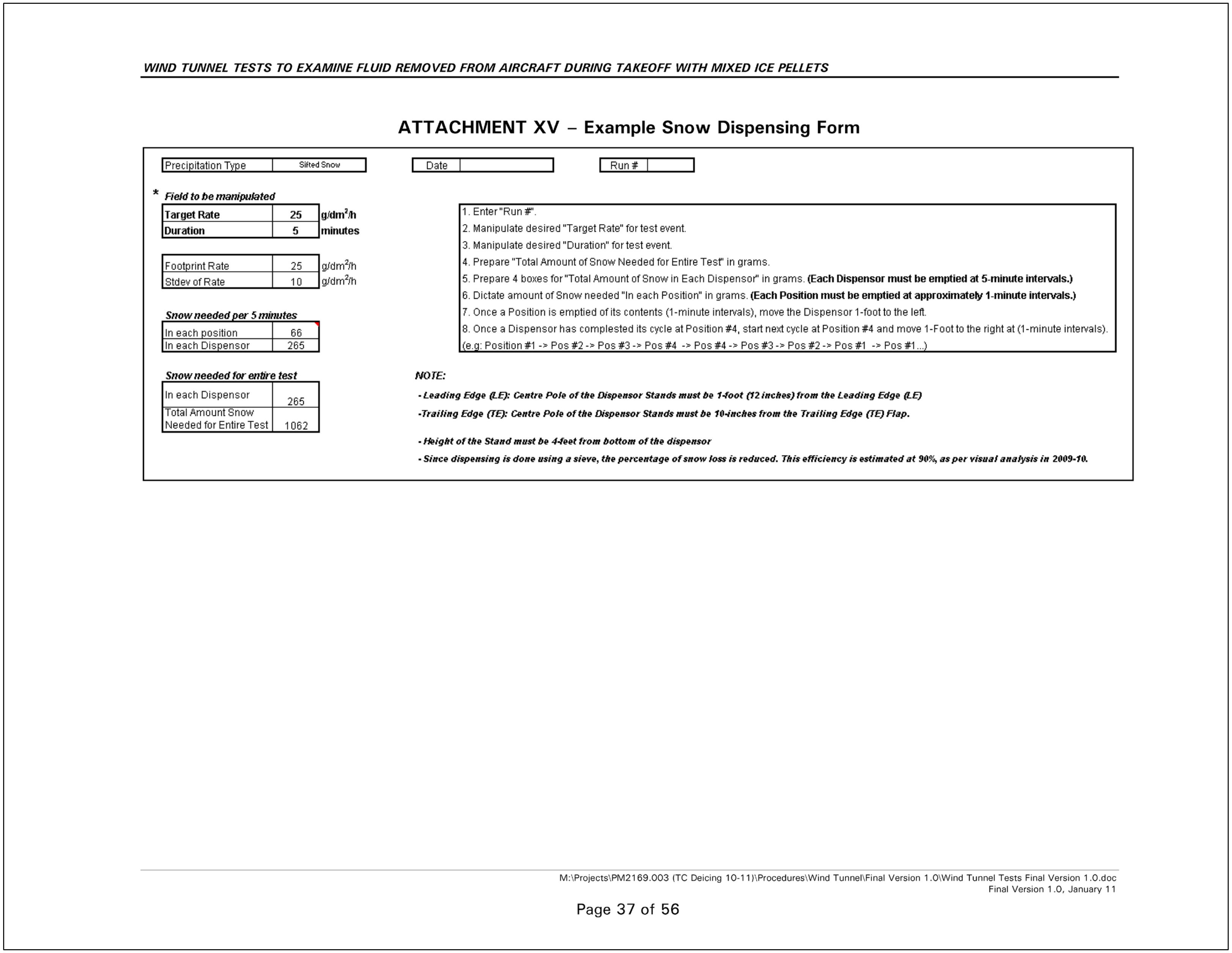
(e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

- Leading Edge (LE): Centre Pole of the Dispensor Stands must be 1-foot (12 inches) from the Leading Edge (LE)

-Trailing Edge (TE): Centre Pole of the Dispensor Stands must be 10-inches from the Trailing Edge (TE) Flap.
The use of Dispensor Stand Extention is needed.

- Height of the Stand must be 4-feet from bottom of the dispensor



ATTACHMENT XV – Example Snow Dispensing Form

Precipitation Type	Sifted Snow

Date	

Run #	

* ***Field to be manipulated***

Target Rate	**25**	**g/dm²/h**
Duration	**5**	**minutes**

Footprint Rate	25	g/dm²/h
Stdev of Rate	10	g/dm²/h

Snow needed per 5 minutes

In each position	66
In each Dispensor	265

Snow needed for entire test

In each Dispensor	265
Total Amount Snow Needed for Entire Test	1062

1. Enter "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Snow Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of Snow in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of Snow needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispensor 1-foot to the left.
8. Once a Dispensor has complested its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals).

(e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

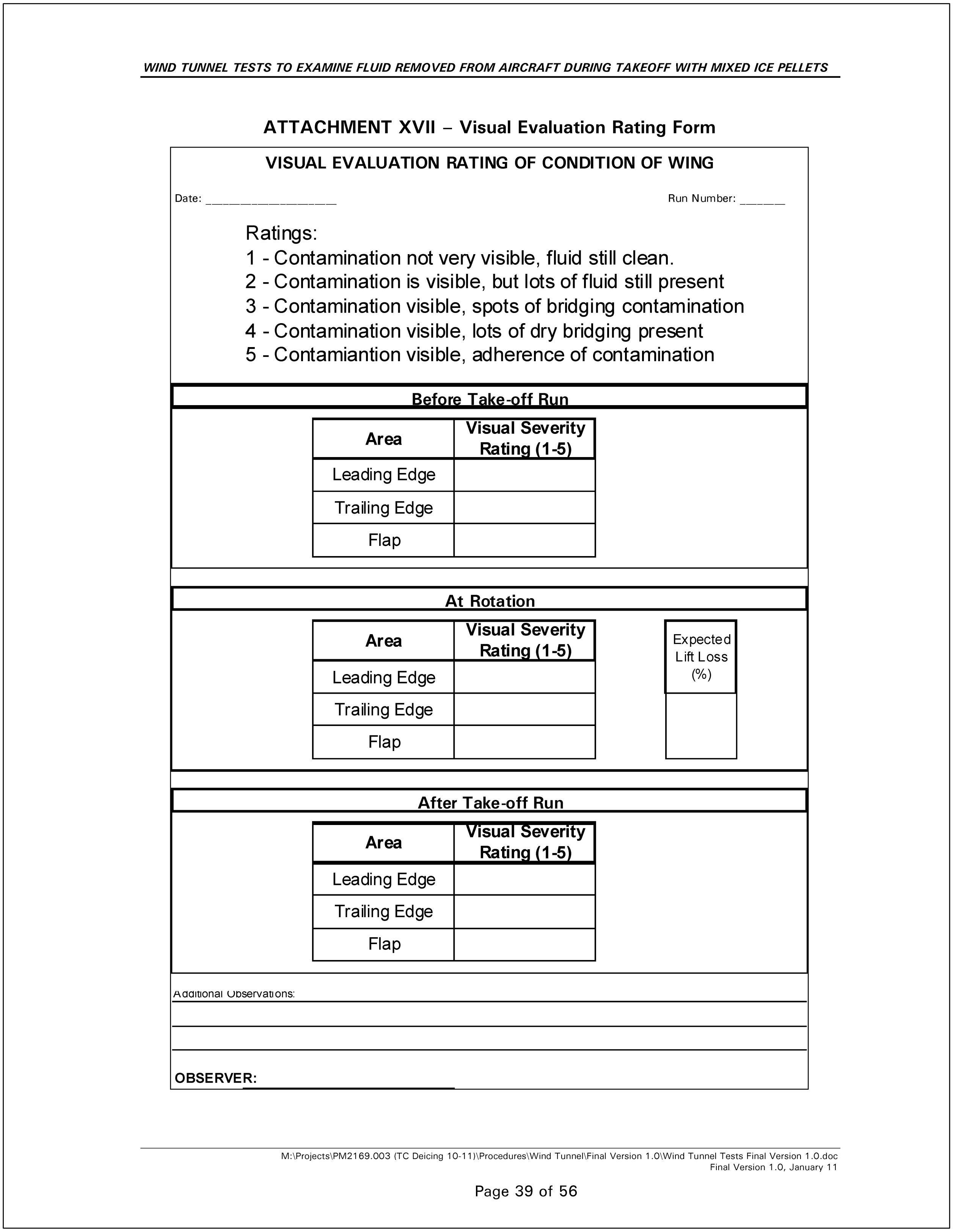
- ***Leading Edge (LE): Centre Pole of the Dispensor Stands must be 1-foot (12 inches) from the Leading Edge (LE)***
- ***Trailing Edge (TE): Centre Pole of the Dispensor Stands must be 10-inches from the Trailing Edge (TE) Flap.***

- ***Height of the Stand must be 4-feet from bottom of the dispensor***
- ***Since dispensing is done using a sieve, the percentage of snow loss is reduced. This efficiency is estimated at 90%, as per visual analysis in 2009-10.***

ATTACHMENT XVI – Sprayer Calibration Form

WIND TUNNEL FREEZING RAIN SPRAYER CALIBRATION

Trail No	Aprox Start Time	Sprayer Settings							Precipitation Rate (g/dm^2/h)	Comments
		Translation		Nozzles	Speed	Water Flow Rate (mL/min/nozzle)	Air Pressure	Software Setting		
		x	y							
2-Feb-09		Full 24 Scans	Full 335 Steps	2x20		500 mL/min	45		50	x-axis=24 Scans, 66.24º. y-axis=60.3º
4-Feb-09		Full 24 Scans	Full 335 Steps	2x20		250 mL/min	45		25	MVD=1-1.2mm. x-axis=24 Scans, 66.24º. y-axis=60.3º
25-Feb-09		Full 24 Scans	Full 335 Steps	2x17		750 mL/min	45		75	x-axis=24 Scans, 66.24º. y-axis=60.3º
1-Mar-09		Full 24 Scans	Full 335 Steps	2x20		150 mL/min	45		15	x-axis=24 Scans, 66.24º. y-axis=60.3º



WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

ATTACHMENT XVII – Visual Evaluation Rating Form

VISUAL EVALUATION RATING OF CONDITION OF WING

Date: ___________________ Run Number: _______

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

Before Take-off Run

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

At Rotation

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

Expected Lift Loss (%)

After Take-off Run

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

Additional Observations: ____

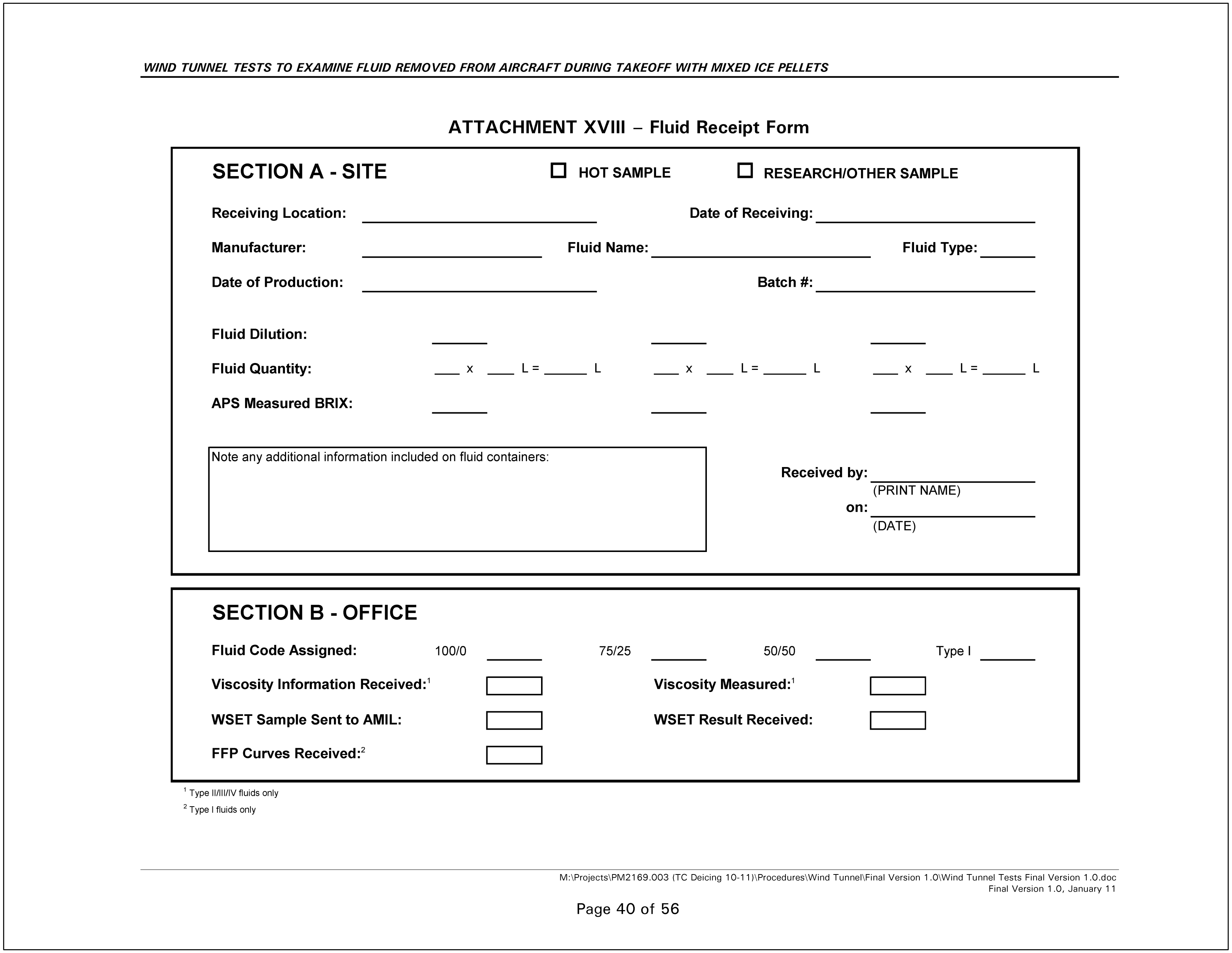
____

____

OBSERVER: ______________________

M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Tests Final Version 1.0.doc
Final Version 1.0, January 11

Page 39 of 56



ATTACHMENT XVIII – Fluid Receipt Form

SECTION A - SITE

☐ **HOT SAMPLE** ☐ **RESEARCH/OTHER SAMPLE**

Receiving Location: ____________________ **Date of Receiving:** ____________________

Manufacturer: ________________ **Fluid Name:** ____________________ **Fluid Type:** _____

Date of Production: ____________________ **Batch #:** ____________________

Fluid Dilution: _____ _____ _____

Fluid Quantity: ___ x ___ L = _____ L ___ x ___ L = _____ L ___ x ___ L = _____ L

APS Measured BRIX: _____ _____ _____

Note any additional information included on fluid containers:

Received by: ____________________
(PRINT NAME)
on: ____________________
(DATE)

SECTION B - OFFICE

Fluid Code Assigned: 100/0 _____ 75/25 _____ 50/50 _____ Type I _____

Viscosity Information Received:[1] ☐ **Viscosity Measured:**[1] ☐

WSET Sample Sent to AMIL: ☐ **WSET Result Received:** ☐

FFP Curves Received:[2] ☐

[1] Type II/III/IV fluids only

[2] Type I fluids only

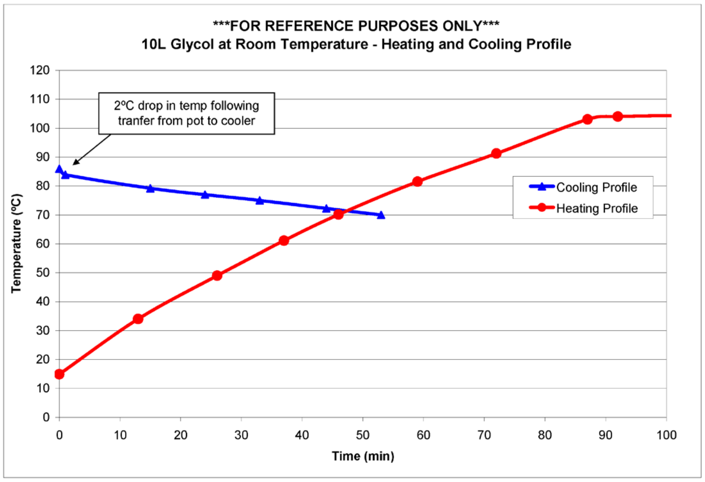
ATTACHMENT XIX – Log of Fluid Sample Bottles

Date of Extraction	Fluid and Dilution	Batch #	Sample Source (i.e. Drum)	Falling Ball Fluid Temp (ºC)	Falling Ball Time (sec)	Comments

ATTACHMENT XX– Application Procedure - Heated Type III Fluid for Wind Tunnel Tests

Heating

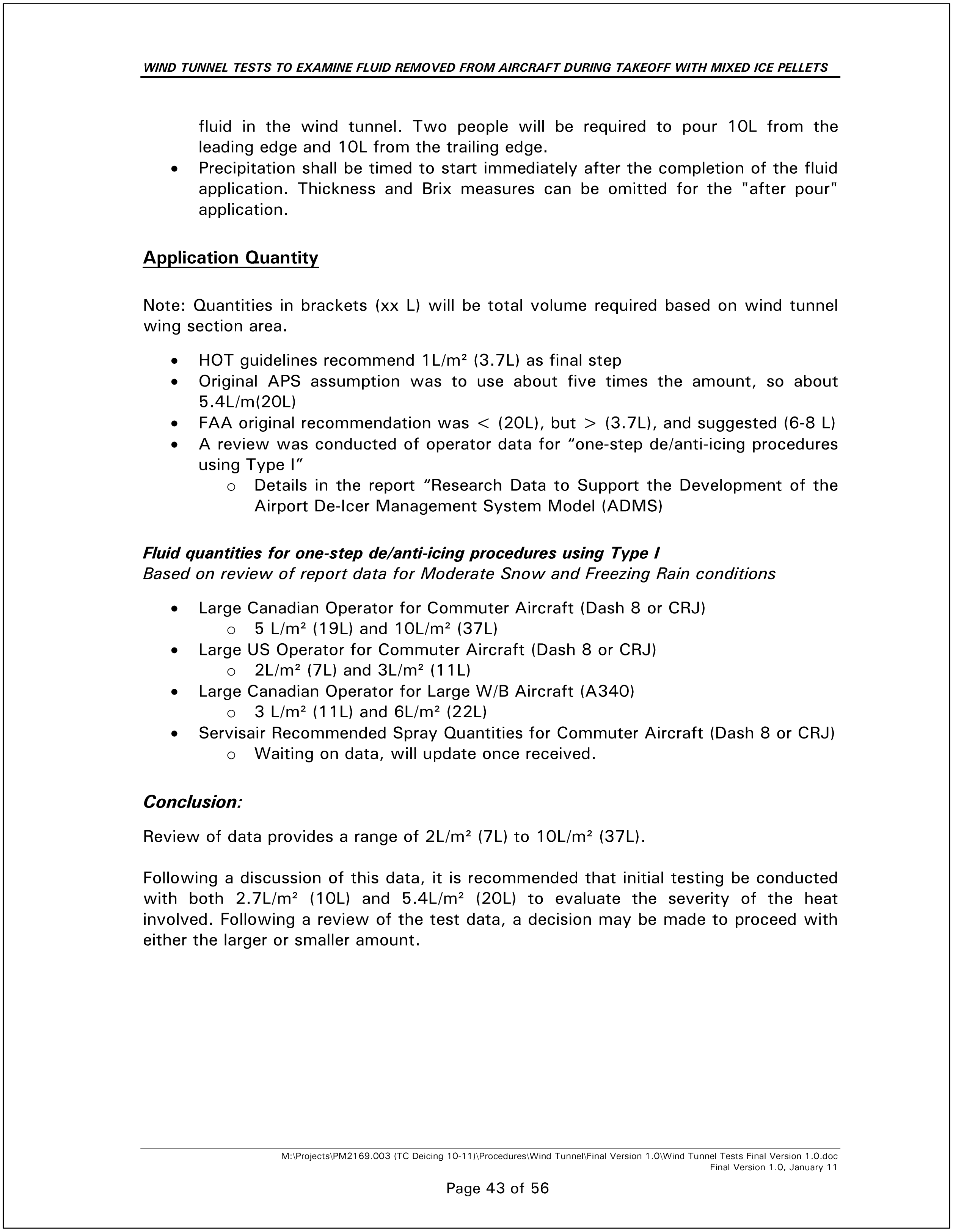
- Type III should be stored indoors at room temperature to minimize heating required;
- Heat Type III fluid 10L at a time using a hotplate and an aluminum cooking pot with a lid. The hotplate should be set to the "Max" setting. Two pots should be heated simultaneously to prepare the 20L required for each test;
- Fluid temperature should be monitored every 10 minutes, and the fluid should be stirred frequently;
- Once a temperature of 70°C is achieved (approx 45 minutes), the two 10L pots of fluid should be transferred to individual warm insulated coolers.
- *Note: Although 60°C is the target application temperature, the fluid will be transferred into the coolers at 70°C to allow for some cooling during transportation to the test section and transfer into the pouring jug*s.



Application

NOTE: It is critical that all precipitation dispensing equipment be ready to go prior to fluid application. Application of precipitation should occur immediately after the fluid application is complete to minimize heat loss from the wing.

- Heated Type III fluid should be transferred from the insulated coolers into hand held 2-3L pour containers;
- 20 L (see "Application Quantity" section for details) of fluid should be applied evenly to the whole wing section using the typical methodology for applying



fluid in the wind tunnel. Two people will be required to pour 10L from the leading edge and 10L from the trailing edge.

- Precipitation shall be timed to start immediately after the completion of the fluid application. Thickness and Brix measures can be omitted for the "after pour" application.

Application Quantity

Note: Quantities in brackets (xx L) will be total volume required based on wind tunnel wing section area.

- HOT guidelines recommend 1L/m² (3.7L) as final step
- Original APS assumption was to use about five times the amount, so about 5.4L/m(20L)
- FAA original recommendation was < (20L), but > (3.7L), and suggested (6-8 L)
- A review was conducted of operator data for “one-step de/anti-icing procedures using Type I”
    - Details in the report “Research Data to Support the Development of the Airport De-Icer Management System Model (ADMS)

Fluid quantities for one-step de/anti-icing procedures using Type I
Based on review of report data for Moderate Snow and Freezing Rain conditions

- Large Canadian Operator for Commuter Aircraft (Dash 8 or CRJ)
    - 5 L/m² (19L) and 10L/m² (37L)
- Large US Operator for Commuter Aircraft (Dash 8 or CRJ)
    - 2L/m² (7L) and 3L/m² (11L)
- Large Canadian Operator for Large W/B Aircraft (A340)
    - 3 L/m² (11L) and 6L/m² (22L)
- Servisair Recommended Spray Quantities for Commuter Aircraft (Dash 8 or CRJ)
    - Waiting on data, will update once received.

Conclusion:

Review of data provides a range of 2L/m² (7L) to 10L/m² (37L).

Following a discussion of this data, it is recommended that initial testing be conducted with both 2.7L/m² (10L) and 5.4L/m² (20L) to evaluate the severity of the heat involved. Following a review of the test data, a decision may be made to proceed with either the larger or smaller amount.

ATTACHMENT XXI – Procedure: Heavy Snow

Background

As a direct result of the ice pellet research conducted, the use of HOTs for determining the protection time provided by anti-icing fluids was questioned. The focus has turned towards "aerodynamic failure" which can be defined as a significant lift loss resulting from contaminated anti-icing fluid. Heavy snow conditions have been selected for this study for two reasons. First, snow conditions account for the most significant portion of de-icing operations globally. Secondly, there has been a recent industry interest for holdover time for heavy snow conditions. Preliminary aerodynamic testing was conducted during the winter of 2006-07, 2008-09, and 2009-10.

Objective

To investigate the fluid aerodynamic flow-off characteristics of anti-icing fluid contaminated with simulated heavy snow versus moderate snow.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow condition tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating moderate snow conditions (rate of 25 $g/dm^2/h$) for an exposure time derived from the HOT table based on the tunnel temperature at the time of the test
- Record lift data, visual observations, and manually collected data;
- Conduct two comparative tests simulating heavy snow conditions (rate of 50 $g/dm^2/h$) for the same exposure time used during the moderate snow test.
    - NOTE: previous testing has indicated that using half, to ¾ of the moderate snow HOT generates similar end conditions, whereas using the full moderate HOT for heavy snow conditions generates a more sever fluid failure which behaves worse aerodynamically. ;
- Record lift data, visual observations, and manually collected data;
- Compare the heavy snow results to the moderate snow results. If the heavy snow results are worse, repeat the heavy snow test with a reduced exposure time, if the results are better, repeat the heavy snow test with an increased exposure time.
- Repeat until similar lift data, and visual observations are achieved for both heavy snow and moderate snow; and
- Document the percentage of the moderate snow HOT that is acceptable for heavy snow conditions.

Test Plan

Ten to twelve comparative tests are anticipated.

ATTACHMENT XXII – Procedure: Aerodynamic Impact of Rotation Wing to CL Max

Background

Historically, the ice pellet allowance time testing conducted in the wind tunnel simulated typical aircraft rotation angles and evaluated the lift losses at the max angle achieved. During the winter of 2009-10, the max rotation angle was selected to be approximately mid way between the typical rotation angle and the stall angle to simulate a worse case condition. Discussions with SAE Aerodynamics working group led to the recommendation to conduct some limited testing rotating the wing section to CL Max during the takeoff profile as this a more common approach used by aerodynamicists. The objective is to verify the differences in results as compared to the protocol that has been historically used in the wind tunnel.

Objective

To investigate the lift loss at CL max with and without fluid and contamination.

Methodology

- Conduct a test simulating an ice pellet allowance time condition and rotate the wing to a angle of rotation typical of aircraft operations (8 deg was used in 2009-10);
- Conduct a comparative test in the same conditions, however rotate the wing section to CL Max;
- Conduct comparative baseline fluid only test for both cases (8 deg max rotation and CL max)
- Calculate the lift losses for both contamination tests at the maximum angle of rotation and compare the results to the baseline fluid only tests;
- Document the results.

Test Plan

Five tests are anticipated, however more tests may be required based on the results.

ATTACHMENT XXIII – Procedure: Aerodynamic Impact of Wing Surface Roughness

Background

Previous testing in the wind tunnel demonstrated that although contamination was present on the wing section, significant lift losses were not apparent. Lift losses were incurred upon application of anti-icing fluid (when compared to a bare wing) however, the presence of contamination, whether adhered or not, did not generate significant list losses when compared to the uncontaminated fluid. Although the presence of adhered contamination may be hazardous with regards to control surfaces, the impact of the surface roughness on the overall aerodynamic performance of the wing needs to be investigated.

Objective

To investigate wing surface roughness and how it pertains to lift loss.

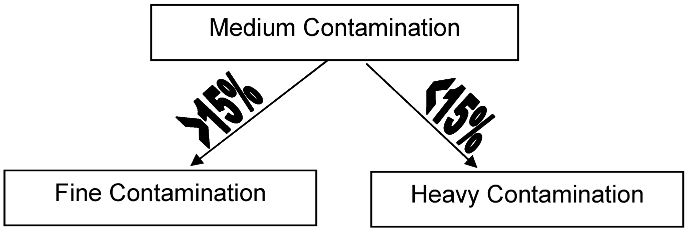
Methodology

Contamination can be in the form of abrasive sandpaper (similar to what is used by the NRC Flight Laboratory) or frozen precipitation on a bare wing. During the winter of 2008-09 and 2009-10, adhered freezing rain, ice pellets, and snow were used to create a rough surface on the wing section.

- Apply abrasive material or contamination to full length of the leading edge of wing section;
- Run wind tunnel test, collect lift loss data, compare to fluid only results;
- Increase grit of sandpaper or level of frozen contamination until appreciable lift losses are observed; and
- Document type and level of contamination and resulting effects on lift loss.

Test Plan

Three to four tests are anticipated. Testing will proceed according to the following decision matrix.



ATTACHMENT XXIV – Procedure: Effects of Wing Geometry on Fluid Failure and Aerodynamic Flow Off

Background

A limitation of conducting testing with a 2-dimesnional wing section is the inability to recreate fluid flow off due to the varying geometry found on a real wing section. An operational aircraft wing will have twist (based on chord location), dihedral effect (based on distance from fuselage), and will have varying chord thickness and upper skin slope (based on chord location. Testing during the winter of 2009-10 with the supercritical wing section demonstrated that fluid flow off was reduced due to the relatively flat top surface inherent of that type of wing. It was recommended that preliminary testing be conducted with different wing rest angles during contamination to simulate the different geometries typically found on an aircraft wing.

Objective

To investigate the impact on fluid failure and aerodynamic performance with different wing rest angles during contamination.

Methodology

- Conduct a typical wind tunnel test with contamination using the typical rest angle (-2 degrees for the supercritical wing);
- Repeat the test with steeper rest angle simulating a different section of the wing;
- Compare results and document.

Test Plan

Two preliminary tests are anticipated.

ATTACHMENT XXV – Procedure: Low Speed Ramp Testing

Background

The current low speed aerodynamic acceptance test for anti-icing fluids simulates a rotation speed of 67 knots on a flat plate; this takeoff profile was developed based on older generation low speed aircraft. In recent years, the newer generation low speed aircraft have rotation speeds closer to 80 to 85 knots. As all of the low speed testing conducted in the wind tunnel has been performed simulating an 80 knot rotation speed (representing the newer generation aircraft), it was recommended to verify the fluid flow-off properties of anti-icing fluid using the historical 67 knot rotation speed takeoff profile used for the aerodynamic acceptance tests.

Objective

To investigate the fluid flow-off performance during low speed ramp take-off.

Methodology

- Testing should be conducted in fluid only conditions;
- Testing will consist of two comparative tests done sequentially with the same fluid in similar weather conditions:
    - 67 knots rotation;
    - 85 knots rotation;
- Compare lift data, visual observations, and manually collected data;

Test Plan

Four to six tests are anticipated with two to three different fluids.

ATTACHMENT XXVI – Procedure: Snow on an Un-Protected Wing

Background

In colder northern operations, it is common for aircraft to depart with "loose, dry, un-adhered snow" on present on their wing sections. Although it is assumed most or all of this contamination will be removed at the time of rotation, it is unknown whether a certain level of contamination will reduce aerodynamic performance. Full-scale testing is required to investigate the aerodynamic performance of a wing section contaminated with dry, un-adhered snow.

Objective

To investigate the aerodynamic performance of a wing section contaminated with dry, un-adhered snow.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow condition tests conducted in the wind tunnel.

- Ensure the wing section and tunnel temperature are well below freezing (-5°C and below);
- Ensure the wing section is clean, dry, and free of any forms of contamination;
- Apply loose, dry snow contamination to the wing section;
- Record lift data, visual observations, and manually collected data;
- Compare the results to baseline fluid only and dry wing test results;

Test Plan

Three to four comparative tests are anticipated.

ATTACHMENT XXVII – Procedure: Scoping Study for the Feasibility of Conducting H-Stab Tests in the Wind Tunnel

Background

Several incidents have been reported of aircraft with un-powered elevator controls failing to rotate, or requiring excessive amounts of stick-force to be able to rotate. The primary suspect is thickened fluid being sucked through the gap of the H-Stab and the elevator and disrupting the aerodynamic flow. This is an ongoing going concern in the industry and an issue for many turbo-prop aircraft currently in service. Although testing will not be conducted in the wind tunnel during the winter of 2009-10, the purpose of this study is to investigate the feasibility of conducting these types of tests in the future.

Objective

To conduct a scoping study to investigate the feasibility of conducting aerodynamic tests with a horizontal stabilizer section in the NRC wind tunnel.

Methodology

- Discuss with NRC the possibility of installing and instrumenting a H-Stab section, and the possibility of having control over the elevator during a test run;
- Discuss with airframe manufacturer possibility of obtaining a H-Stab section for testing;
- Perform preliminary photographic tests (using the current wing section and flap as a surrogate for a H-Stab) to investigate if photos of the underside of the H-Stab would be possible and if any modifications to the wind tunnel would be required.

Test Plan

No testing is required, however a dry run with photography would be recommended.

ATTACHMENT XXVIII – Procedure: Rain on an Un-Protected Wing (Also do with Freezing Drizzle)

Background

In order to determine an acceptable level of lift loss, it was recommended that aerodynamic testing be conducted under known conditions which are safe for flying. The condition of rain (non-freezing) on an un-protected wing could provide insight into an acceptable level of lift loss (if any) which is present during a typical aircraft takeoff scenario. Full-scale testing is required to investigate the aerodynamic performance of a wing section during rain conditions.

It was also recommended that some preliminary testing be done with freezing drizzle on a dry wing surface. Due to the roughness of drizzle when precipitation first begins (before it becomes smoothed out after extensive exposure), the aerodynamic severity may be closer to what is observed with frost as compared to freezing rain which is generally smooth.

Objective

To investigate the aerodynamic performance of a wing section during rain conditions. As a secondary objective, conduct testing with freezing drizzle on a dry wing section.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow condition tests conducted in the wind tunnel.

- Ensure the wing section, tunnel temperature, and outside ambient temperature are ABOVE freezing (+1°C and above);
- Ensure the wing section is clean, dry, and free of any forms of contamination;
- Apply rain using the freezing rain sprayer. If possible, keep the rain sprayer working during the ramp up;
- Record lift data, visual observations, and manually collected data;
- Compare the results to baseline fluid only and dry wing test results;
- Consider conducted similar tests in below 0°C with freezing drizzle on a dry wing.

Test Plan

Three to four comparative tests are anticipated.

ATTACHMENT XXIX – Procedure: Effect of Ice Phobic Coatings on Contaminated Airfoil Aerodynamic Performance

Background

There has been a recent industry interest in the use of ice phobic coatings to protect aircraft critical surfaces. Currently, some non-commercial operators are using ice phobic coatings on the aircraft radome and other aircraft surfaces. Previous work was conducted during the winter of 2009-10 with a severely contaminated wing section. It was recommended that application of these materials on different parts of the wing surface be investigated i.e. wing and flap leading edge, quiet areas, etc. It was recommended that testing be continued to investigate the protective properties of these coatings in precipitation conditions, and to verify the compatibility of these products with glycol de/anti-icing fluids.

Objective

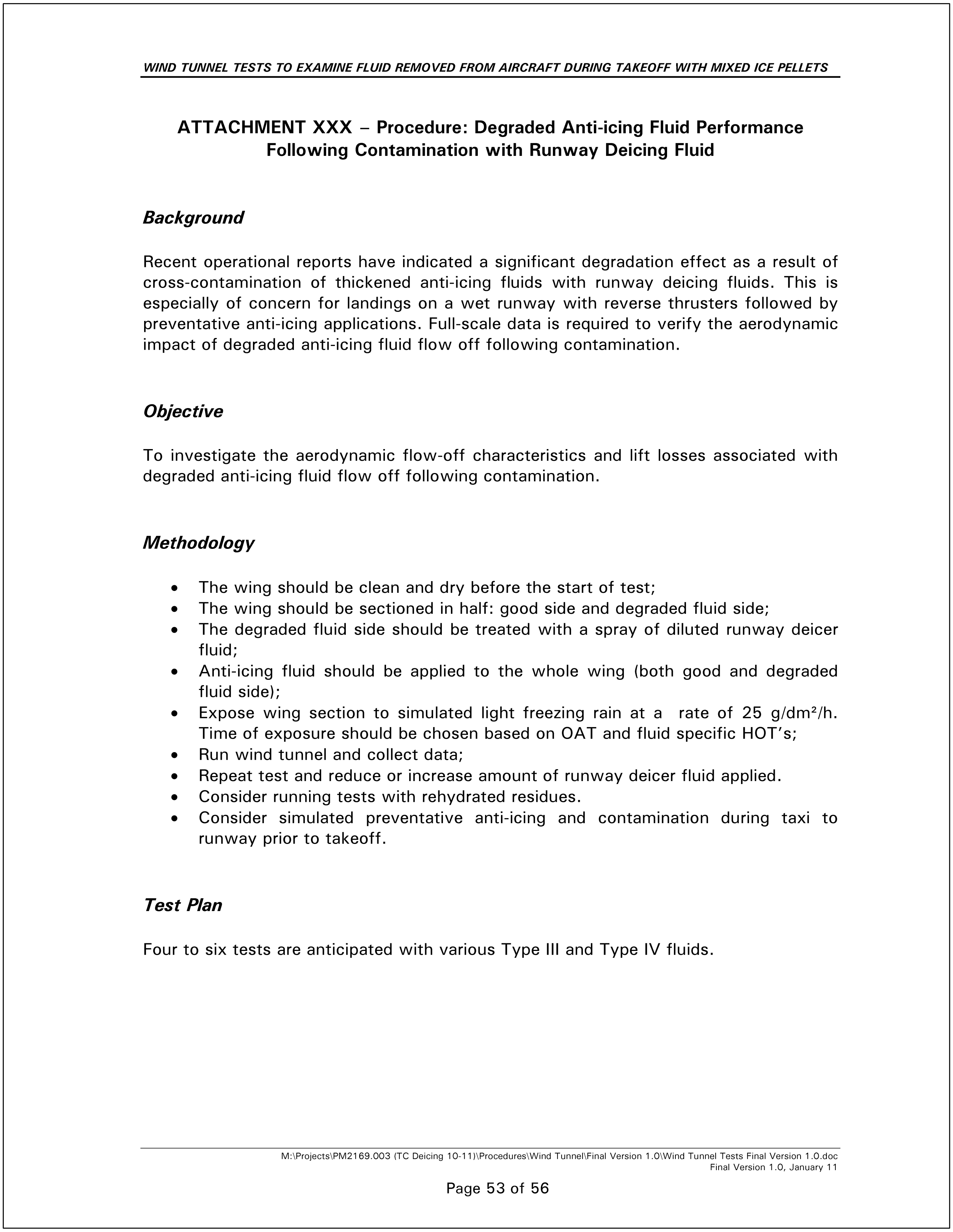
To investigate the aerodynamic flow-off characteristics and lift losses associated with a wing section treated with ice-phobic coatings following contamination, with and without anti-icing fluid.

Methodology

- The wing should be clean and dry before the start of test;
- The wing section should be covered with speed tape. If it is not feasible to cover the entire wing, the first 12-24" of the leading edge should be covered with speed tape;
- The wing should be sectioned in half: un-treated and treated with ice-phobic coating;
- One side should be treated with the ice phobic coating as per the manufacturer specification. The other side should be left untreated;
- The first test should be conducted with no fluid protection during light freezing rain conditions;
- Run wind tunnel and collect data;
- The following test should be conducted with anti-icing fluid protection. The wing should be exposed to simulated light freezing rain at a rate of 25 g/dm²/h and the time of exposure should be chosen based on OAT and fluid specific HOT's;
- Run wind tunnel and collect data;
- The performance of the treated and un-treated sections of the wing should be compared.

Test Plan

Two to four tests are anticipated.



ATTACHMENT XXX – Procedure: Degraded Anti-icing Fluid Performance Following Contamination with Runway Deicing Fluid

Background

Recent operational reports have indicated a significant degradation effect as a result of cross-contamination of thickened anti-icing fluids with runway deicing fluids. This is especially of concern for landings on a wet runway with reverse thrusters followed by preventative anti-icing applications. Full-scale data is required to verify the aerodynamic impact of degraded anti-icing fluid flow off following contamination.

Objective

To investigate the aerodynamic flow-off characteristics and lift losses associated with degraded anti-icing fluid flow off following contamination.

Methodology

- The wing should be clean and dry before the start of test;
- The wing should be sectioned in half: good side and degraded fluid side;
- The degraded fluid side should be treated with a spray of diluted runway deicer fluid;
- Anti-icing fluid should be applied to the whole wing (both good and degraded fluid side);
- Expose wing section to simulated light freezing rain at a rate of 25 g/dm²/h. Time of exposure should be chosen based on OAT and fluid specific HOT's;
- Run wind tunnel and collect data;
- Repeat test and reduce or increase amount of runway deicer fluid applied.
- Consider running tests with rehydrated residues.
- Consider simulated preventative anti-icing and contamination during taxi to runway prior to takeoff.

Test Plan

Four to six tests are anticipated with various Type III and Type IV fluids.

ATTACHMENT XXXI – Procedure: Heavily Contaminated Vertical Stabilizer (Testing Feasibility)

Background

Preliminary flat plate testing has indicated that fluid endurance times can be significantly reduced on vertical surfaces, primarily due to fluid flow off and increased "catch-factor" resulting from high winds. The preliminary endurance time testing indicated that during snow conditions, a vertical surface failure is similar to a heavy snow condition due to the increased "catch-factor". It was recommended that preliminary testing be conducted on the current wing section to investigate the lift losses associated, which could then be translated to a vertical stabilizer.

Objective

To investigate the aerodynamic effects of a heavily contaminated vertical stabilizer.

Methodology

- Conduct a heavy snow test on the upper surface of the wing;
- Once the contamination is complete, apply a generous coating of the same anti-icing fluid to the underside of the wing;
- Run the wind tunnel to obtain aerodynamic data;
- Repeat test with un-contaminated fluid on both the upper and underside of the wing;
- Document results and develop methodology to translate the results to a vertical surface to simulate un-even contamination due to cross winds.

Test Plan

Testing should be limited due to the preliminary nature of the procedure. If results are promising, investigate feasibility of using a vertical stabilizer wing section for future wind tunnel testing.

ATTACHMENT XXXII – Procedure: Type I Deicing and Spot During CSW Frost Conditions

Background

The fundamental difference between both types of frost is how the wing skin temperature is cooled below ambient: radiation cooling versus conduction cooling. During natural active frost, the wing skin temperature will be cooled below ambient temperature as a result of radiation cooling from the cold clear sky. During cold soak wing conditions, however, the wing skin temperature is cooled and maintained at a temperature below ambient as a result of conduction cooling from the cold fluid stored inside the wing; either the aircraft was refueled with cold fuel, or following a flight, the wing and fluid will be cold soaked. Full-scale data is recommended to investigate the aerodynamic effects of CSW frost on a deiced airfoil protected with Type I fluid.

Objective

To investigate the aerodynamic effects of CSW frost on a deiced airfoil protected with Type I fluid.

Methodology

- Dilute Type I fluid to a 0ºC buffer with respect to the wing skin temperature (to simulate CSW);
- Apply fluid heated to 60ºC to wing section;
- Wait 45 minutes (the Type I HOT in frost) or until fluid fails;
- Run the wind tunnel and collect data; and
- Compare results to baseline uncontaminated Type I tests.

Test Plan

Two to three tests are anticipated; frost contamination tests and one fluid only test.

ATTACHMENT XXXIII – Procedure: Light Freezing Rain and Moderate Snow

Background

As the accuracy of meteorological reporting continues to improve, there has been a need to provide improved guidance material during these transitional periods of mixed precipitation. During the winter of 2008-09, guidance material was developed for operations during light snow mixed with light rain conditions. As a result of this work, there was industry interest in guidance material for operations during light freezing rain and moderate snow conditions. The objective of these tests is to collect data to determine if the current HOT guidelines can be expanded to include mixed conditions of light freezing rain and moderate snow conditions.

Objective

To investigate if the current HOT guidelines can be expanded to include mixed conditions of light freezing rain and moderate snow conditions.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow and light freezing rain tests conducted in the wind tunnel. The light freezing rain and moderate snow endurance times will be compared to the light freezing rain only HOT's.

- For a chosen fluid, conduct a test simulating light freezing rain and moderate snow conditions for an exposure time derived from the HOT table based on light freezing rain conditions.
- Record lift data, visual observations, and manually collected data;
- Conduct a comparative test simulating light freezing rain conditions for the same exposure time used during the light freezing rain and moderate snow test;
- Record lift data, visual observations, and manually collected data;
- Compare the light freezing rain and moderate snow conditions results to the light freezing rain results. If the light freezing rain and moderate snow results are worse, repeat the test with a reduced exposure time, if the results are better, repeat the test with a increased exposure time.
- Repeat until similar lift data, and visual observations are achieved for both heavy snow and moderate snow; and
- Document the percentage of the moderate snow HOT that is acceptable for heavy snow conditions.

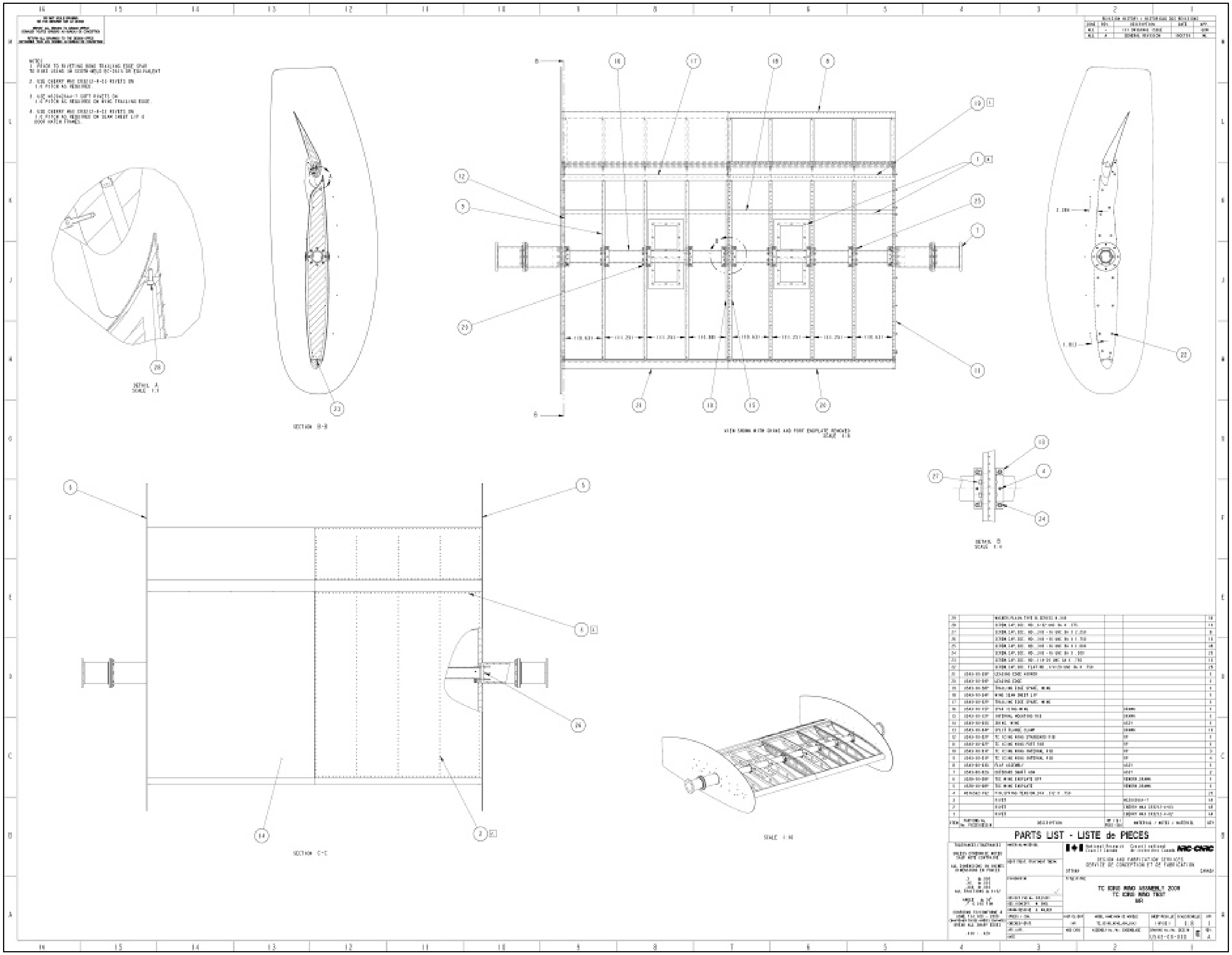
Test Plan

Four to six comparative tests are anticipated.

APPENDIX C

WING COORDINATES

Main Airfoil (Flap 0º) Coordinates		Main Airfoil (Flap 0º) Coordinates Cont'd		Main Airfoil (Flap 0º) Coordinates Cont'd		Flap Deployed (20º) Coordinates		Main Aft Coordinates	
1.000	-0.0011	0.069	-0.0240	0.375	0.0540	1.017	-0.0849	0.773	0.0314
0.999	-0.0011	0.065	-0.0235	0.400	0.0536	1.009	-0.0823	0.772	0.0311
0.997	-0.0012	0.060	-0.0228	0.425	0.0531	1.001	-0.0794	0.770	0.0309
0.995	-0.0012	0.055	-0.0221	0.450	0.0524	0.992	-0.0762	0.769	0.0305
0.990	-0.0013	0.049	-0.0213	0.475	0.0515	0.982	-0.0727	0.767	0.0302
0.985	-0.0014	0.043	-0.0205	0.500	0.0506	0.971	-0.0688	0.765	0.0297
0.980	-0.0015	0.037	-0.0195	0.525	0.0495	0.960	-0.0647	0.764	0.0294
0.970	-0.0017	0.032	-0.0185	0.550	0.0482	0.947	-0.0604	0.762	0.0289
0.960	-0.0020	0.026	-0.0174	0.575	0.0469	0.934	-0.0559	0.760	0.0283
0.950	-0.0022	0.021	-0.0161	0.600	0.0454	0.921	-0.0514	0.758	0.0278
0.940	-0.0024	0.016	-0.0148	0.620	0.0441	0.907	-0.0469	0.757	0.0273
0.930	-0.0027	0.012	-0.0132	0.640	0.0427	0.893	-0.0424	0.755	0.0267
0.920	-0.0030	0.009	-0.0116	0.660	0.0413	0.879	-0.0380	0.753	0.0256
0.910	-0.0034	0.006	-0.0098	0.680	0.0398	0.865	-0.0338	0.750	0.0247
0.900	-0.0038	0.004	-0.0080	0.700	0.0382	0.852	-0.0298	0.749	0.0240
0.880	-0.0048	0.002	-0.0061	0.720	0.0364	0.840	-0.0260	0.747	0.0231
0.860	-0.0058	0.001	-0.0043	0.740	0.0346	0.828	-0.0225	0.745	0.0222
0.840	-0.0071	0.000	-0.0027	0.760	0.0327	0.817	-0.0193	0.744	0.0213
0.820	-0.0084	0.000	-0.0012	0.780	0.0307	0.807	-0.0164	0.741	0.0199
0.800	-0.0099	0.000	0.0000	0.800	0.0286	0.798	-0.0137	0.739	0.0188
0.780	-0.0114	0.000	0.0013	0.820	0.0264	0.790	-0.0114	0.738	0.0177
0.760	-0.0129	0.000	0.0029	0.840	0.0241	0.783	-0.0093	0.736	0.0167
0.740	-0.0145	0.001	0.0049	0.860	0.0217	0.777	-0.0075	0.735	0.0158
0.720	-0.0162	0.001	0.0071	0.880	0.0192	0.771	-0.0058	0.733	0.0142
0.700	-0.0179	0.002	0.0096	0.900	0.0166	0.766	-0.0043	0.731	0.0129
0.680	-0.0196	0.004	0.0124	0.910	0.0152	0.762	-0.0023	0.729	0.0117
0.660	-0.0213	0.006	0.0152	0.920	0.0139	0.760	0.0002	0.727	0.0100
0.640	-0.0231	0.010	0.0181	0.930	0.0125	0.758	0.0030	0.725	0.0081
0.620	-0.0248	0.013	0.0210	0.940	0.0110	0.758	0.0058	0.724	0.0066
0.600	-0.0265	0.018	0.0237	0.950	0.0096	0.758	0.0081	0.723	0.0055
0.575	-0.0285	0.023	0.0261	0.960	0.0081	0.759	0.0104	0.721	0.0041
0.550	-0.0303	0.029	0.0282	0.970	0.0065	0.761	0.0126	0.720	0.0032
0.525	-0.0319	0.035	0.0300	0.980	0.0048	0.764	0.0149	0.719	0.0020
0.500	-0.0333	0.041	0.0316	0.985	0.0039	0.767	0.0171	0.718	0.0007
0.475	-0.0345	0.047	0.0331	0.990	0.0030	0.771	0.0192	0.717	-0.0009
0.450	-0.0356	0.053	0.0345	0.995	0.0021	0.776	0.0209	0.716	-0.0023
0.425	-0.0364	0.059	0.0356	0.997	0.0017	0.782	0.0225	0.714	-0.0036
0.400	-0.0370	0.065	0.0366	0.999	0.0013	0.789	0.0238	0.713	-0.0049
0.375	-0.0375	0.070	0.0374	1.000	0.0011	0.796	0.0247	0.712	-0.0058
0.350	-0.0378	0.074	0.0381			0.805	0.0247	0.711	-0.0067
0.325	-0.0379	0.082	0.0393			0.815	0.0234	0.709	-0.0080
0.300	-0.0379	0.090	0.0405			0.825	0.0203	0.708	-0.0090
0.280	-0.0377	0.098	0.0417			0.836	0.0159	0.706	-0.0107
0.260	-0.0373	0.108	0.0429			0.847	0.0103	0.704	-0.0116
0.240	-0.0368	0.117	0.0440			0.859	0.0041	0.703	-0.0126
0.220	-0.0362	0.127	0.0451			0.872	-0.0024	0.701	-0.0136
0.200	-0.0354	0.138	0.0462			0.885	-0.0092	0.699	-0.0145
0.187	-0.0347	0.150	0.0473			0.899	-0.0163	0.698	-0.0150
0.174	-0.0340	0.162	0.0483			0.912	-0.0235	0.696	-0.0159
0.161	-0.0332	0.174	0.0494			0.925	-0.0307	0.695	-0.0164
0.149	-0.0323	0.187	0.0504			0.938	-0.0377	0.693	-0.0169
0.138	-0.0315	0.200	0.0512			0.951	-0.0446	0.692	-0.0174
0.127	-0.0305	0.220	0.0522			0.963	-0.0513	0.690	-0.0179
0.117	-0.0296	0.240	0.0529			0.974	-0.0575	0.688	-0.0183
0.107	-0.0286	0.260	0.0535			0.985	-0.0634	0.687	-0.0186
0.098	-0.0276	0.280	0.0539			0.994	-0.0689	0.684	-0.0191
0.089	-0.0265	0.300	0.0541			1.003	-0.0740	0.681	-0.0195
0.081	-0.0255	0.325	0.0543			1.011	-0.0787		
0.073	-0.0246	0.350	0.0543			1.018	-0.0829		


SECTION B-B
SECTION C-C
PARTS LIST - LISTE de PIECES
NRC-CNRC
DESIGN AND FABRICATION SERVICES
SERVICE DE CONCEPTION ET DE FABRICATION
TC ICING WING ASSEMBLY 2008
TC ICING WING TEST
NR

APPENDIX D

LIFT COEFFICIENT DATA PROVIDED BY NRC

LIST OF FIGURES

LIGHT ICE PELLETS

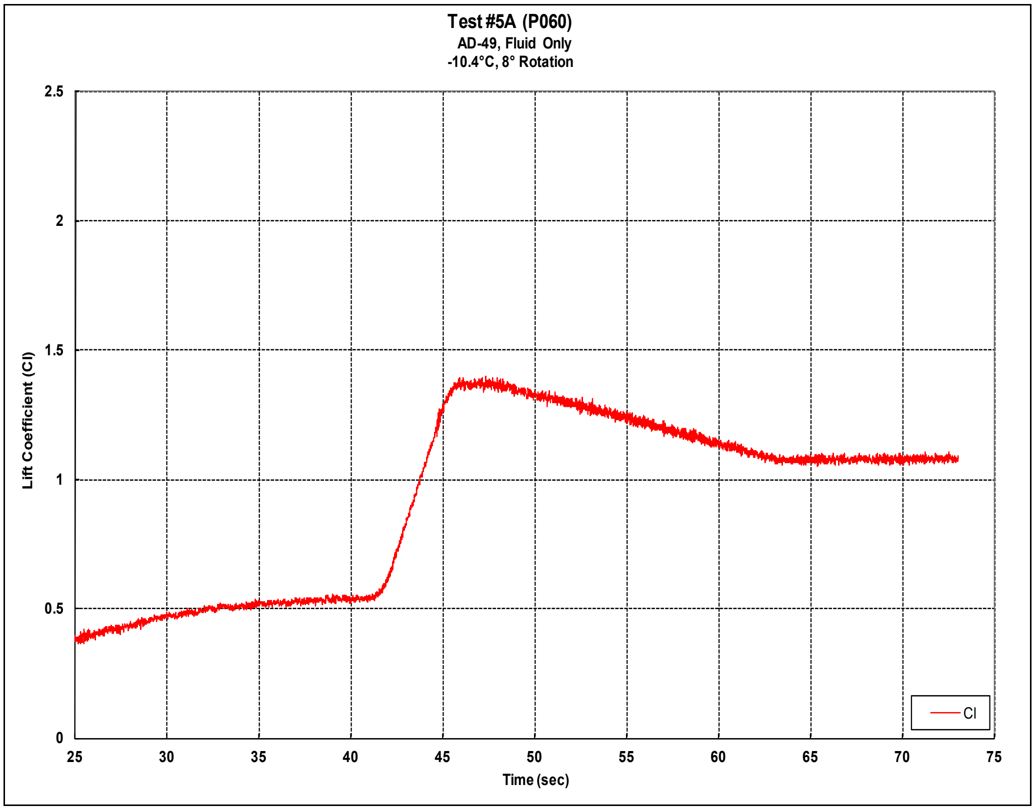


Figure D1: Run #5A

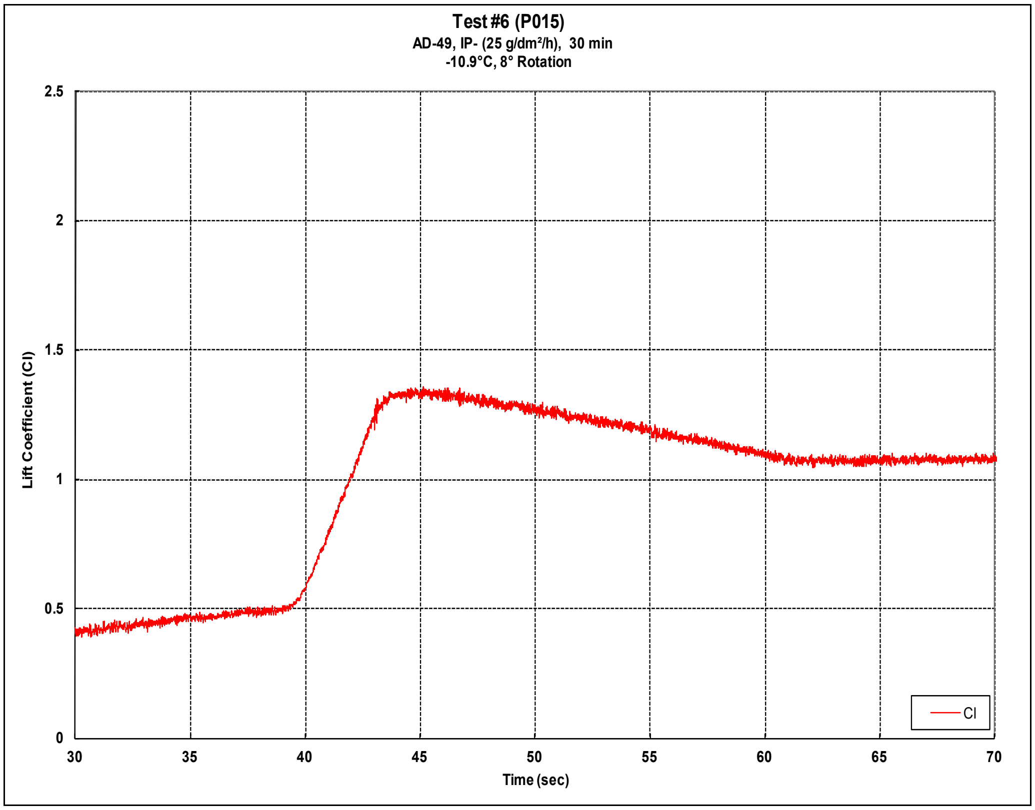


Figure D2: Run #6

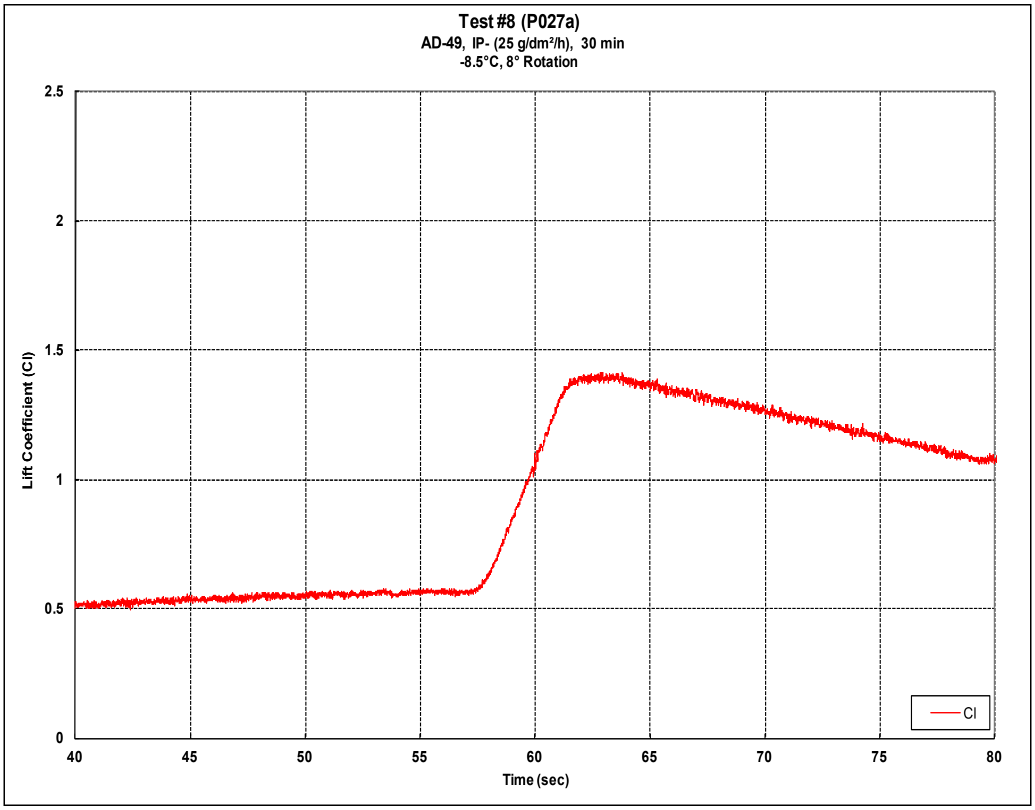


Figure D3: Run #8

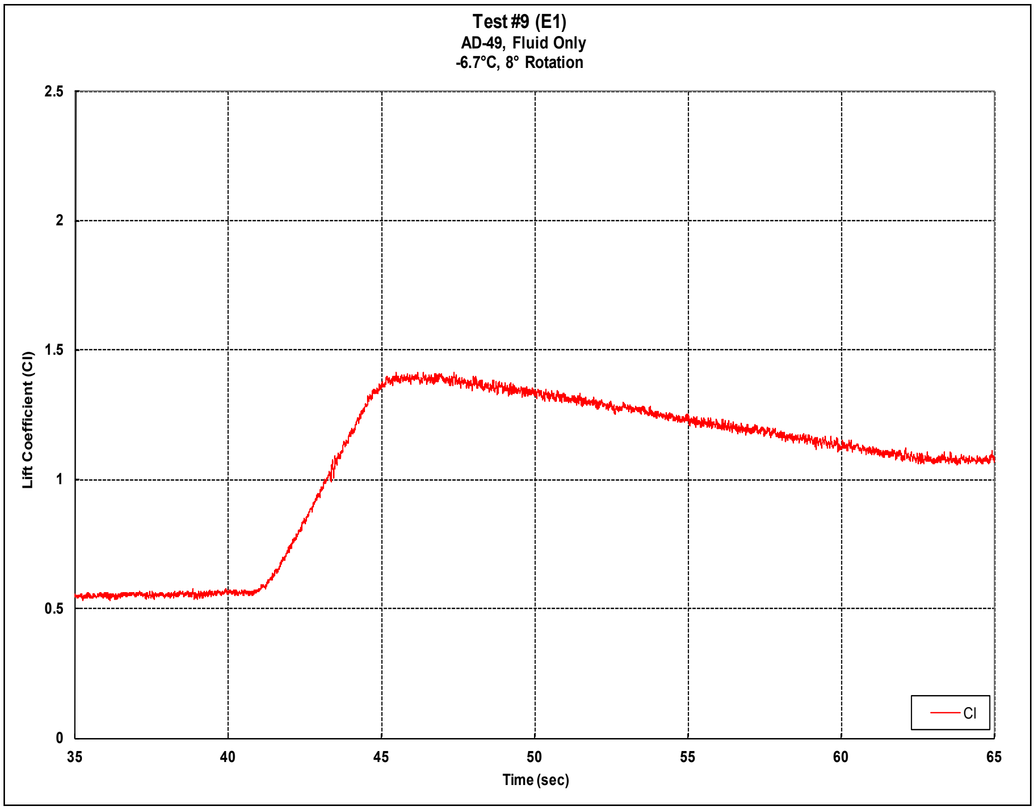


Figure D4: Run #9

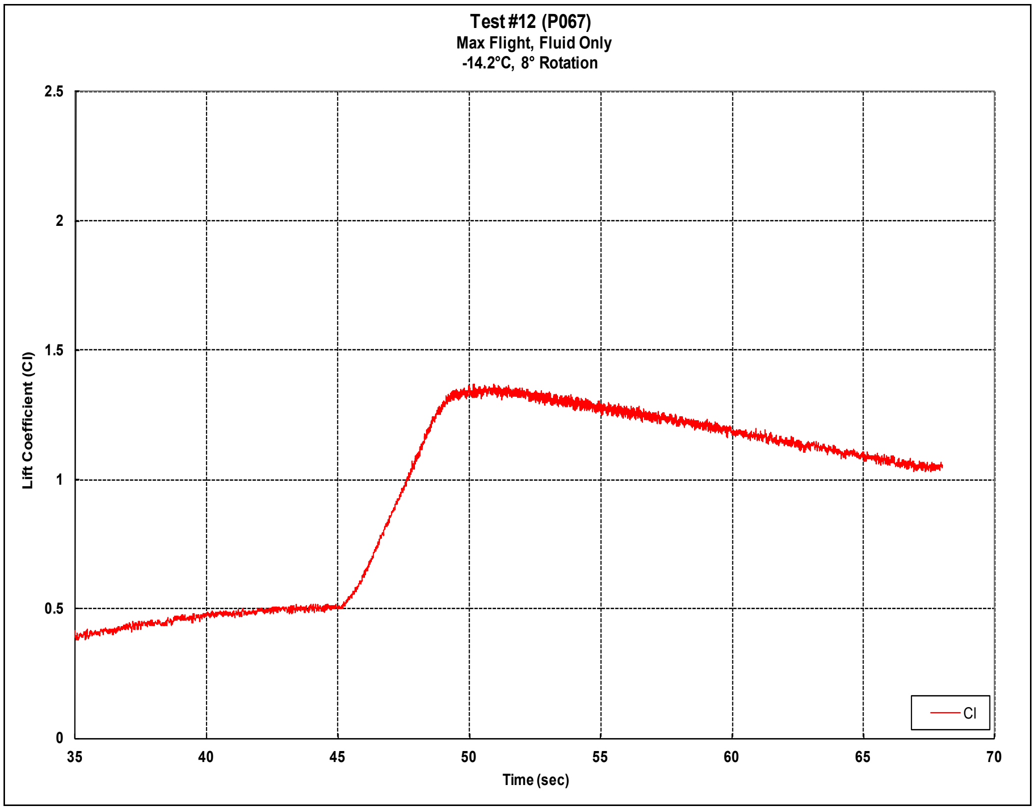


Figure D5: Run #12

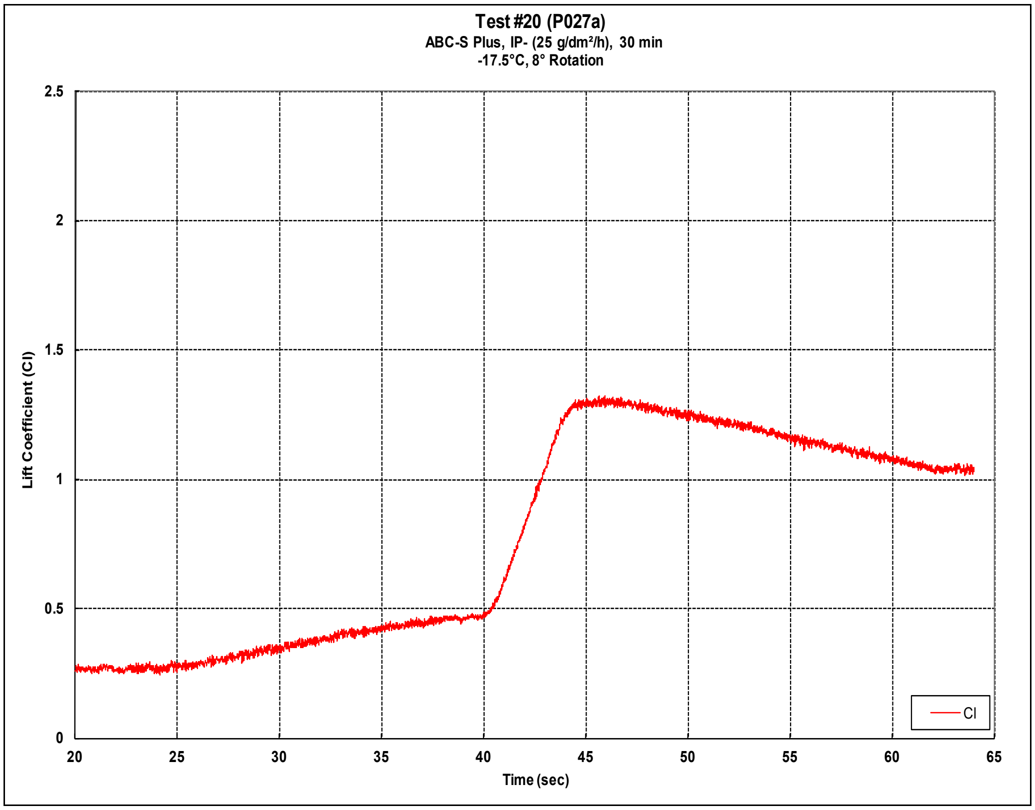


Figure D6: Run #20

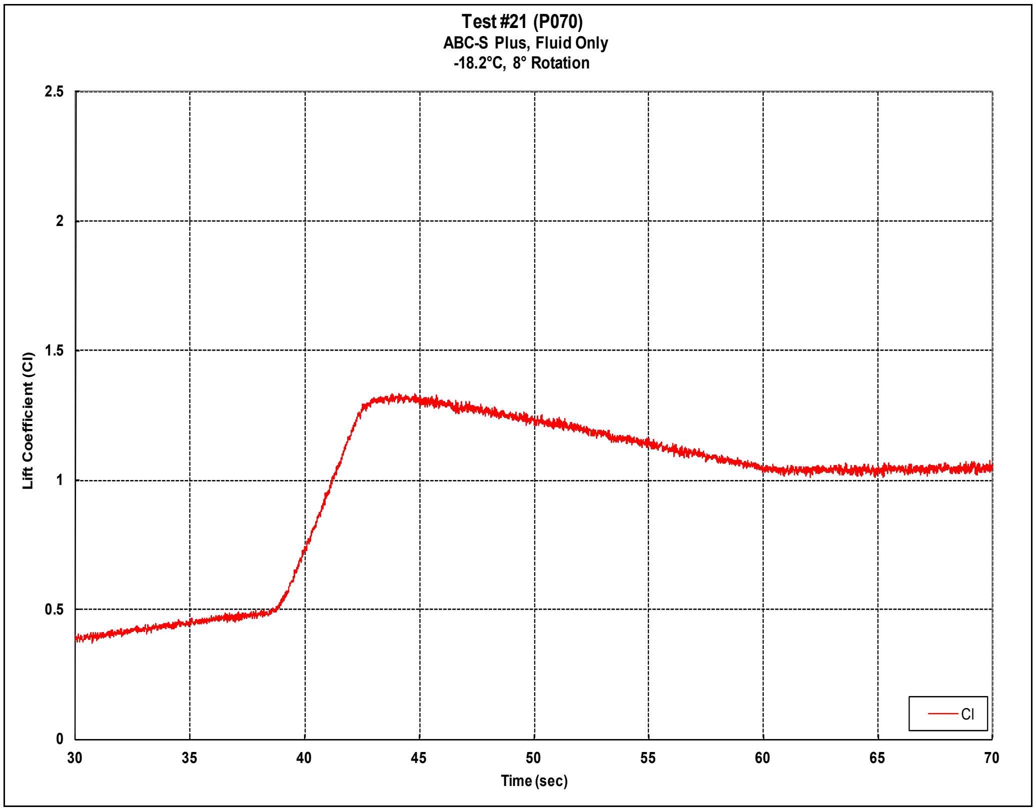


Figure D7: Run #21

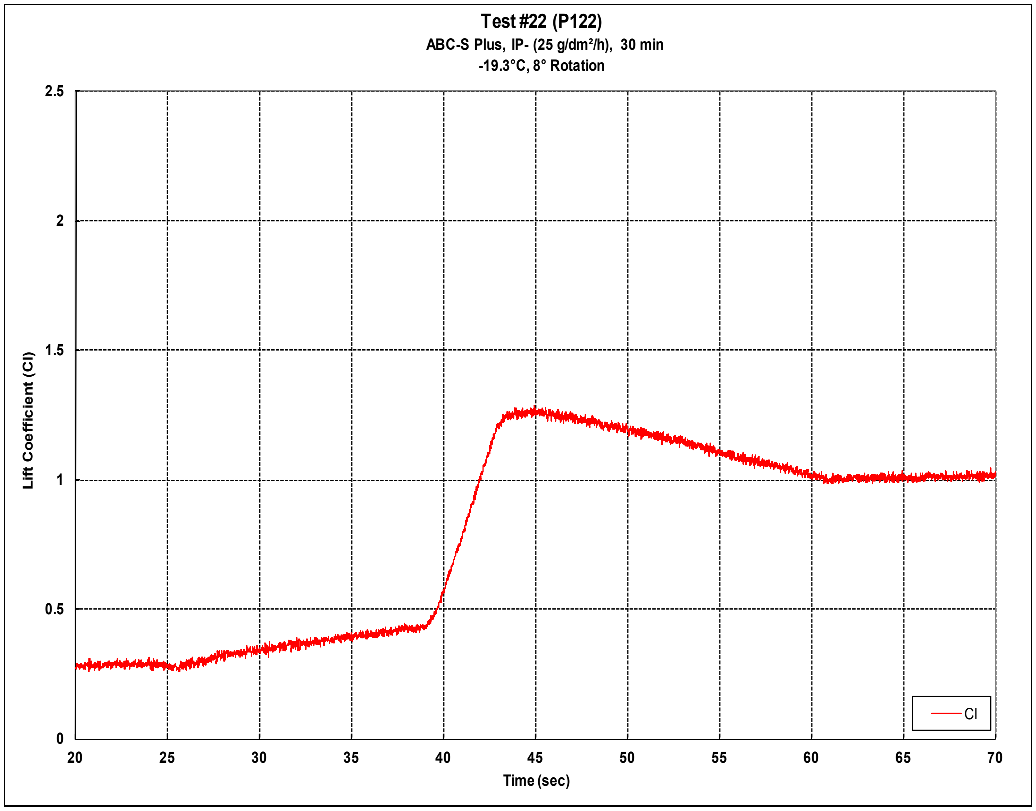


Figure D8: Run #22

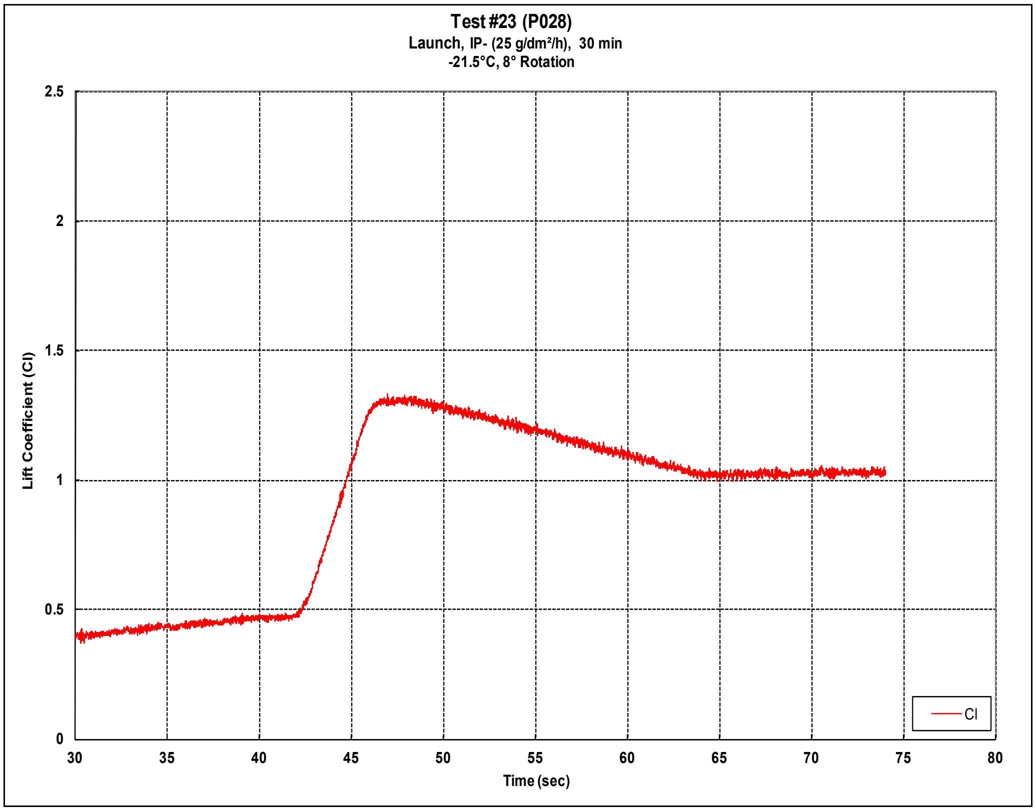


Figure D9: Run #23

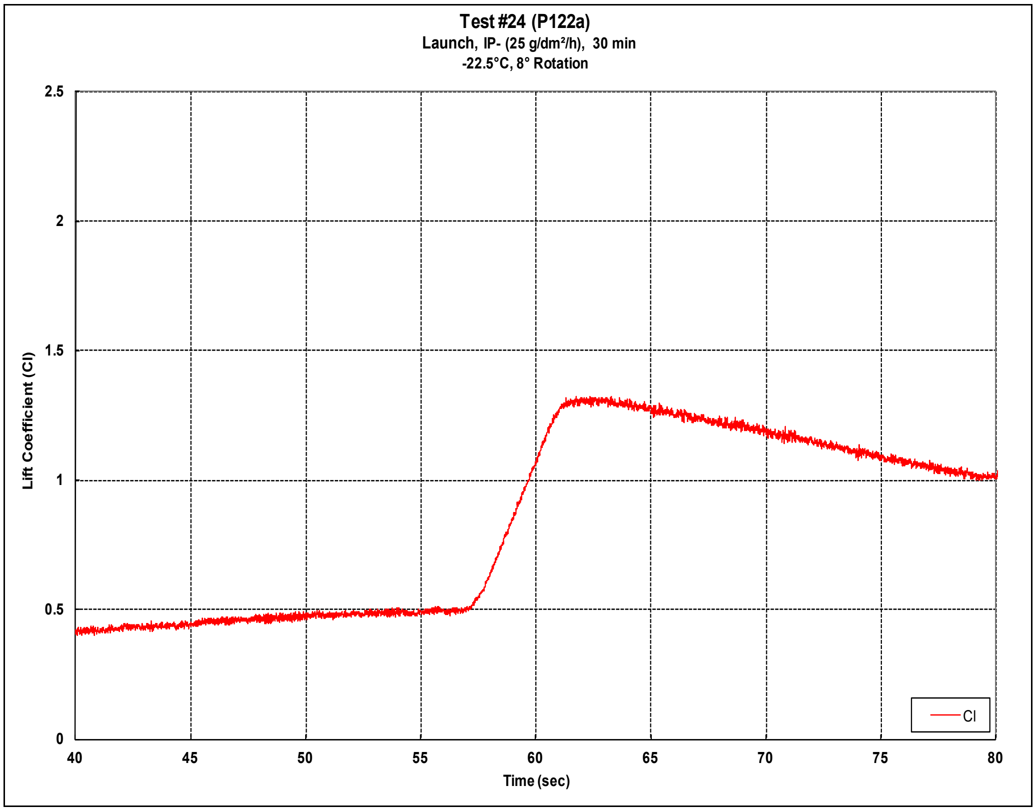


Figure D10: Run #24

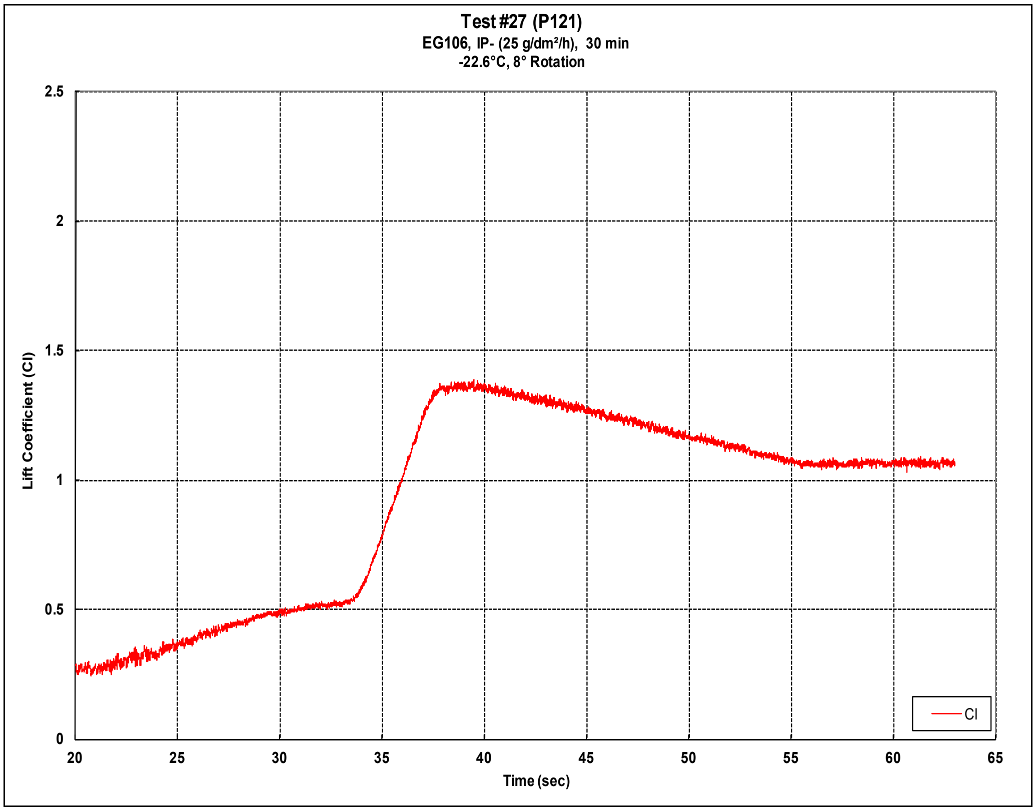


Figure D11: Run #27

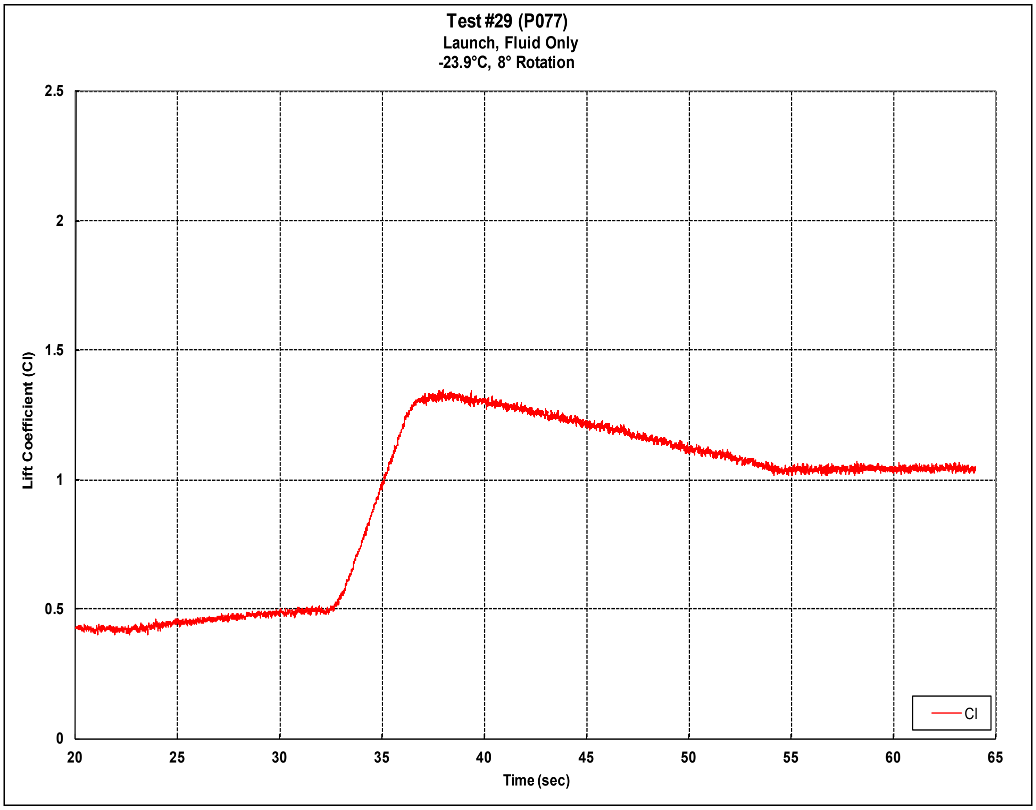


Figure D12: Run#29

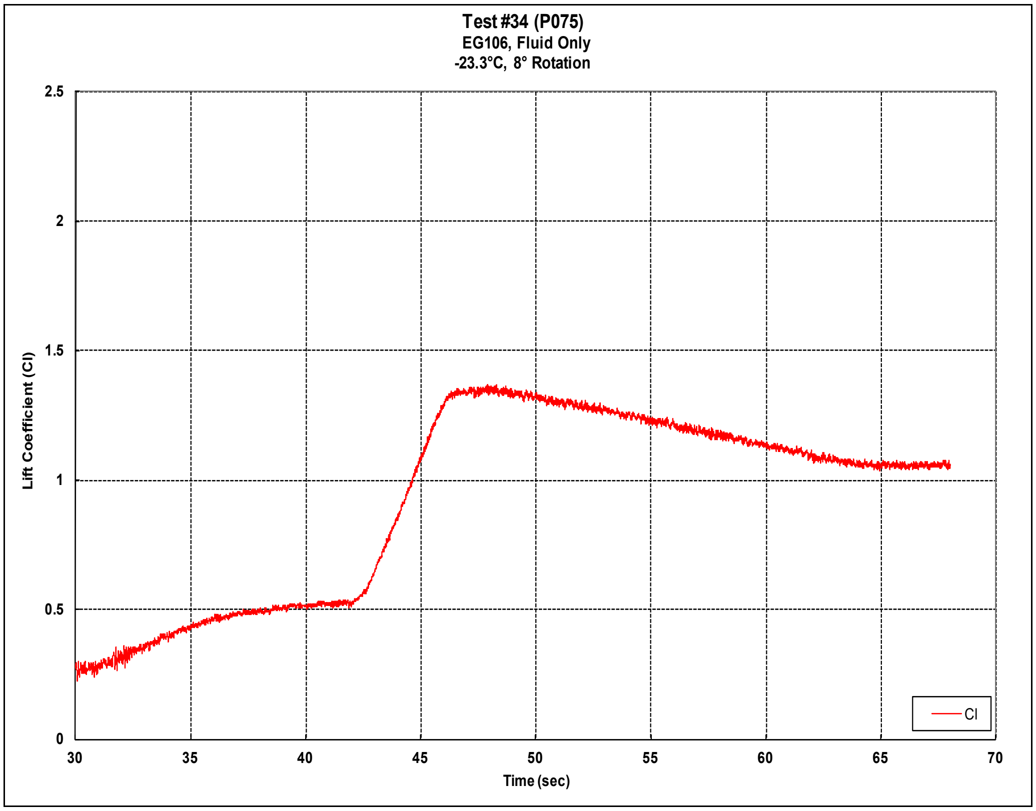


Figure D13: Run #34

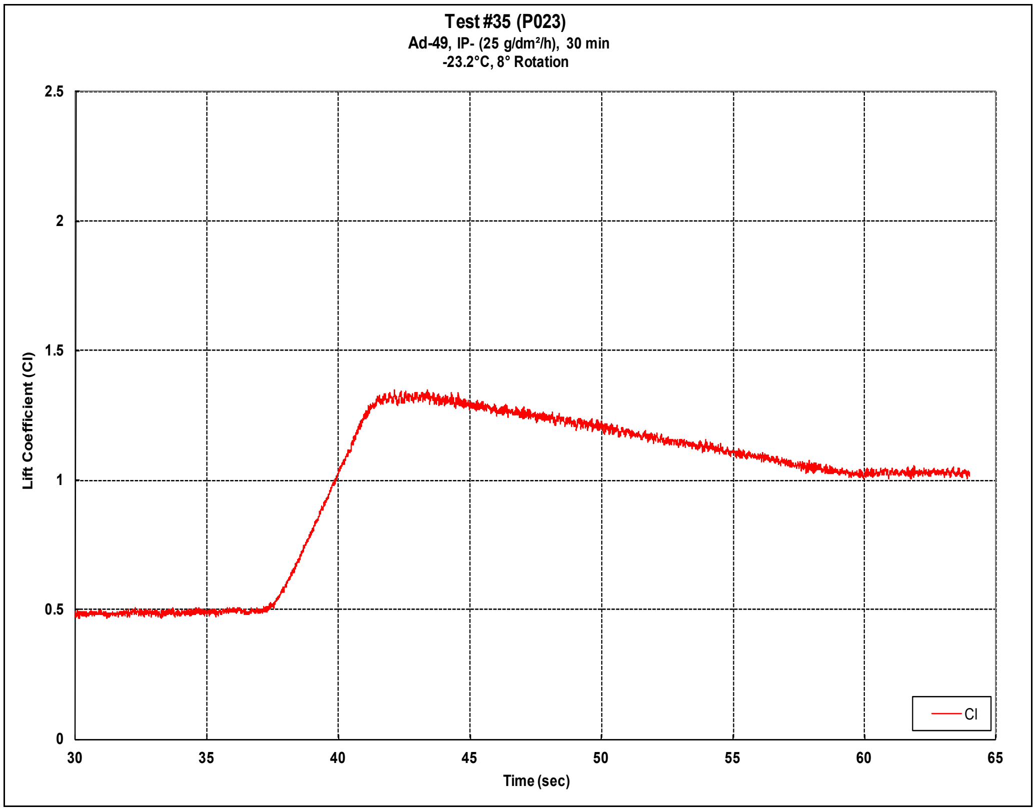


Figure D14: Run #35

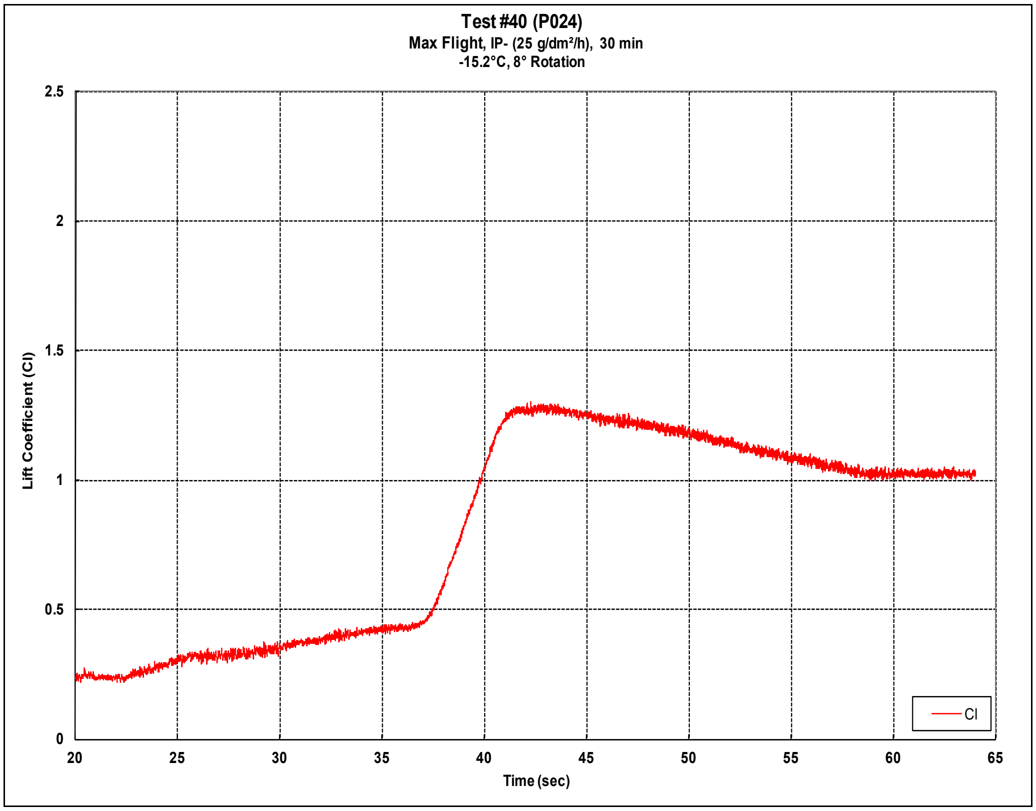


Figure D15: Run #40

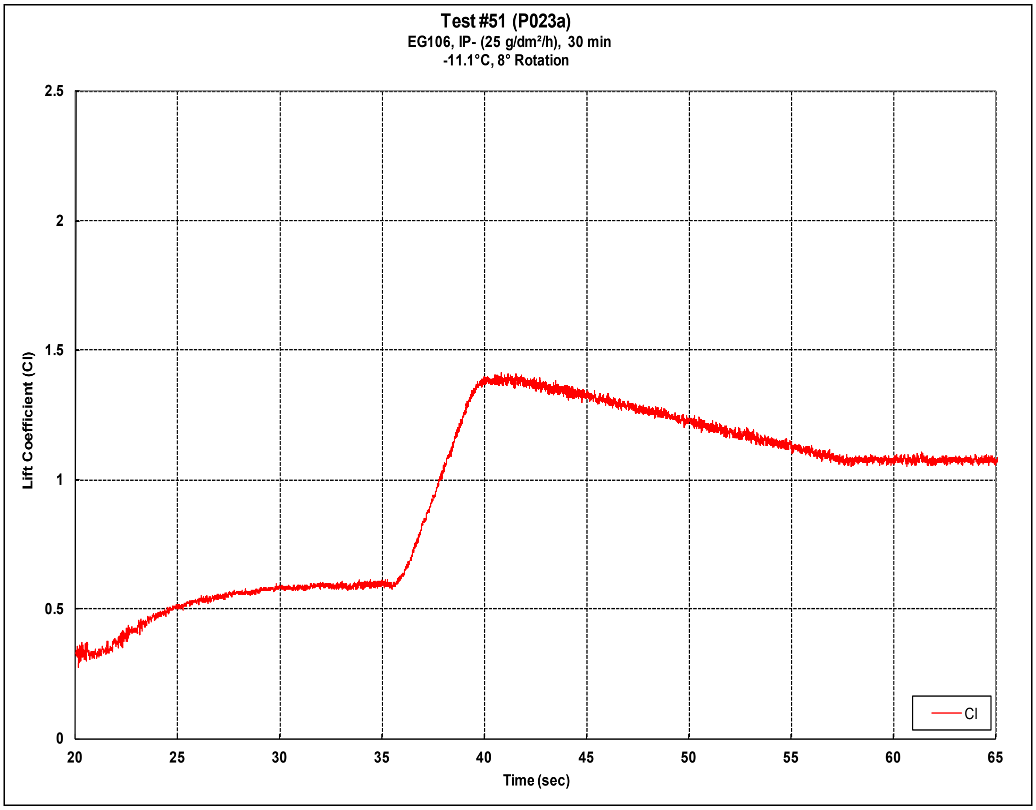


Figure D16: Run #51

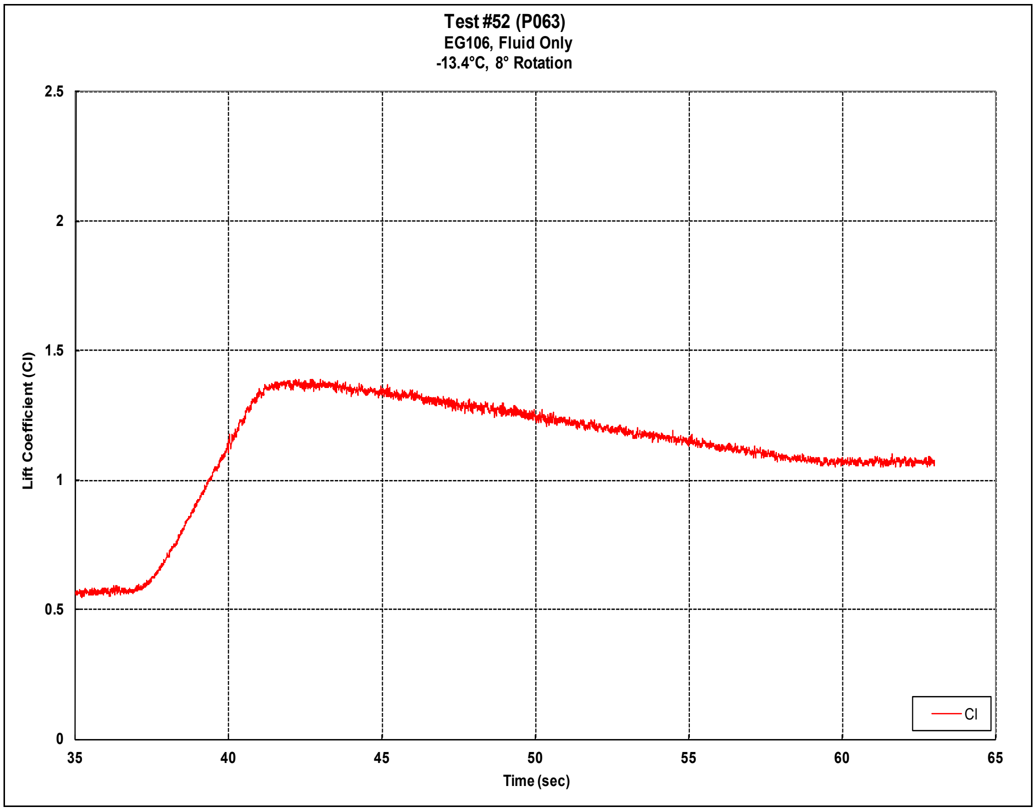


Figure D17: Run #52

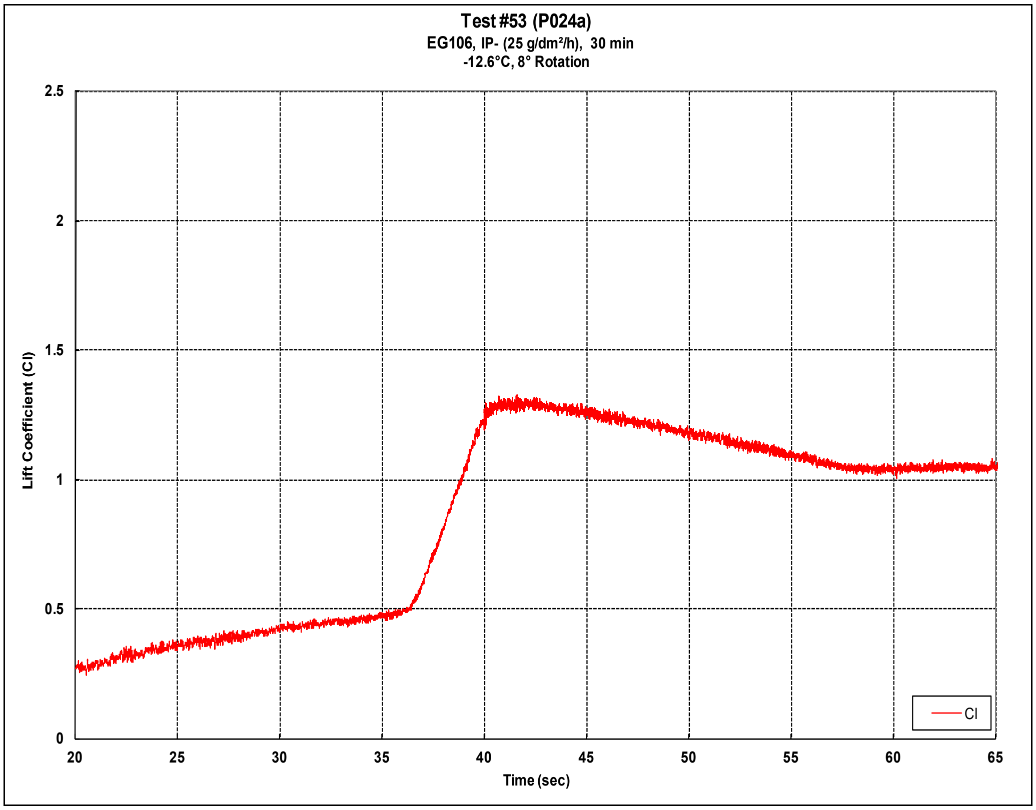


Figure D18: Run #53

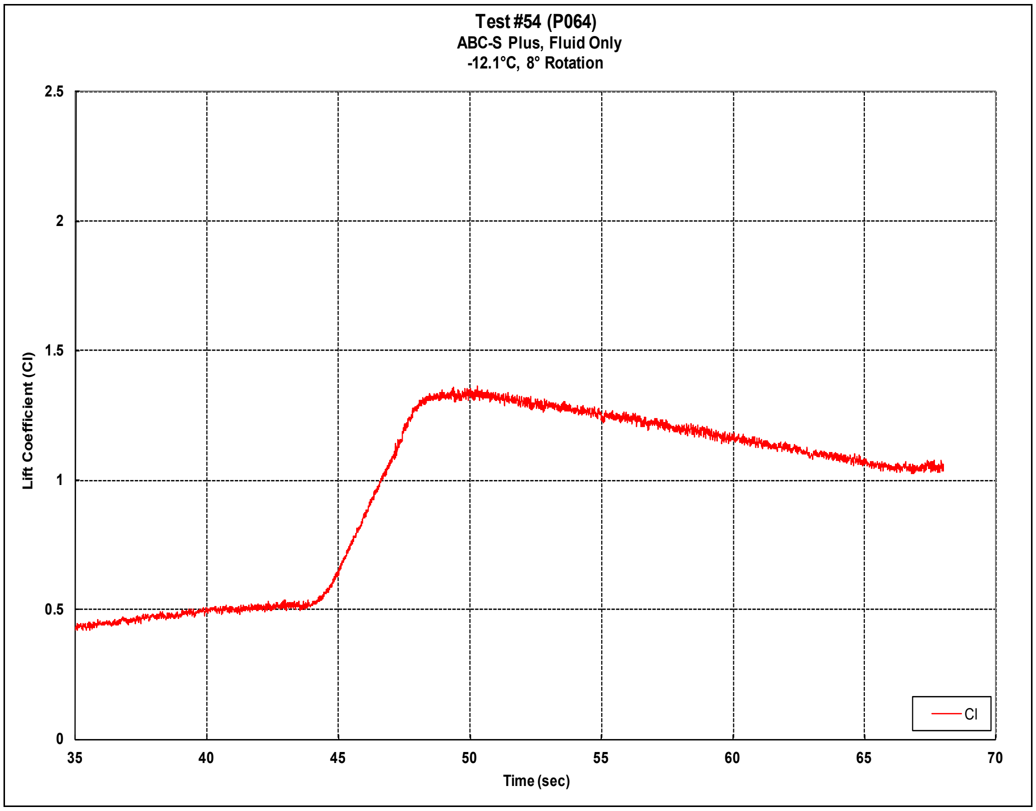


Figure D19: Run #54

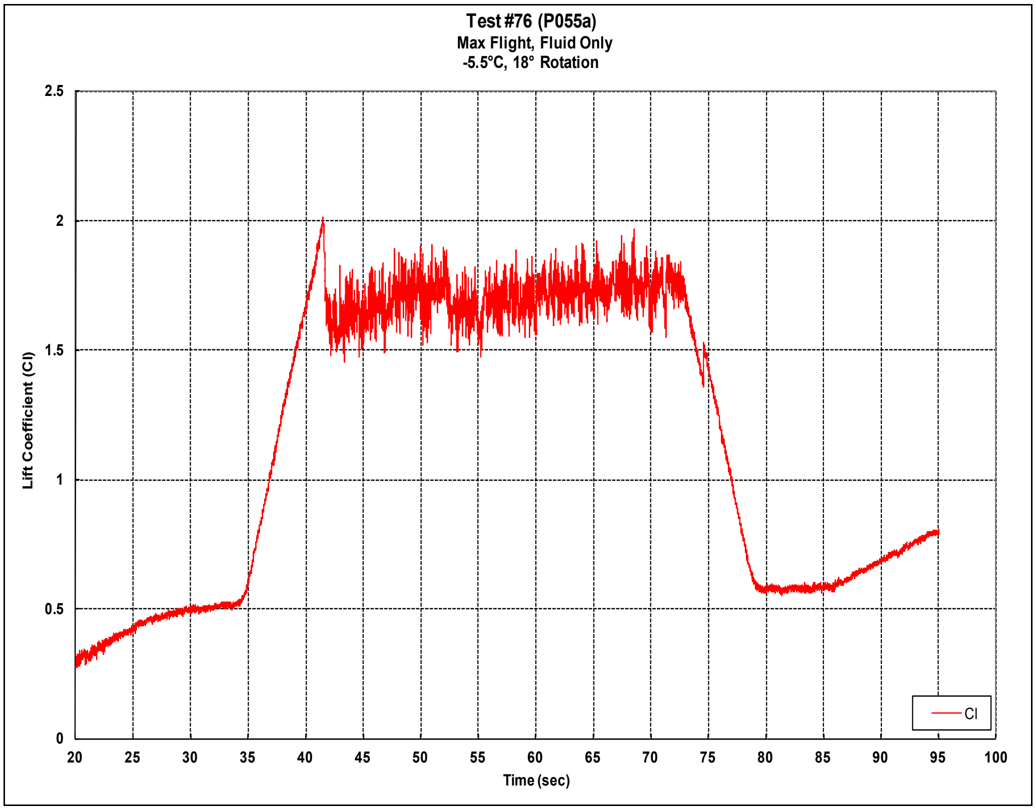


Figure D20: Run #76

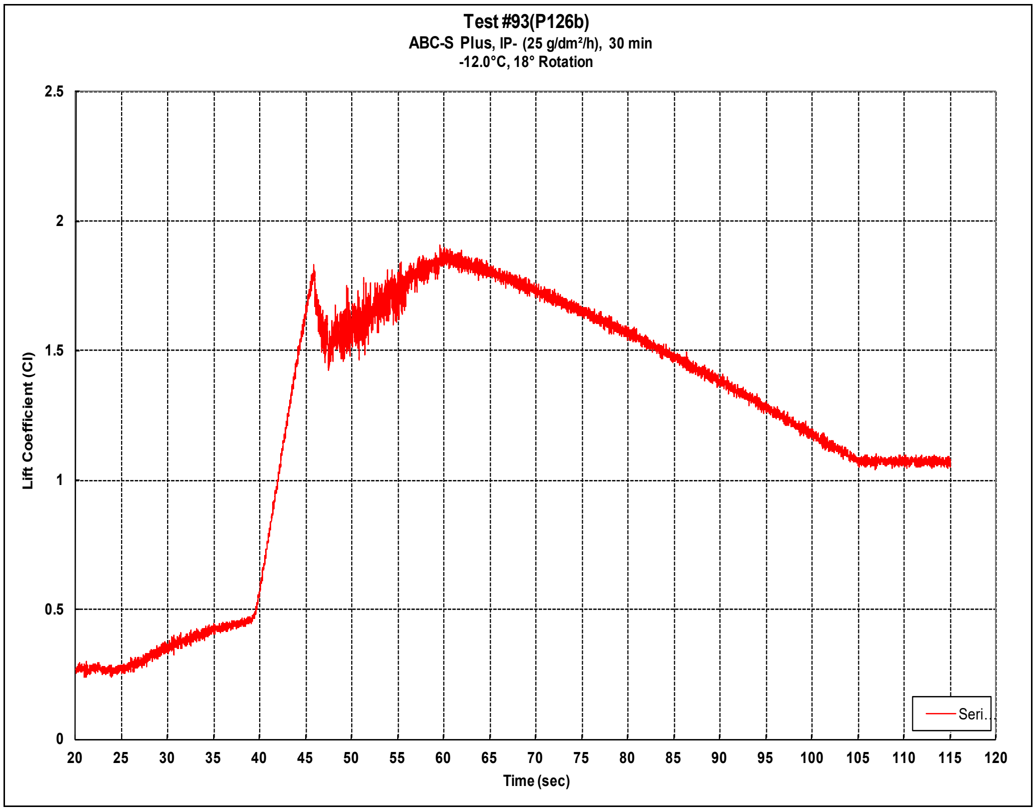


Figure D21: Run #93

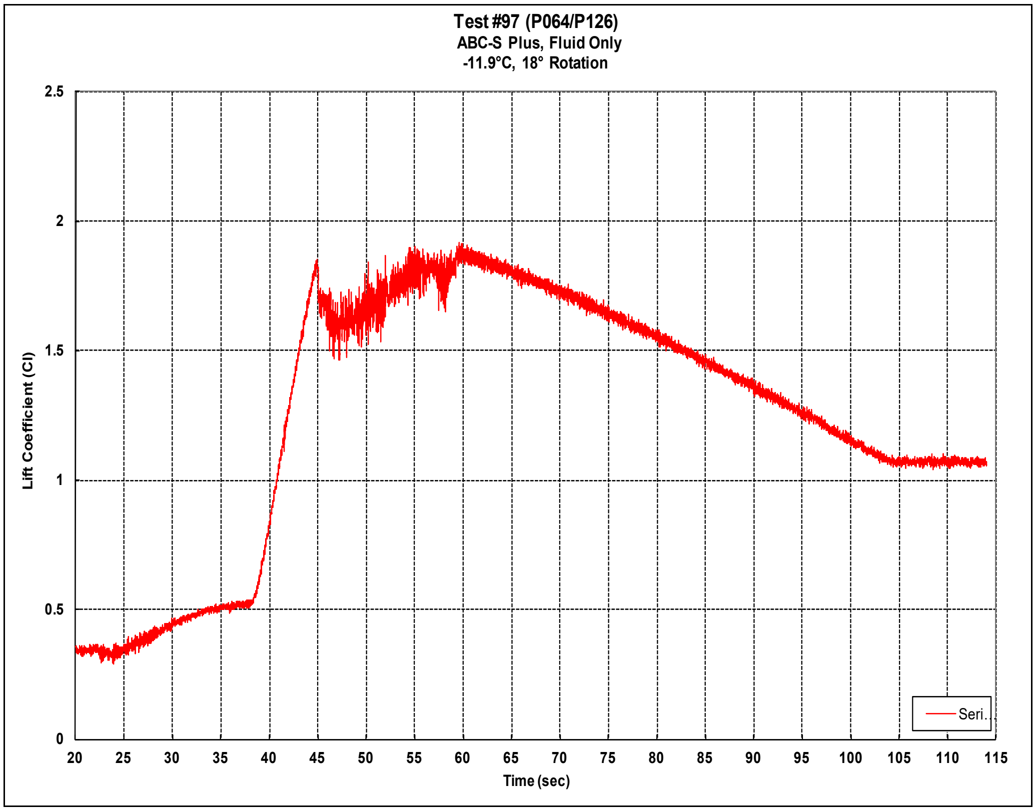


Figure D22: Run # 97

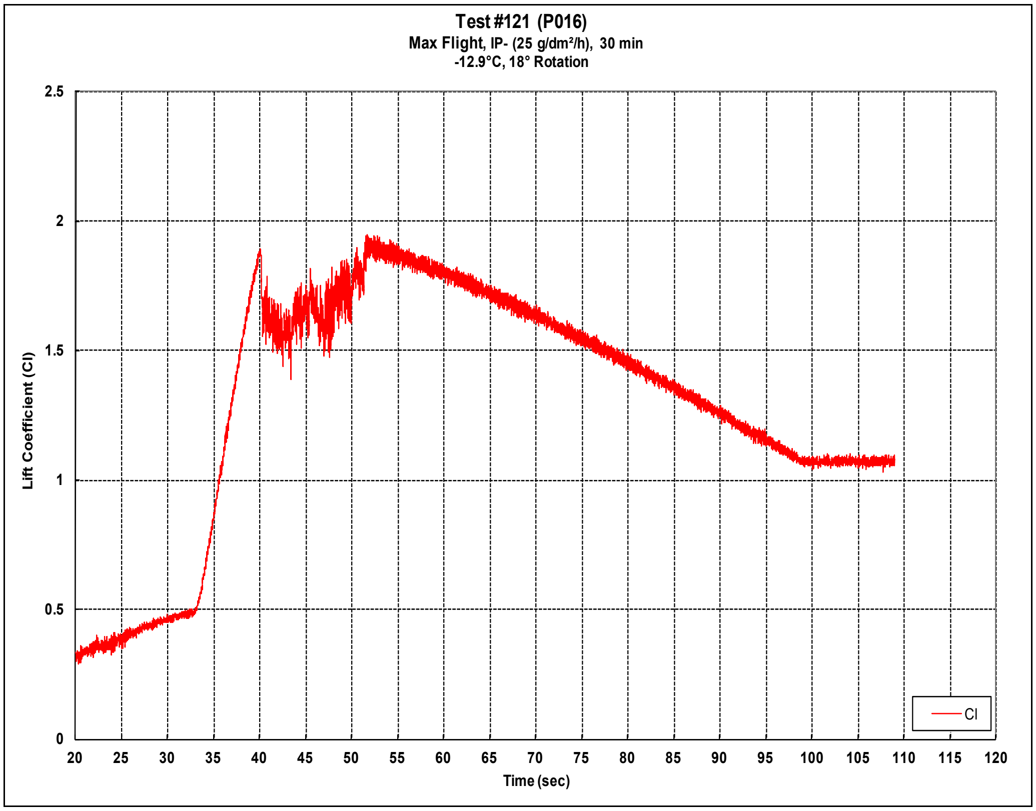


Figure D23: Run # 121

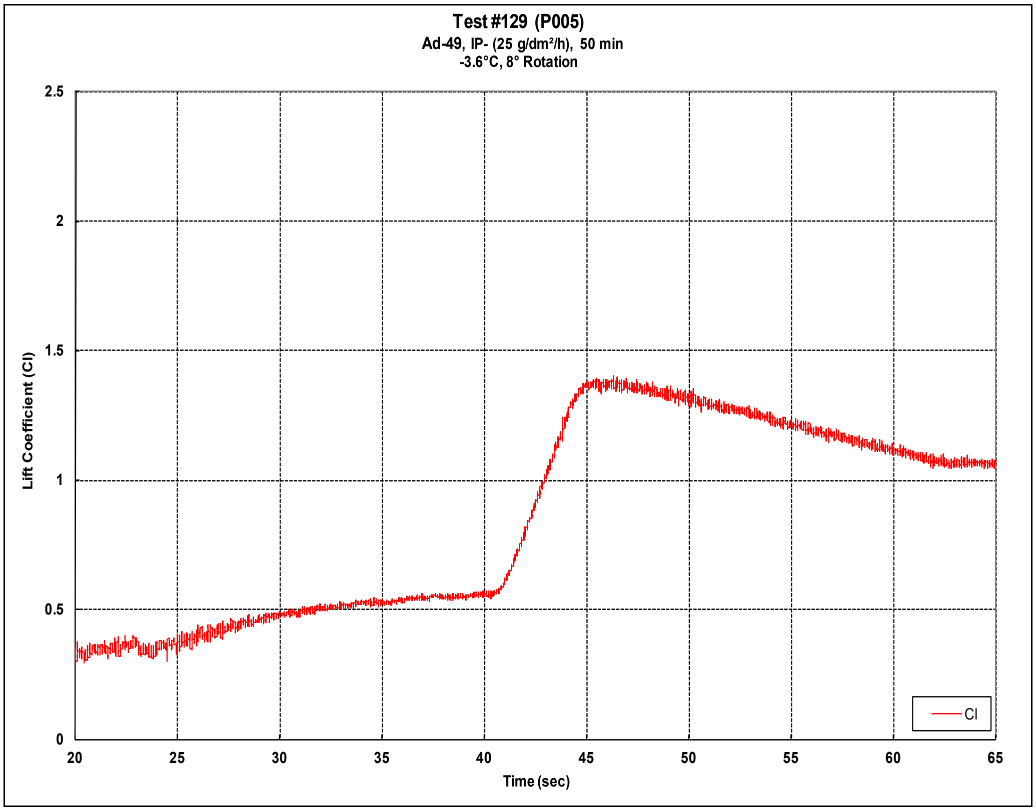


Figure D24: Run #129

MODERATE ICE PELLETS

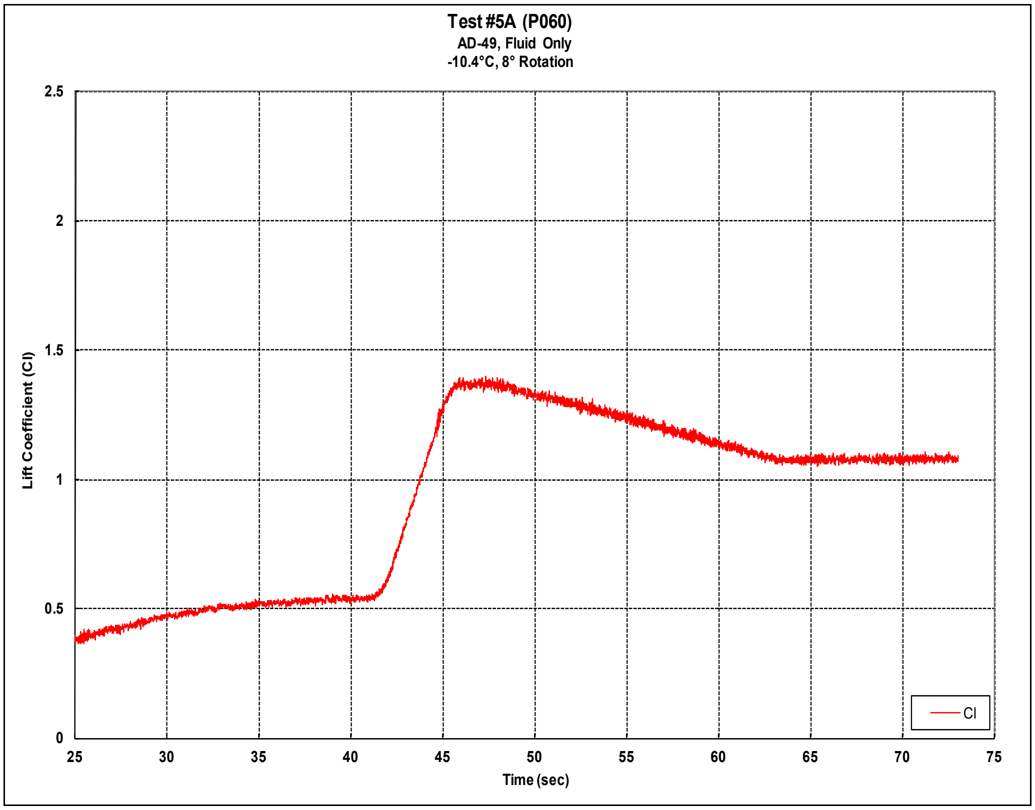


Figure D25: Run #5A

Run 7: No Data Available

Figure D26: Run #7

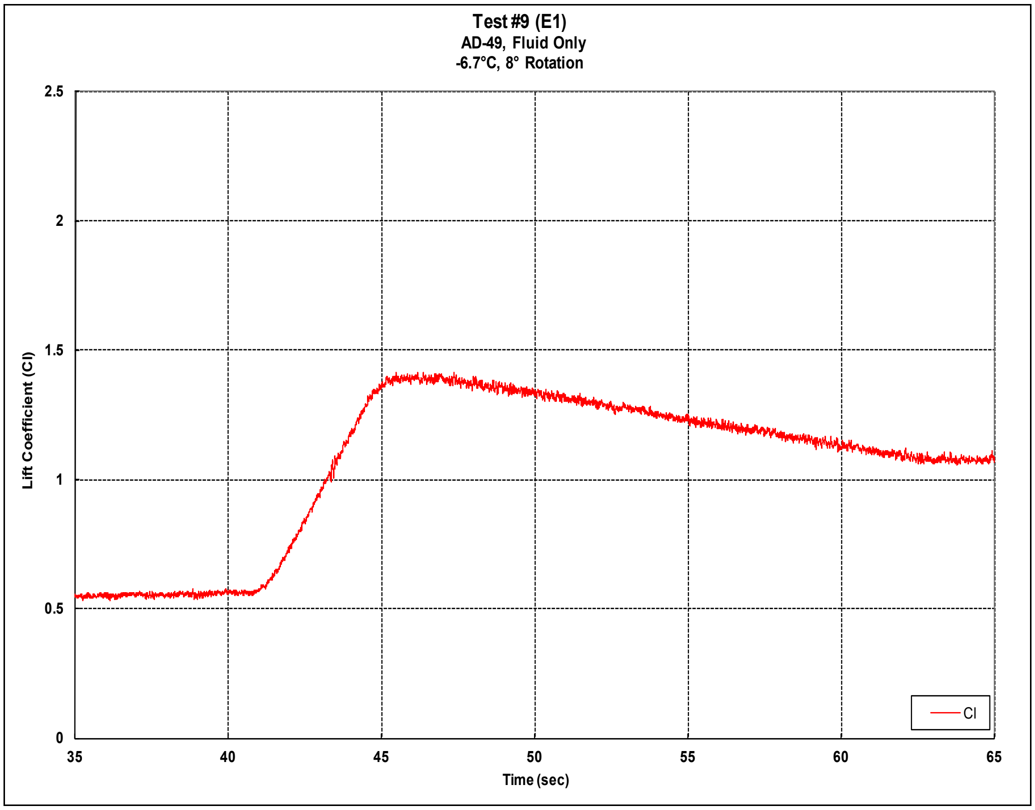


Figure D27: Run #9

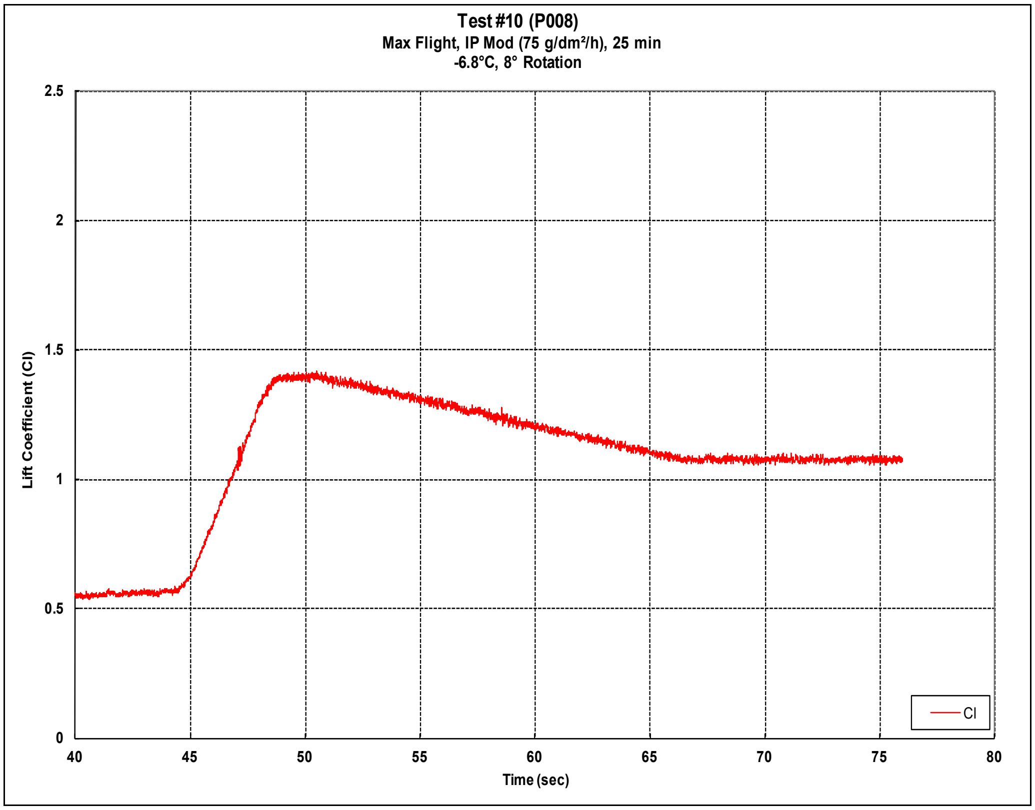


Figure D28: Run #10

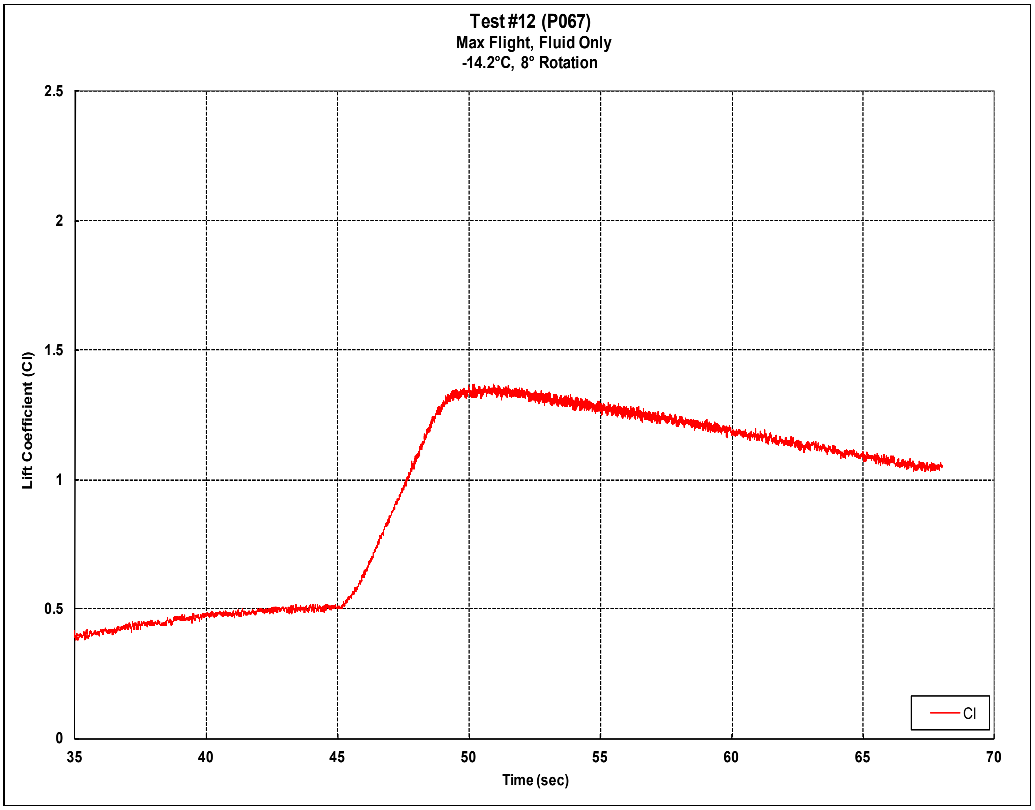


Figure D29: Run #12

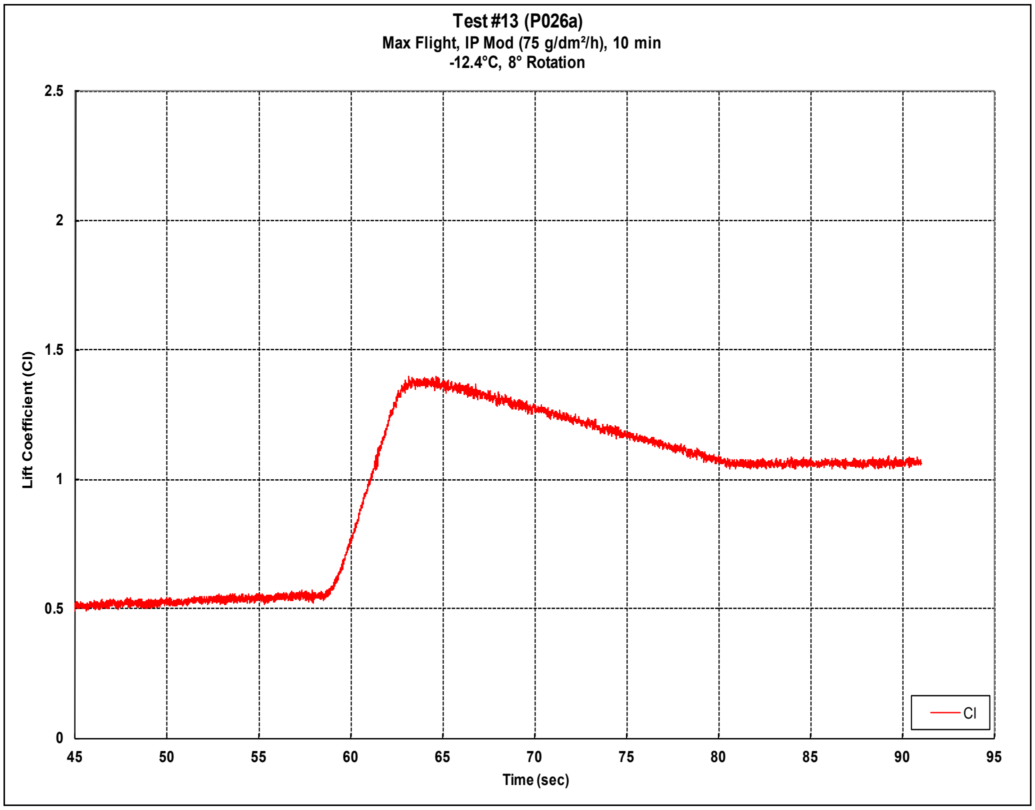


Figure D30: Run #13

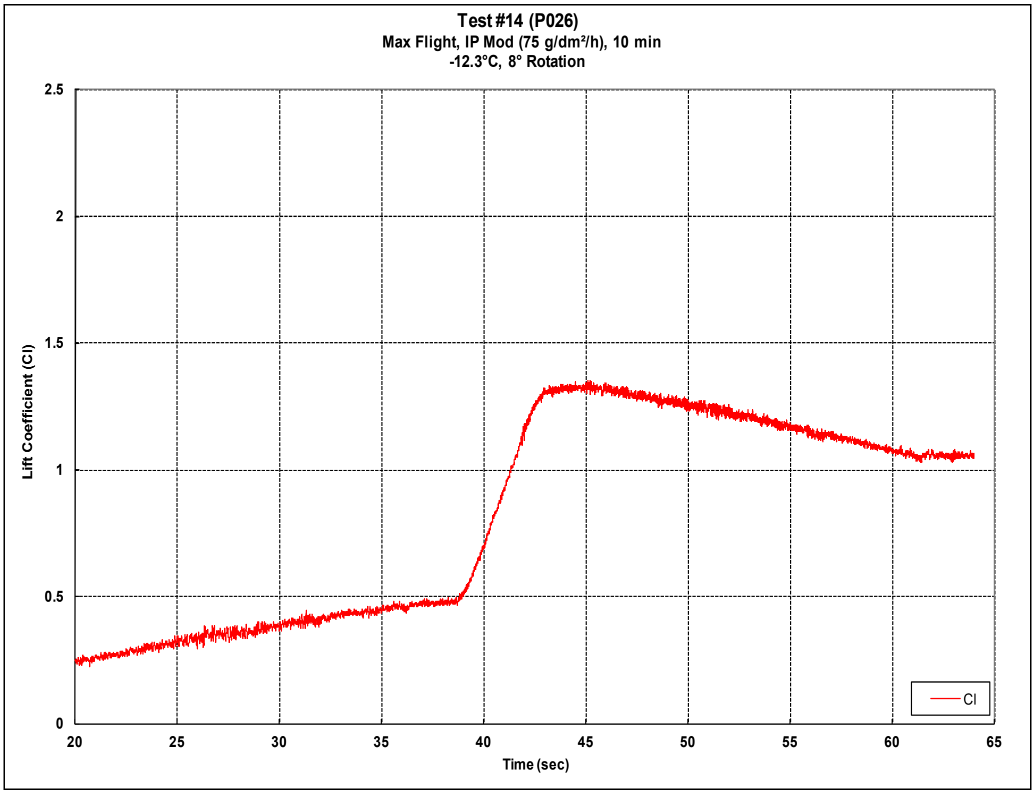


Figure D31: Run #14

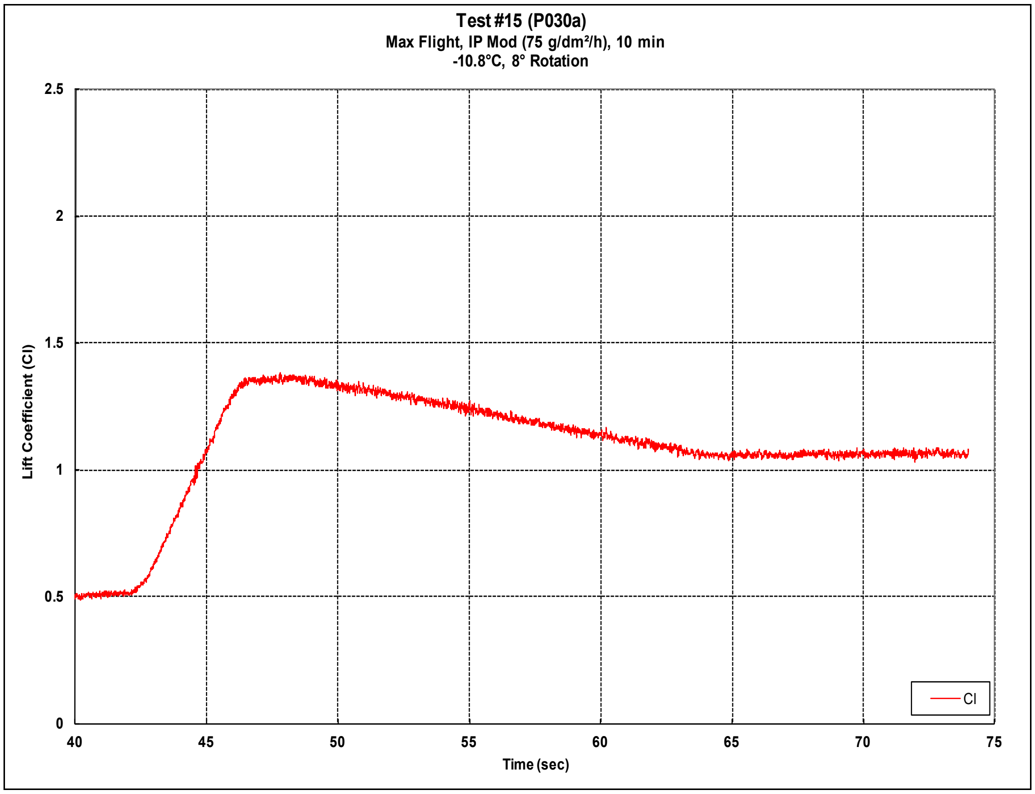


Figure D32: Run #15

Run 15A: No Data Available

Figure D33: Run #15A

Run 15B: No Data Available

Figure D34: Run #15B

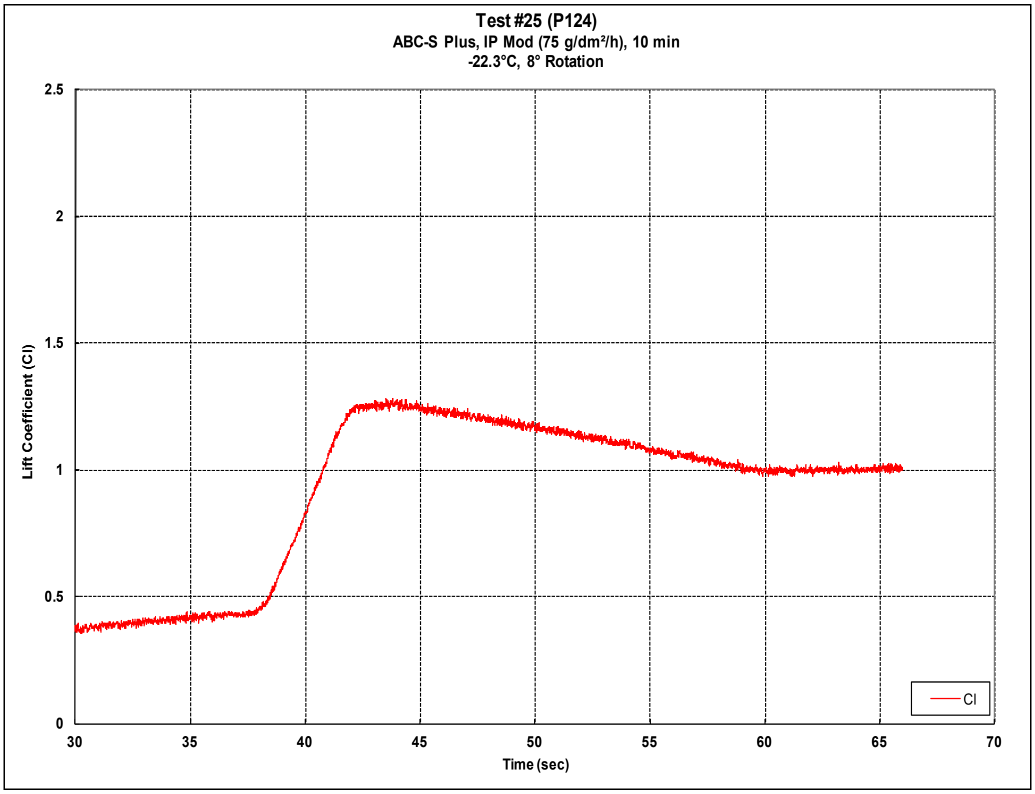


Figure D35: Run #25

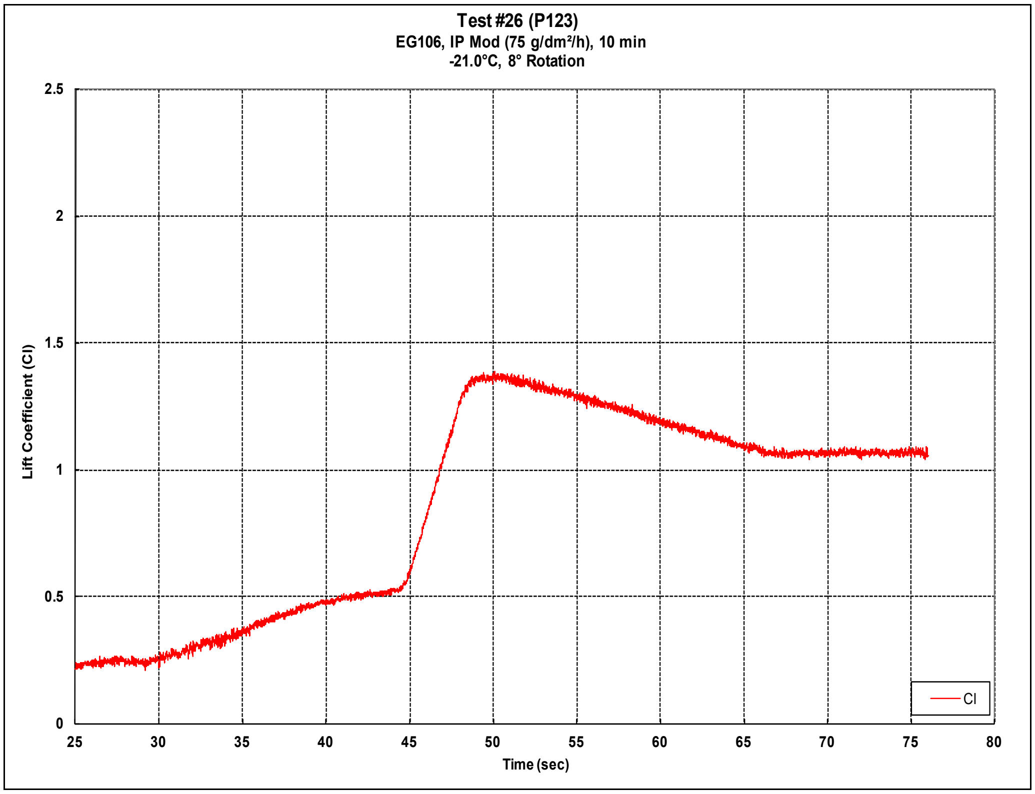


Figure D36: Run #26

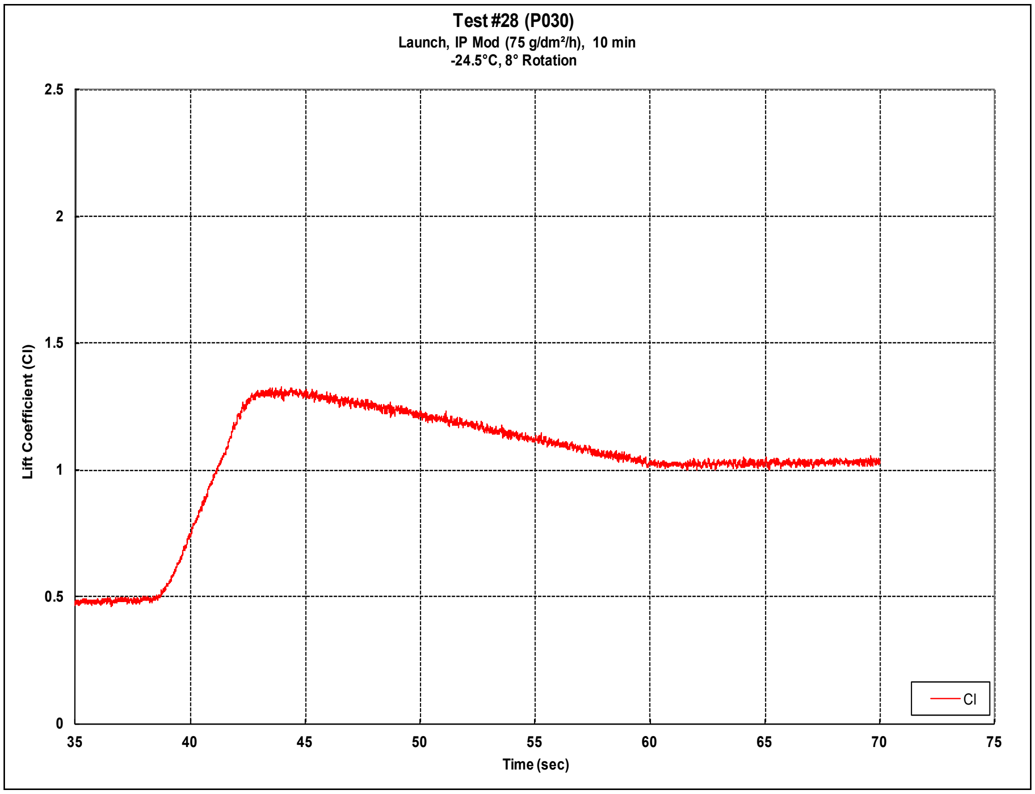


Figure D37: Run #28

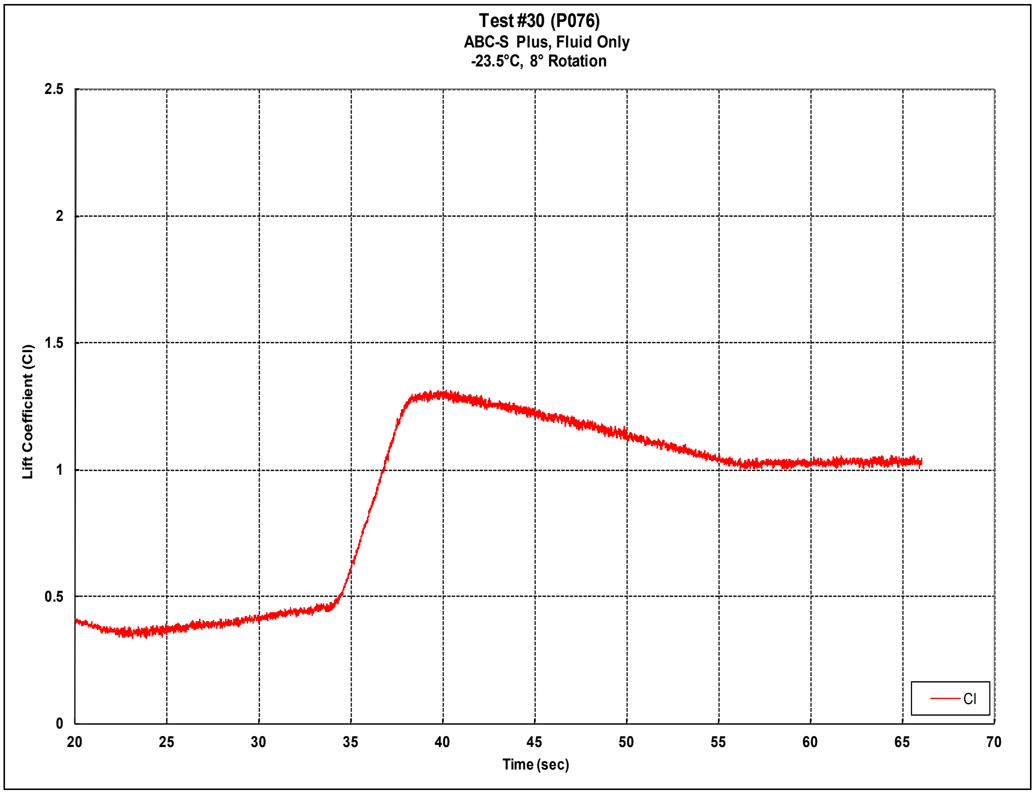


Figure D38: Run #30

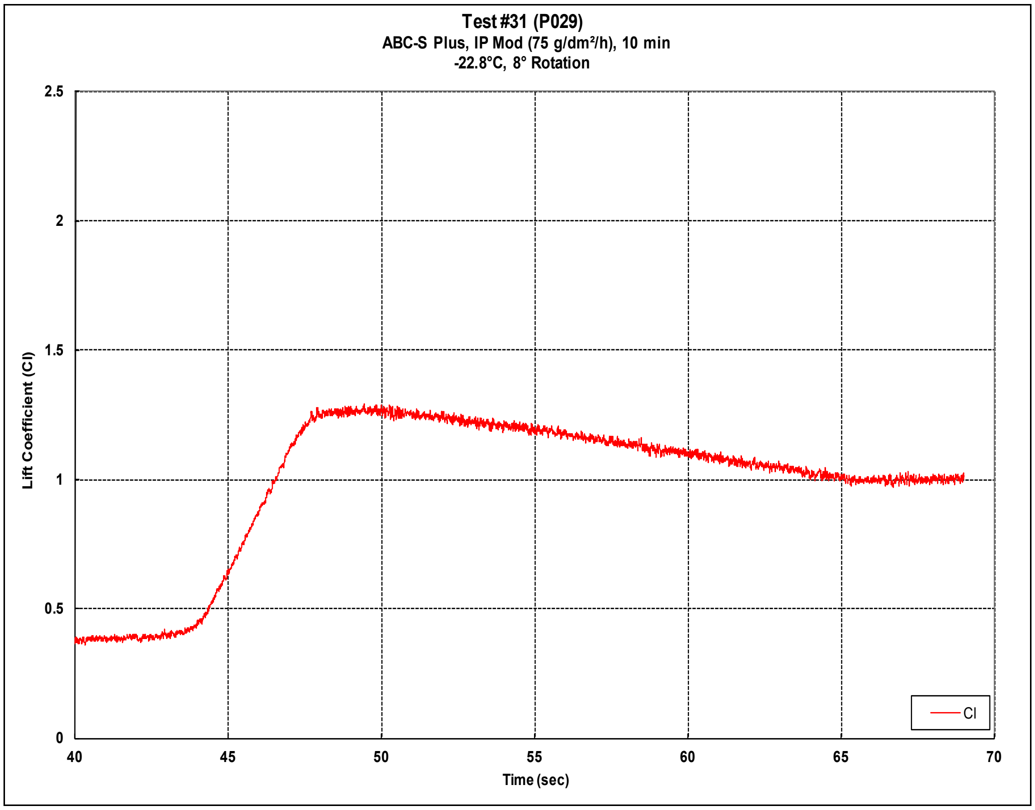


Figure D39: Run #31

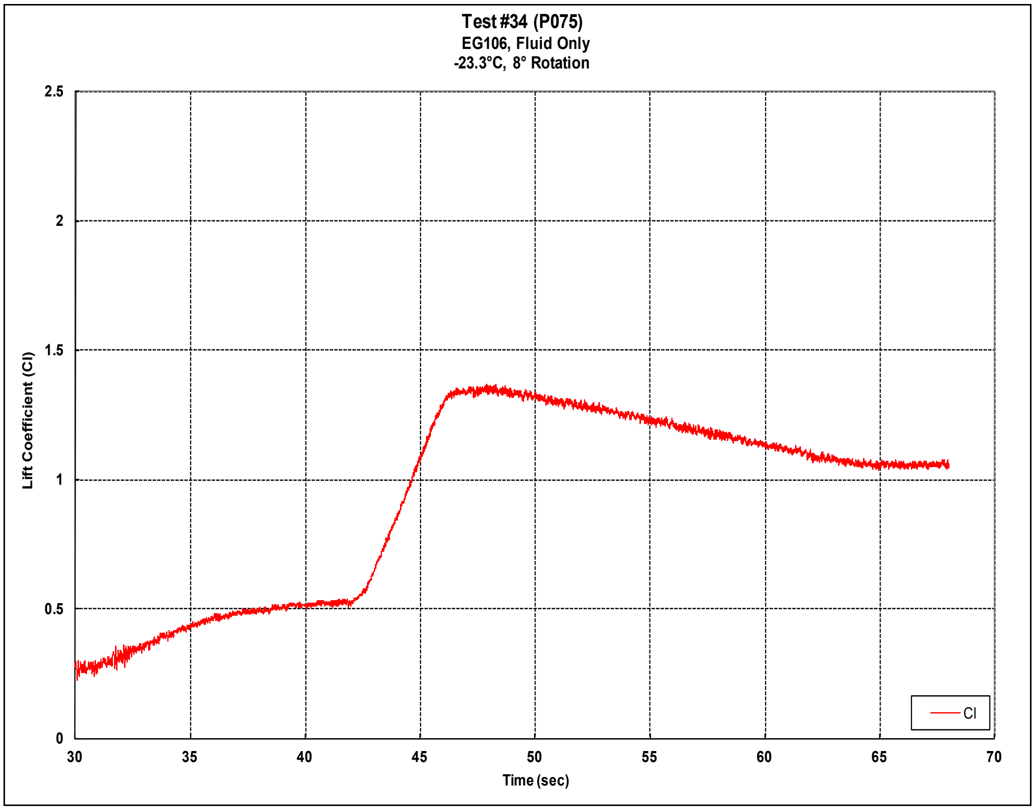


Figure D40: Run # 34

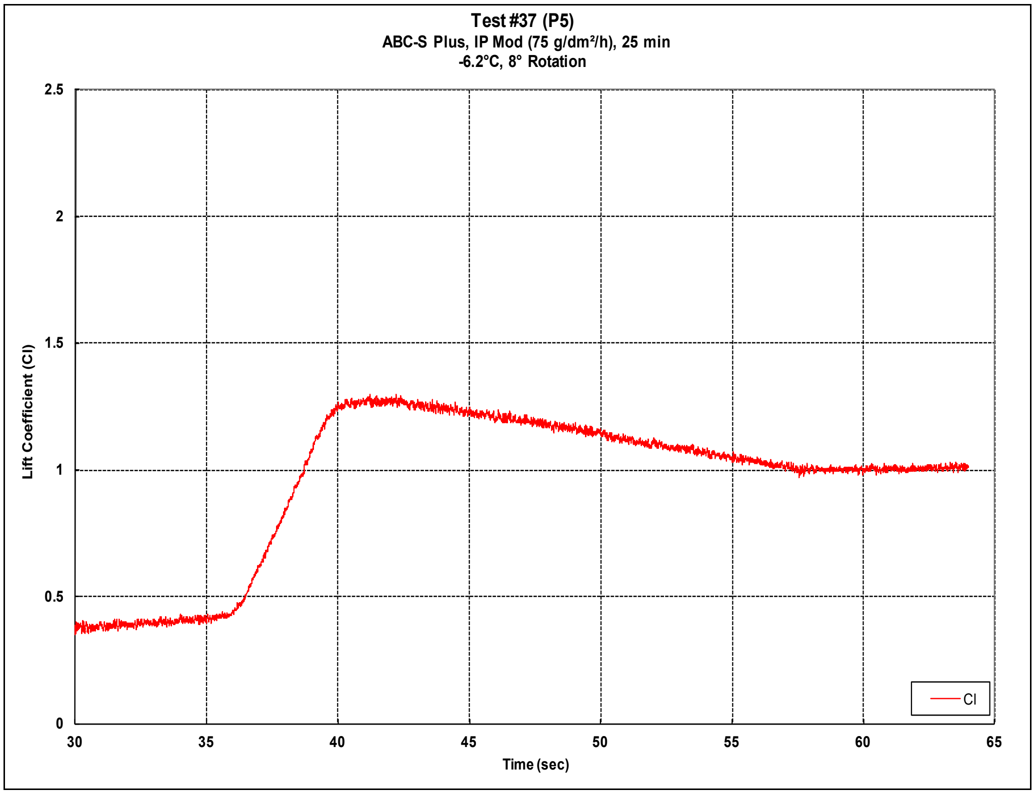


Figure D41: Run #37

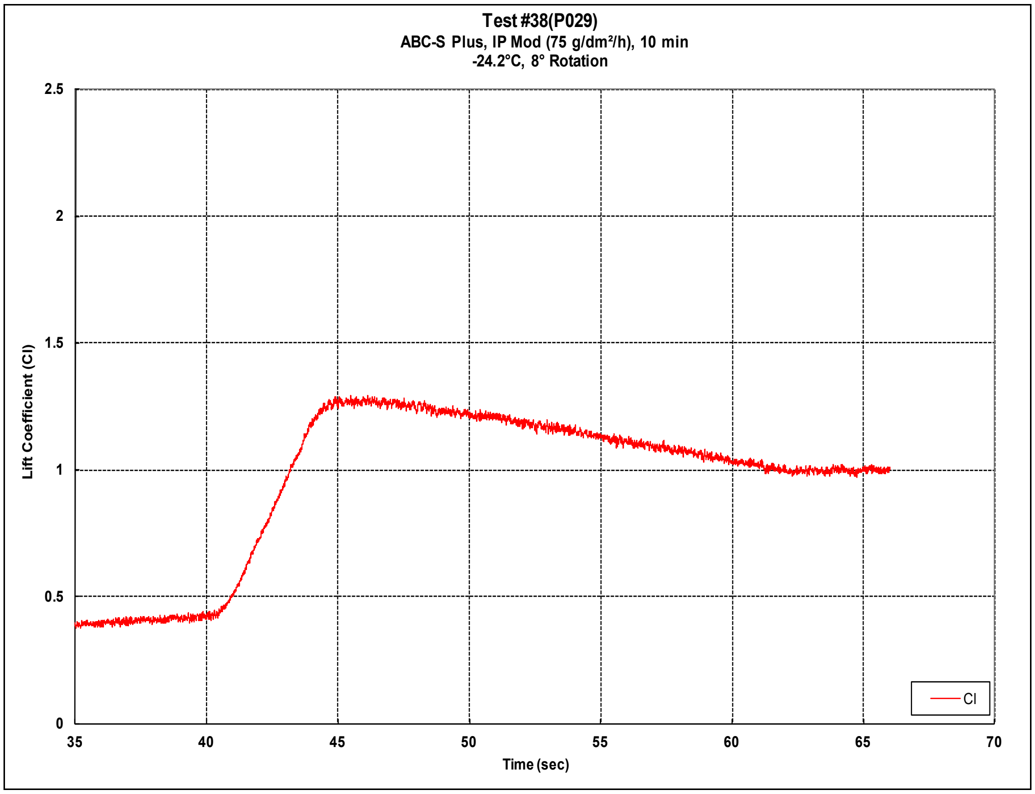


Figure D42: Run #38

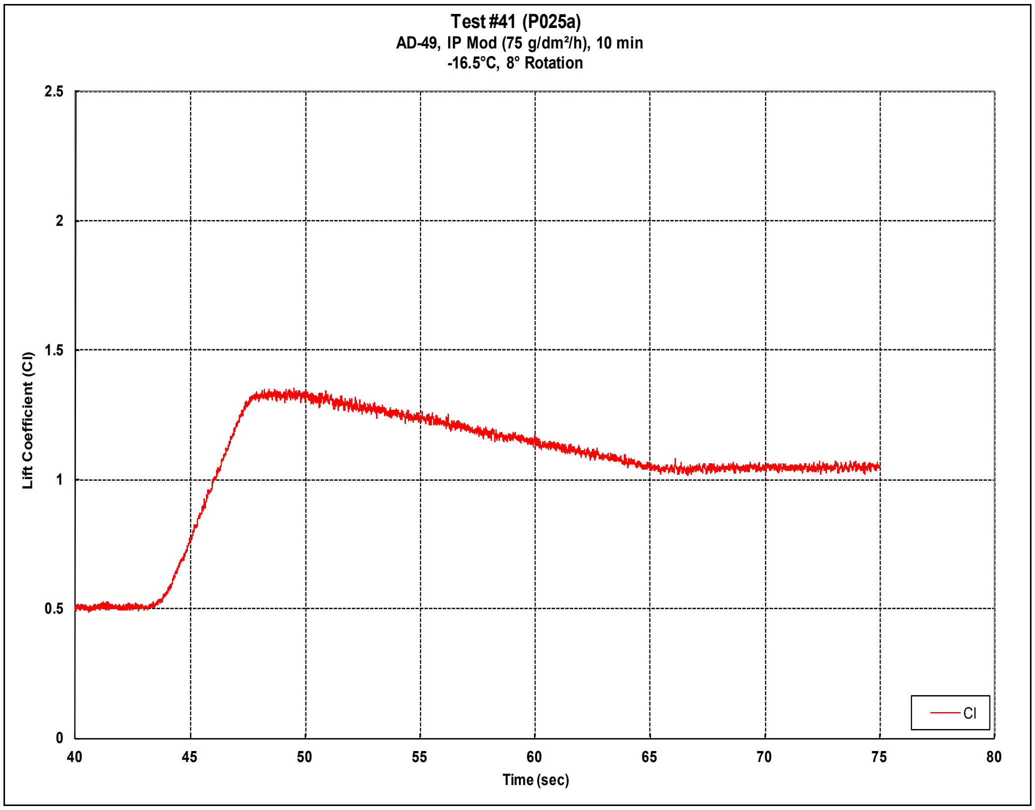


Figure D43: Run #41

Run 41A: No Data Available

Figure D44: Run #41A

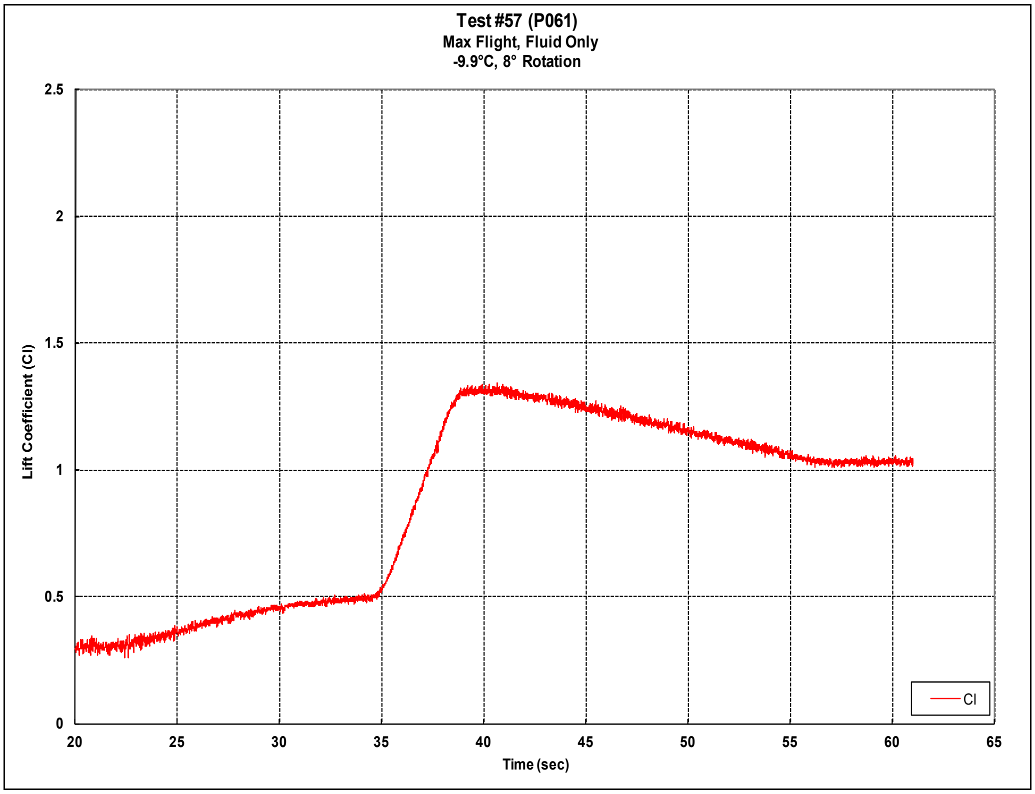


Figure D45: Run #57

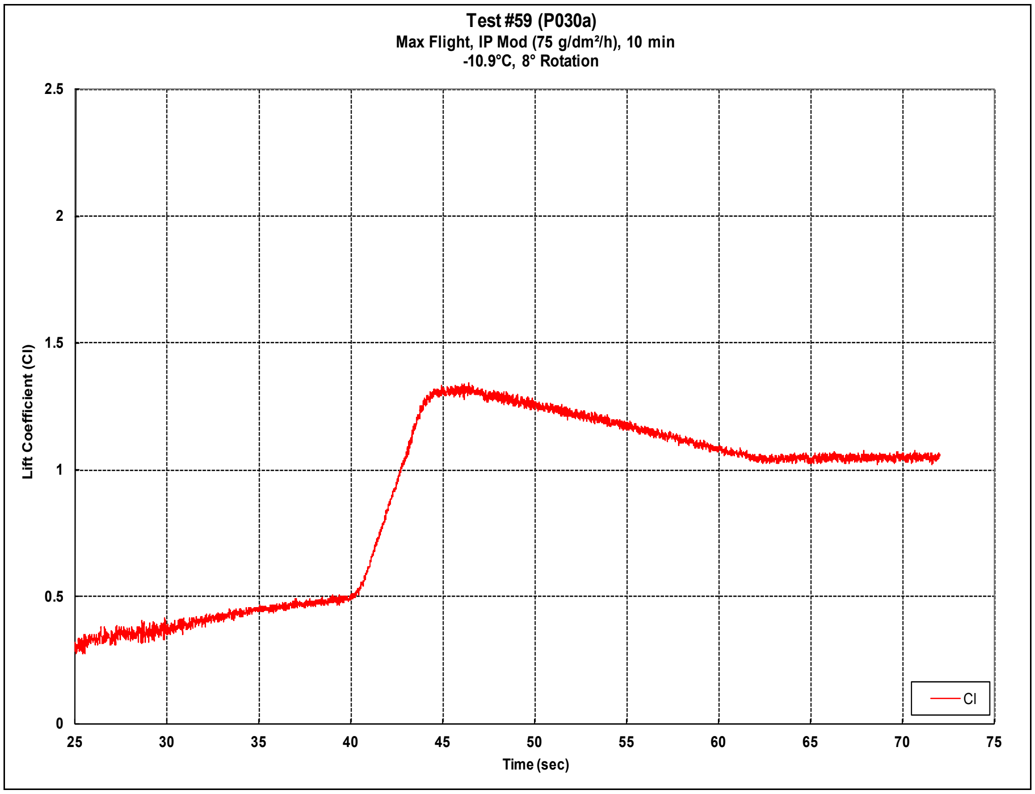


Figure D46: Run #59

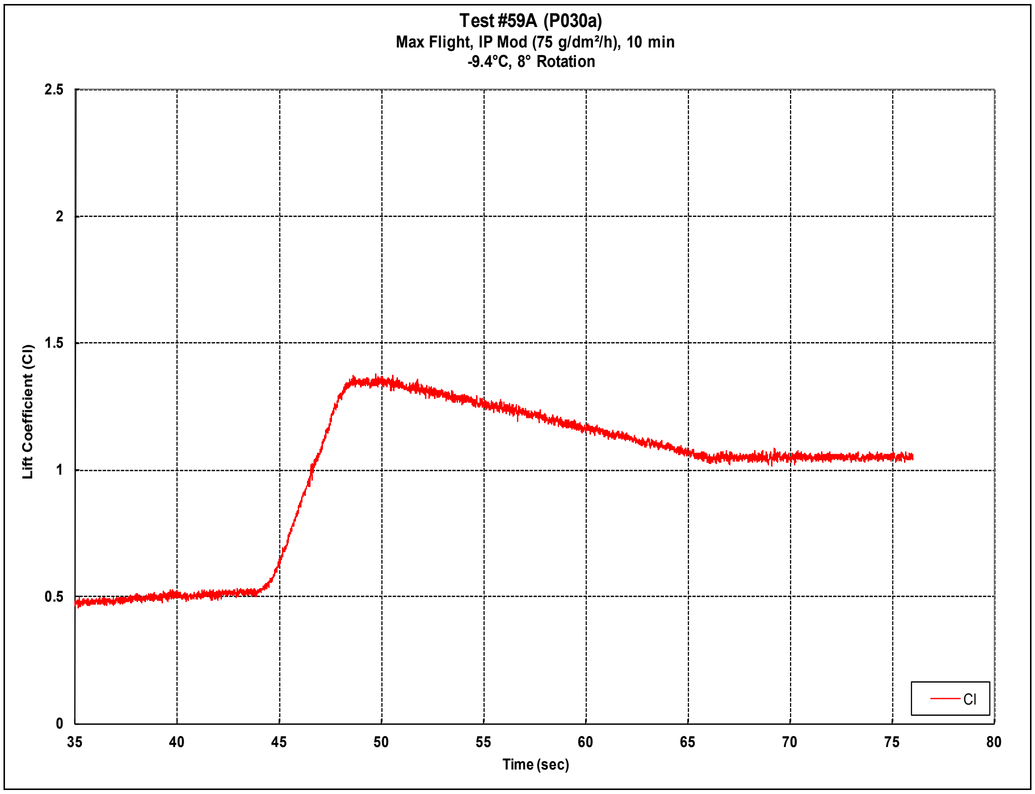


Figure D47: Run #59A

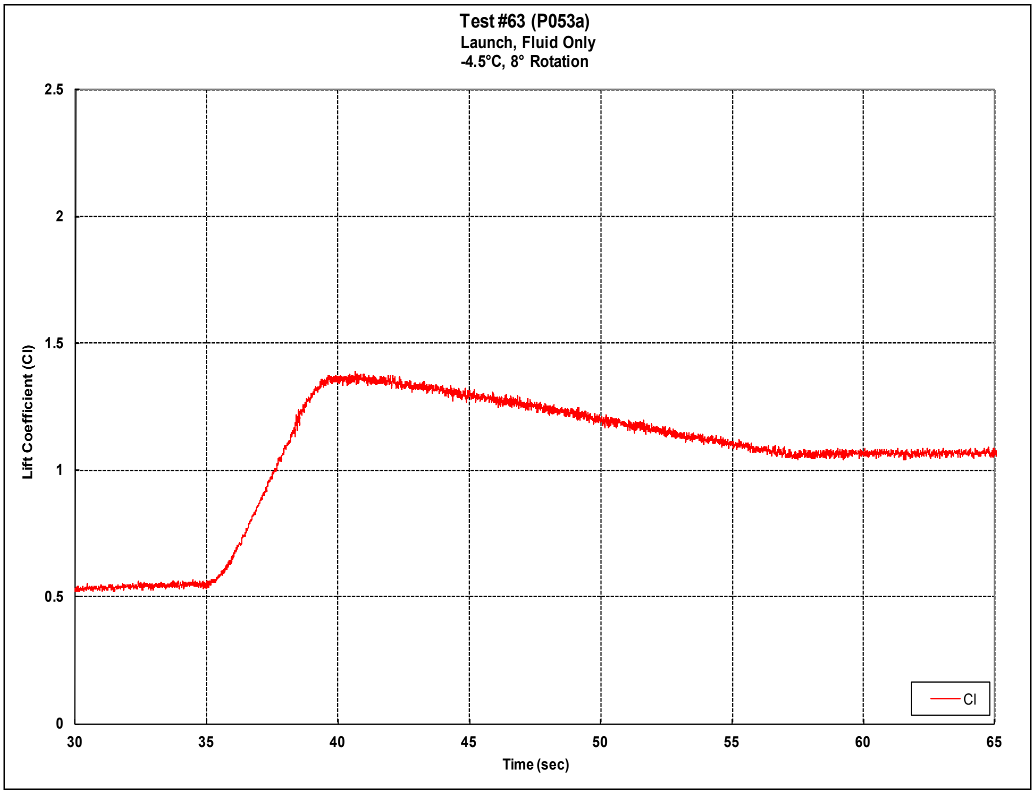


Figure D48: Run # 63

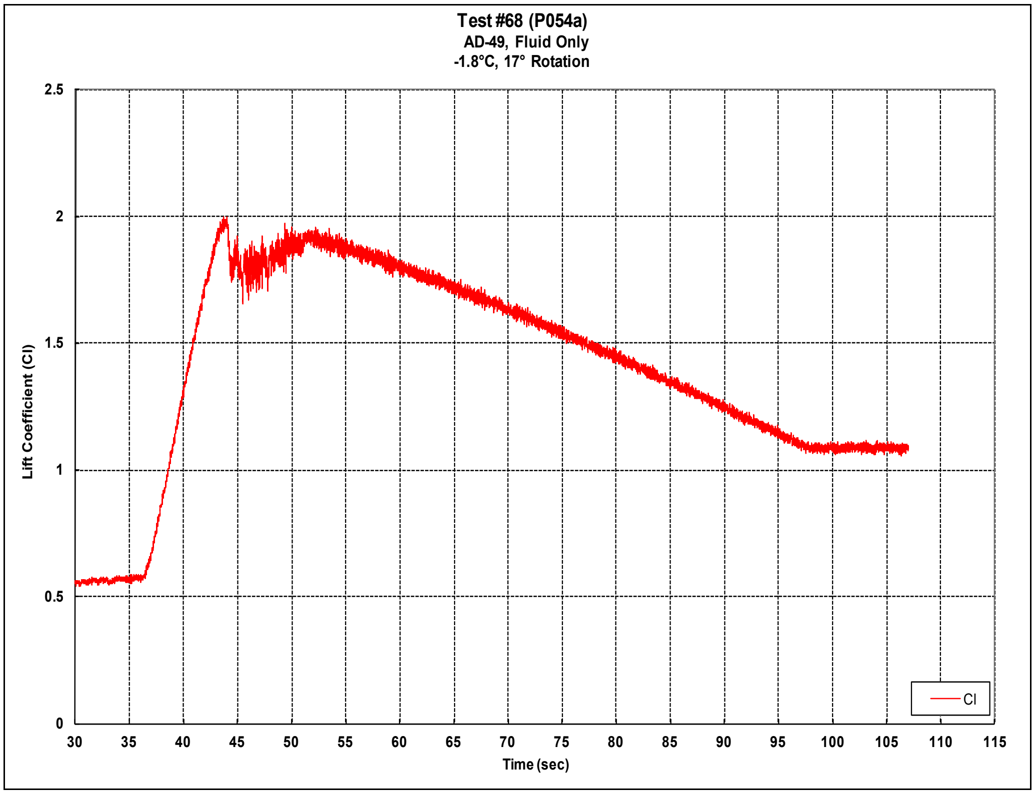


Figure D49: Run # 68

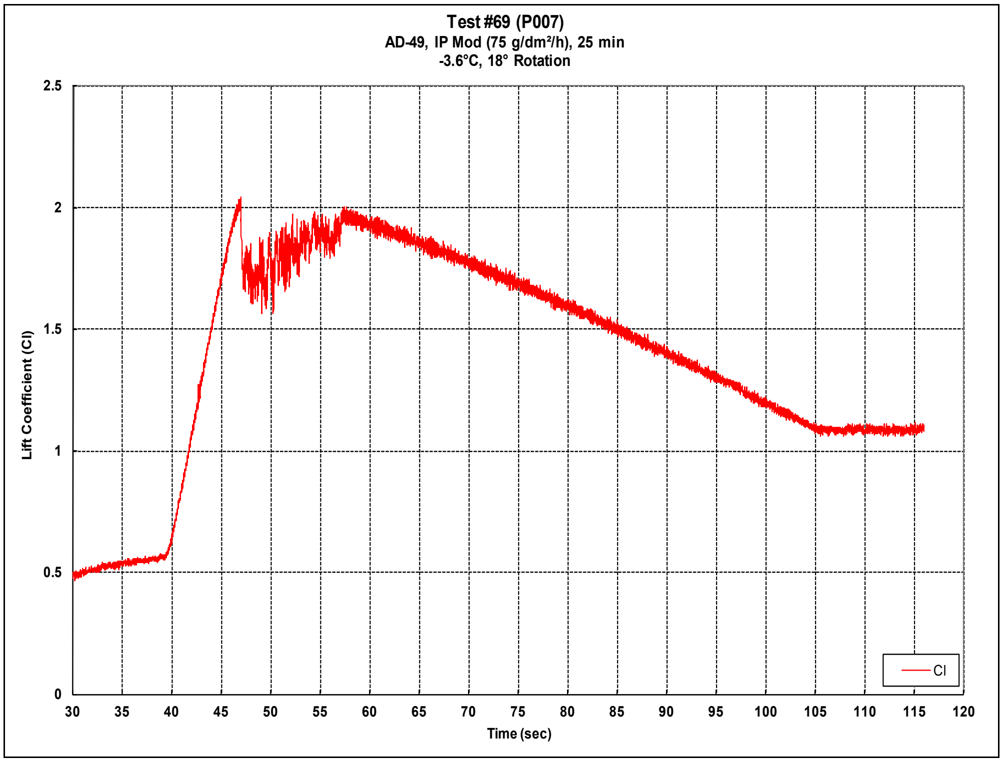


Figure D50: Run #69

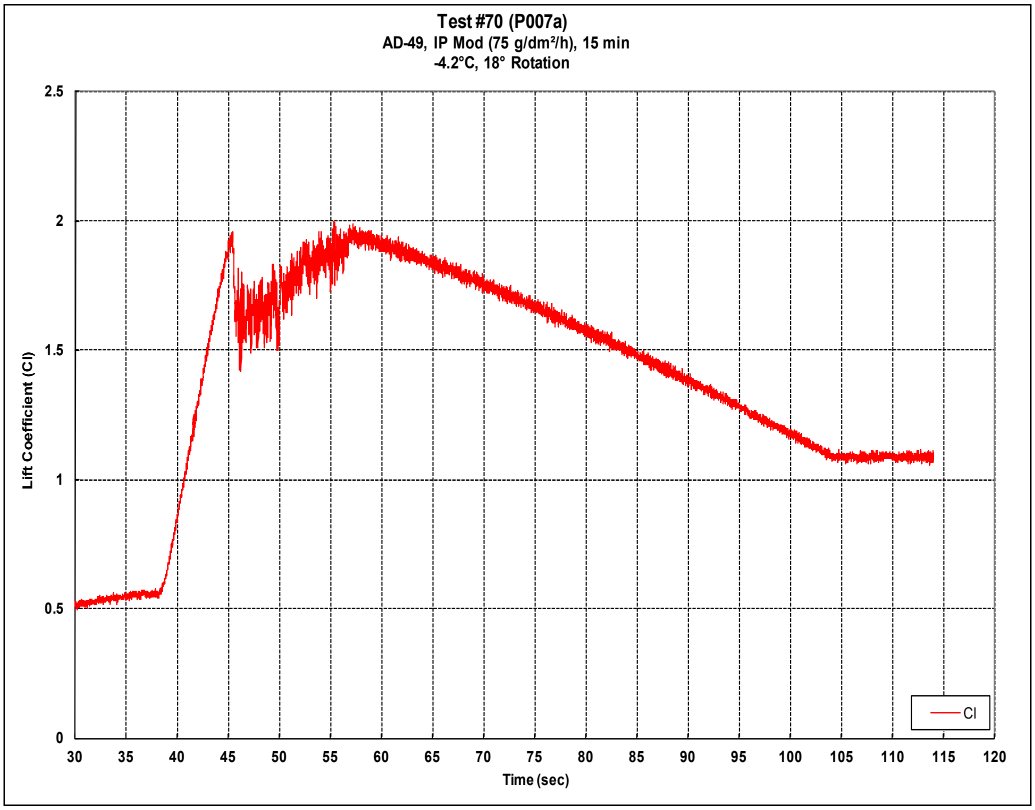


Figure D51: Run #70

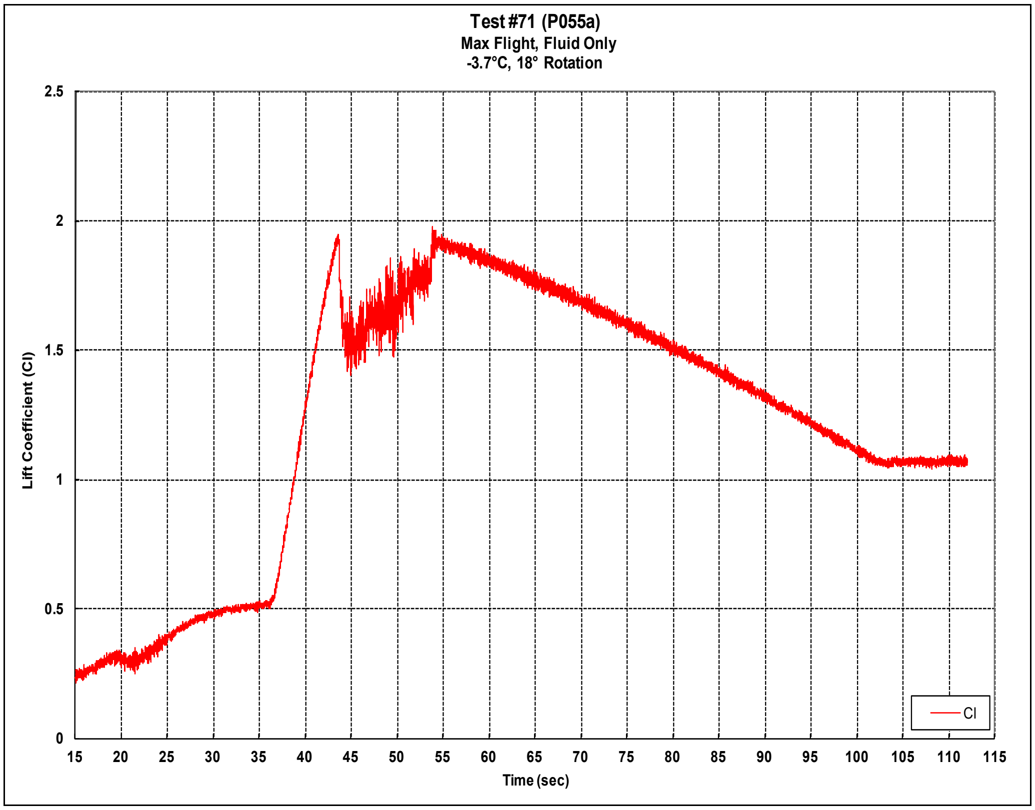


Figure D52: Run #71

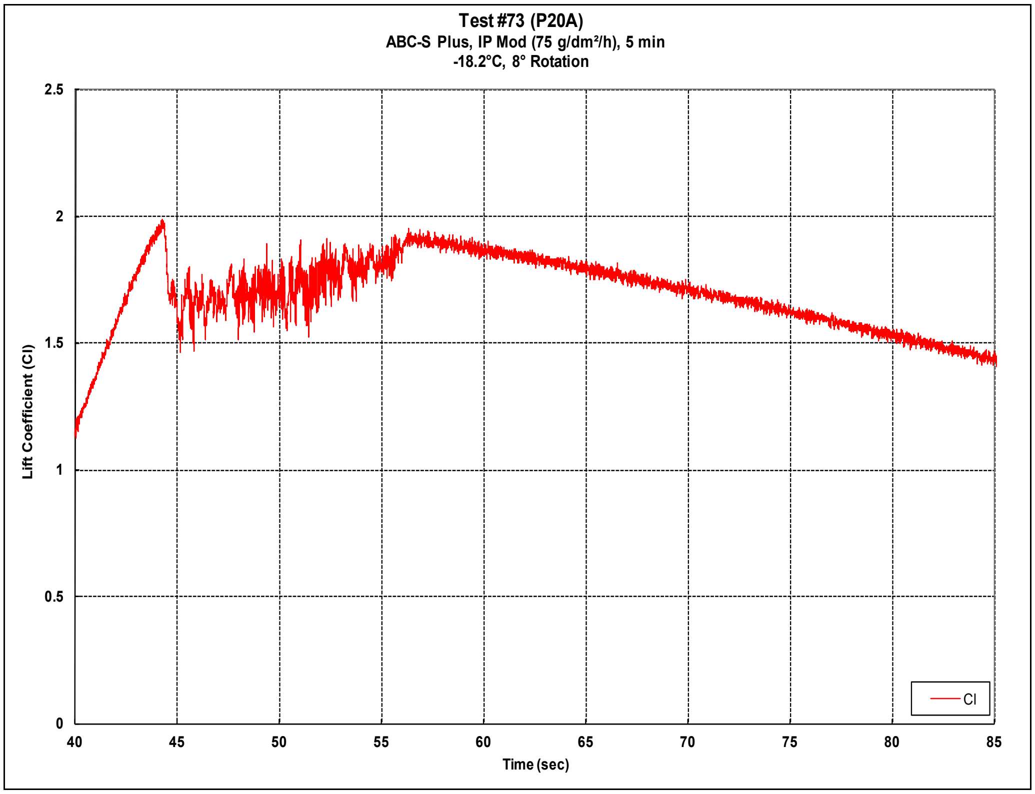


Figure D53: Run #73

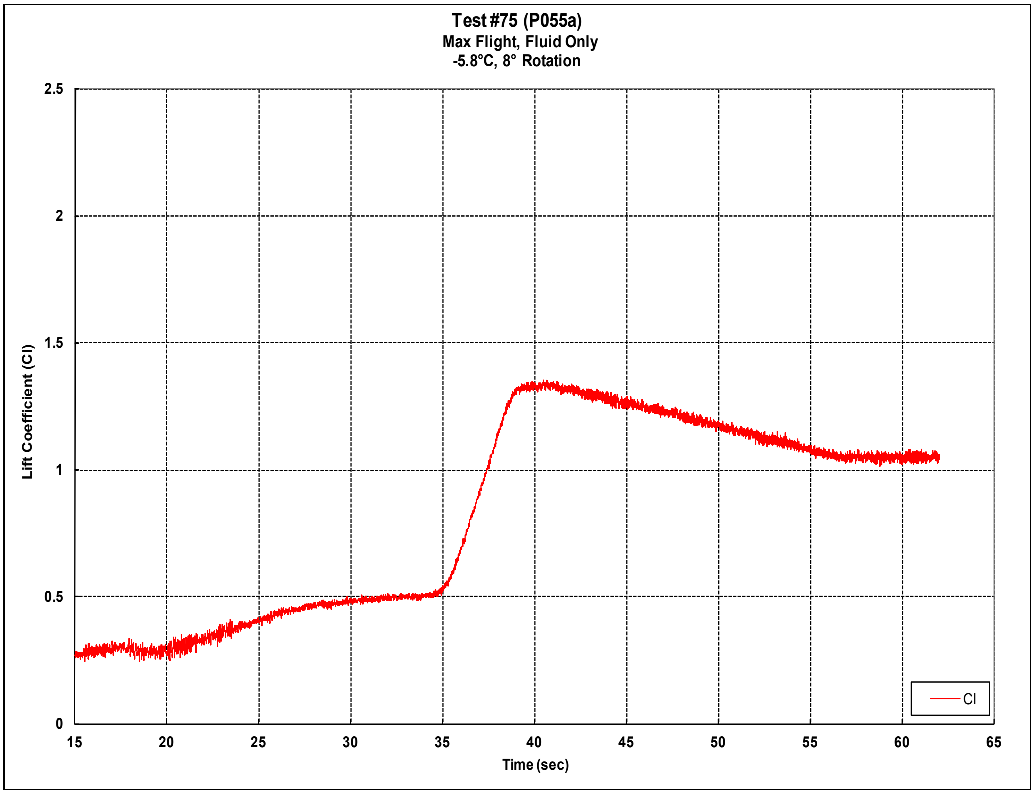


Figure D54: Run #75

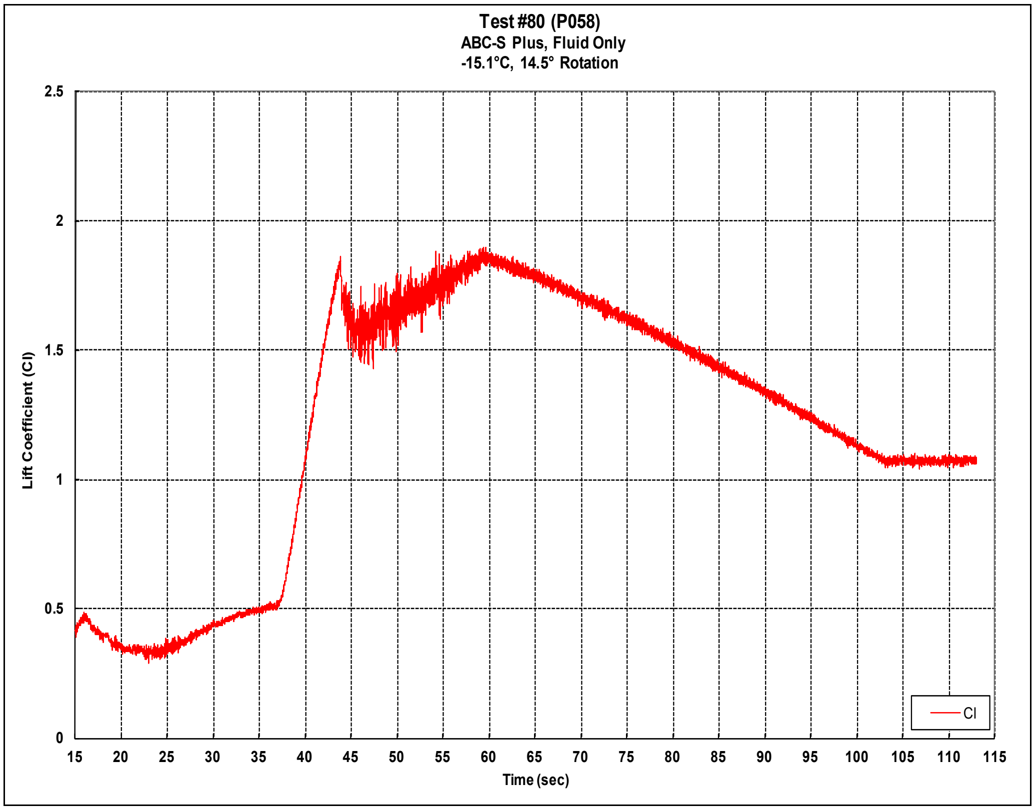


Figure D55: Run #80

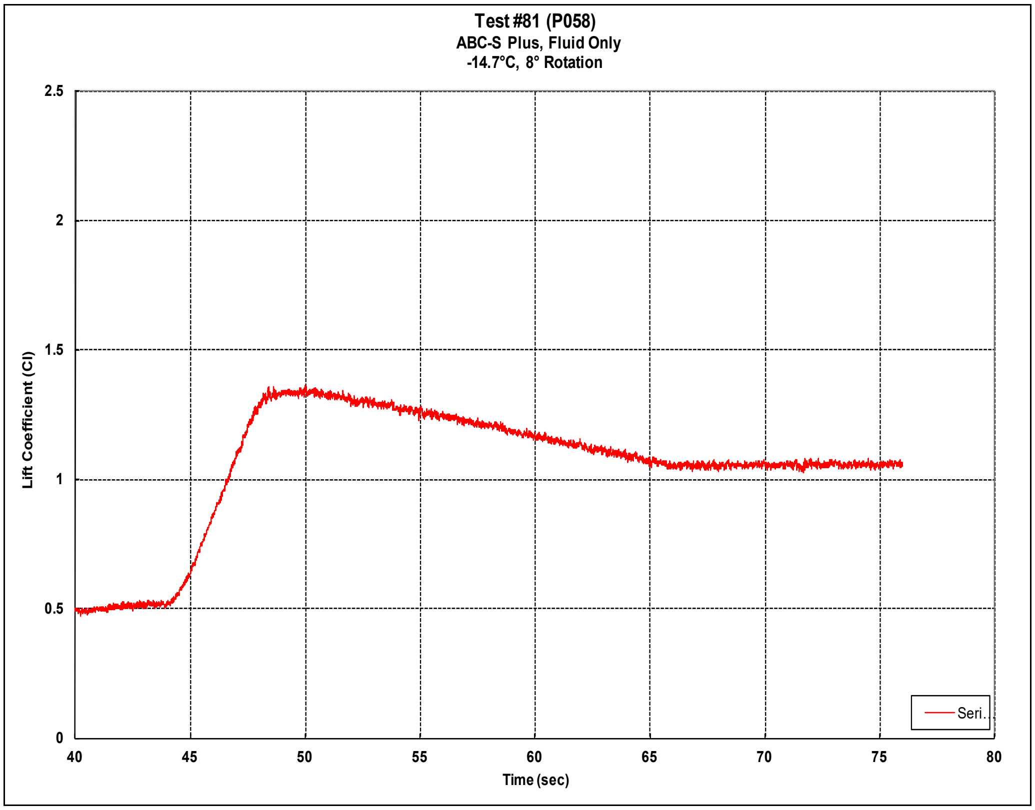


Figure D56: Run #81

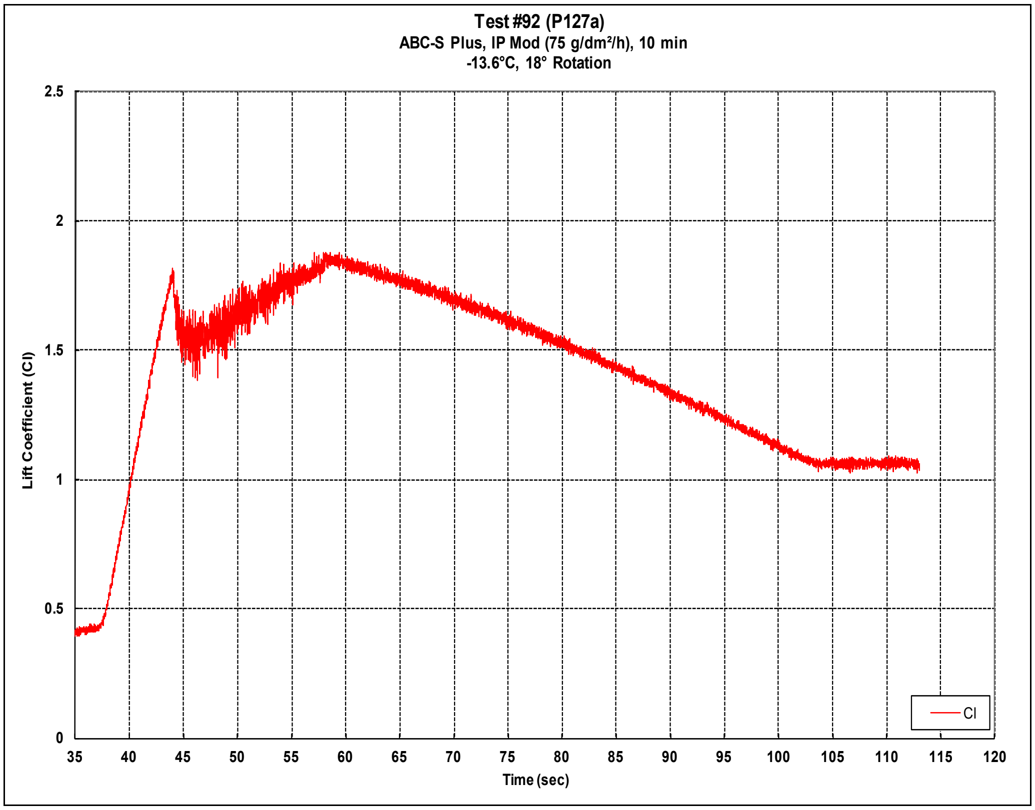


Figure D57: Run #92

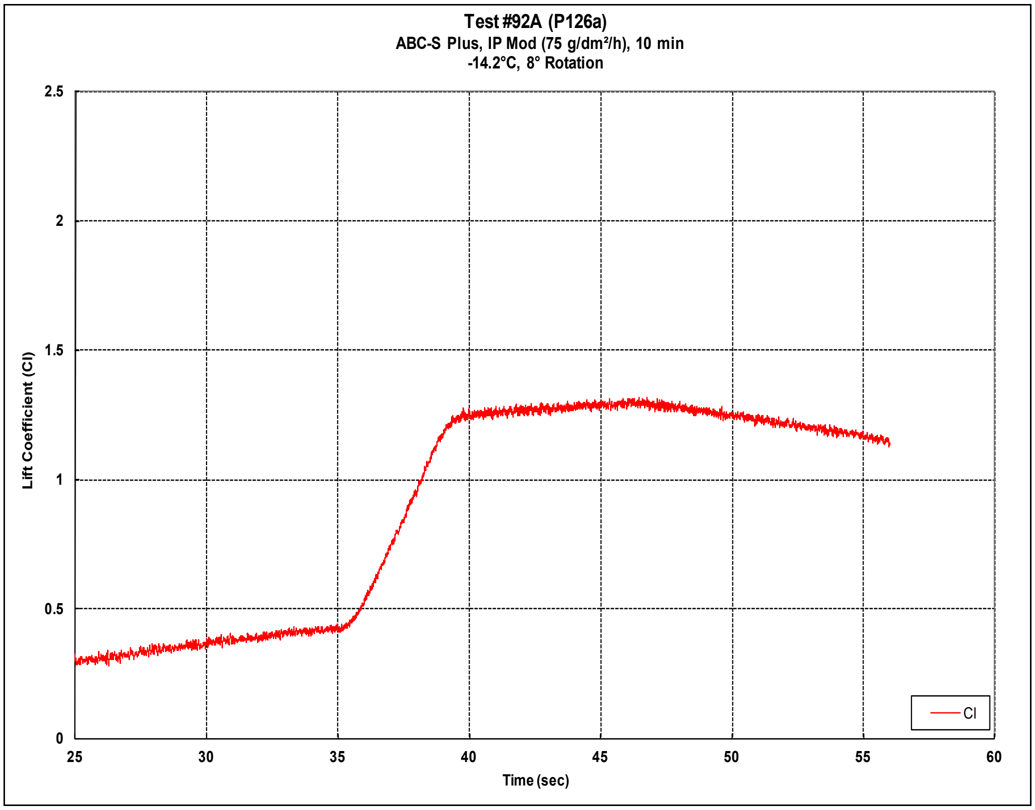


Figure D58: Run #92A

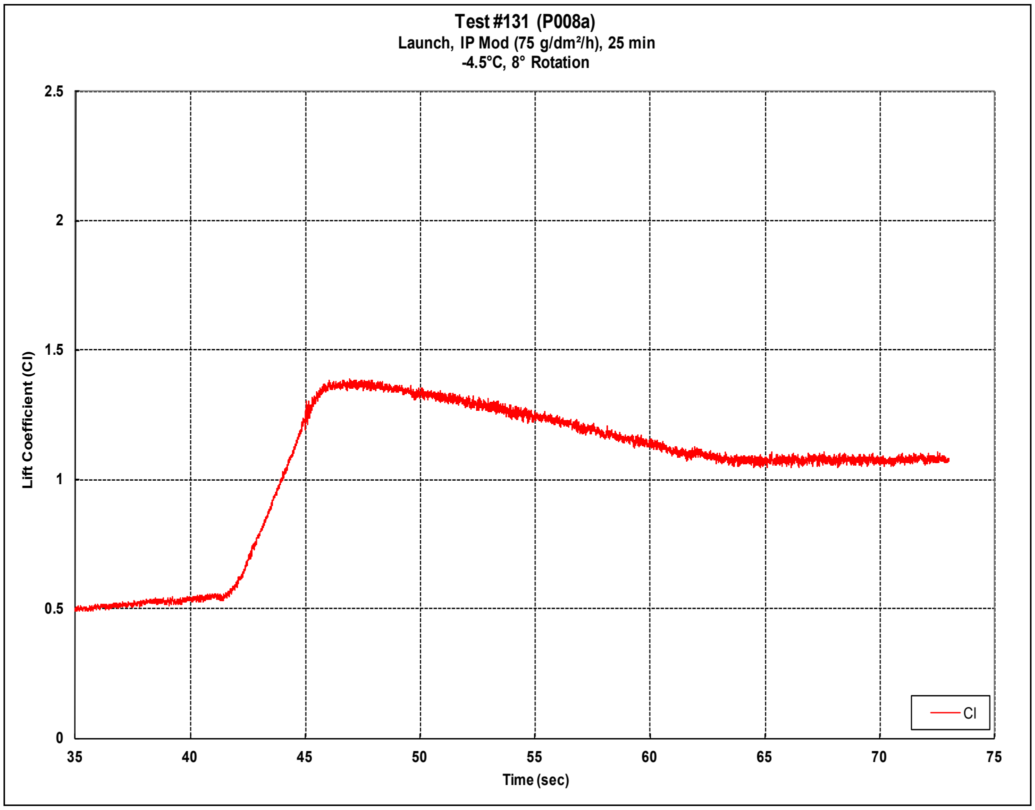


Figure D59: Run #131

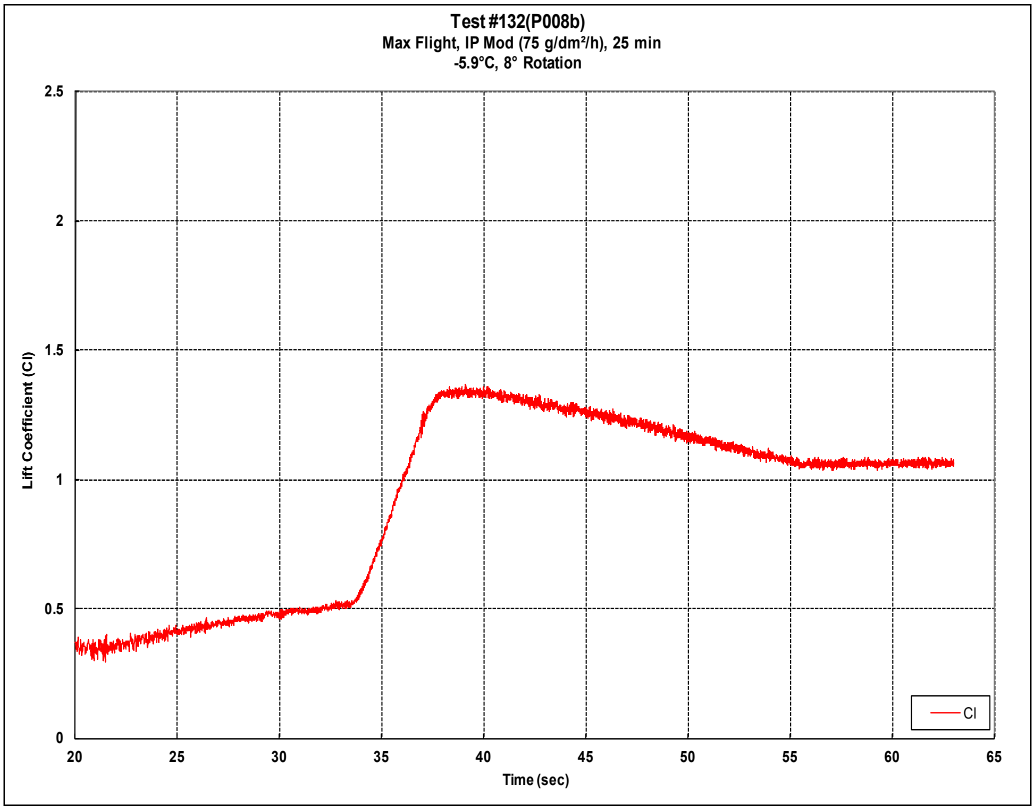


Figure D60: Run #132

LIGHT ICE PELLETS MIXED WITH MODERATE RAIN

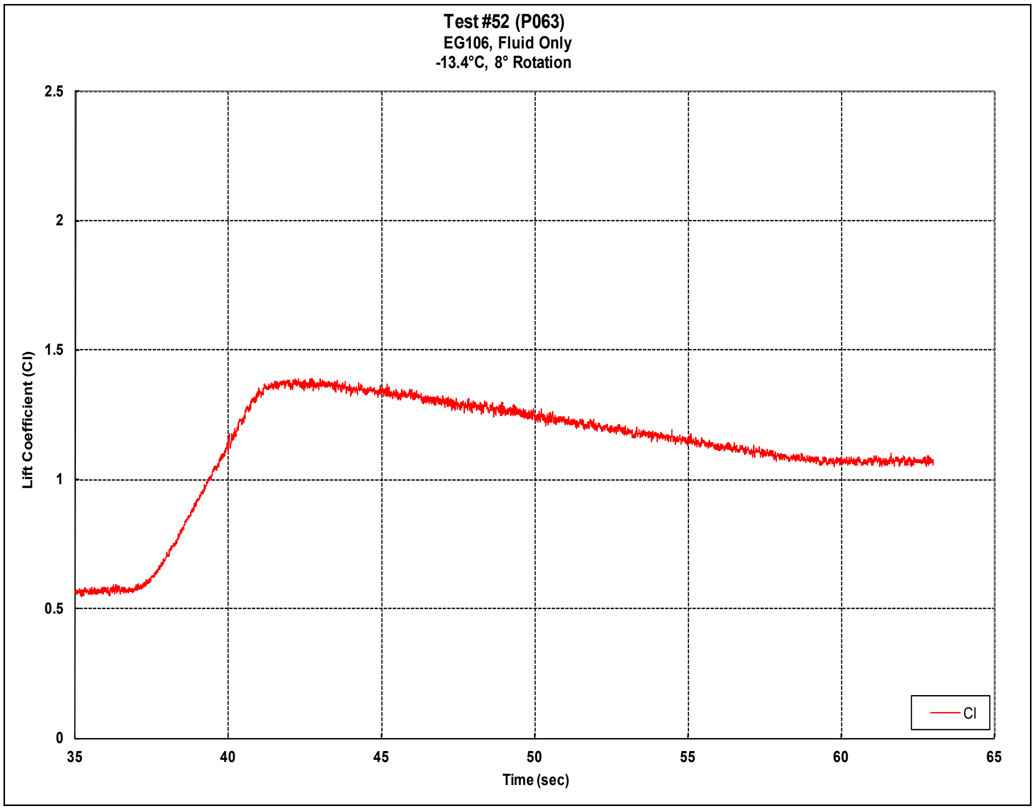


Figure D61: Run #52

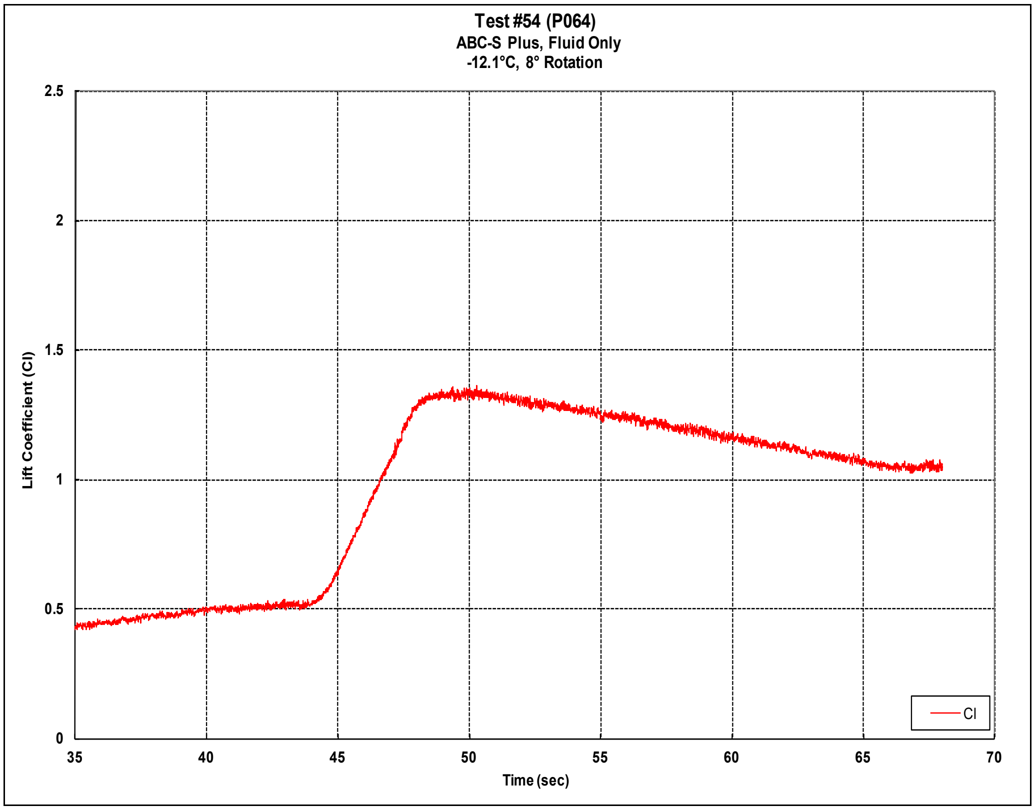


Figure D62: Run #54

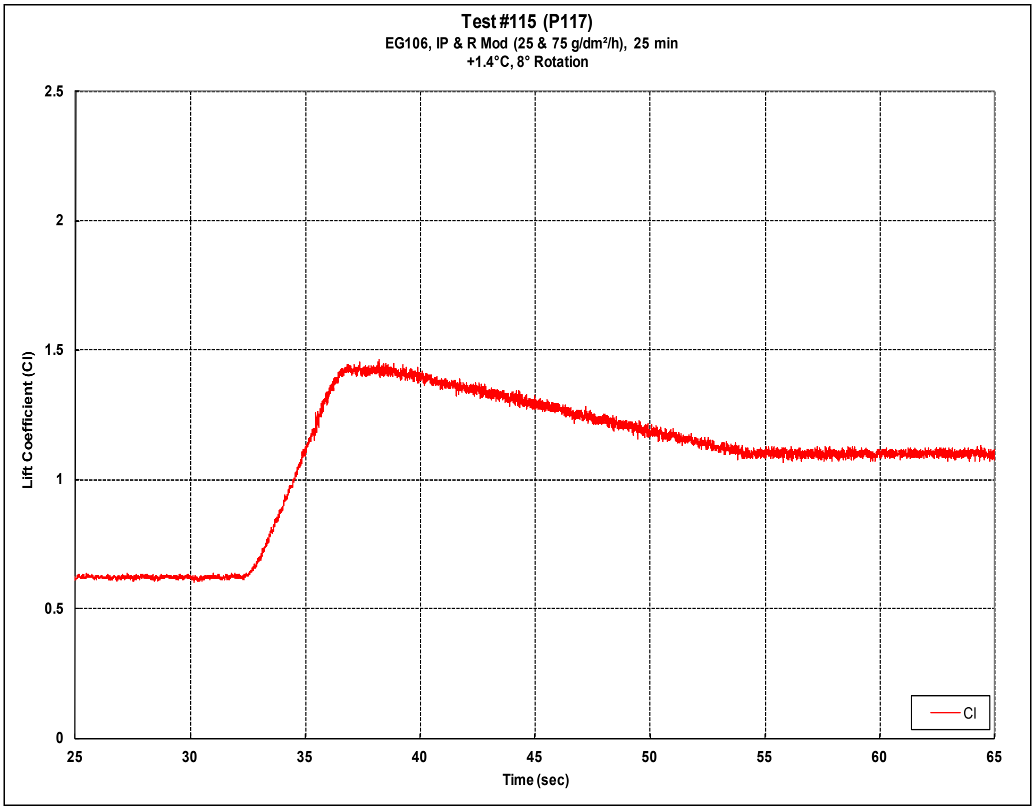


Figure D63: Run #115

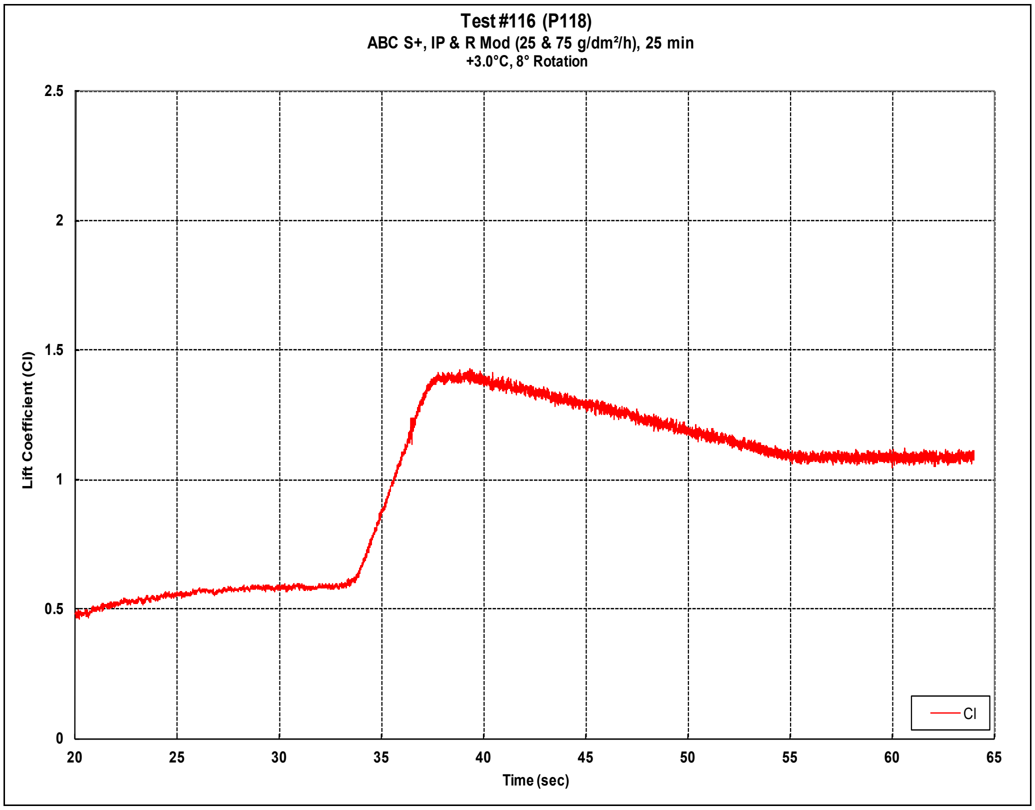


Figure D64: Run #116

LIGHT ICE PELLETS MIXED WITH LIGHT SNOW

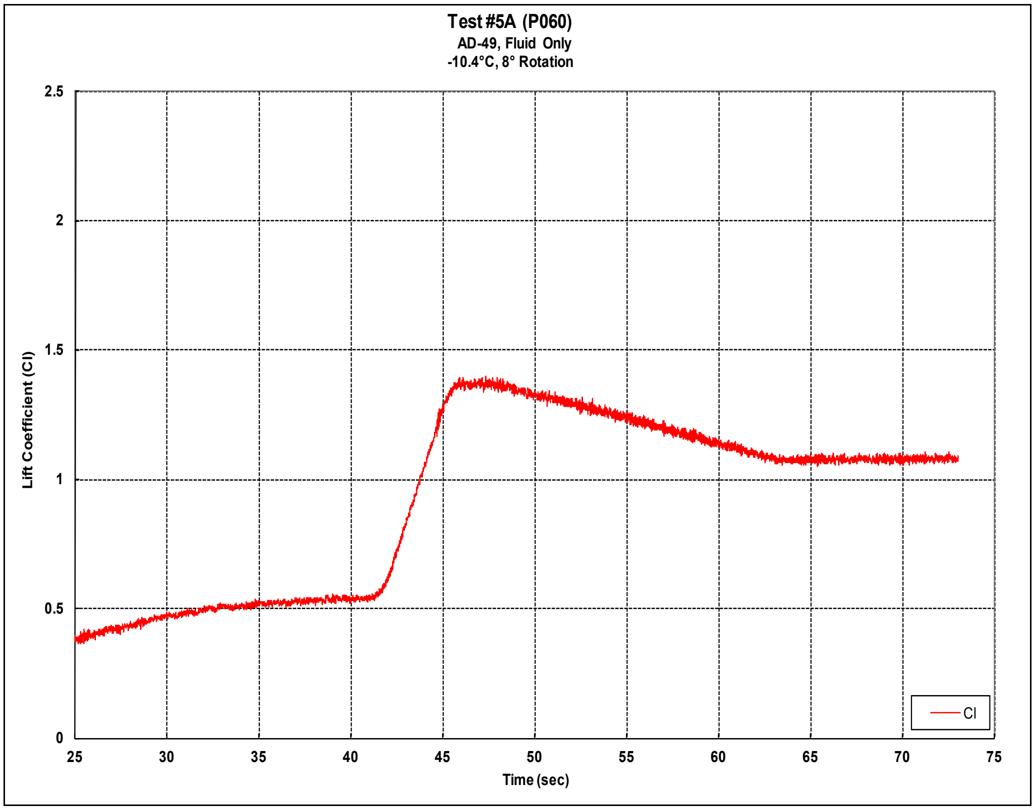


Figure D65: Run #5A

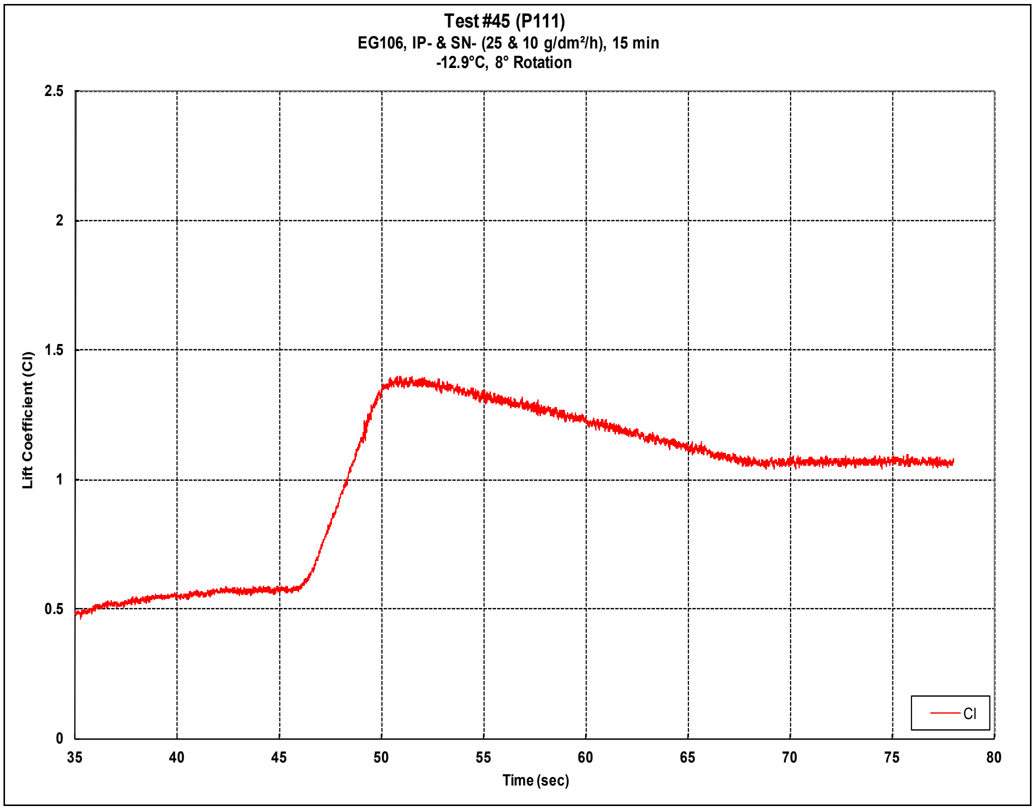


Figure D66: Run #45

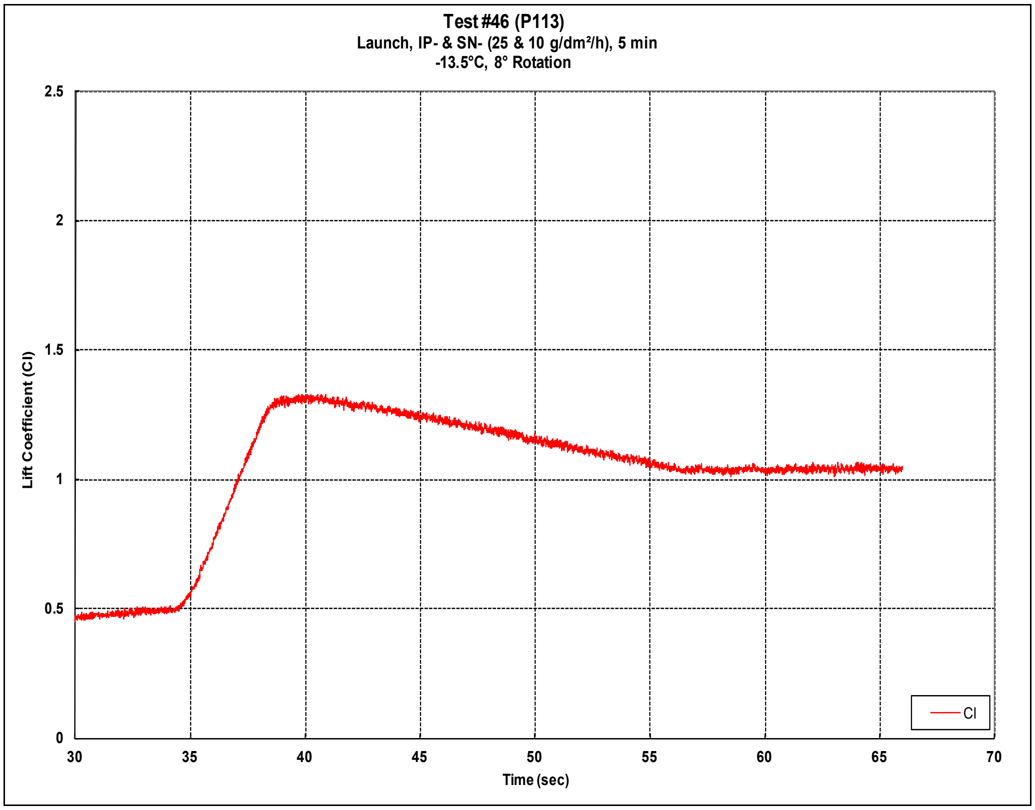


Figure D67: Run #46

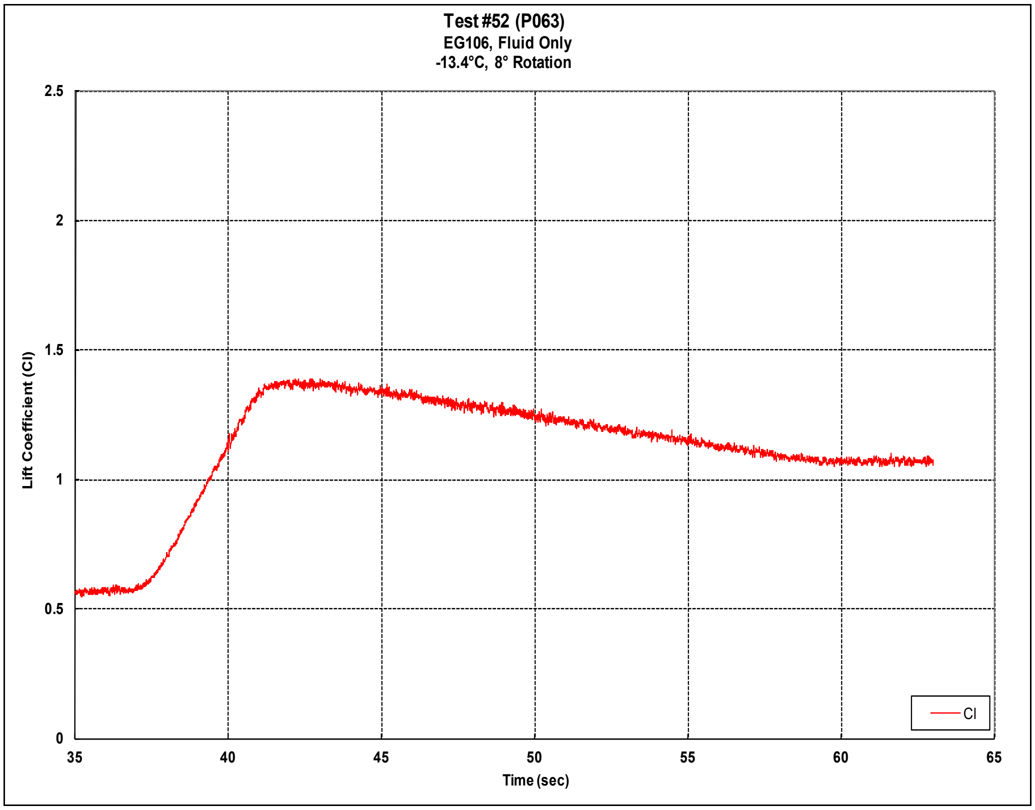


Figure D68: Run #52

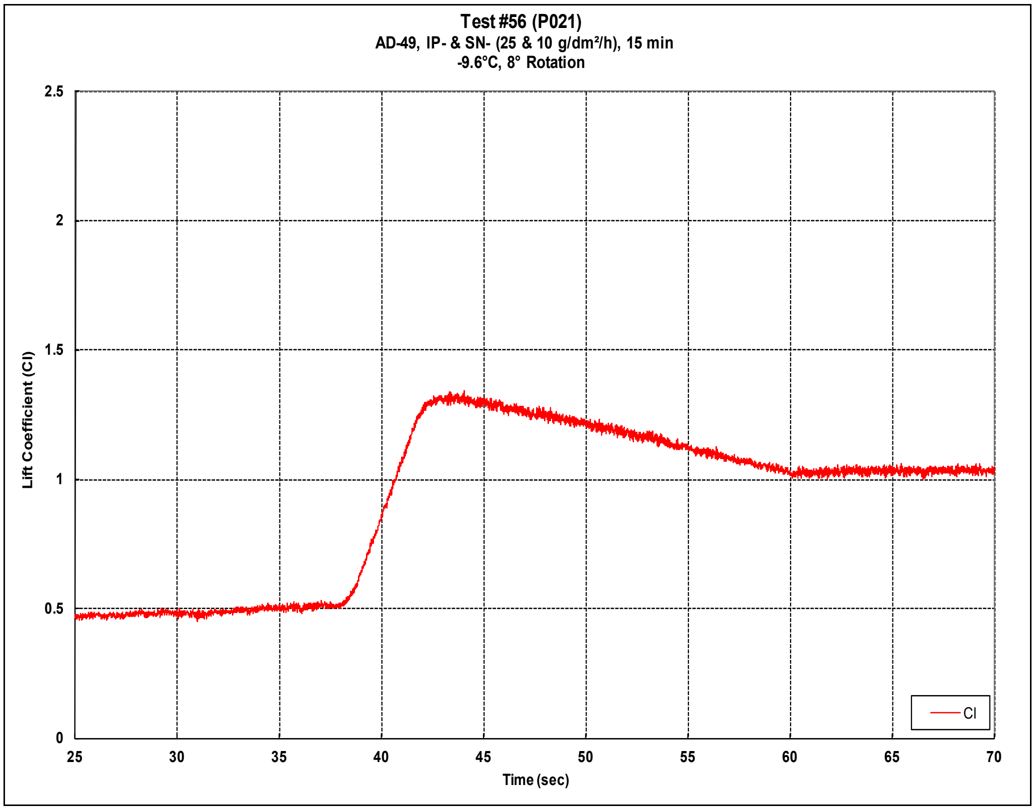


Figure D69: Run #56

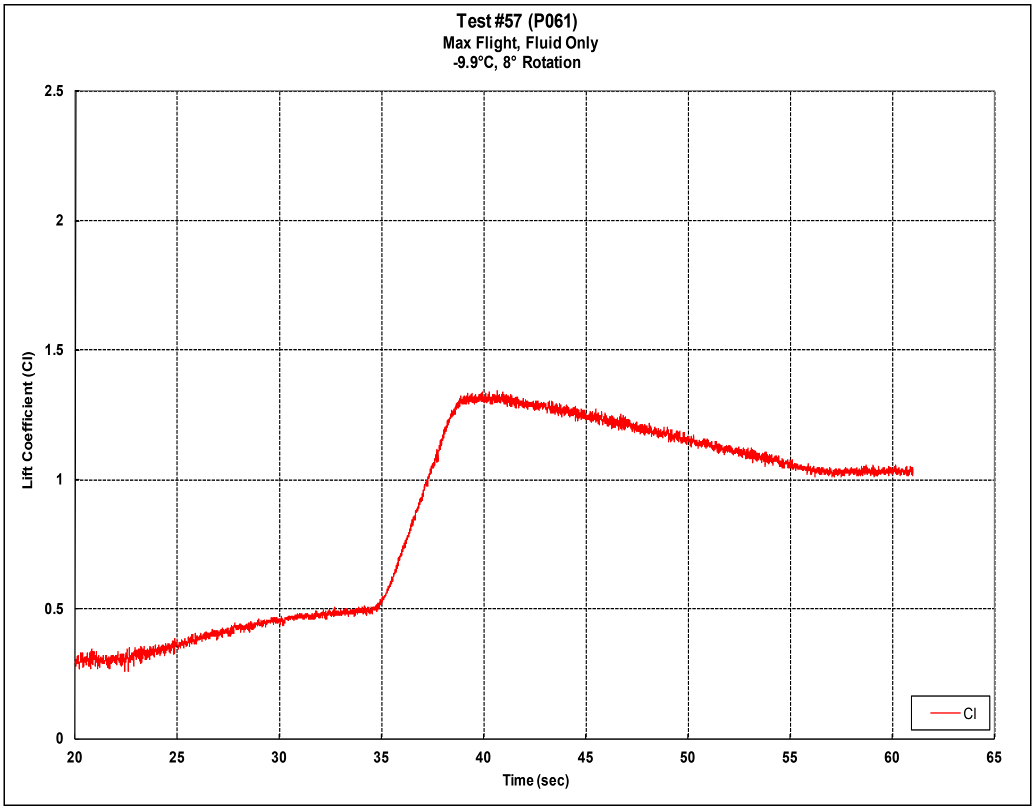


Figure D70: Run #57

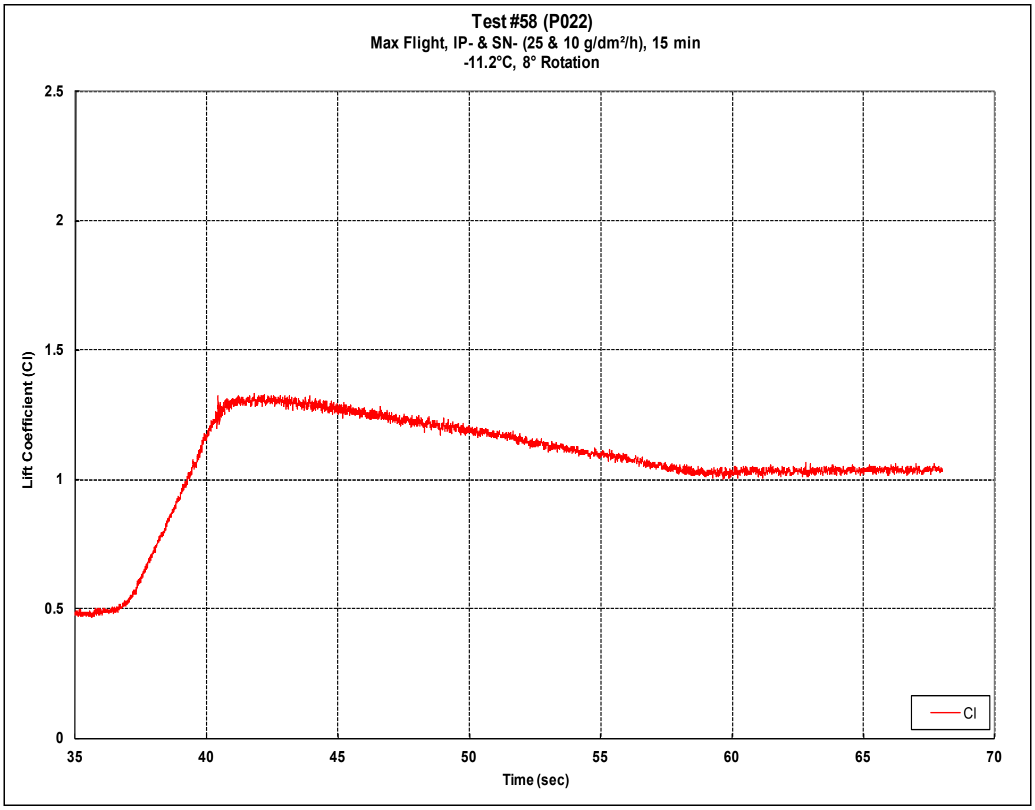


Figure D71: Run #58

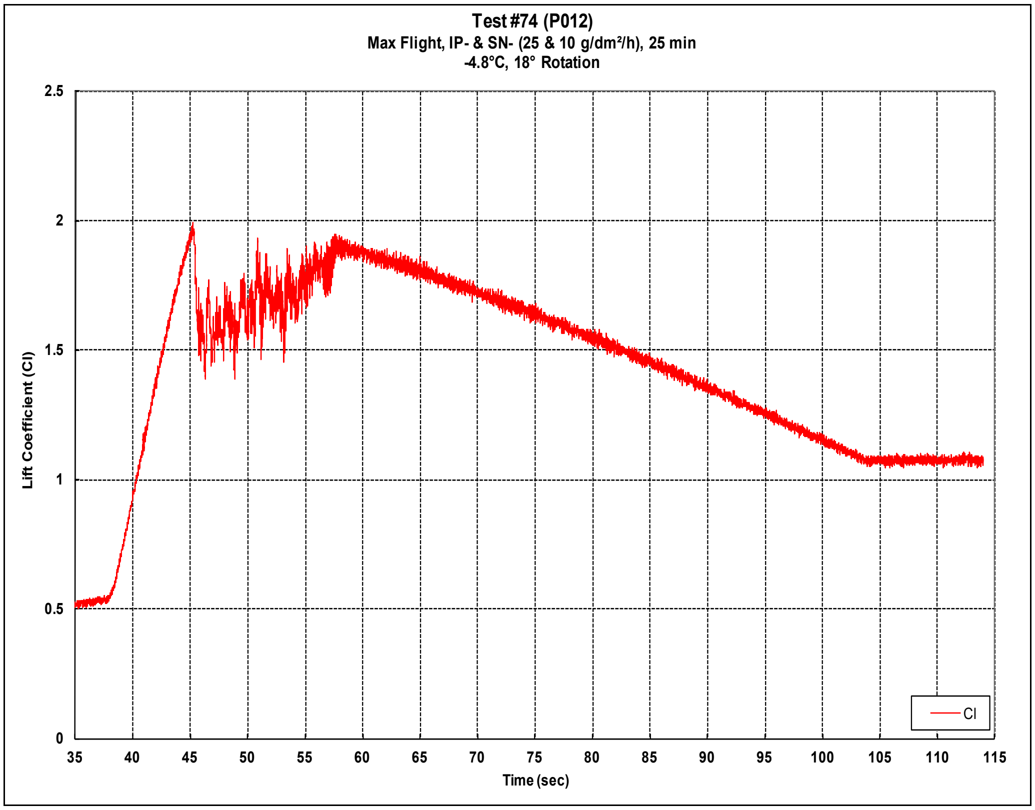


Figure D72: Run #74

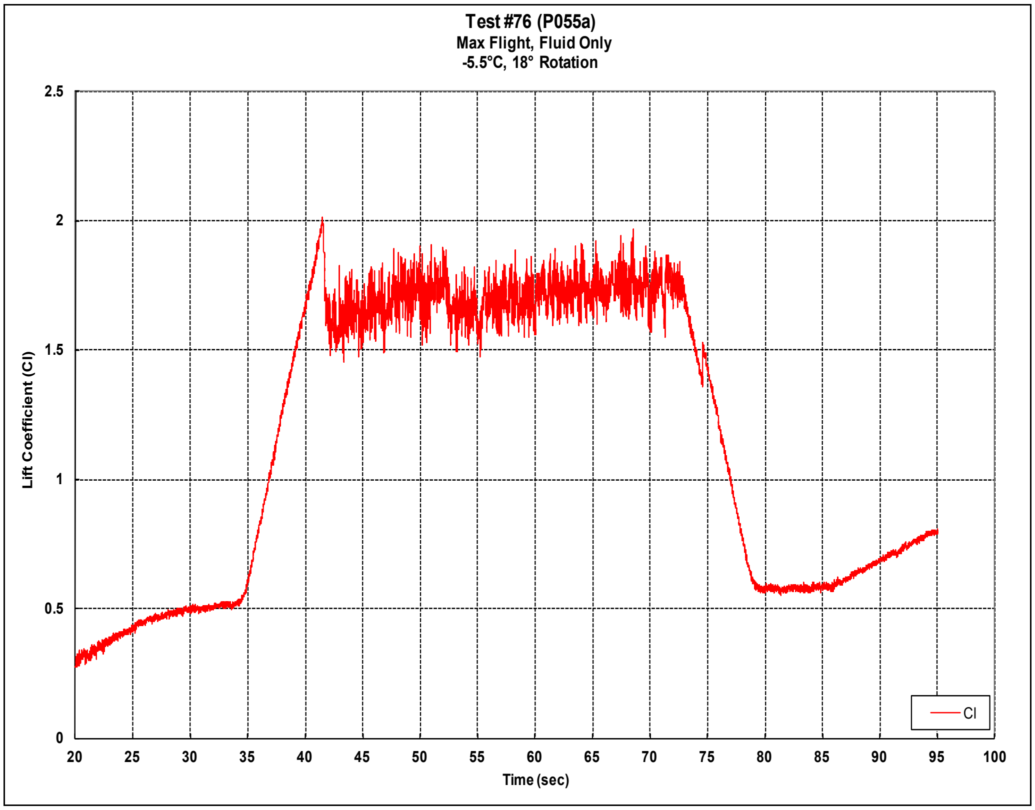


Figure D73: Run #76

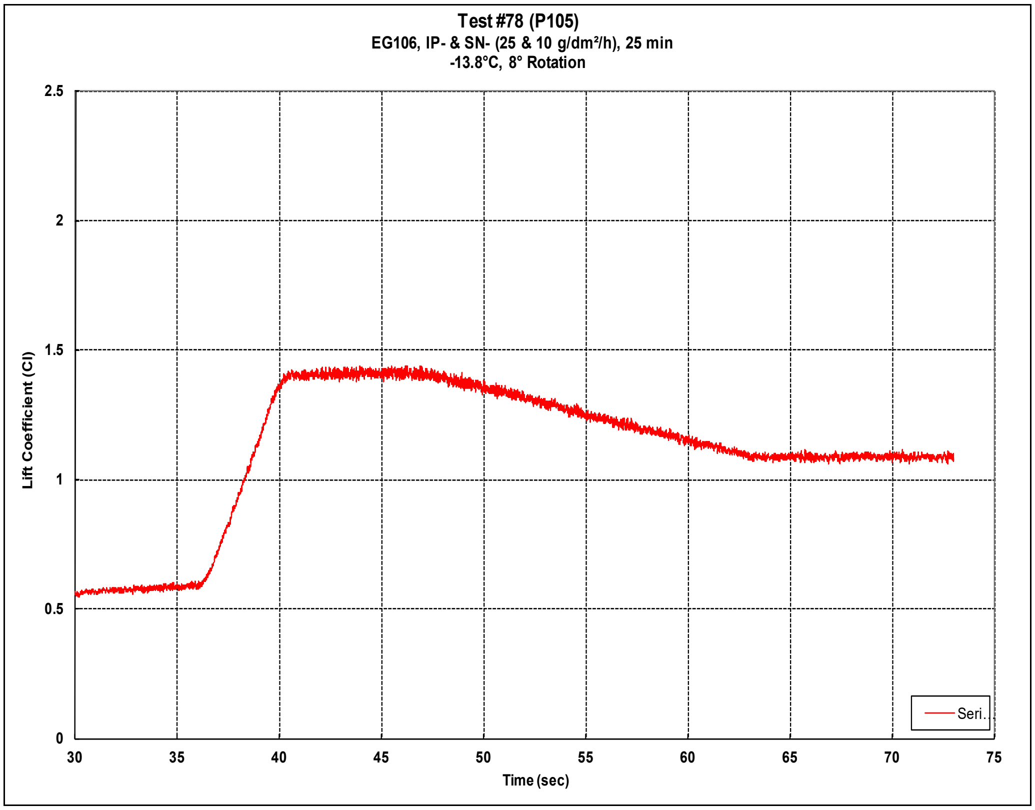


Figure D74: Run #78

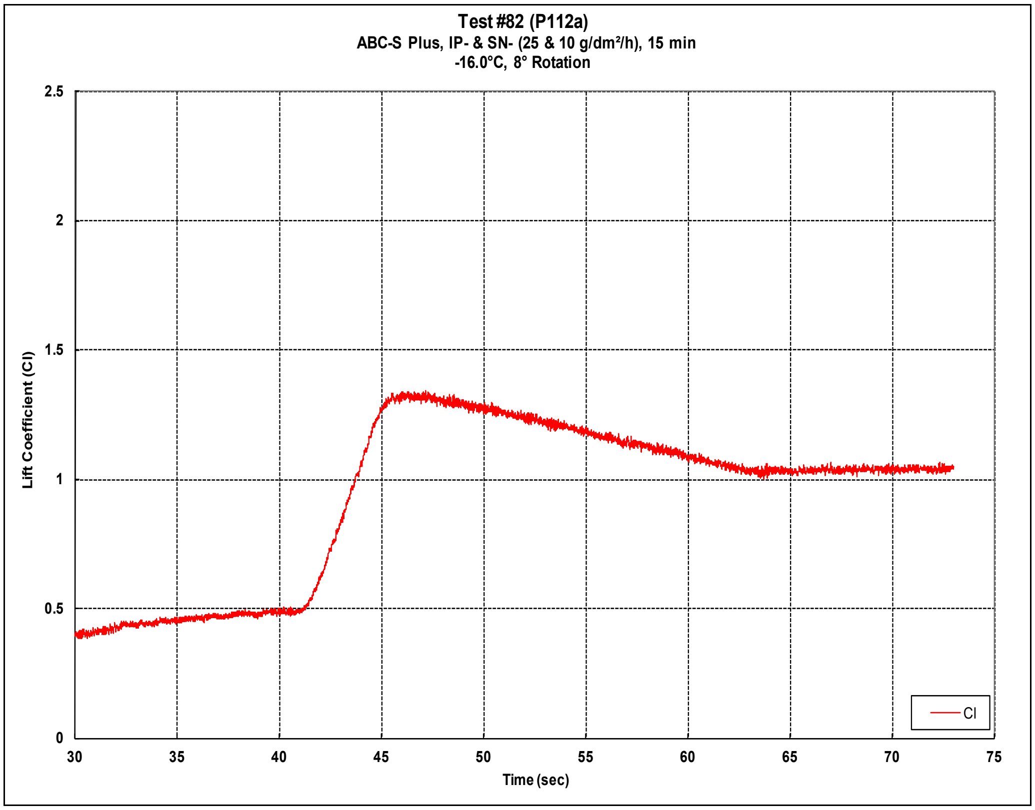


Figure D75: Run #82

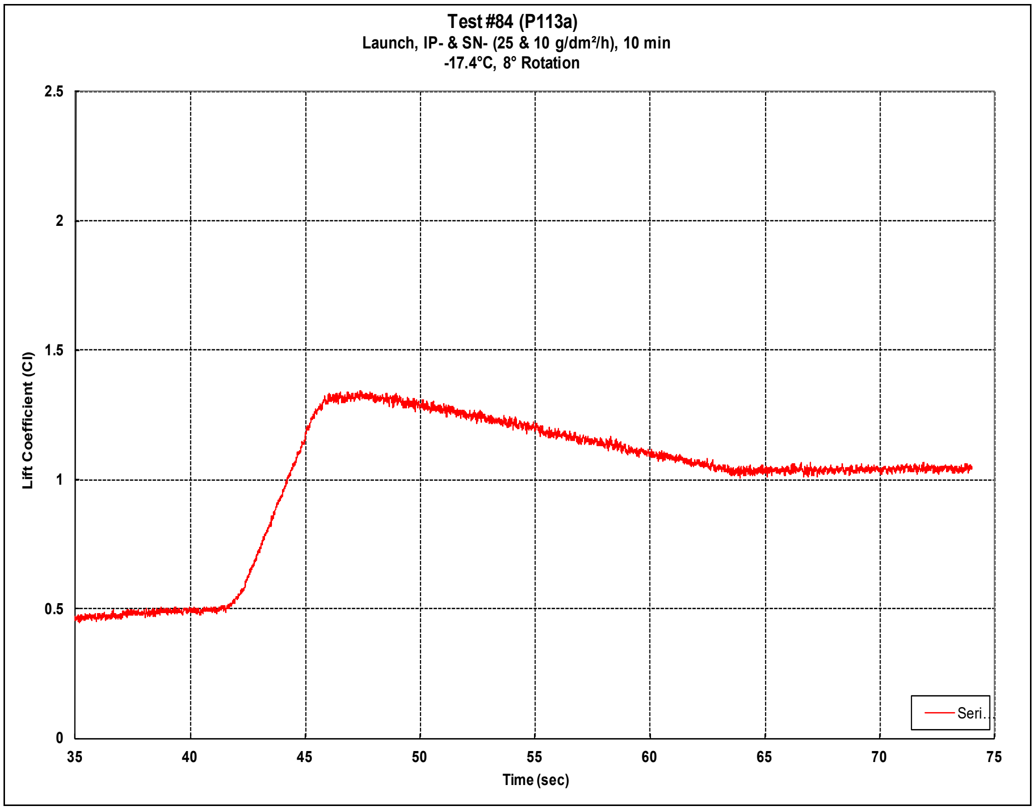


Figure D76: Run #84

LIGHT ICE PELLETS MIXED WITH LIGHT FREEZING RAIN

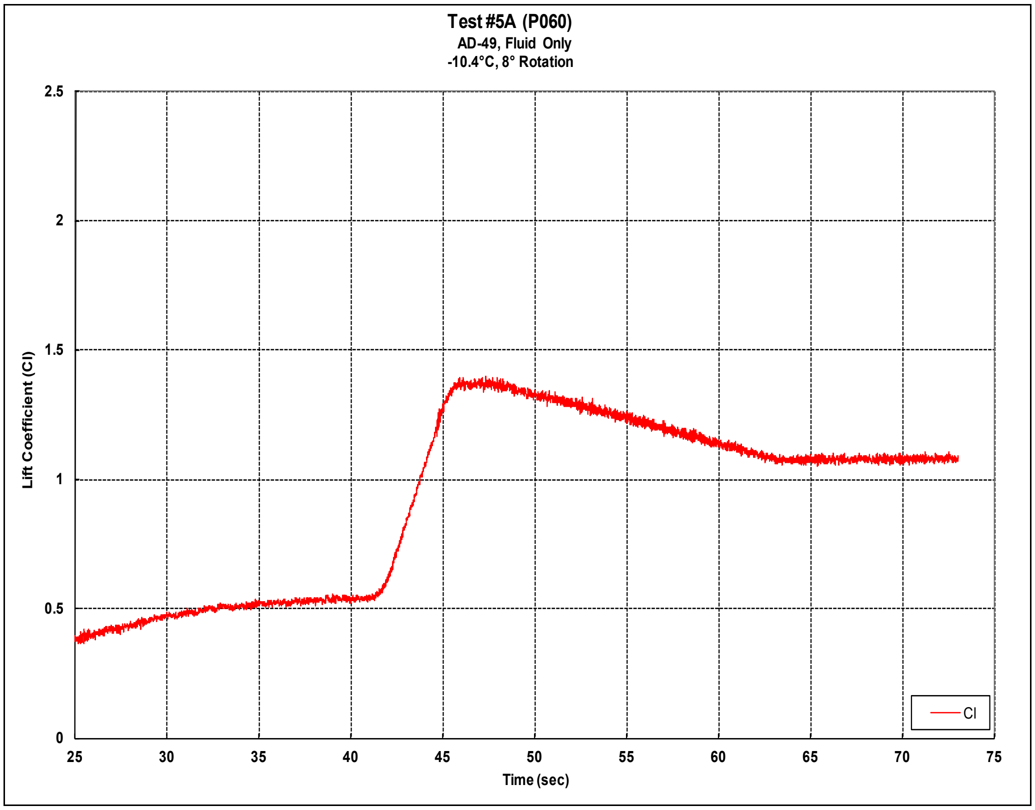


Figure D77: Run #5A

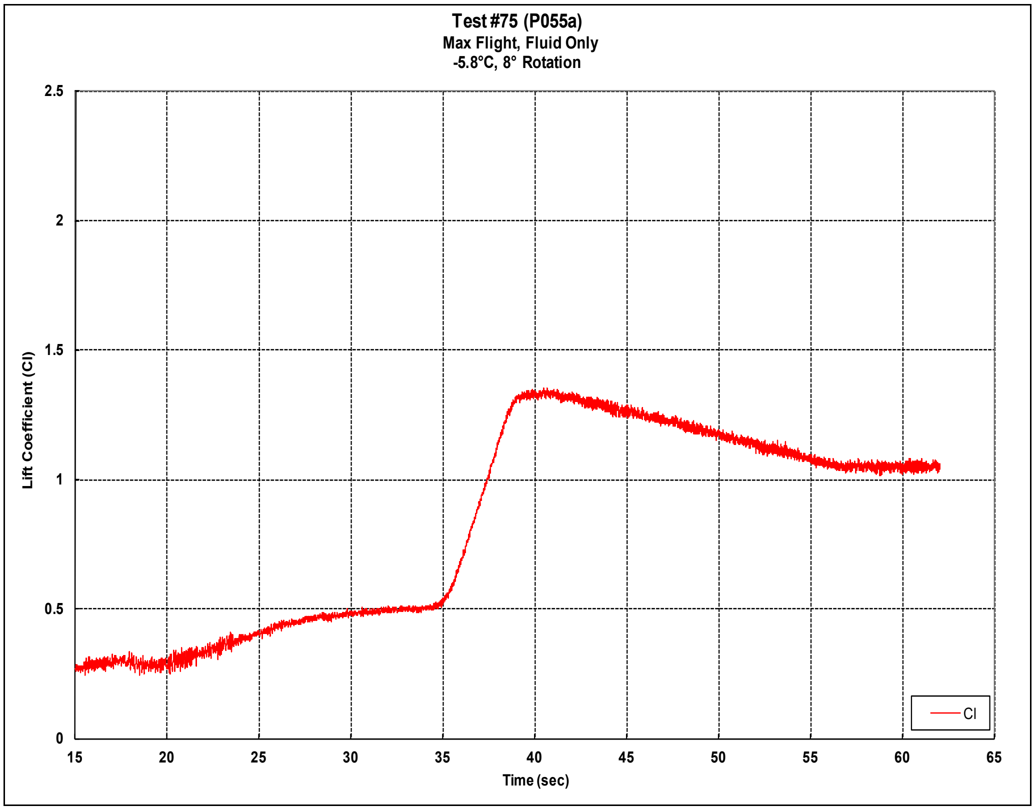


Figure D78: Run #75

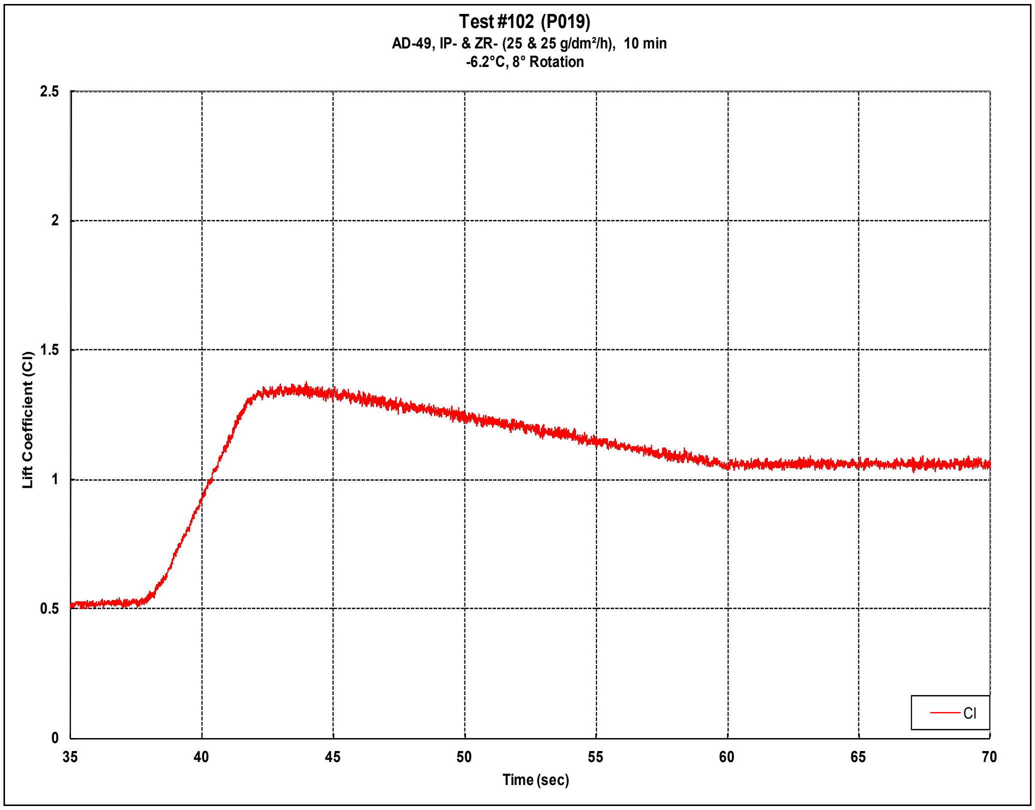


Figure D79: Run #102

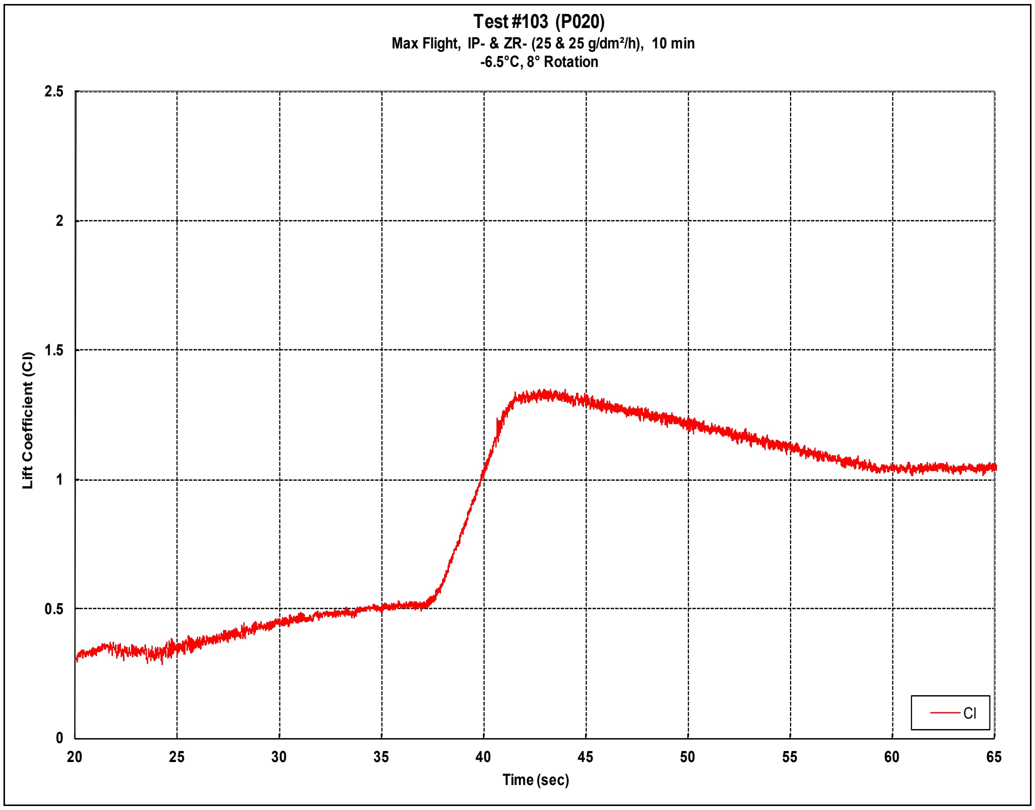


Figure D80: Run #103

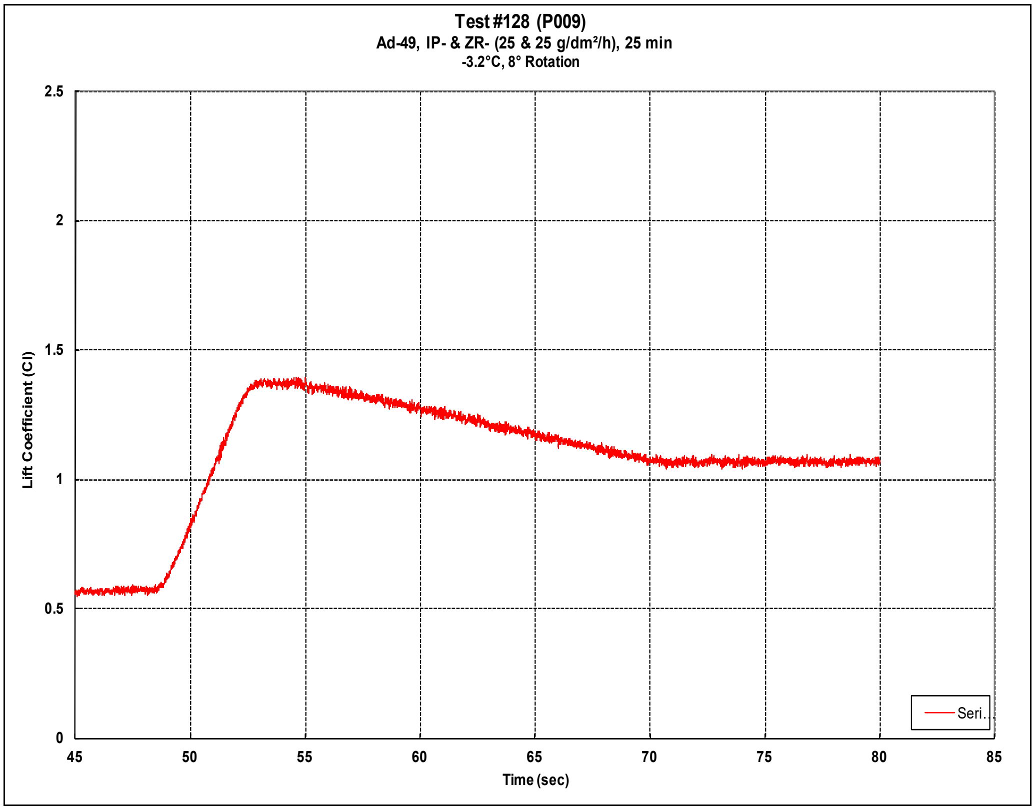


Figure D81: Run #128

This page intentionally left blank.

LIGHT ICE PELLETS MIXED WITH MODERATE SNOW

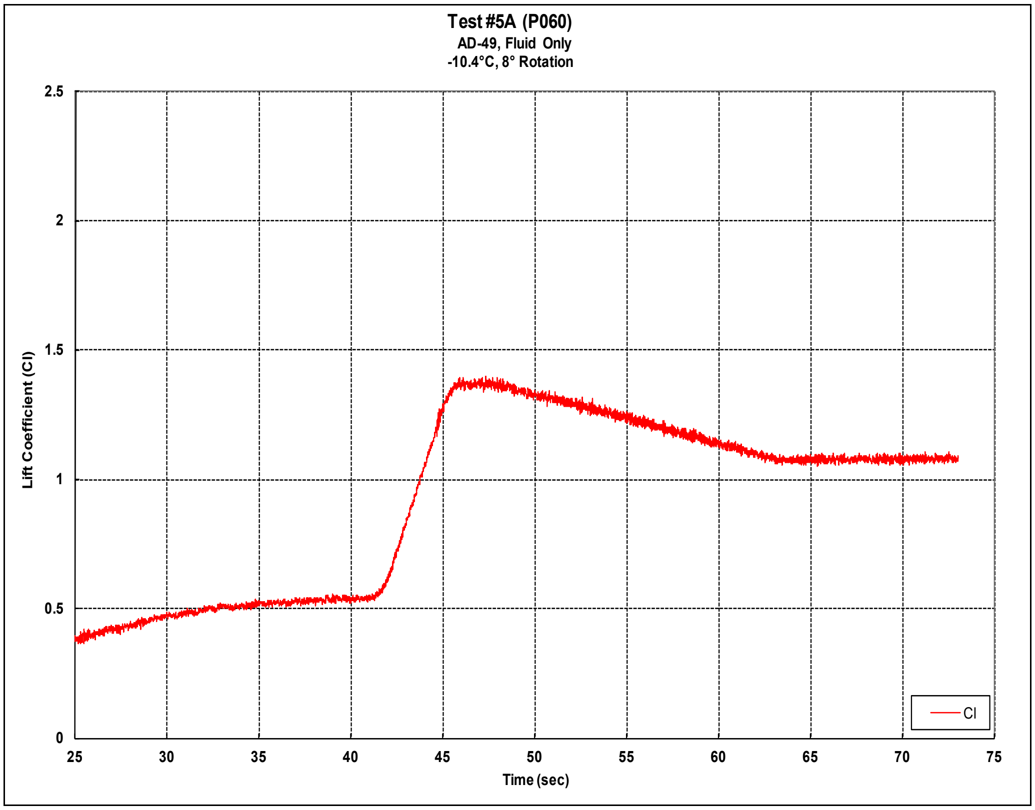


Figure D82: Run #5A

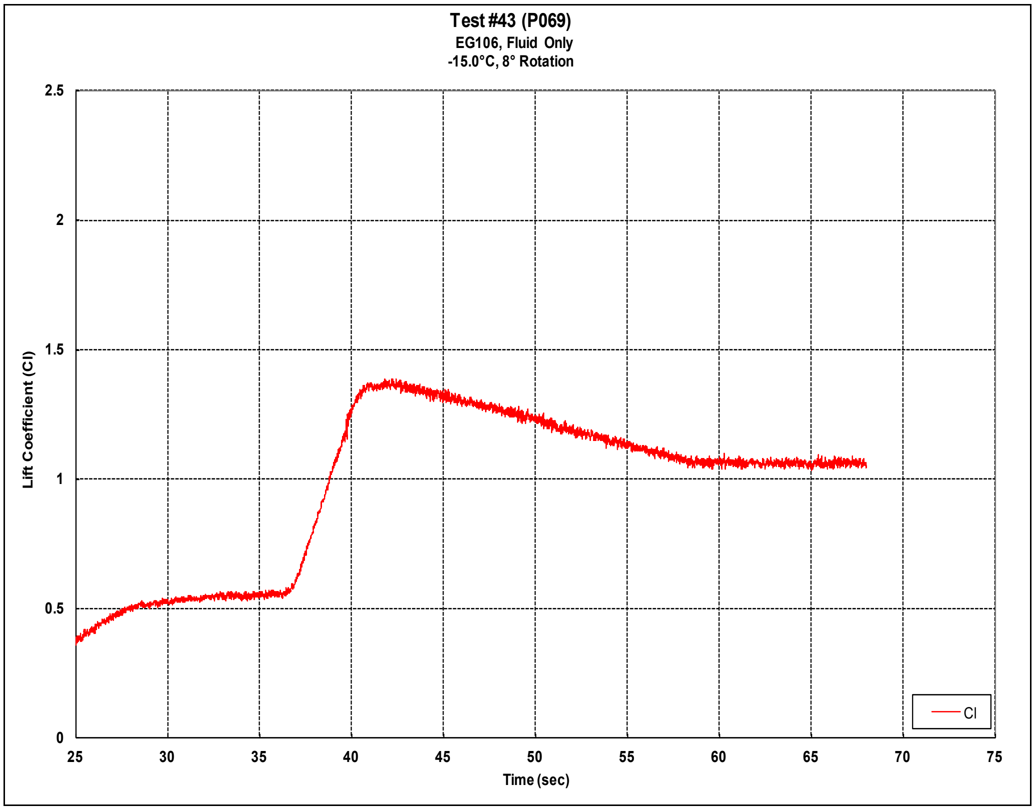


Figure D83: Run #43

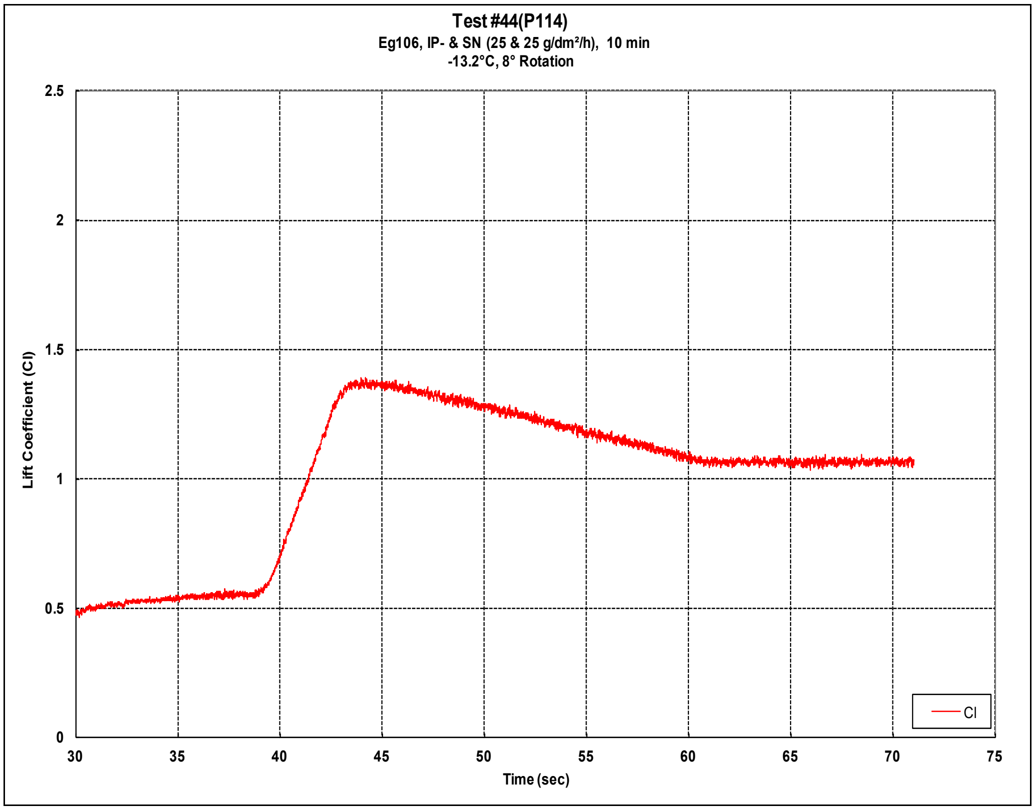


Figure D84: Run #44

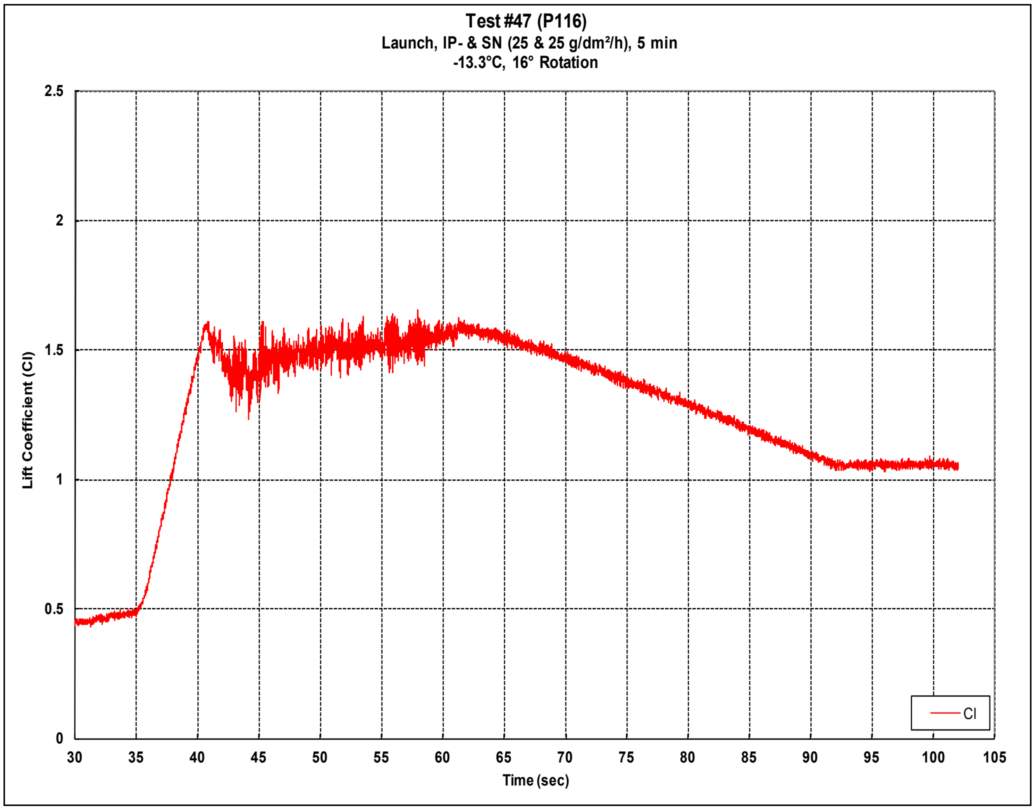


Figure D85: Run #47

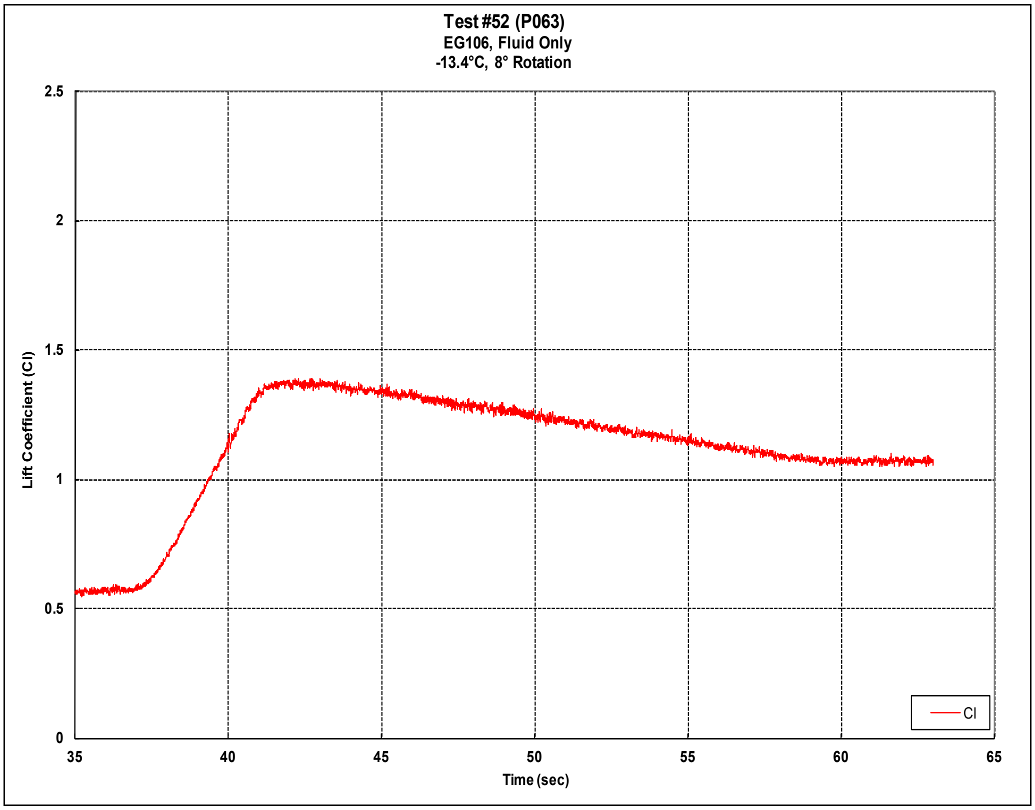


Figure D86: Run #52

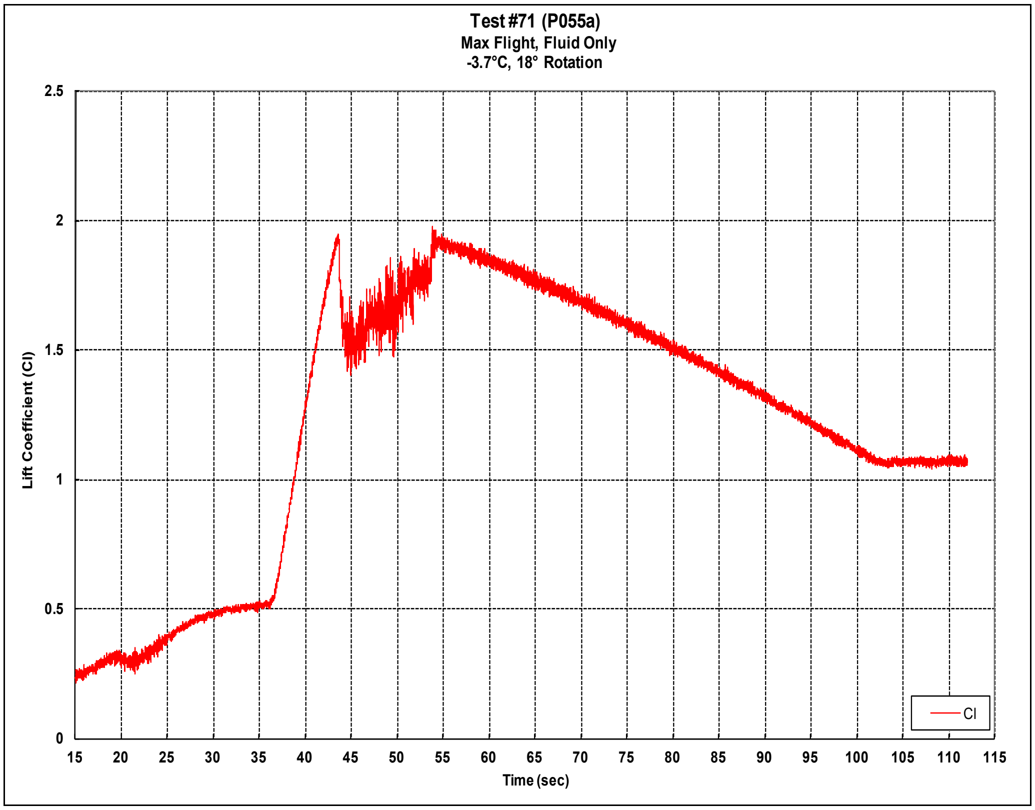


Figure D87: Run #71

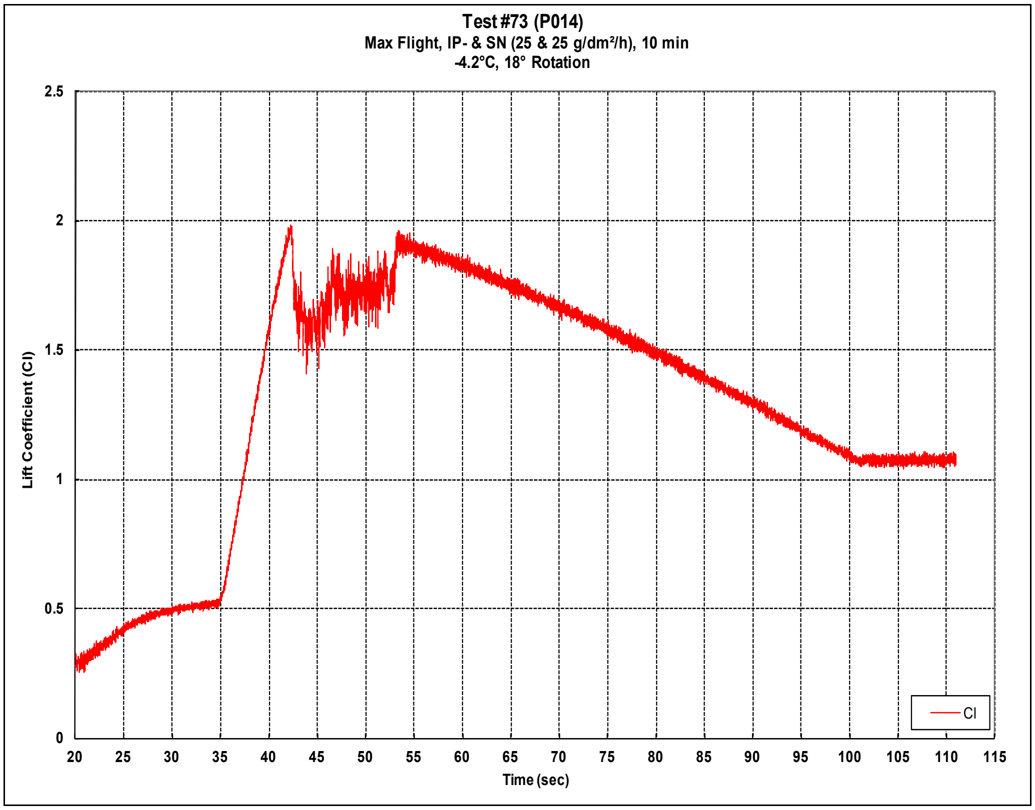


Figure D88: Run #73

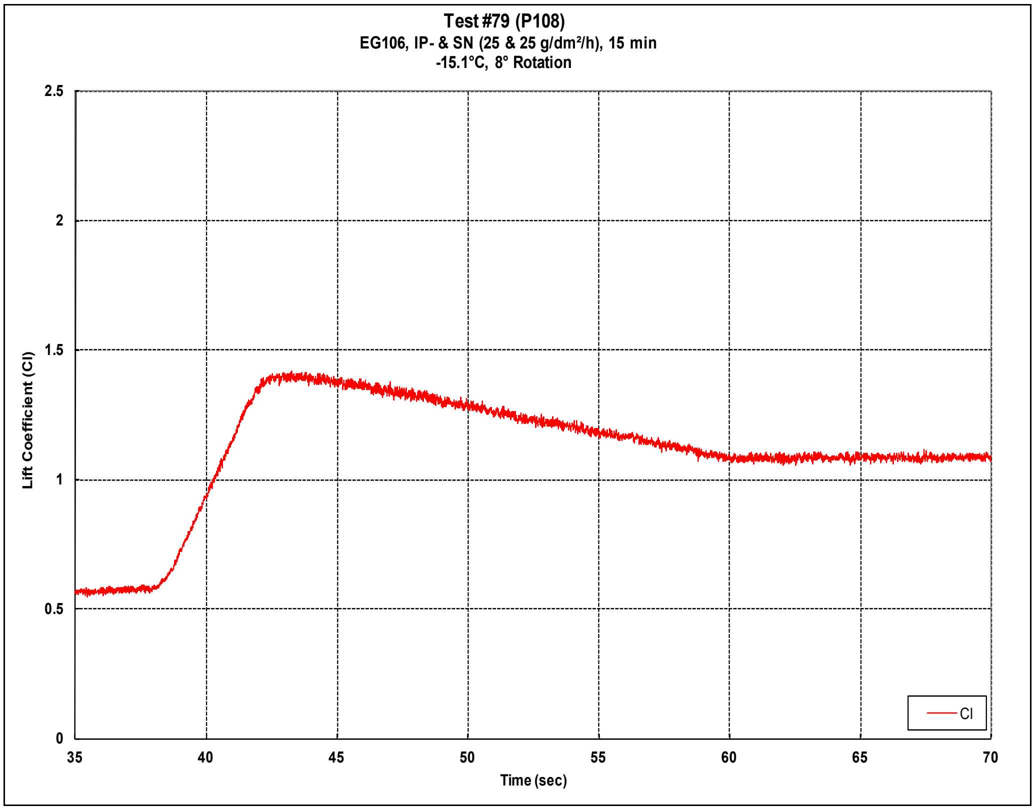


Figure D89: Run #79

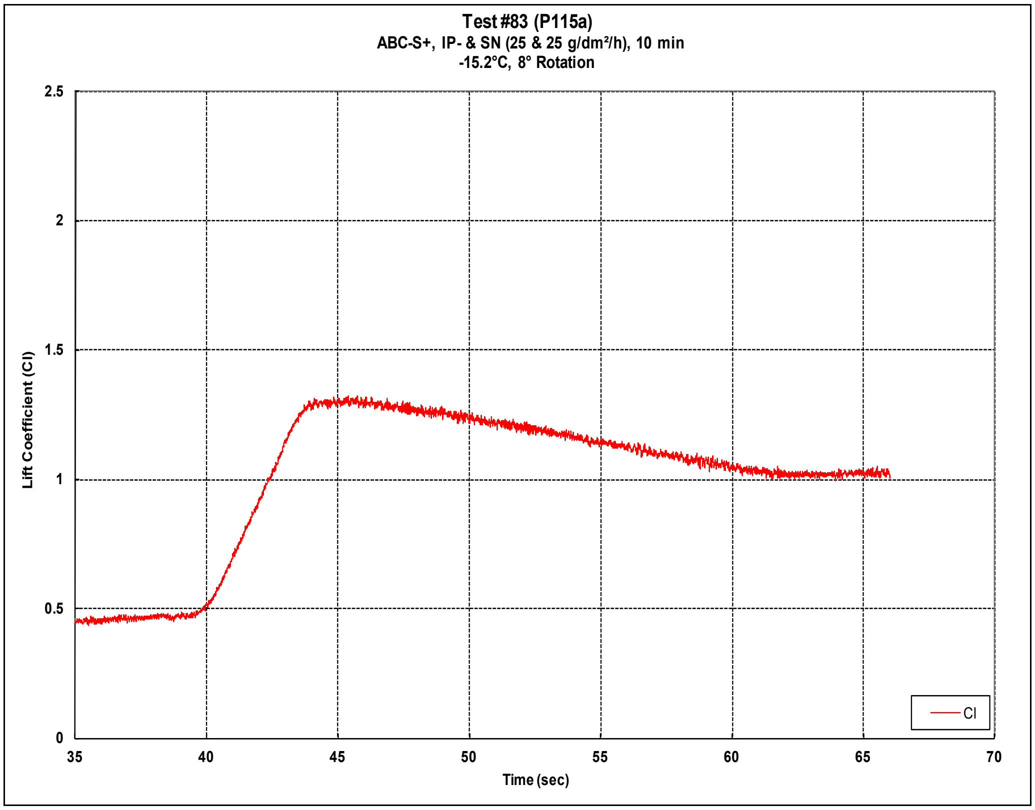


Figure D90: Run #83

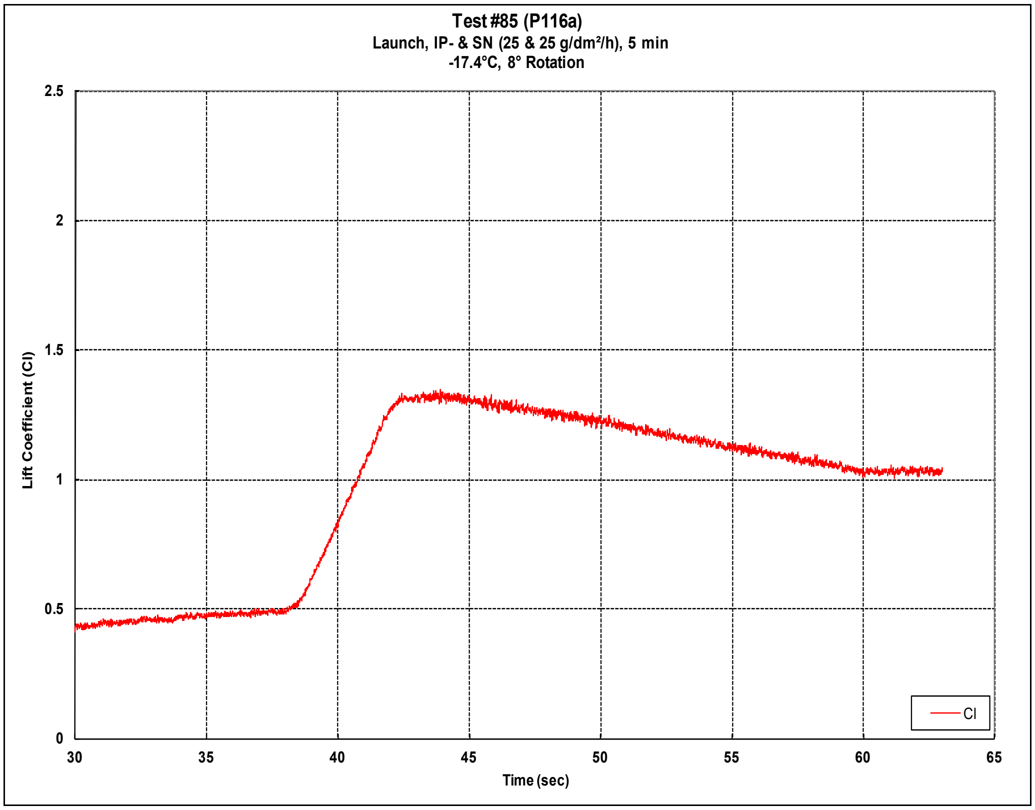


Figure D91: Run #85

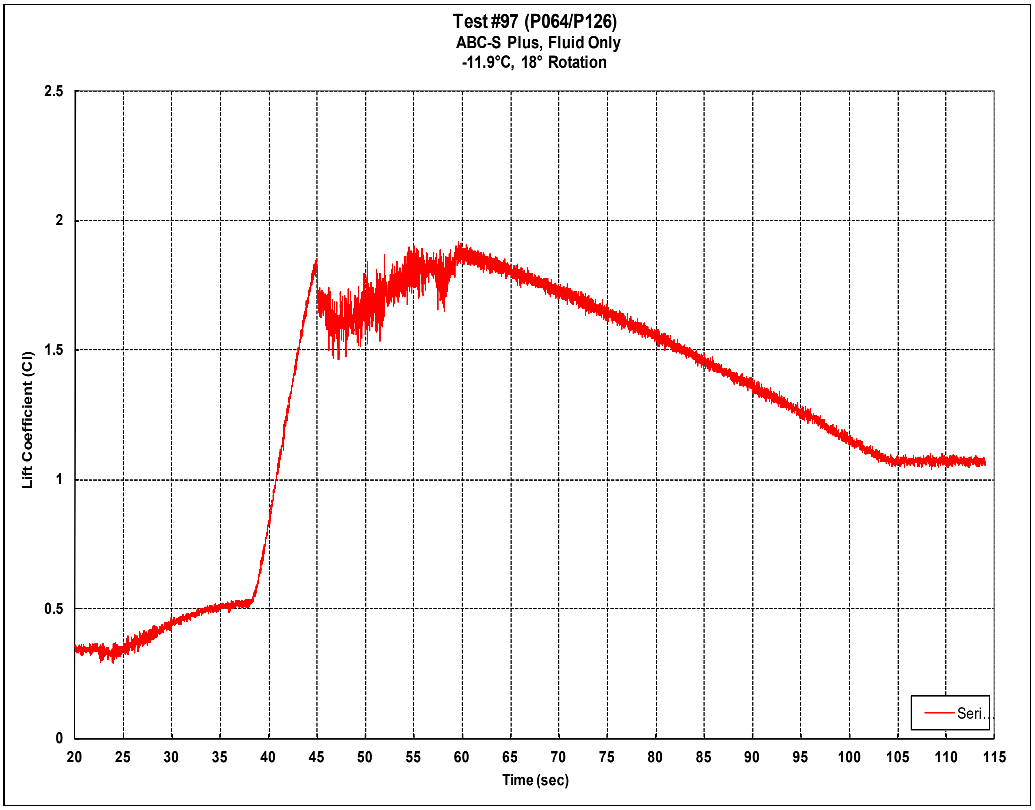


Figure D92: Run #97

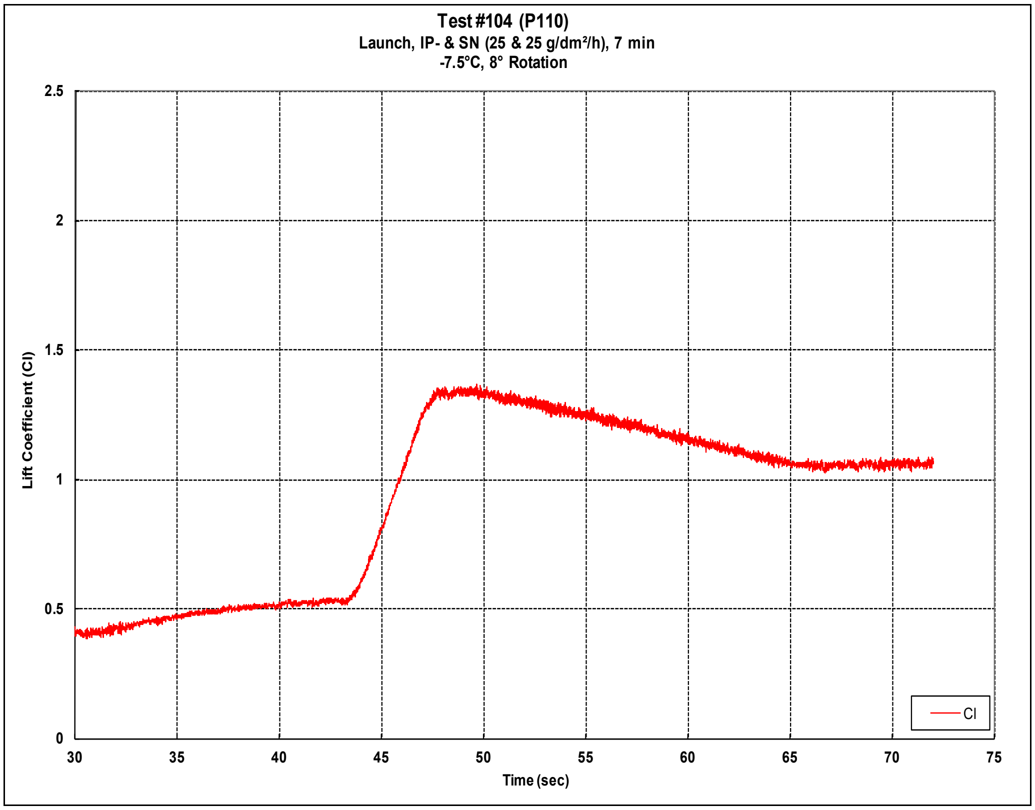


Figure D93: Run #104

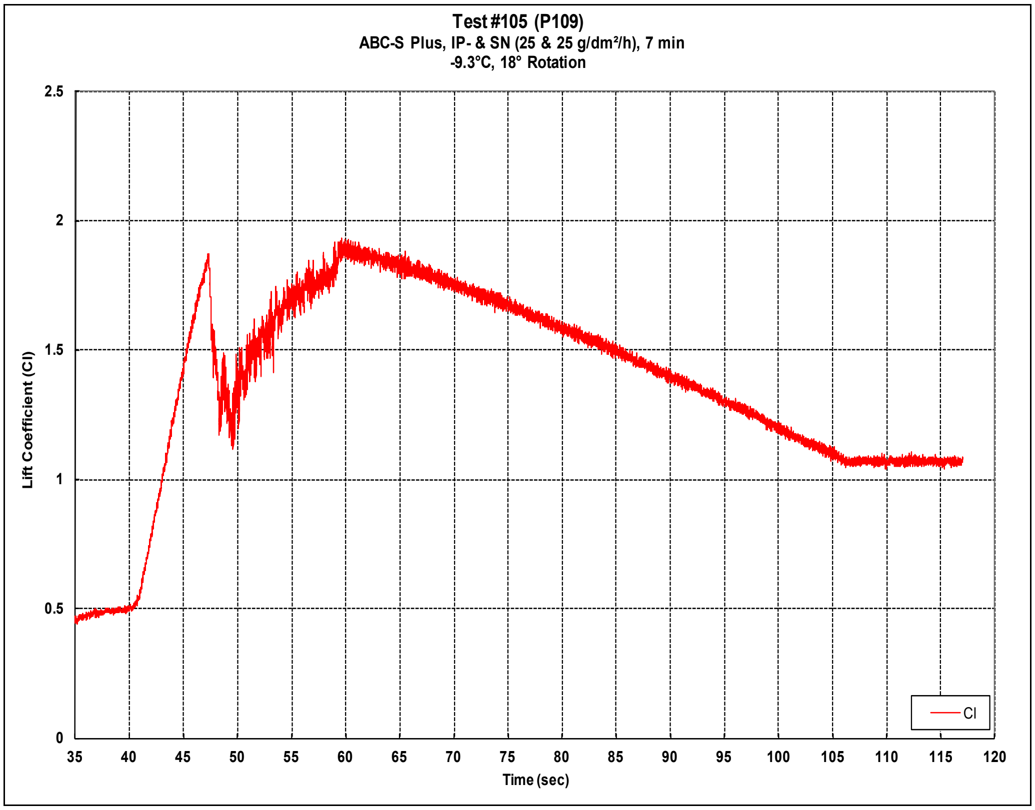


Figure D94: Run #105

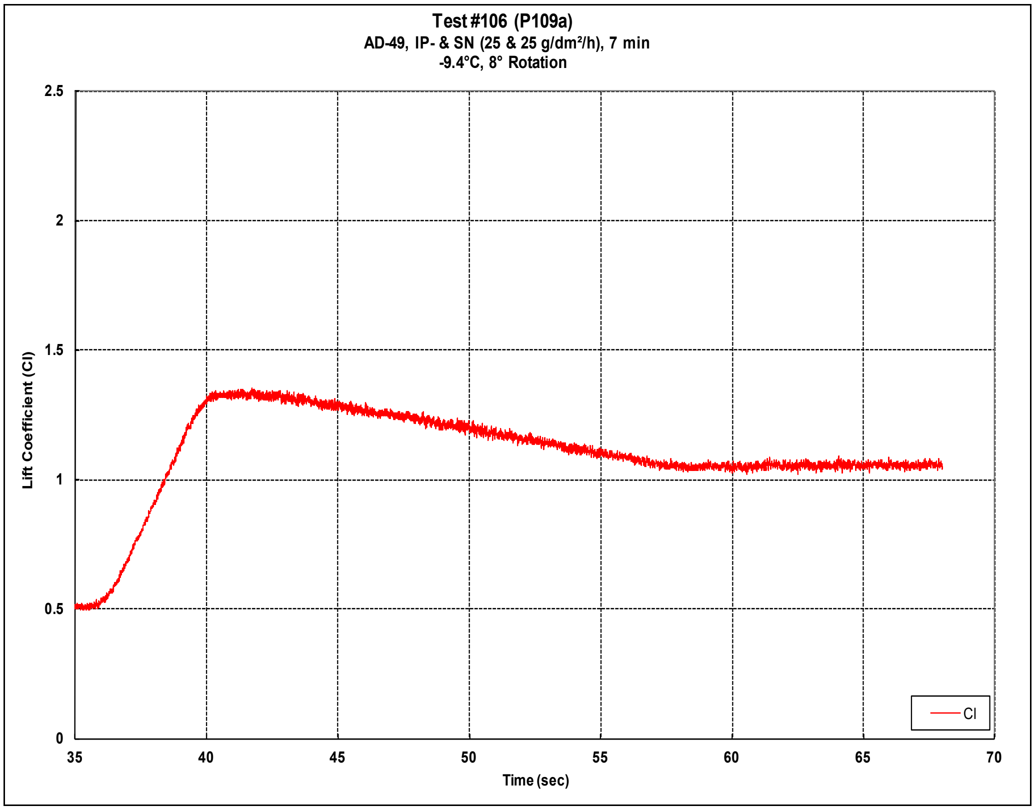


Figure D95: Run #106

This page intentionally left blank.

LIGHT ICE PELLETS MIXED WITH LIGHT RAIN

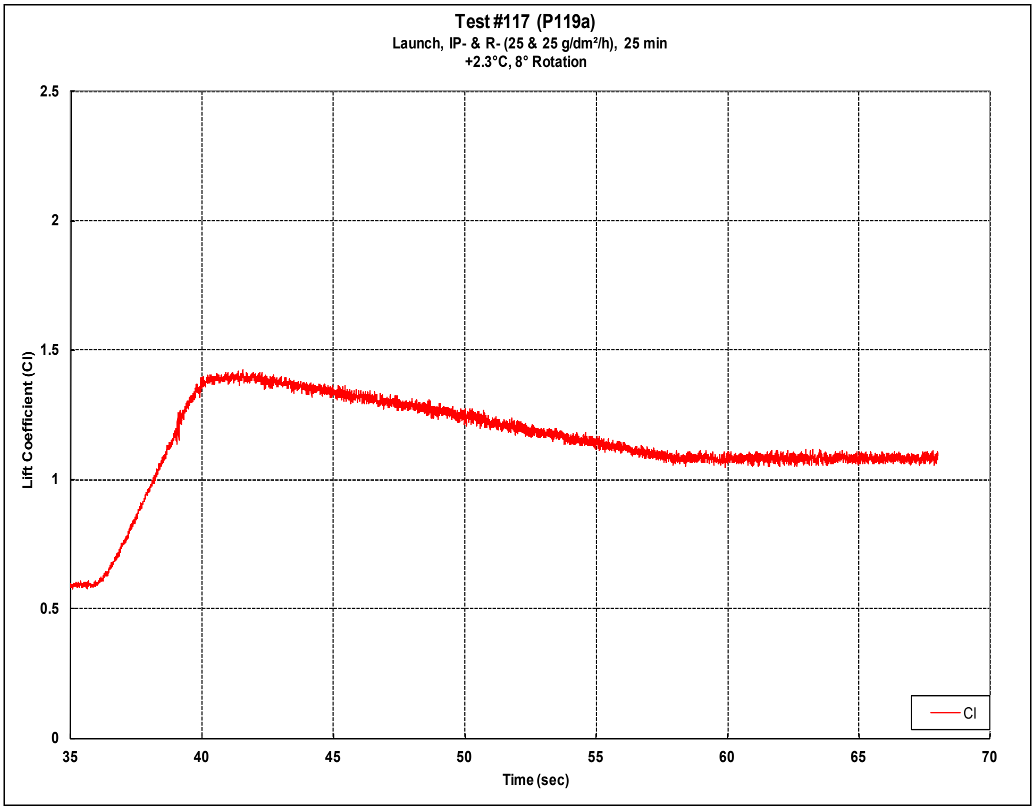


Figure D96: Run #117

This page intentionally left blank.

APPENDIX E

ADDITIONAL NOTES AND OBSERVATIONS AT NRC WIND TUNNEL

Form 5

CAMERA LOCATIONS FORM

(Fill in only once unless camera locations are changed)

Date: February 2, 2010 Time: 23:30 Run Numbers: ______

Camera ~~1~~: 2 Wide Angle ☑ 18-50 Zoom ☐

Distance from window edge (C1): 50.5" (5.25')

Height from window base: 13"

window to lens: 2.75"

Flash ~~1~~: 2 Distance from window edge (F1): 33"

45° angle Height from window base: 29"

Actual window to Mount 15.75"

Sony Prime

Camera ~~2~~: 1 Wide Angle ☐ Zoom ☐

Distance from window edge (C2): 3"

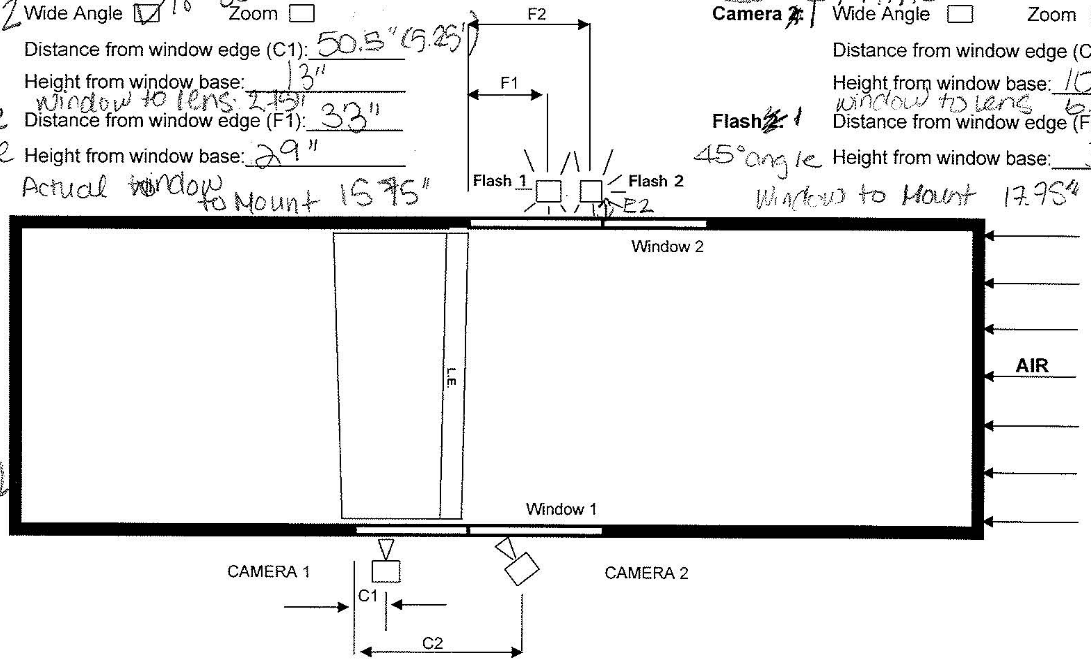
Height from window base: 10"

window to lens 6.75"

Flash ~~2~~: 1 Distance from window edge (F2): 29" *

45° angle Height from window base: 39°

Window to Mount 17.75"



*99.5" from edge of window FLASH 2

OBSERVER: Ben

ASSISTED BY: VICTORIA

Observations: ______

M:/Groups/PM2020(TC-Deicing 05-06)/Procedures/Data Forms/WT VZ docs

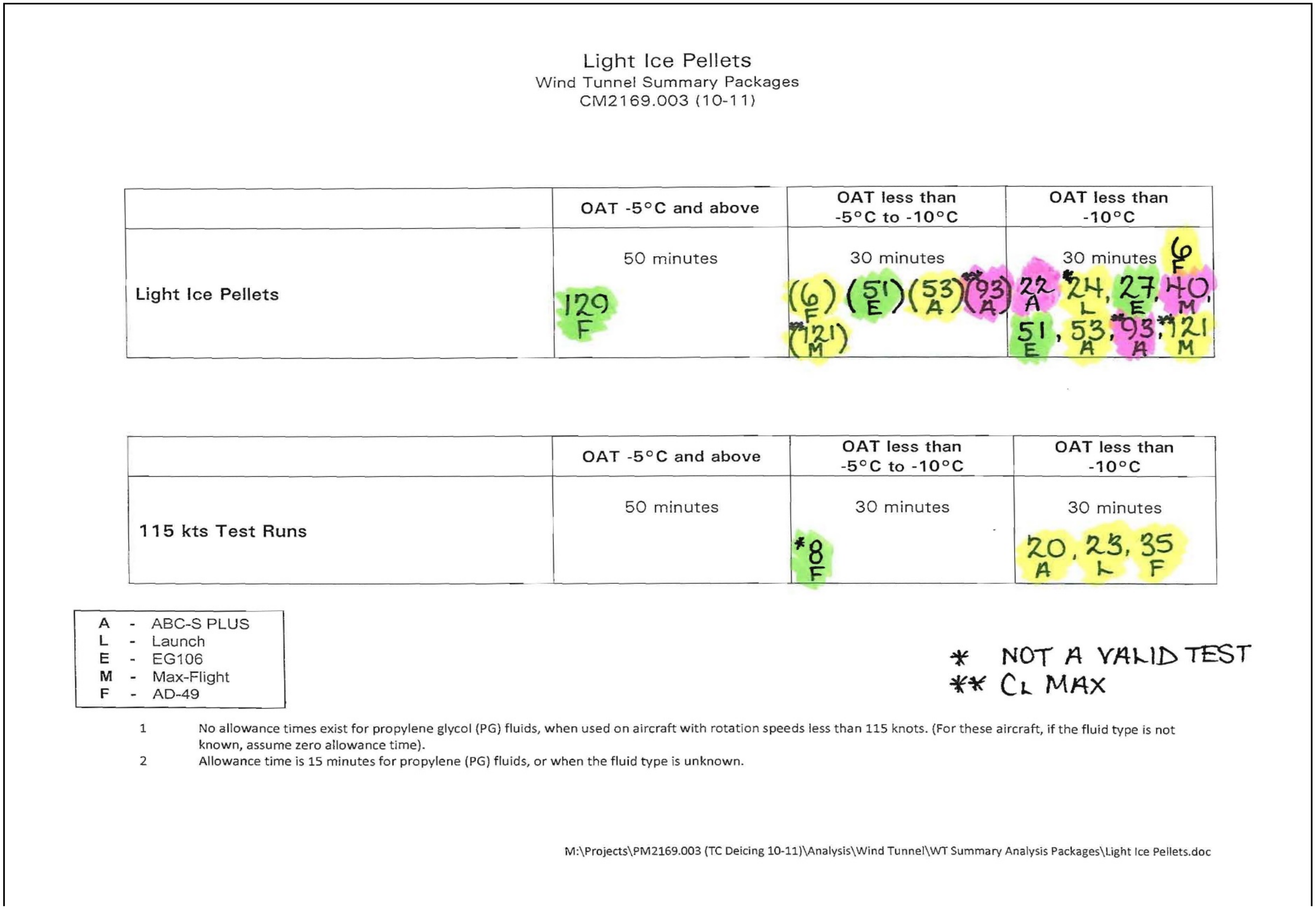
This page intentionally left blank.

APPENDIX F

ICE PELLET ALLOWANCE TIMES SUMMARY SHEETS 2010-11

LIST OF FIGURES

LIGHT ICE PELLETS



Light Ice Pellets

Wind Tunnel Summary Packages
CM2169.003 (10-11)

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets	50 minutes 129 F	30 minutes (6 F) (51 E) (53 A) **(93 A) **(121 M)	30 minutes 6 F 22 A *24 L, 27 E, 40 M, 51 E, 53 A, **93 A, **121 M

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
115 kts Test Runs	50 minutes	30 minutes *8 F	30 minutes 20 A, 23 L, 35 F

A	-	ABC-S PLUS
L	-	Launch
E	-	EG106
M	-	Max-Flight
F	-	AD-49

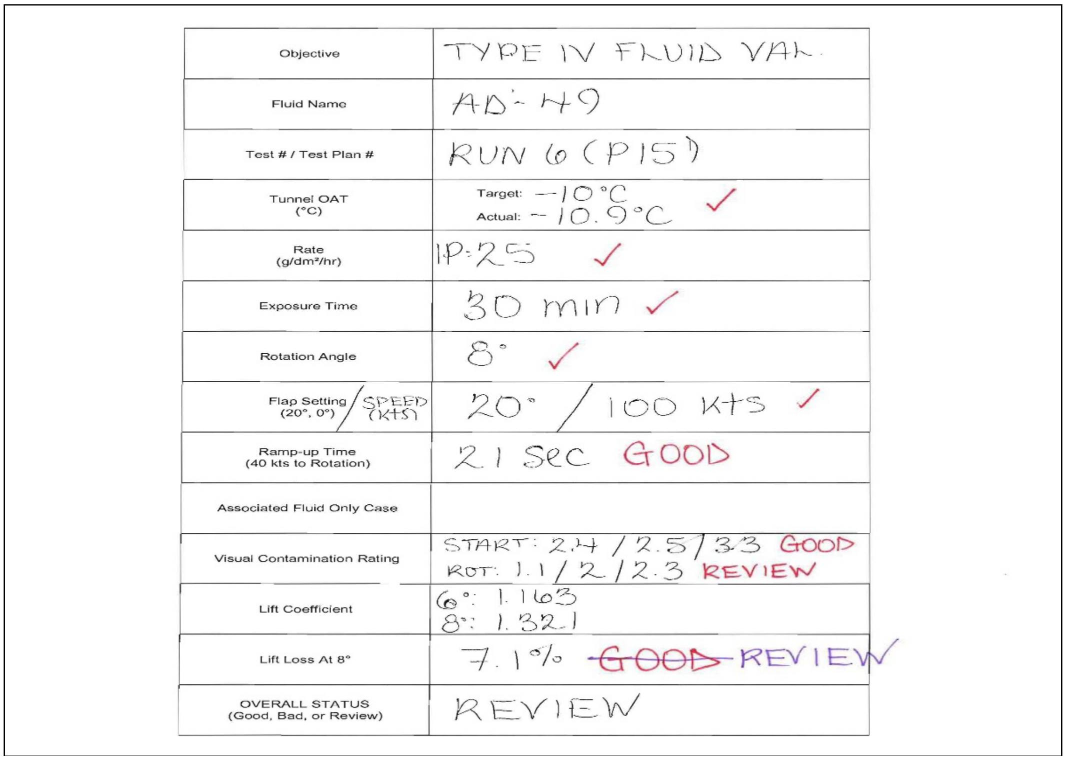
* NOT A VALID TEST
** CL MAX

1 No allowance times exist for propylene glycol (PG) fluids, when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time).

2 Allowance time is 15 minutes for propylene (PG) fluids, or when the fluid type is unknown.

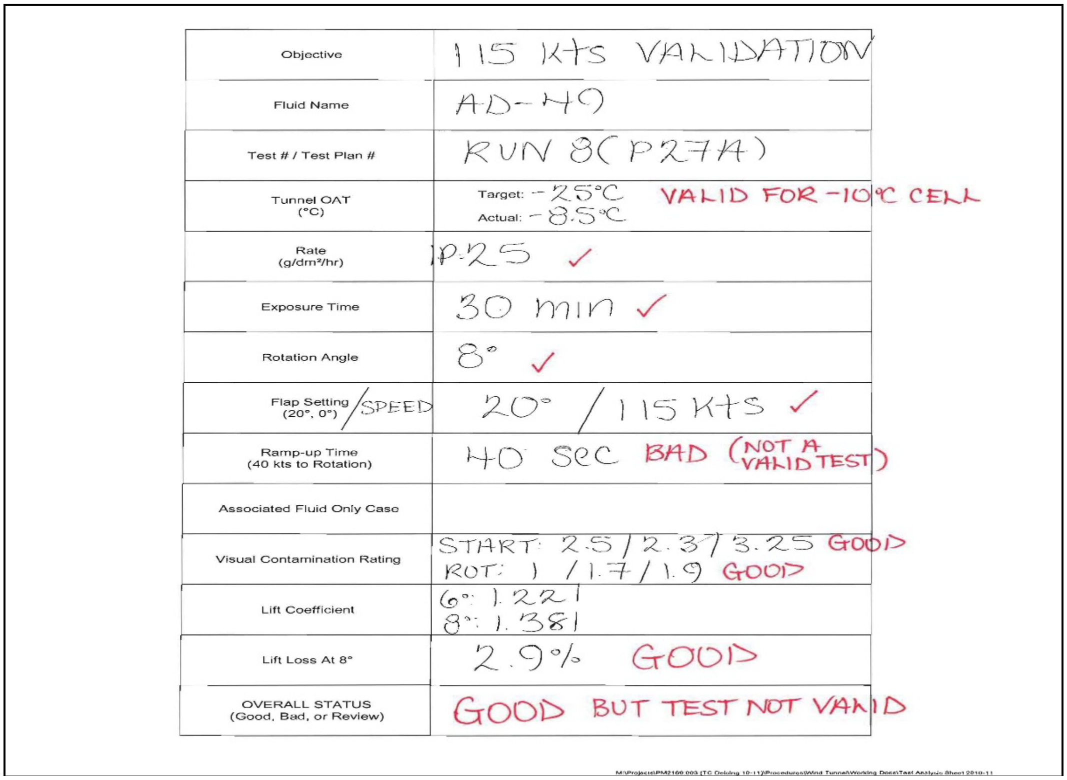
M:\Projects\PM2169.003 (TC Deicing 10-11)\Analysis\Wind Tunnel\WT Summary Analysis Packages\Light Ice Pellets.doc

Figure F1: Light Ice Pellets Allowance Table



Objective	TYPE IV FLUID VAL.
Fluid Name	AD-49
Test # / Test Plan #	RUN 6 (P15)
Tunnel OAT (°C)	Target: -10°C Actual: -10.9°C ✓
Rate (g/dm²/hr)	IP:25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	21 Sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.4 / 2.5 / 3.3 GOOD ROT: 1.1 / 2 / 2.3 REVIEW
Lift Coefficient	6°: 1.163 8°: 1.321
Lift Loss At 8°	7.1% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

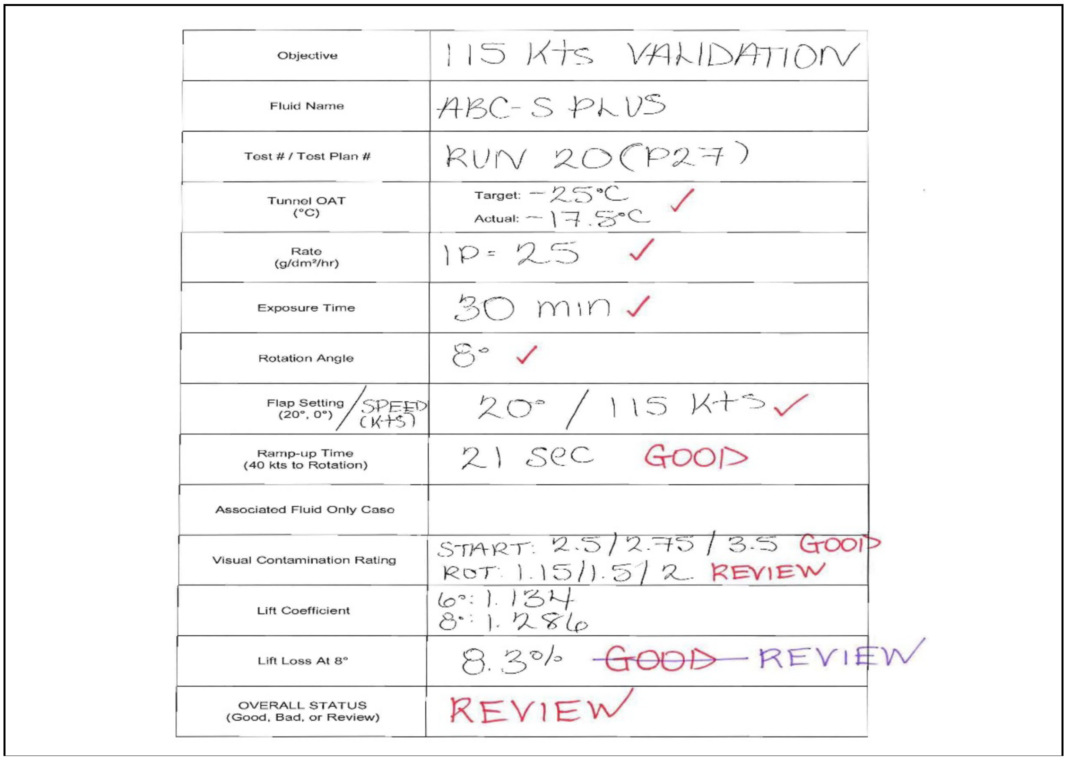
Figure F2: Run #6



Objective	115 KTS VALIDATION
Fluid Name	AD-49
Test # / Test Plan #	RUN 8(P27A)
Tunnel OAT (°C)	Target: -25°C VALID FOR -10°C CELL Actual: -8.5°C
Rate (g/dm²/hr)	IP:25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED	20° / 115 KTS ✓
Ramp-up Time (40 kts to Rotation)	40 Sec BAD (NOT A VALID TEST)
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5 / 2.3 / 3.25 GOOD ROT: 1 / 1.7 / 1.9 GOOD
Lift Coefficient	6°: 1.221 8°: 1.381
Lift Loss At 8°	2.9% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD BUT TEST NOT VALID

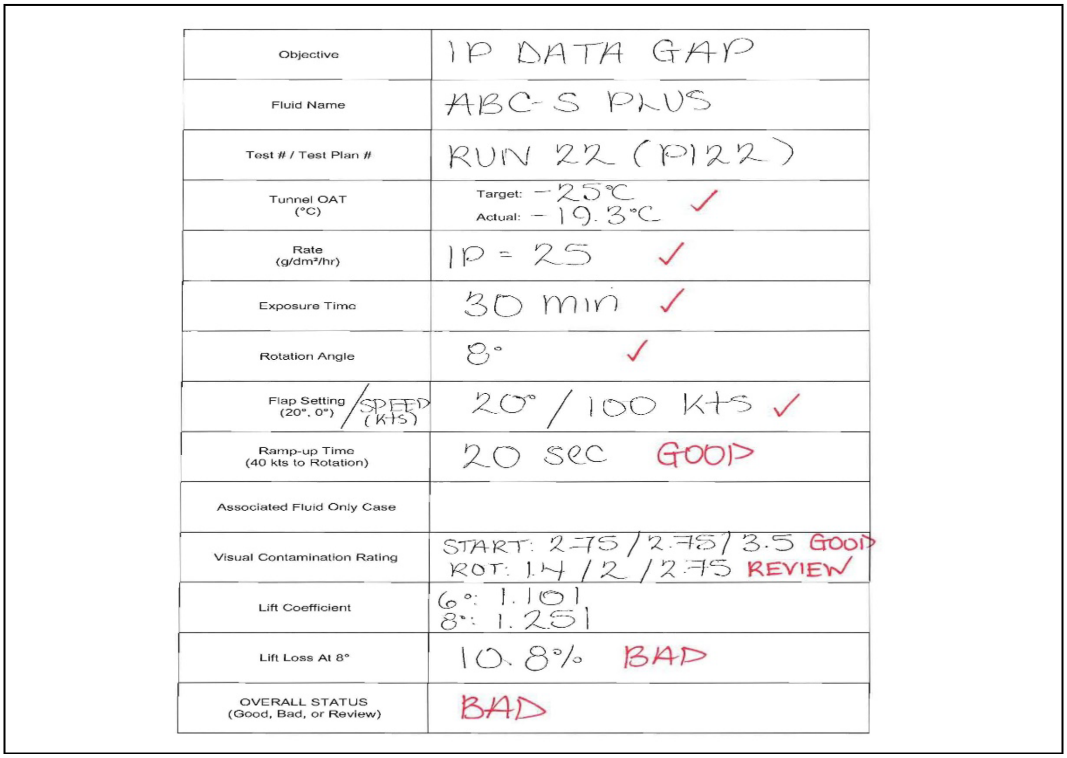
M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Working Docs\Test Analysis Sheet 2010-11

Figure F3: Run #8



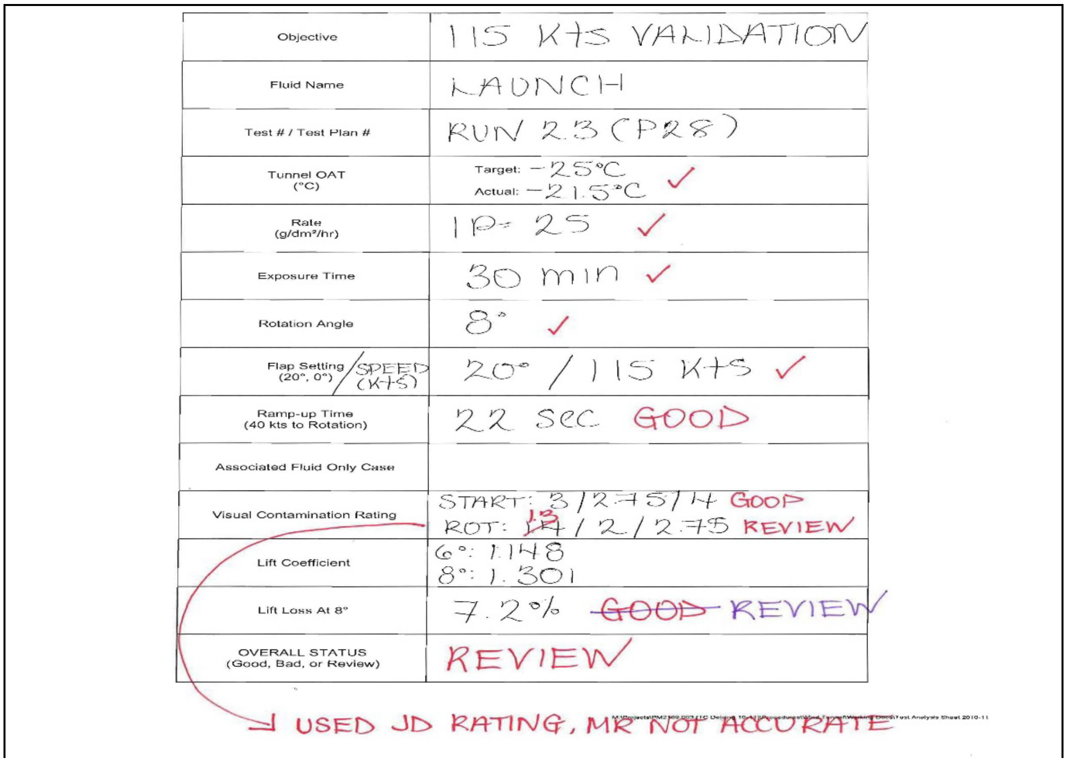
Objective	115 Kts VALIDATION
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 20(P27)
Tunnel OAT (°C)	Target: −25°C Actual: −17.5°C ✓
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5/2.75/3.5 GOOD ROT: 1.15/1.5/2 REVIEW
Lift Coefficient	6°: 1.134 8°: 1.286
Lift Loss At 8°	8.3% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F4: Run #20



Objective	IP DATA GAP
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 22 (P122)
Tunnel OAT (°C)	Target: −25°C Actual: −19.3°C ✓
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	20 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 275/2.75/3.5 GOOD ROT: 1.4/2/2.75 REVIEW
Lift Coefficient	6°: 1.101 8°: 1.251
Lift Loss At 8°	10.8% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

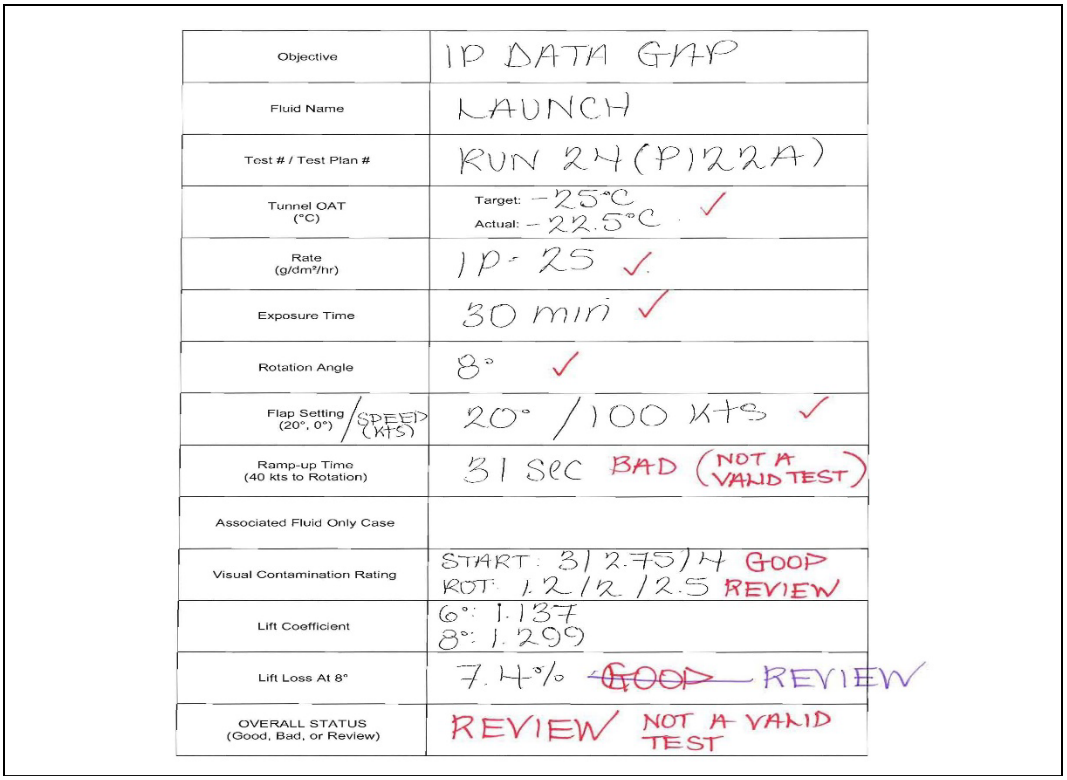
Figure F5: Run #22



Objective	115 KTS VALIDATION
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 23 (P28)
Tunnel OAT (°C)	Target: −25°C Actual: −21.5°C ✓
Rate (g/dm²/hr)	IP-25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 KTS ✓
Ramp-up Time (40 kts to Rotation)	22 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/2.75/4 GOOD ROT: ~~14~~ 13 / 2 / 2.75 REVIEW
Lift Coefficient	6°: 1.148 8°: 1.301
Lift Loss At 8°	7.2% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

USED JD RATING, MR NOT ACCURATE

Figure F6: Run #23

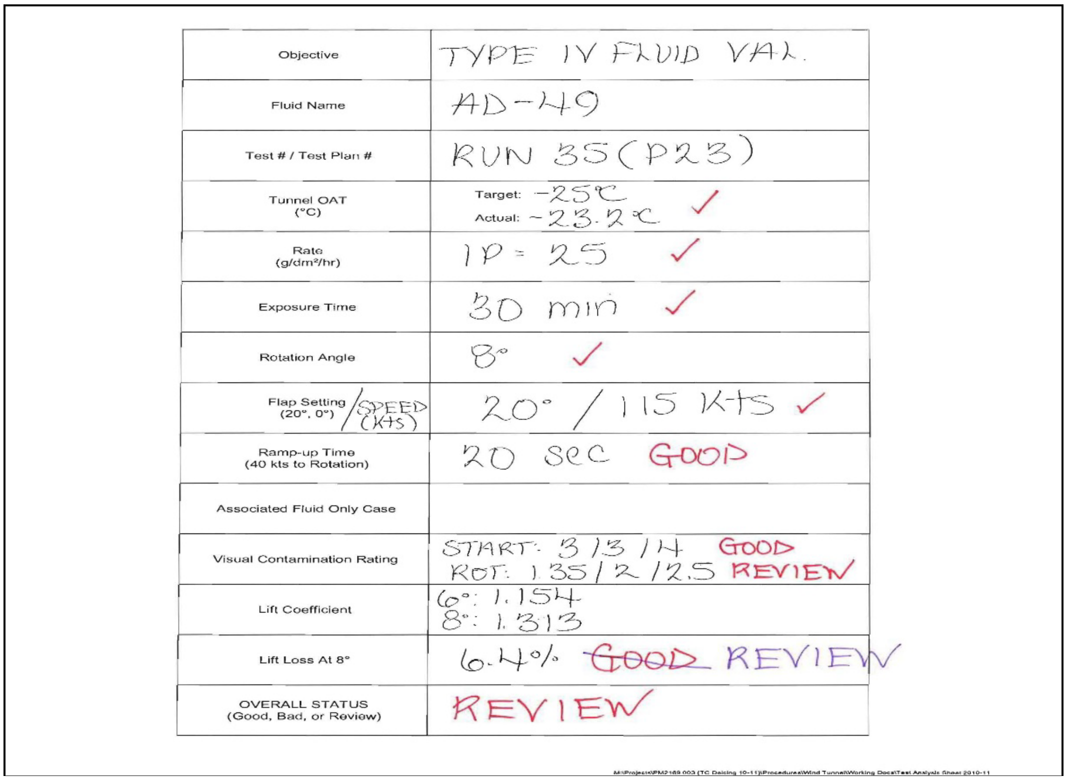


Objective	IP DATA GAP
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 24 (P122A)
Tunnel OAT (°C)	Target: −25°C Actual: −22.5°C ✓
Rate (g/dm²/hr)	IP-25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	31 sec BAD (NOT A VALID TEST)
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/2.75/4 GOOD ROT: 1.2/2/2.5 REVIEW
Lift Coefficient	6°: 1.137 8°: 1.299
Lift Loss At 8°	7.4% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW NOT A VALID TEST

Figure F7: Run #24

Objective	IP DATA GAP
Fluid Name	EG106
Test # / Test Plan #	RUN 27 (P121)
Tunnel OAT (°C)	Target: −25°C Actual: −22.6°C ✓
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	17 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START : 2.35/2.35/3 GOOD ROT: 1/1.2/1.5 GOOD
Lift Coefficient	6°: 1.208 8°: 1.357
Lift Loss At 8°	3.2% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

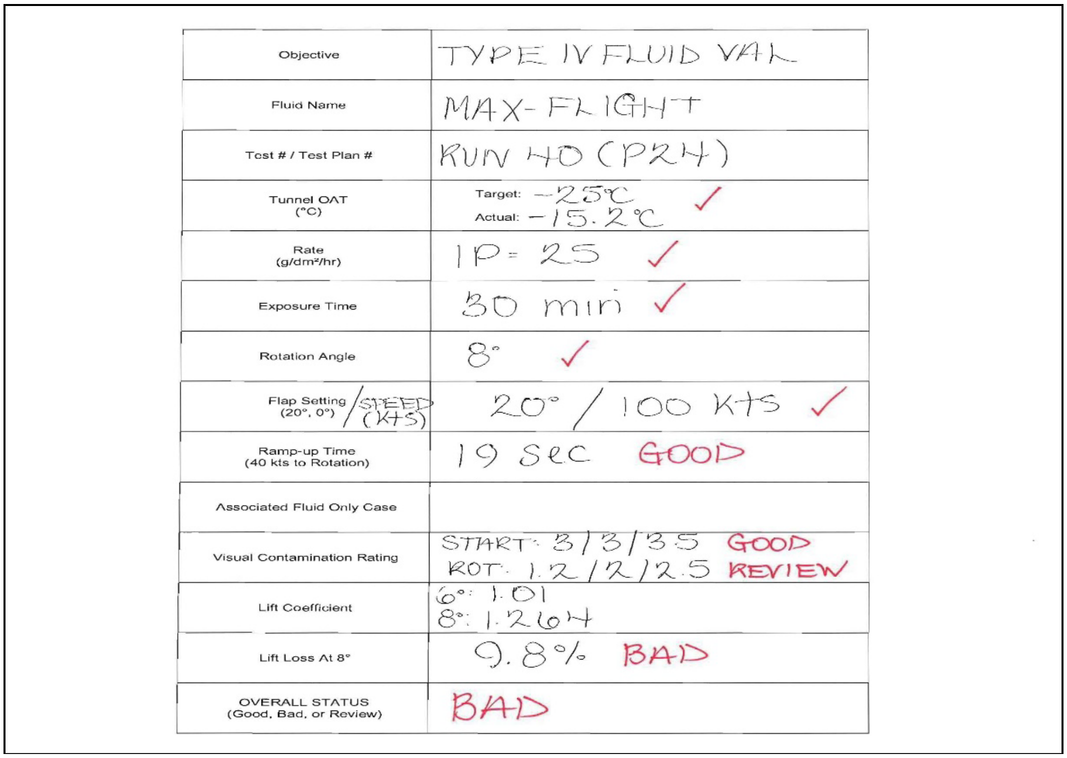
Figure F8: Run #27



Objective	TYPE IV FLUID VAL.
Fluid Name	AD-49
Test # / Test Plan #	RUN 35 (P23)
Tunnel OAT (°C)	Target: −25°C Actual: −23.2°C ✓
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 KTS ✓
Ramp-up Time (40 kts to Rotation)	20 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/3/4 GOOD ROT: 1.35/2/2.5 REVIEW
Lift Coefficient	6°: 1.154 8°: 1.313
Lift Loss At 8°	6.4% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

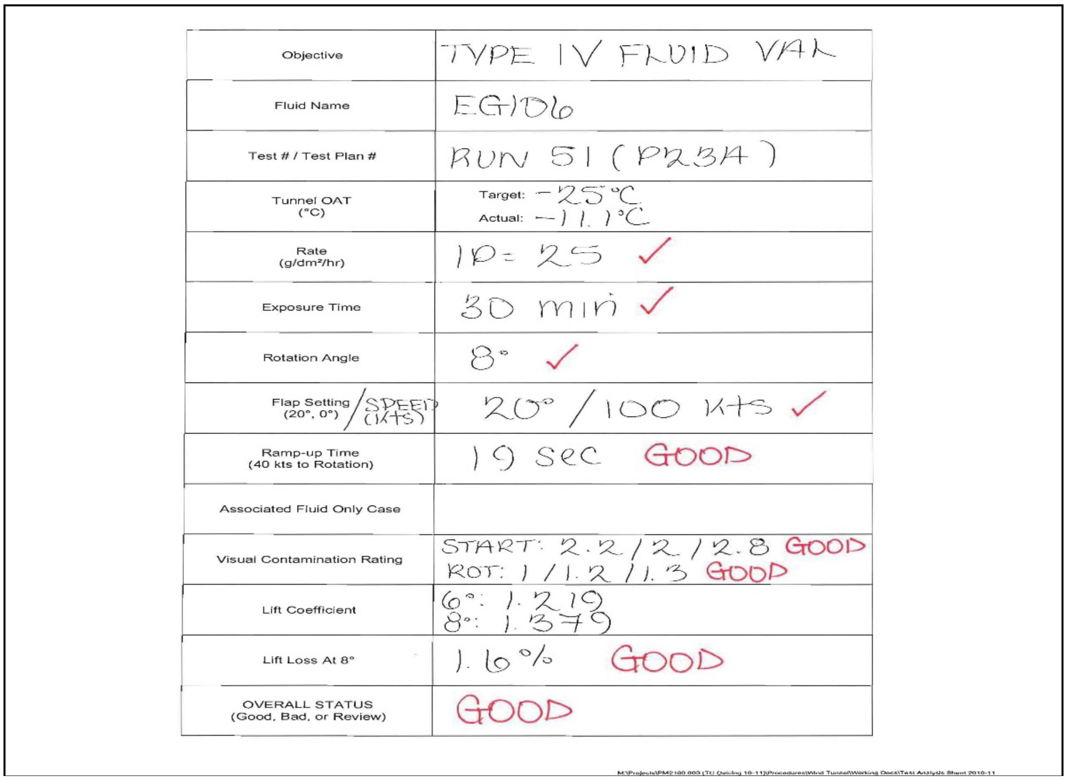
M:\Projects\PM2169.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Working Docs\Test Analysis Sheet 2010-11

Figure F9: Run #35



Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 40 (P24)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -15.2°C
Rate (g/dm²/hr)	IP= 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	19 SEC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/3/3.5 GOOD ROT: 1.2/2/2.5 REVIEW
Lift Coefficient	6°: 1.01 8°: 1.264
Lift Loss At 8°	9.8% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

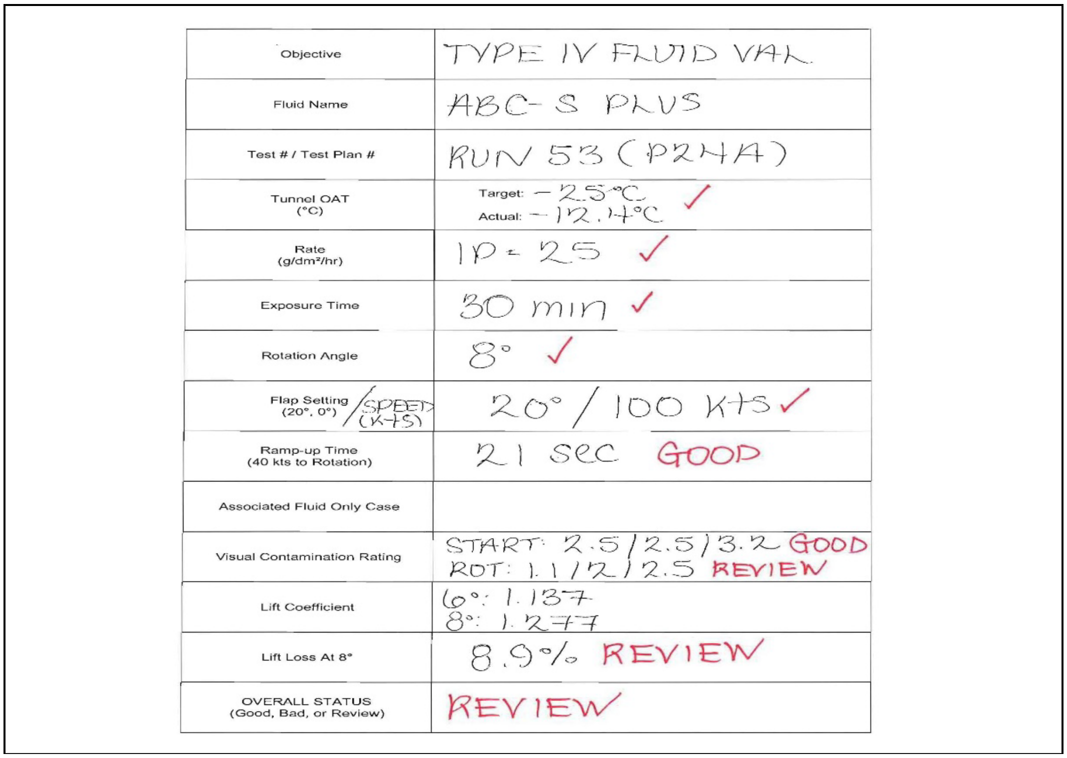
Figure F10: Run #40



Objective	TYPE IV FLUID VAL
Fluid Name	EG106
Test # / Test Plan #	RUN 51 (P23A)
Tunnel OAT (°C)	Target: -25°C Actual: -11.1°C
Rate (g/dm²/hr)	IP= 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	19 SEC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.2/2/2.8 GOOD ROT: 1/1.2/1.3 GOOD
Lift Coefficient	6°: 1.219 8°: 1.379
Lift Loss At 8°	1.16% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

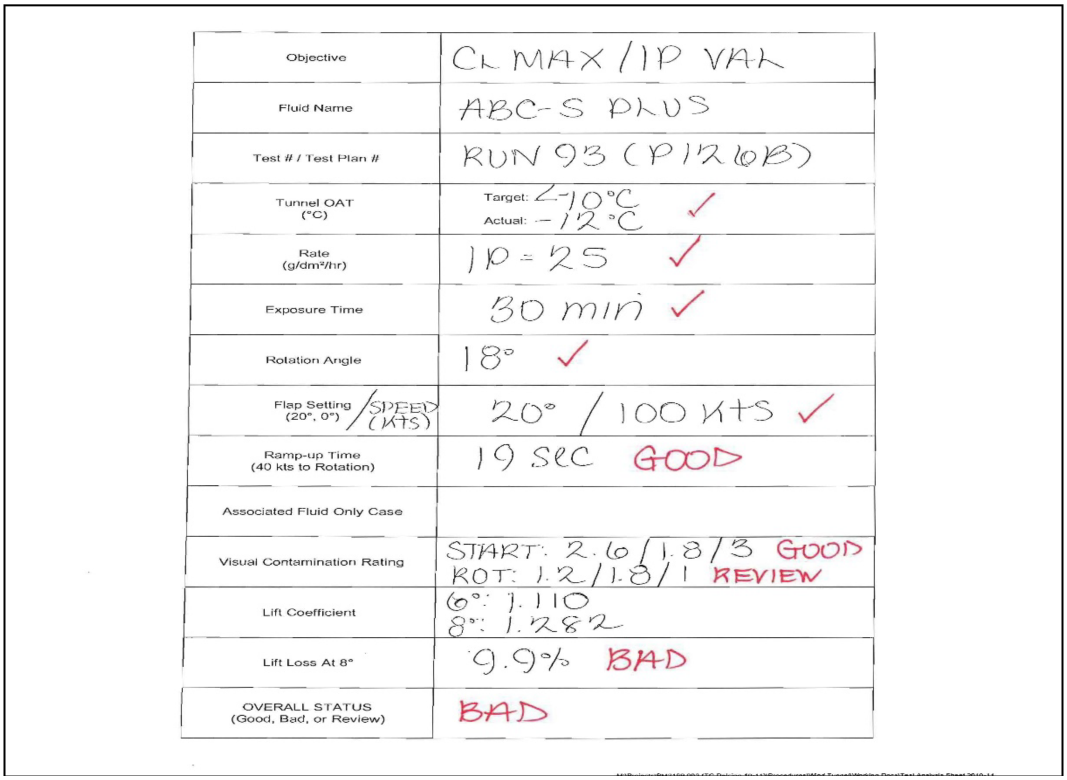
M:\Projects\PM2180.003 (TC Deicing 10-11)\Procedures\Wind Tunnel\Working Docs\Test Analysis Sheet 2010-11

Figure F11: Run #51



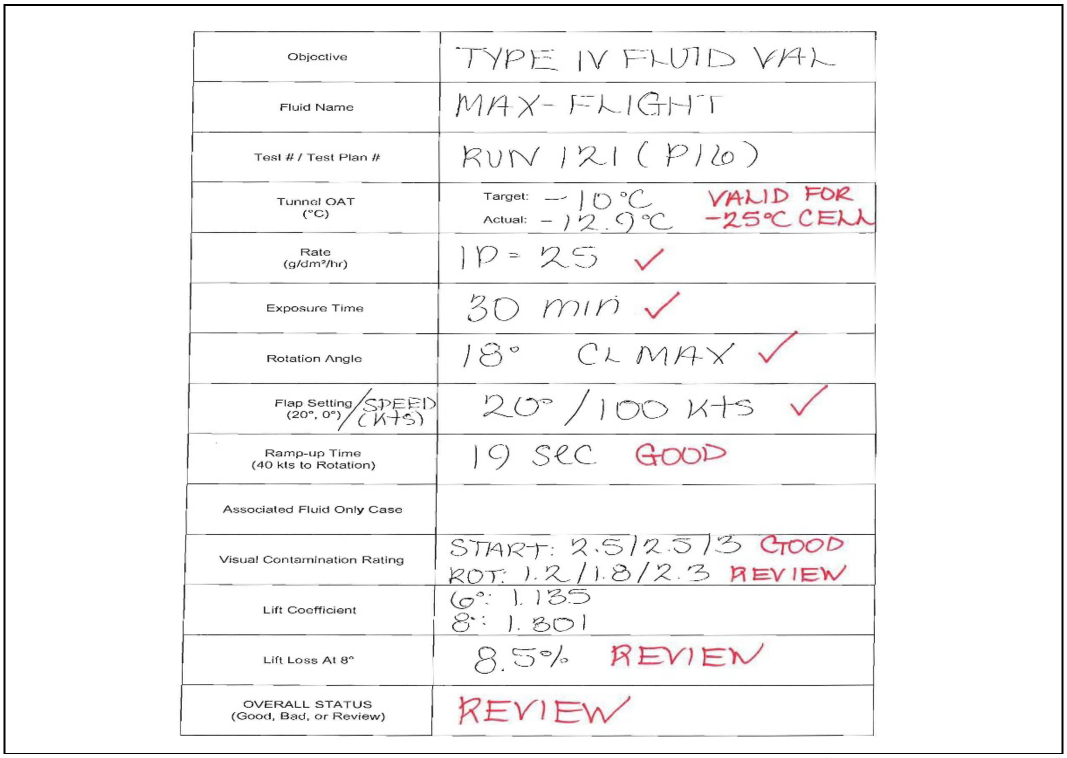
Objective	TYPE IV FLUID VAL
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 53 (P24A)
Tunnel OAT (°C)	Target: −25°C ✓ Actual: −12.4°C
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5/2.5/3.2 GOOD ROT: 1.1/2/2.5 REVIEW
Lift Coefficient	6°: 1.137 8°: 1.277
Lift Loss At 8°	8.9% REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F12: Run #53



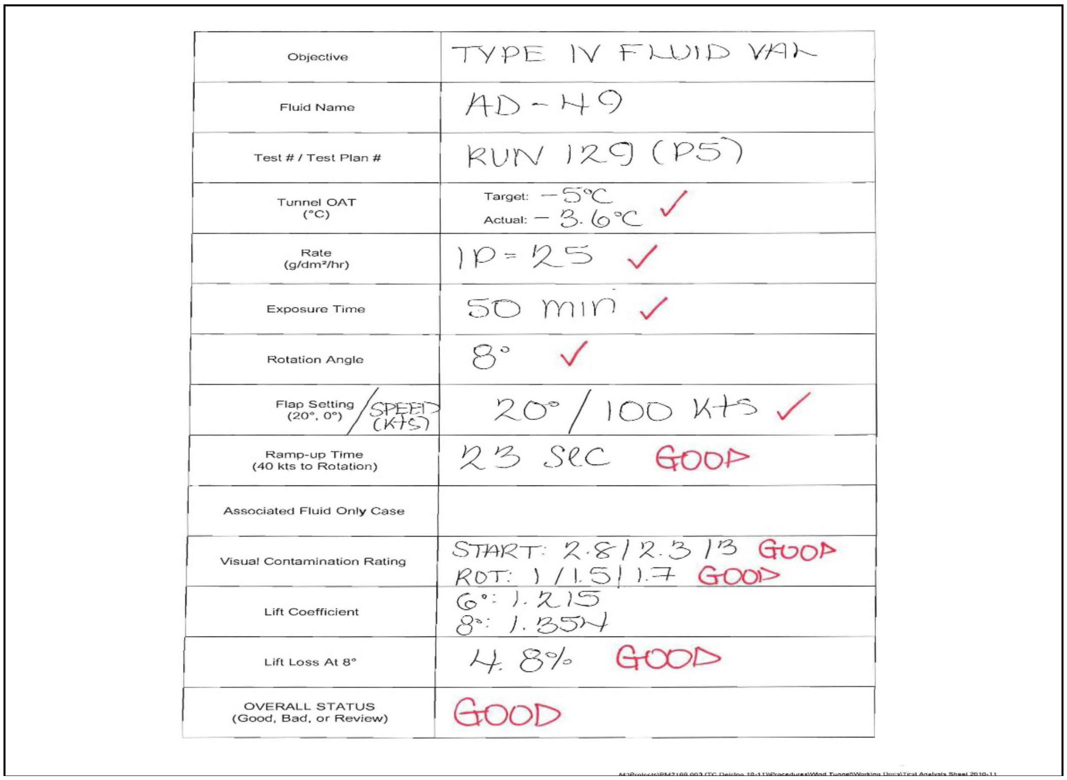
Objective	CL MAX / IP VAL
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 93 (P126B)
Tunnel OAT (°C)	Target: <-10°C ✓ Actual: −12°C
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	30 min ✓
Rotation Angle	18° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	19 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.6/1.8/3 GOOD ROT: 1.2/1.8/1 REVIEW
Lift Coefficient	6°: 1.110 8°: 1.282
Lift Loss At 8°	9.9% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

Figure F13: Run #93



Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 121 (P16)
Tunnel OAT (°C)	Target: -10°C Actual: -12.9°C VALID FOR -25°C CELL
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	30 min ✓
Rotation Angle	18° CL MAX ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	19 SEC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5/2.5/3 GOOD ROT: 1.2/1.8/2.3 REVIEW
Lift Coefficient	6°: 1.135 8: 1.801
Lift Loss At 8°	8.5% REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

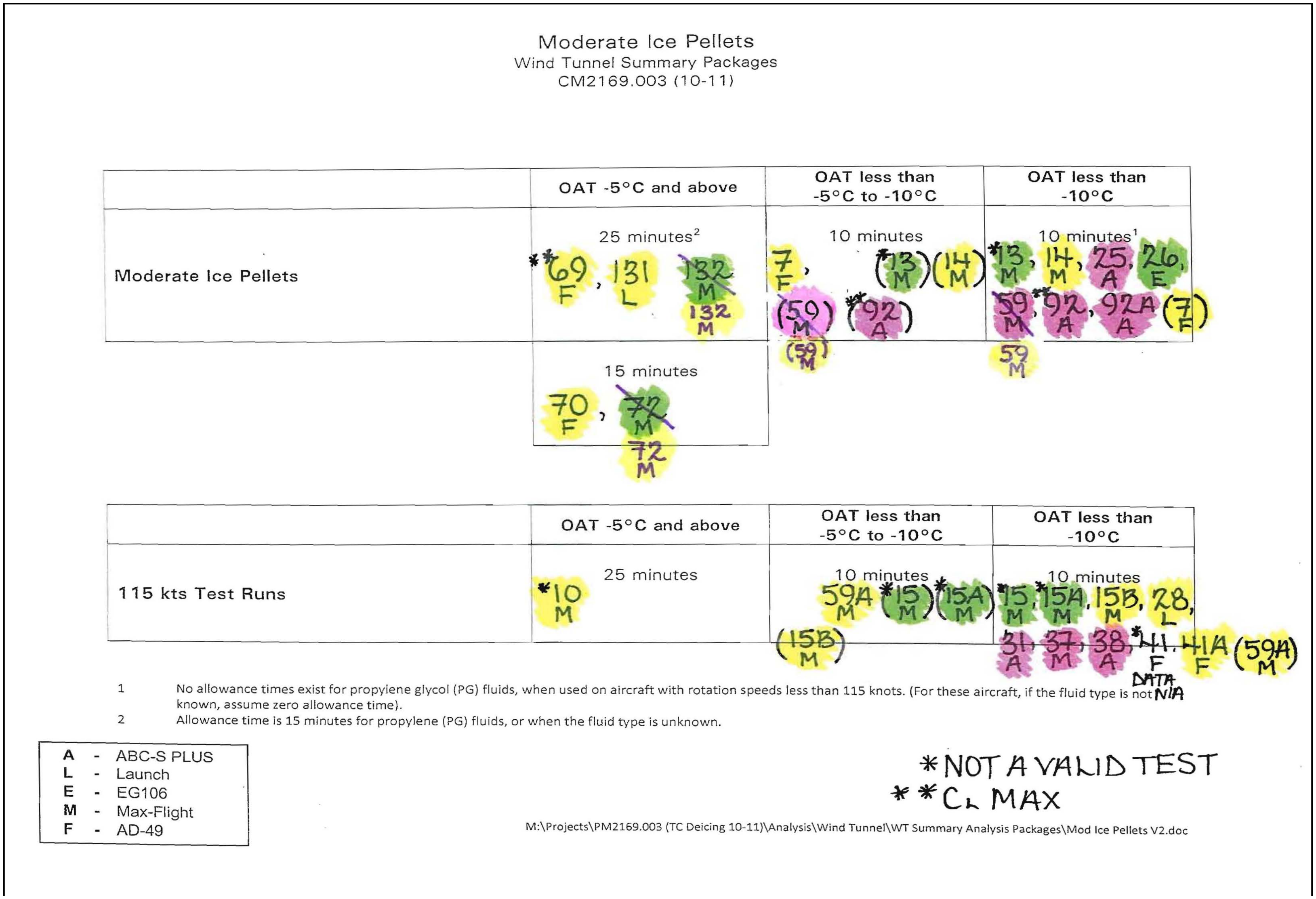
Figure F14: Run #121



Objective	TYPE IV FLUID VAL
Fluid Name	AD-49
Test # / Test Plan #	RUN 129 (P5)
Tunnel OAT (°C)	Target: -5°C Actual: -3.6°C ✓
Rate (g/dm²/hr)	IP = 25 ✓
Exposure Time	50 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	23 SEC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.8/2.3/3 GOOD ROT: 1/1.5/1.7 GOOD
Lift Coefficient	6°: 1.215 8°: 1.354
Lift Loss At 8°	4.8% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

Figure F15: Run #129

MODERATE ICE PELLETS



Moderate Ice Pellets
Wind Tunnel Summary Packages
CM2169.003 (10-11)

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Moderate Ice Pellets	25 minutes[2] **69 F, 131 L ~~132 M~~ 132 M	10 minutes 7 F, *(13 M) (14 M) ~~(59 M)~~ **(92 A) (59 M)	10 minutes[1] *13 M, 14 M, 25 A, 26 E, ~~59 M~~, **92 A, 92A A (7 F) 59 M
	15 minutes 70 F, ~~72 M~~ 72 M		

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
115 kts Test Runs	25 minutes *10 M	10 minutes 59A M *(15 M) *(15A M) (15B M)	10 minutes *15 M, *15A M, 15B M, 28 L, 31 A, 37 M, 38 A, *41 F DATA N/A, 41A F (59A M)

1 No allowance times exist for propylene glycol (PG) fluids, when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time).

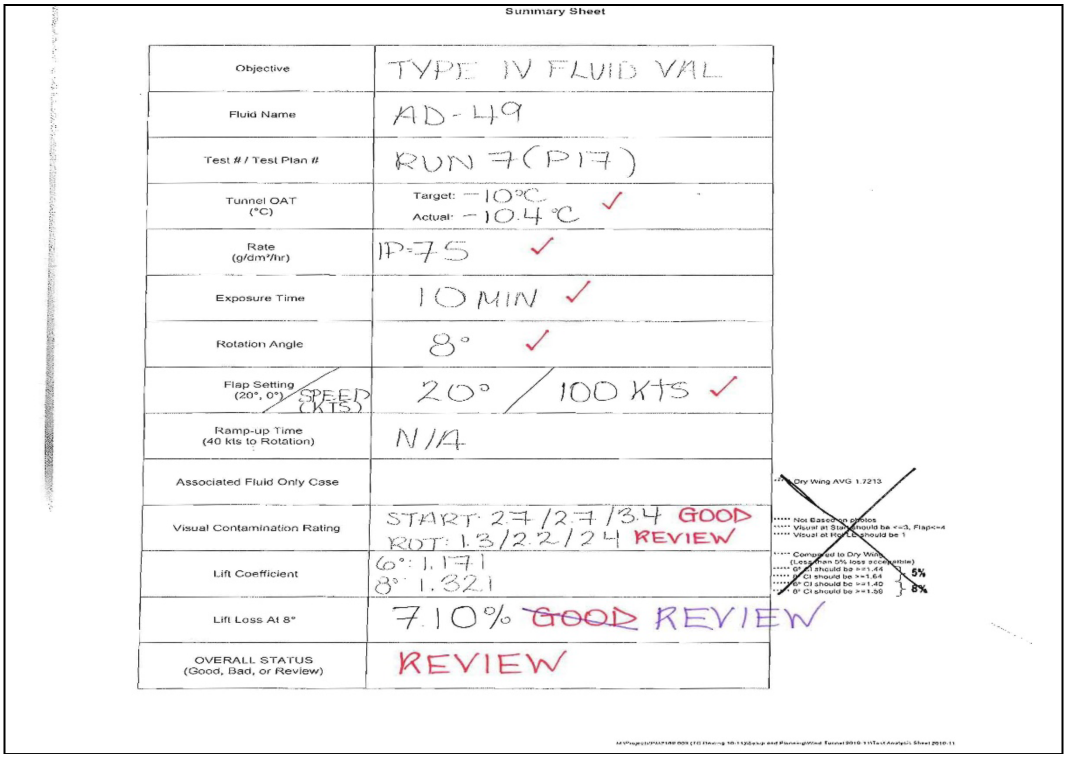
2 Allowance time is 15 minutes for propylene (PG) fluids, or when the fluid type is unknown.

A - ABC-S PLUS
L - Launch
E - EG106
M - Max-Flight
F - AD-49

* NOT A VALID TEST
** CL MAX

M:\Projects\PM2169.003 (TC Deicing 10-11)\Analysis\Wind Tunnel\WT Summary Analysis Packages\Mod Ice Pellets V2.doc

Figure F16: Moderate Ice Pellets Allowance Table



Summary Sheet

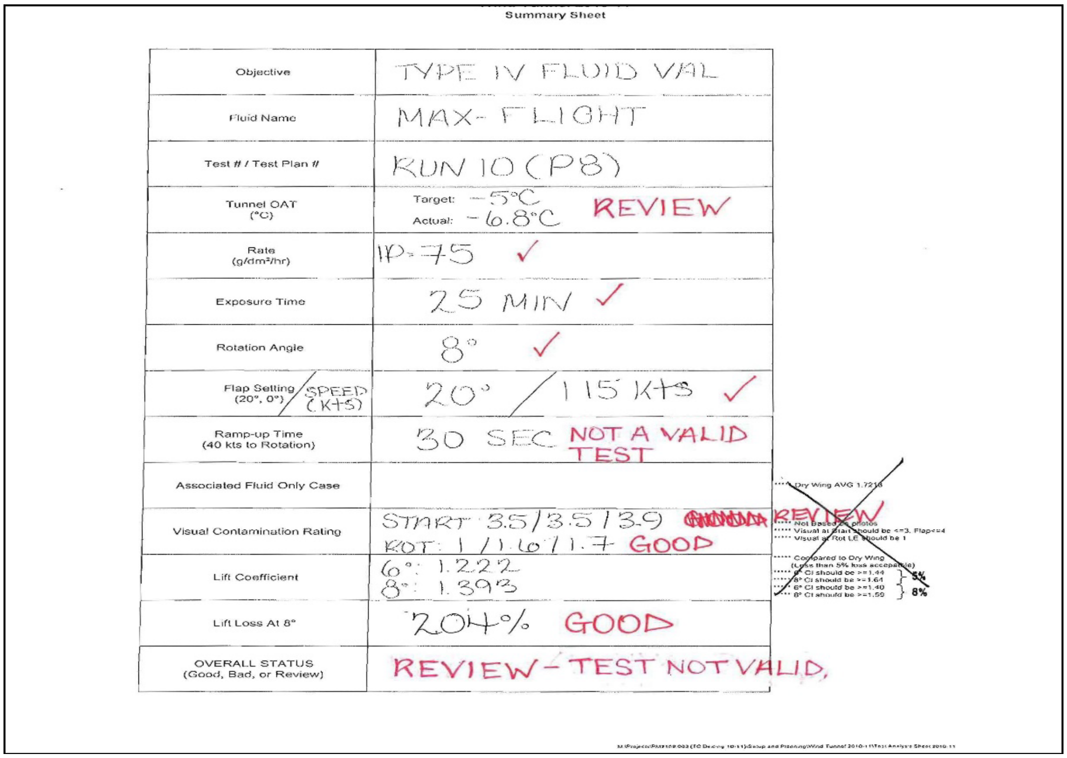
Objective	TYPE IV FLUID VAL
Fluid Name	AD-49
Test # / Test Plan #	RUN 7 (P17)
Tunnel OAT (°C)	Target: −10°C Actual: −10.4°C ✓
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	N/A
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.7/2.7/3.4 GOOD ROT: 1.3/2.2/2.4 REVIEW
Lift Coefficient	6°: 1.171 8°: 1.321
Lift Loss At 8°	7.10% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~**** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss acceptable)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F17: Run #7



Summary Sheet

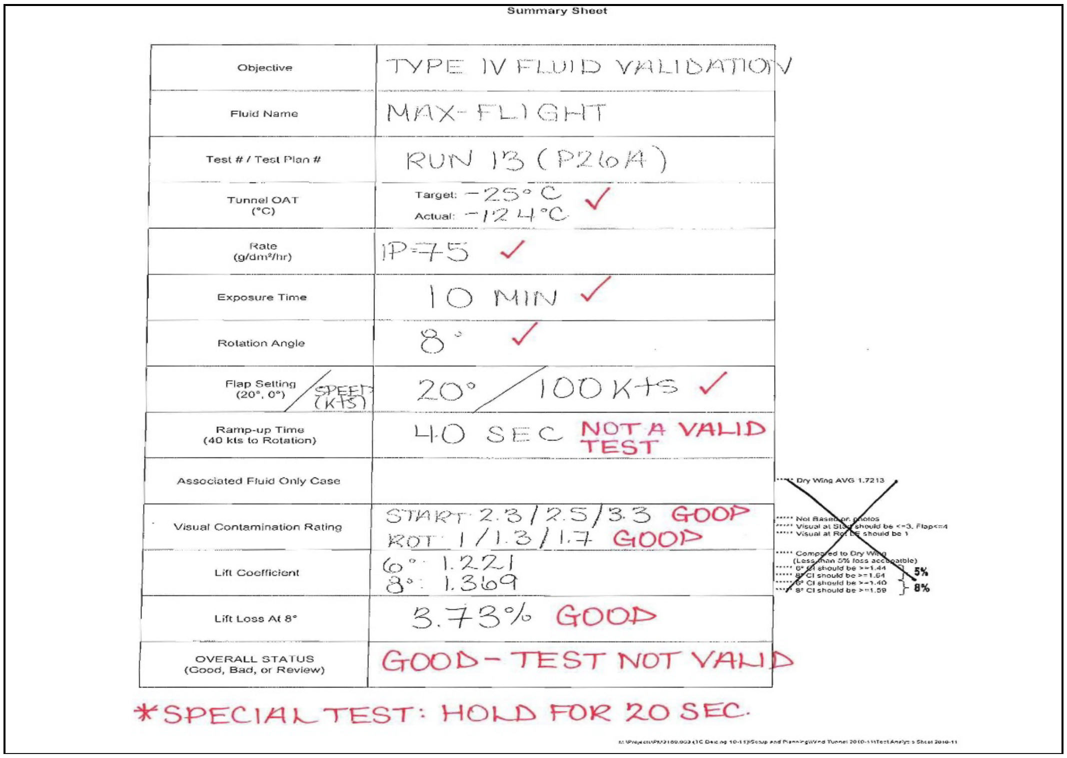
Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 10 (P8)
Tunnel OAT (°C)	Target: −5°C Actual: −6.8°C REVIEW
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	25 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 KTS ✓
Ramp-up Time (40 kts to Rotation)	30 SEC NOT A VALID TEST
Associated Fluid Only Case	
Visual Contamination Rating	START: 3.5/3.5/3.9 REVIEW ROT: 1/1.6/1.7 GOOD
Lift Coefficient	6°: 1.222 8°: 1.393
Lift Loss At 8°	2.04% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW – TEST NOT VALID.

~~**** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss acceptable)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F18: Run #10



Summary Sheet

Objective	TYPE IV FLUID VALIDATION
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 13 (P26A)
Tunnel OAT (°C)	Target: -25° C Actual: -12.4°C ✓
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	40 SEC NOT A VALID TEST
Associated Fluid Only Case	
Visual Contamination Rating	START 2.3/2.5/3.3 GOOD ROT 1/1.3/1.7 GOOD
Lift Coefficient	6°: 1.221 8°: 1.369
Lift Loss At 8°	3.73% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD - TEST NOT VALID

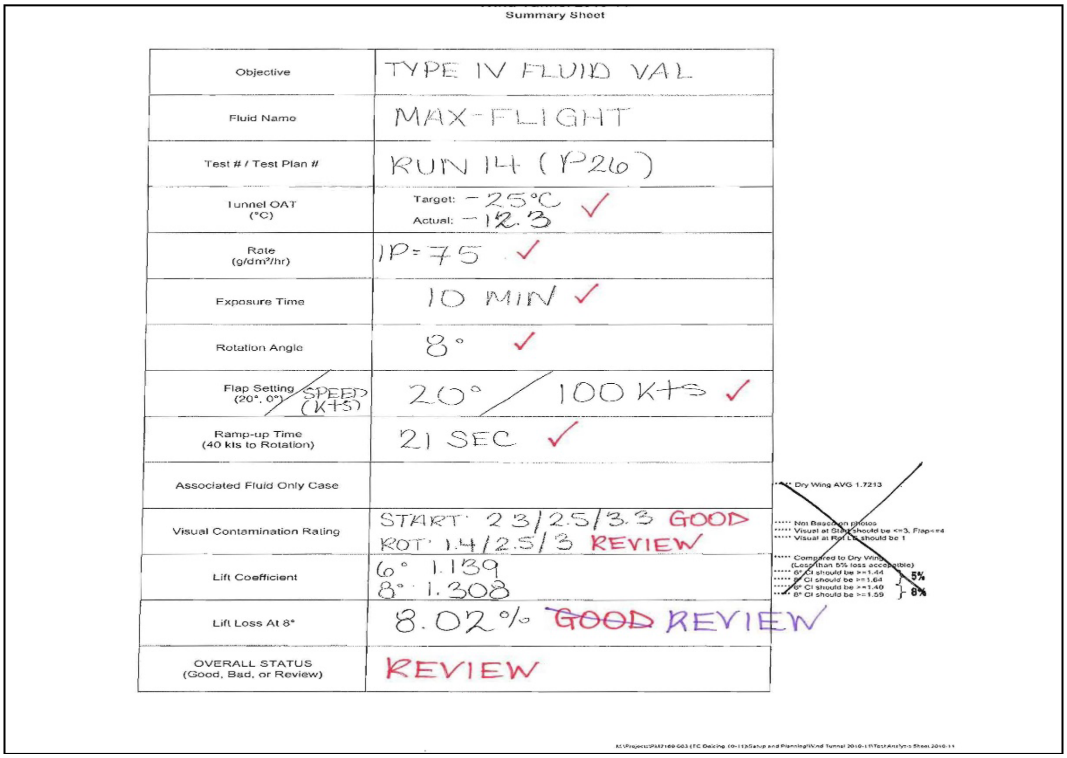
~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss acceptable)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ 8%

*SPECIAL TEST: HOLD FOR 20 SEC.

Figure F19: Run #13



Summary Sheet

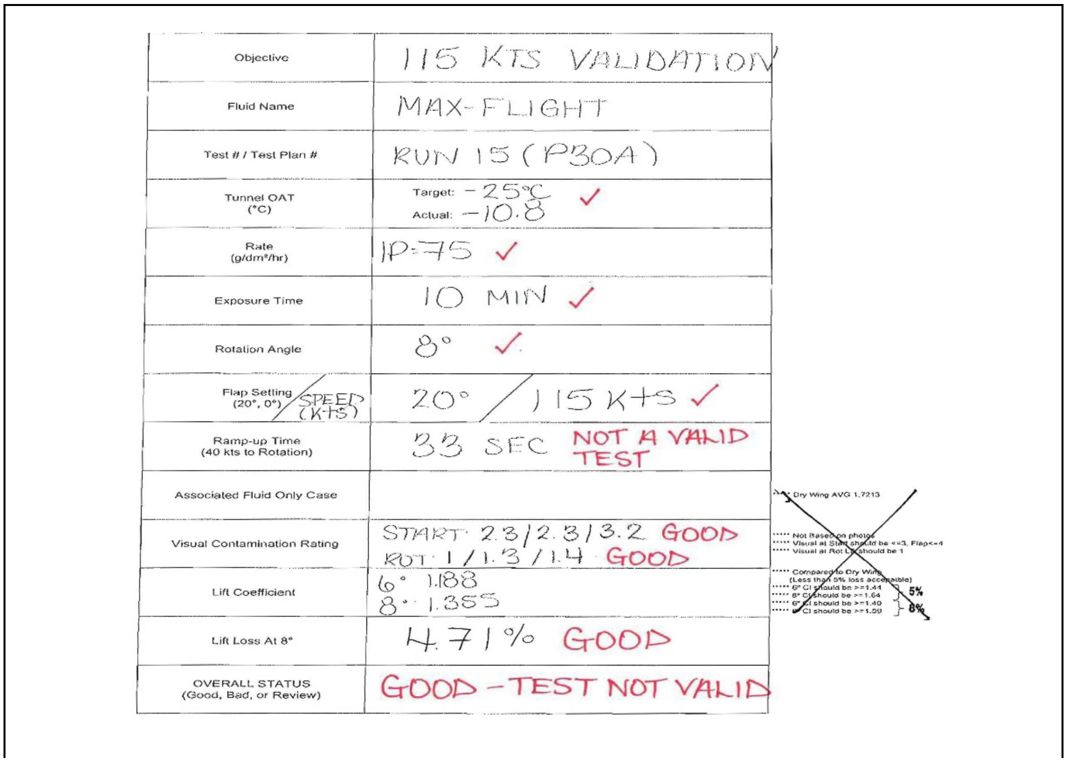
Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 14 (P26)
Tunnel OAT (°C)	Target: -25°C Actual: -12.3 ✓
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	21 SEC ✓
Associated Fluid Only Case	
Visual Contamination Rating	START 2.3/2.5/3.3 GOOD ROT 1.4/2.5/3 REVIEW
Lift Coefficient	6° 1.139 8° 1.308
Lift Loss At 8°	8.02% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss acceptable)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ 8%

Figure F20: Run #14



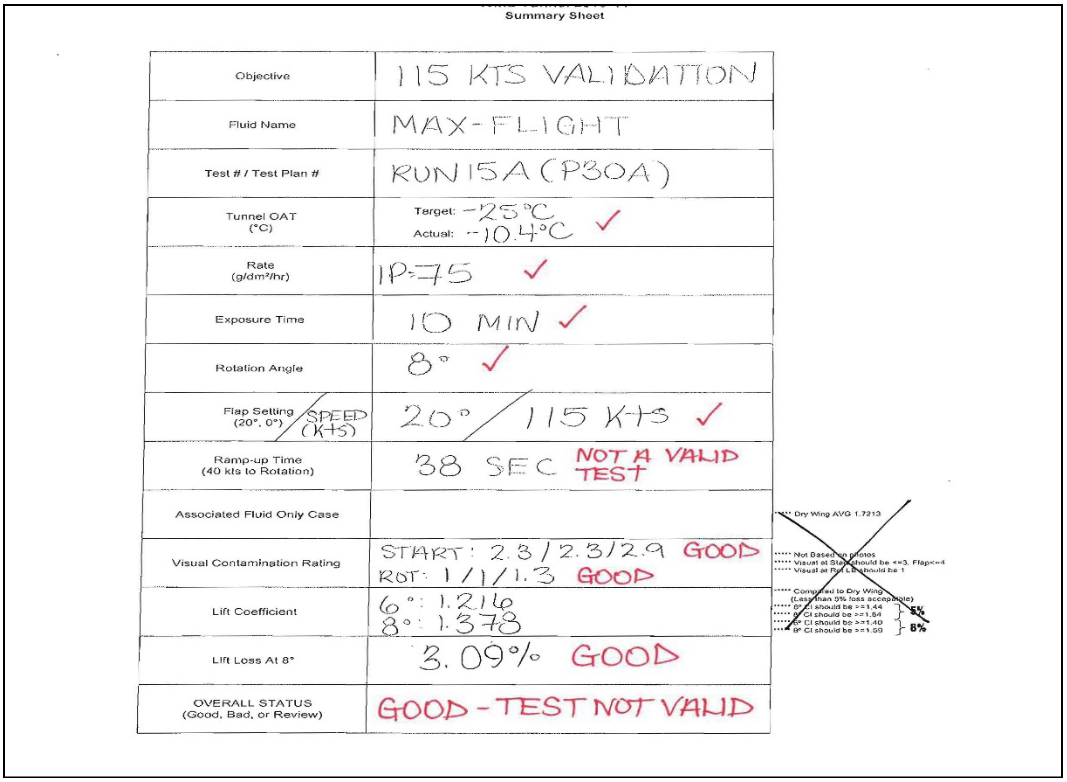
Objective	115 KTS VALIDATION
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 15 (P30A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -10.8
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	33 SEC NOT A VALID TEST
Associated Fluid Only Case	
Visual Contamination Rating	START 2.3/2.3/3.2 GOOD ROT 1/1.3/1.4 GOOD
Lift Coefficient	6° 1.188 8° 1.355
Lift Loss At 8°	4.71% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD - TEST NOT VALID

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F21: Run #15



Summary Sheet

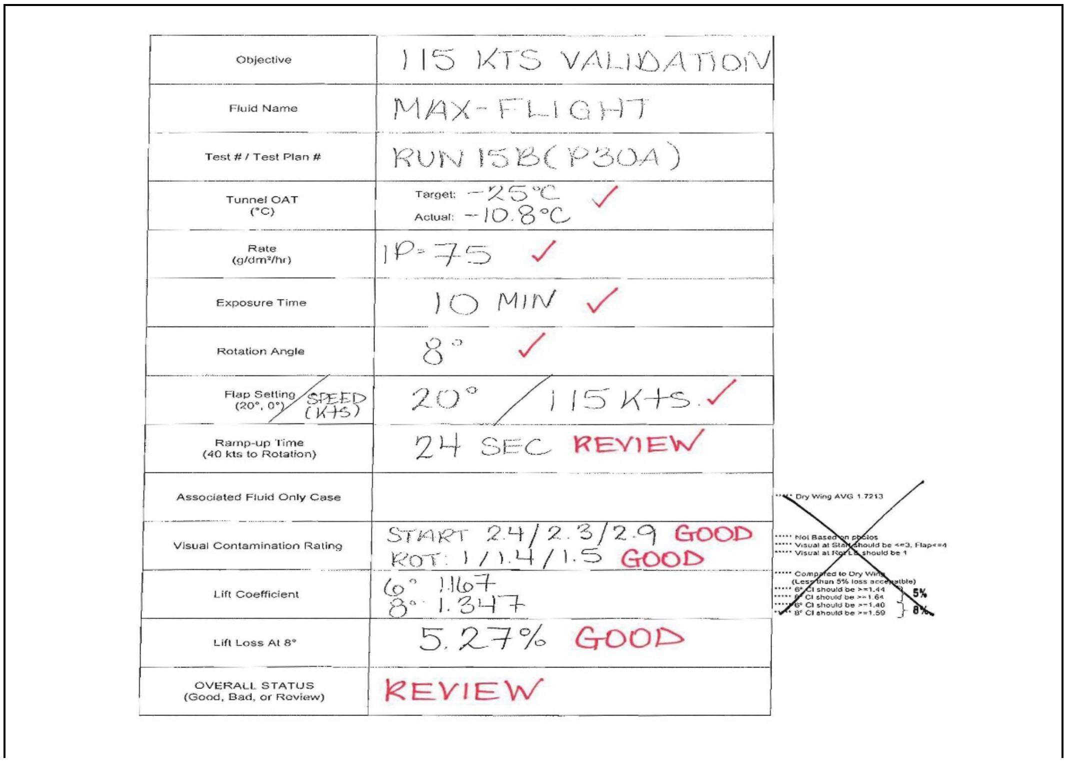
Objective	115 KTS VALIDATION
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 15A (P30A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -10.4°C
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	38 SEC NOT A VALID TEST
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.3/2.3/2.9 GOOD ROT: 1/1/1.3 GOOD
Lift Coefficient	6°: 1.216 8°: 1.378
Lift Loss At 8°	3.09% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD - TEST NOT VALID

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss acceptable)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F22: Run #15A



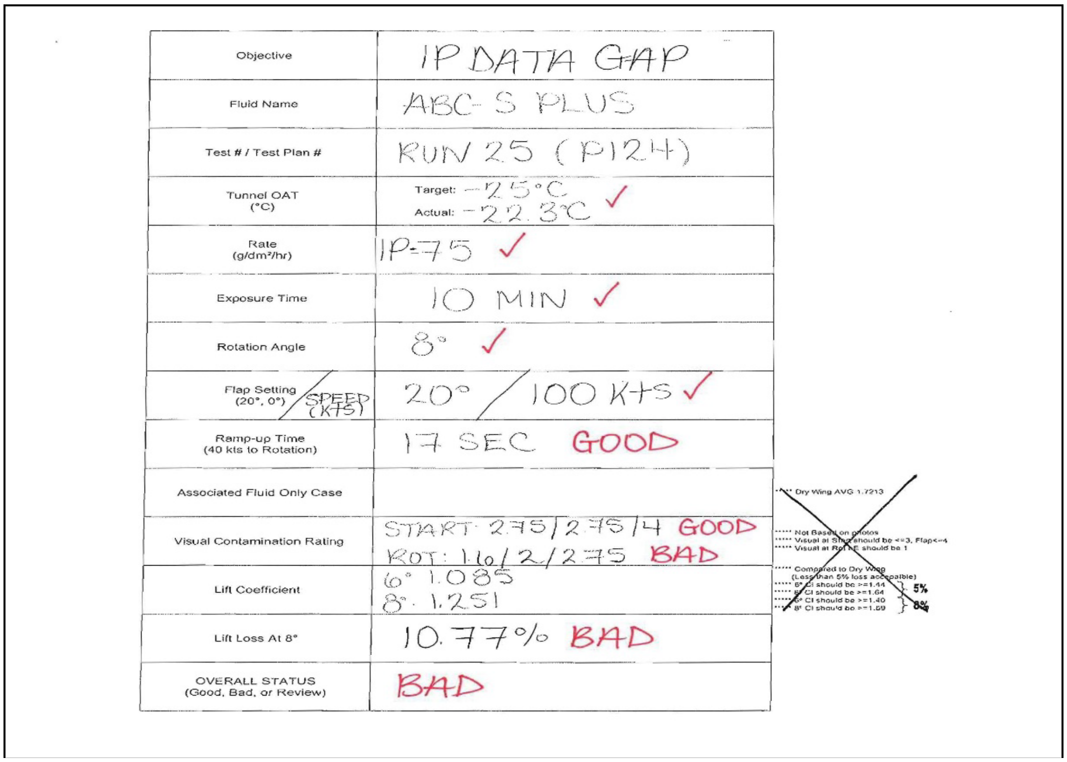
Objective	115 KTS VALIDATION
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 15B (P30A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -10.8°C
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	24 SEC REVIEW
Associated Fluid Only Case	
Visual Contamination Rating	START 2.4/2.3/2.9 GOOD ROT: 1/1.4/1.5 GOOD
Lift Coefficient	6° 1.167 8° 1.347
Lift Loss At 8°	5.27% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F23: Run # 15B



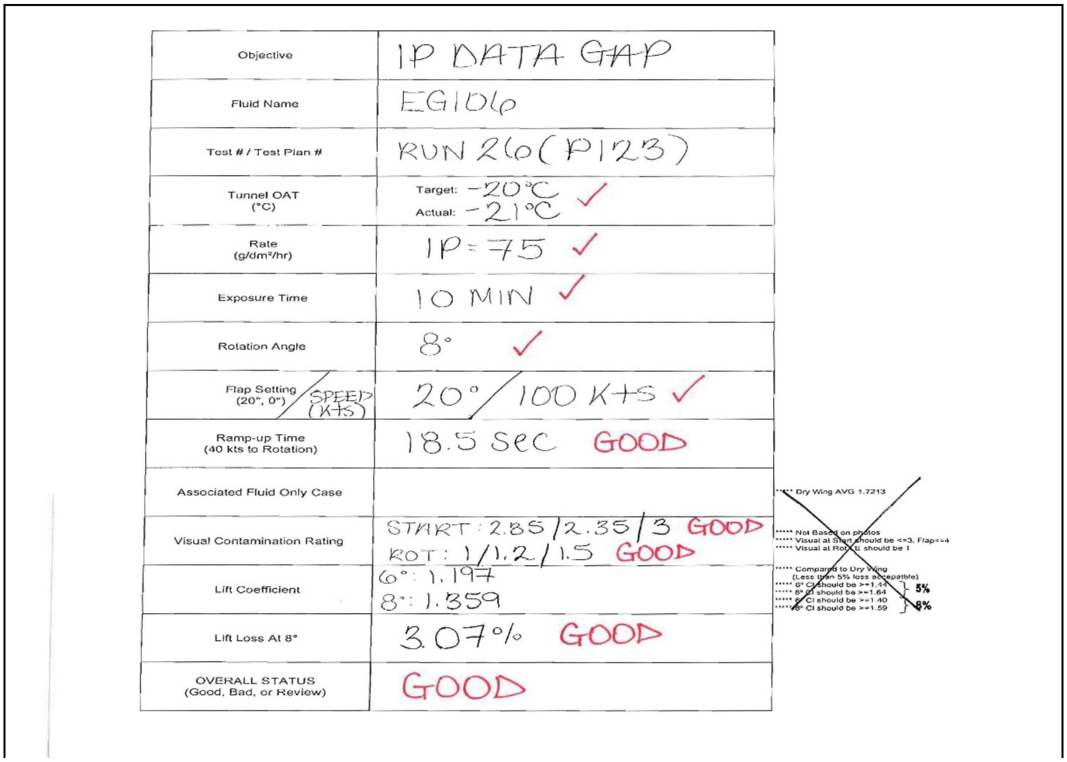
Objective	IP DATA GAP
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 25 (P124)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -22.3°C
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	17 SEC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START 2.75/2.75/4 GOOD ROT: 1.6/2/2.75 BAD
Lift Coefficient	6° 1.085 8° 1.251
Lift Loss At 8°	10.77% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F24: Run 25



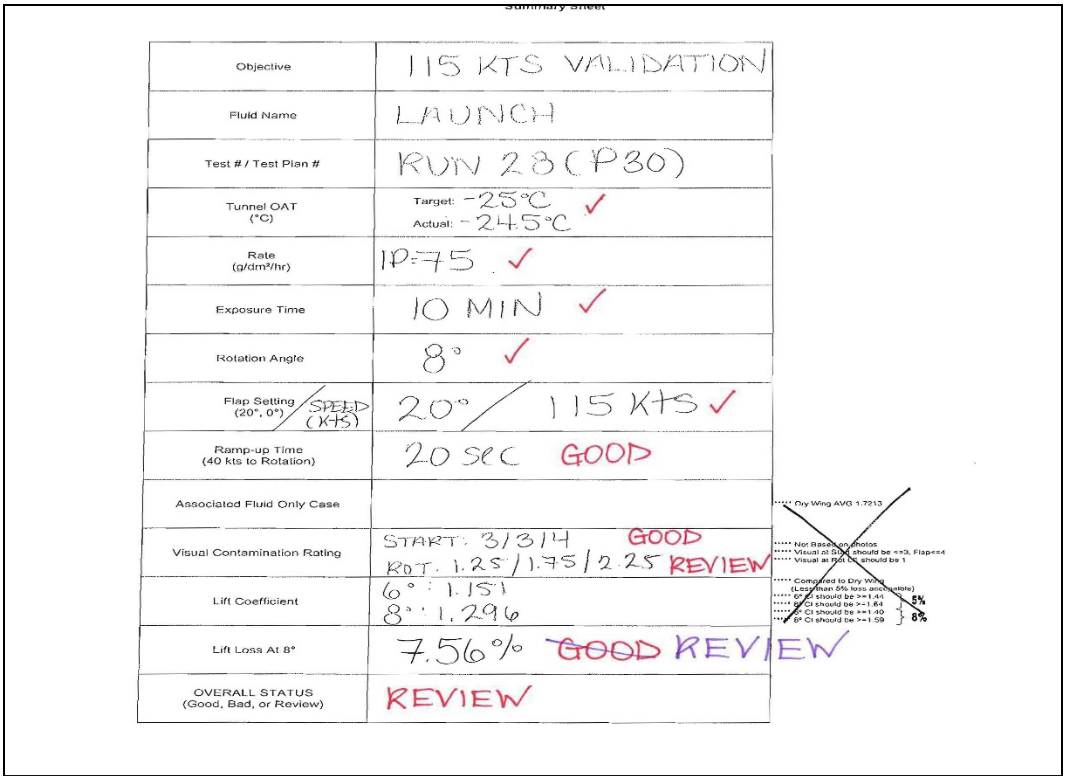
Objective	IP DATA GAP
Fluid Name	EG106
Test # / Test Plan #	RUN 26 (P123)
Tunnel OAT (°C)	Target: -20°C ✓ Actual: -21°C
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	18.5 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.85 / 2.35 / 3 GOOD ROT: 1 / 1.2 / 1.5 GOOD
Lift Coefficient	6°: 1.197 8°: 1.359
Lift Loss At 8°	3.07% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F25: Run # 26



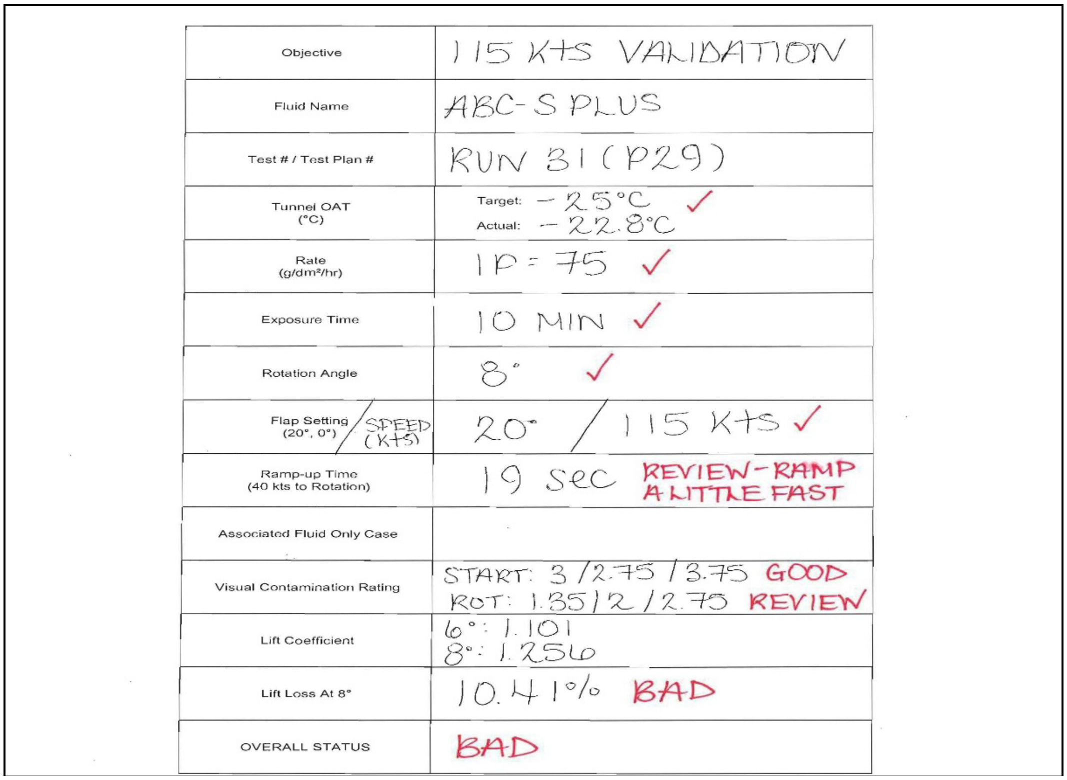
Objective	115 KTS VALIDATION
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 28 (P30)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -24.5°C
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	20 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/3/4 GOOD ROT: 1.25 / 1.75 / 2.25 REVIEW
Lift Coefficient	6°: 1.151 8°: 1.296
Lift Loss At 8°	7.56% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

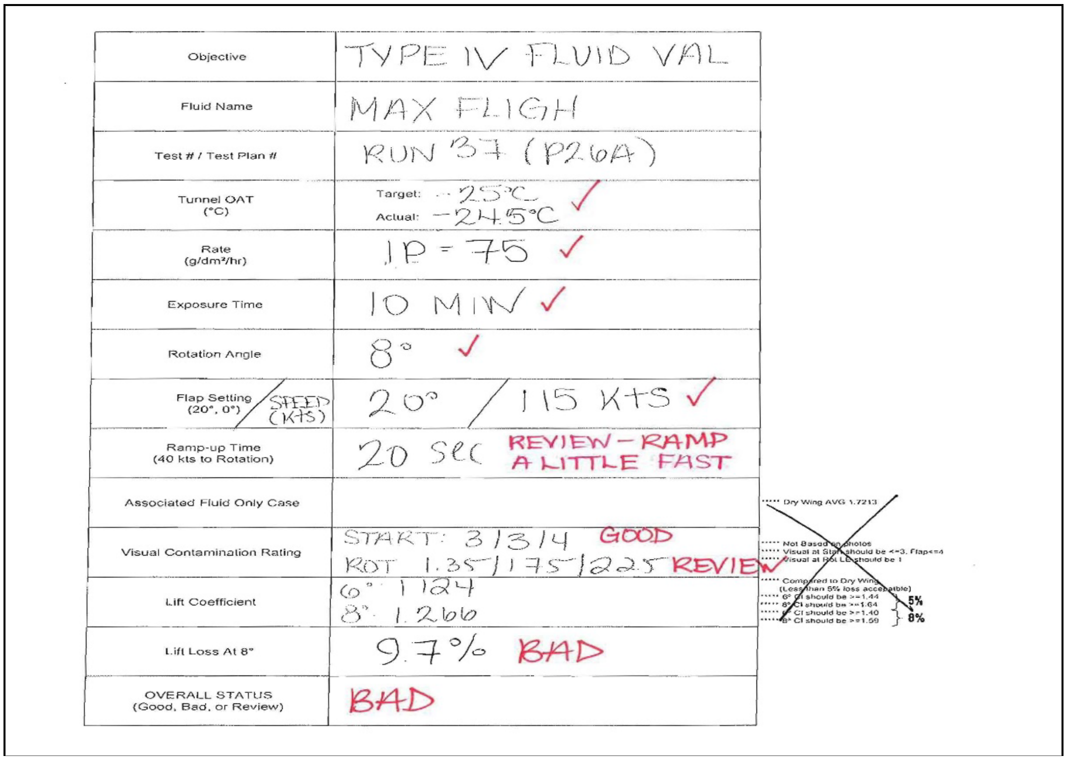
~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F26: Run #28



Objective	115 Kts VALIDATION
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 31 (P29)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -22.8°C
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	19 sec REVIEW - RAMP A LITTLE FAST
Associated Fluid Only Case	
Visual Contamination Rating	START: 3 / 2.75 / 3.75 GOOD ROT: 1.35 / 2 / 2.75 REVIEW
Lift Coefficient	6°: 1.101 8°: 1.256
Lift Loss At 8°	10.41% BAD
OVERALL STATUS	BAD

Figure F27: Run # 31



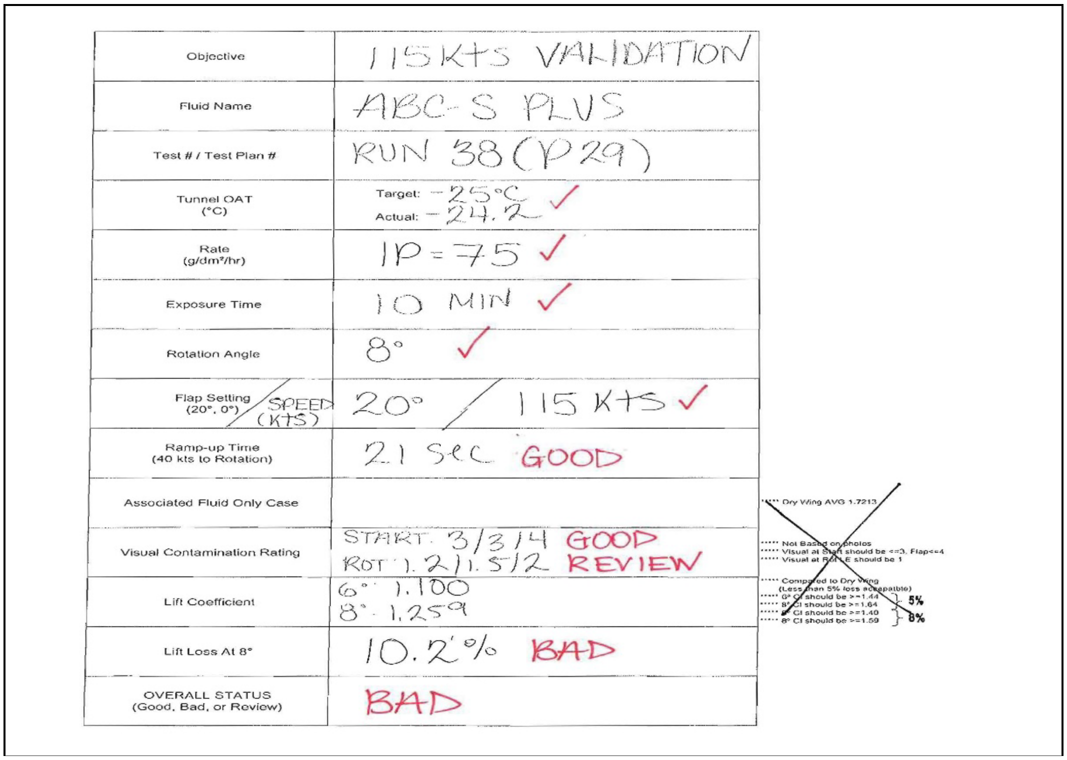
Objective	TYPE IV FLUID VAL
Fluid Name	MAX FLIGH
Test # / Test Plan #	RUN 37 (P26A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -24.5°C
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	20 sec REVIEW - RAMP A LITTLE FAST
Associated Fluid Only Case	
Visual Contamination Rating	START: 3 / 3 / 4 GOOD ROT 1.35 / 1.75 / 2.25 REVIEW
Lift Coefficient	6° 1.124 8° 1.266
Lift Loss At 8°	9.7% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing~~
~~(Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F28: Run #37



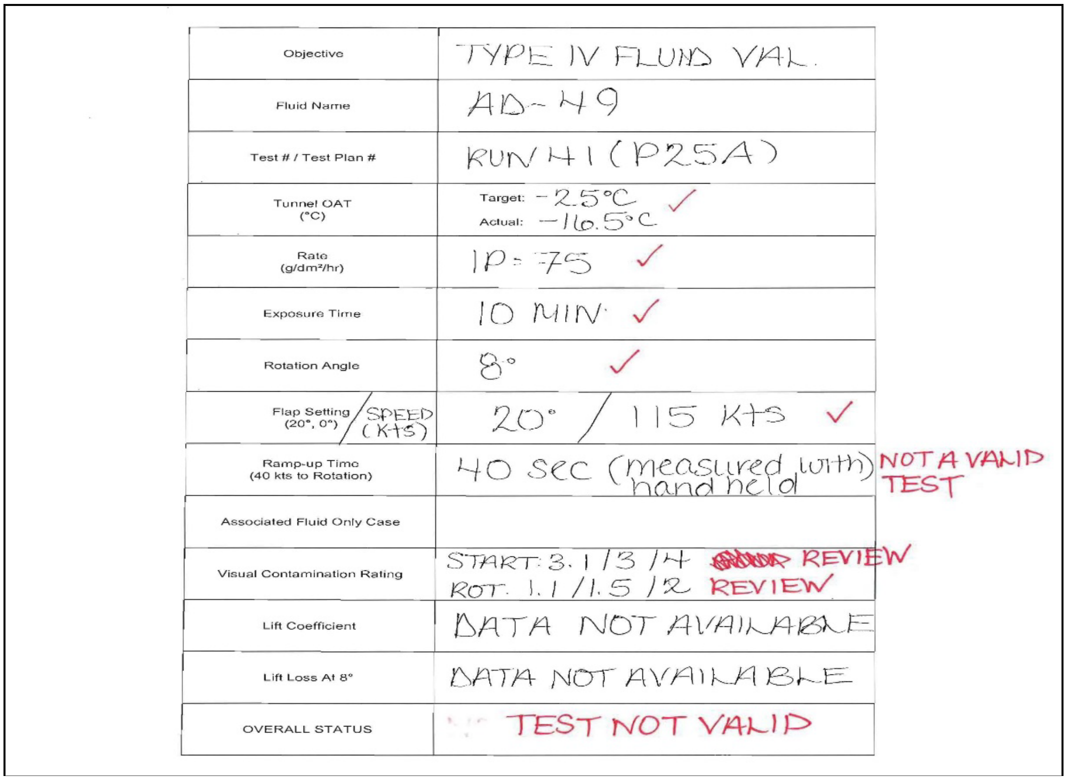
Objective	115 KtS VALIDATION
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 38 (P29)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -24.2
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 115 KtS ✓
Ramp-up Time (40 kts to Rotation)	21 Sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START. 3/3/4 GOOD ROT. 1.2/1.5/2 REVIEW
Lift Coefficient	6° 1.100 8° 1.259
Lift Loss At 8°	10.2% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

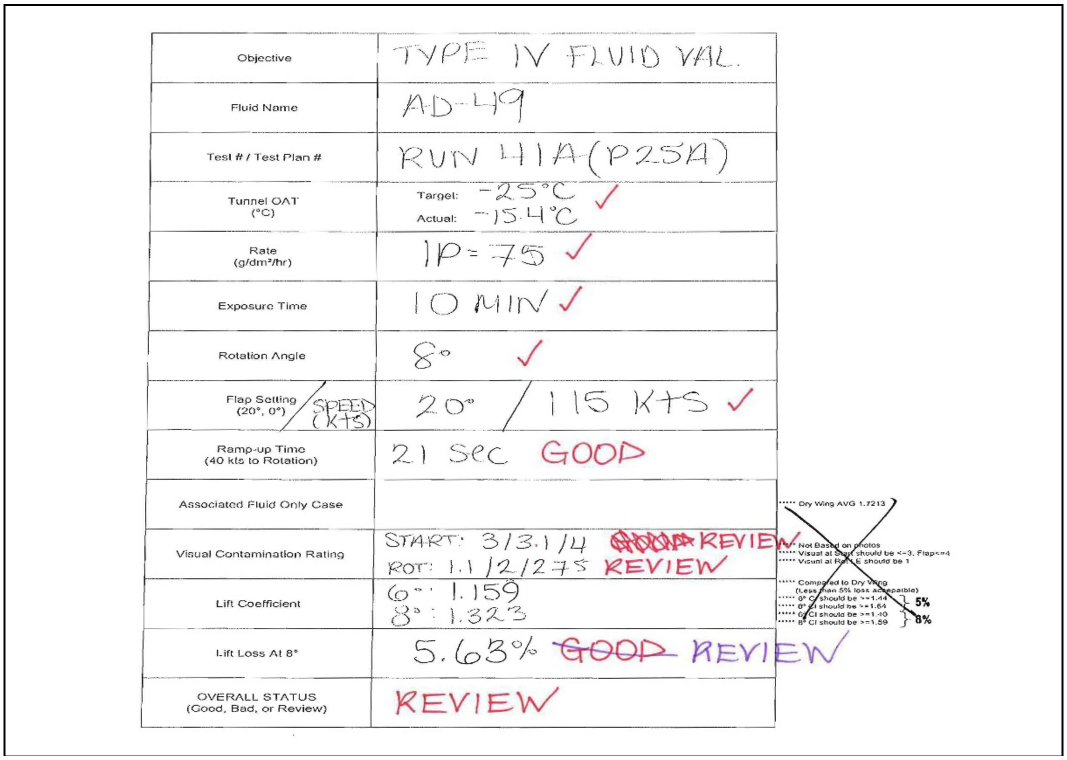
~~***** Compared to Dry Wing~~
~~(Less than 5% loss acceptable)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F29: Run #38



Objective	TYPE IV FLUID VAL.
Fluid Name	AD-49
Test # / Test Plan #	RUN 41 (P25A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -16.5°C
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 115 KtS ✓
Ramp-up Time (40 kts to Rotation)	40 sec (measured with hand held) NOT A VALID TEST
Associated Fluid Only Case	
Visual Contamination Rating	START 3.1/3/4 REVIEW ROT. 1.1/1.5/2 REVIEW
Lift Coefficient	DATA NOT AVAILABLE
Lift Loss At 8°	DATA NOT AVAILABLE
OVERALL STATUS	TEST NOT VALID

Figure F30: Run 41



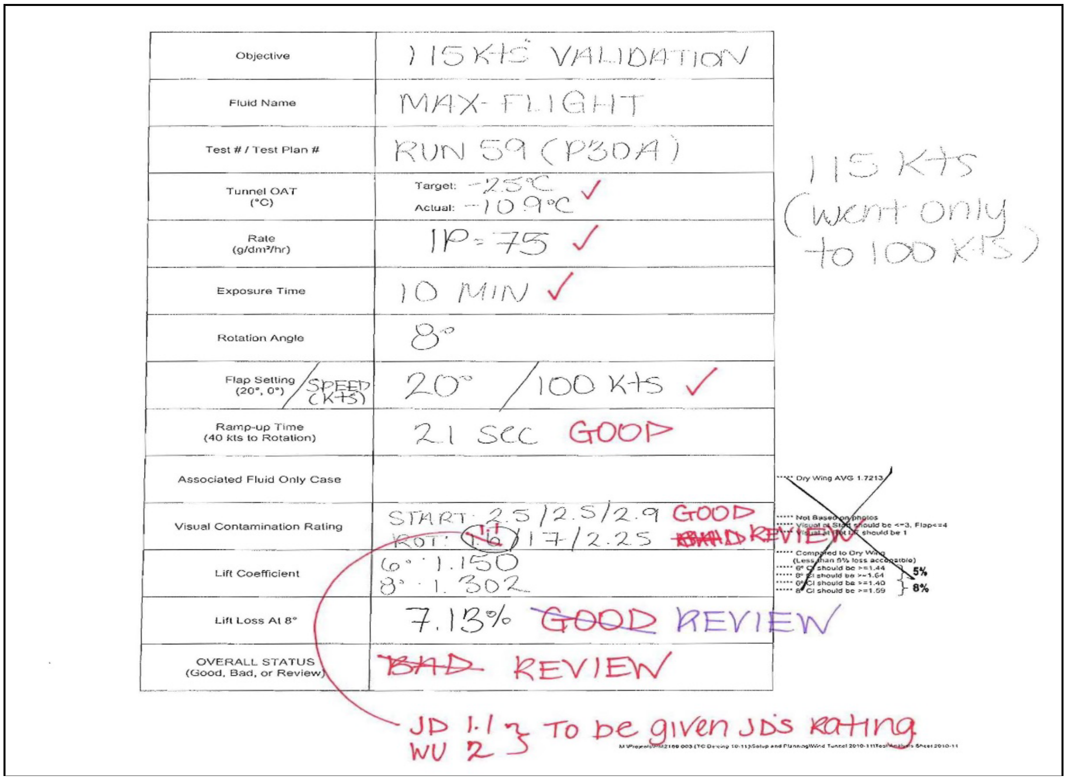
Objective	TYPE IV FLUID VAL.
Fluid Name	AD-49
Test # / Test Plan #	RUN 41A (P25A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -15.4°C
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (K+S)	20° / 115 K+S ✓
Ramp-up Time (40 kts to Rotation)	21 Sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/3.1/4 ~~GOOD~~ REVIEW ROT: 1.1/2/2.75 REVIEW
Lift Coefficient	6°: 1.159 8°: 1.323
Lift Loss At 8°	5.63% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~ } 5%
~~***** 8° Cl should be >=1.64~~
~~***** 6° Cl should be >=1.40~~ } 8%
~~***** 8° Cl should be >=1.59~~

Figure F31: Run #41A



Objective	115 K+S VALIDATION
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 59 (P30A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -10.9°C
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8°
Flap Setting (20°, 0°) / SPEED (K+S)	20° / 100 K+S ✓
Ramp-up Time (40 kts to Rotation)	21 Sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5/2.5/2.9 GOOD ROT: ~~1.6~~ 1.1 /1.7/2.25 ~~BAD~~ REVIEW
Lift Coefficient	6°: 1.150 8°: 1.302
Lift Loss At 8°	7.13% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	~~BAD~~ REVIEW

115 K+S (went only to 100 K+S)

~~***** Dry Wing AVG 1.7213~~

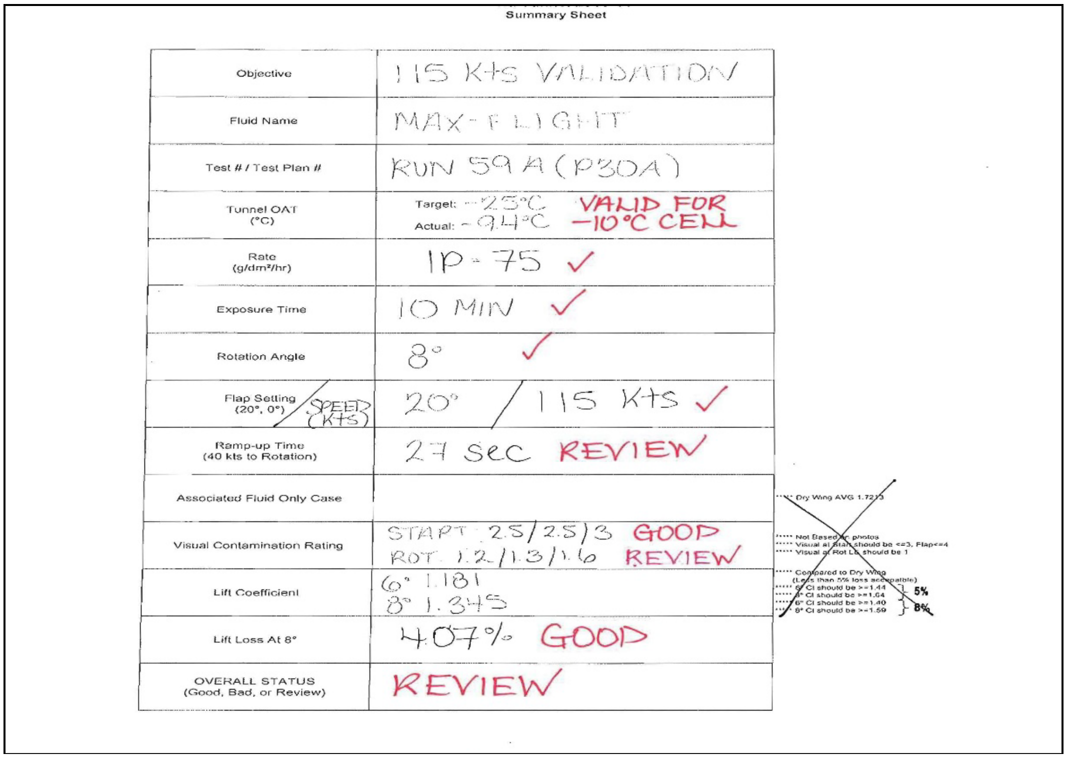
~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~ } 5%
~~***** 8° Cl should be >=1.64~~
~~***** 6° Cl should be >=1.40~~ } 8%
~~***** 8° Cl should be >=1.59~~

JD 1.1 }
WU 2 } To be given JD's Rating

M:\Projects\PM2189.003 (TC Deicing 10-11)\Setup and Planning\Wind Tunnel 2010-11\Test Analysis Sheet 2010-11

Figure F32: Run #59



Summary Sheet

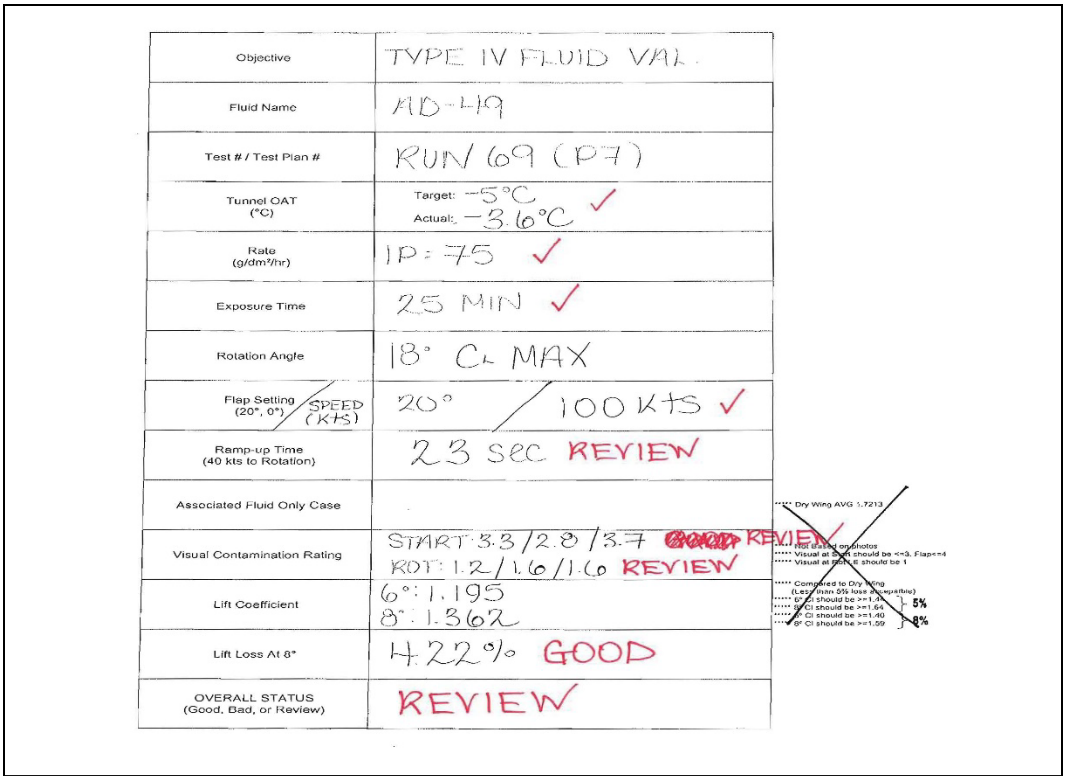
Objective	115 Kts VALIDATION
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 59A (P30A)
Tunnel OAT (°C)	Target: -25°C Actual: -9.4°C VALID FOR -10°C CELL
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	27 sec REVIEW
Associated Fluid Only Case	
Visual Contamination Rating	START 2.5/2.5/3 GOOD ROT 1.2/1.3/1.6 REVIEW
Lift Coefficient	6° 1.181 8° 1.345
Lift Loss At 8°	4.07% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~ ~~} 5%~~
~~***** 8° Cl should be >=1.64~~
~~***** 6° Cl should be >=1.40~~ ~~} 8%~~
~~***** 8° Cl should be >=1.59~~

Figure F33: Run #59A



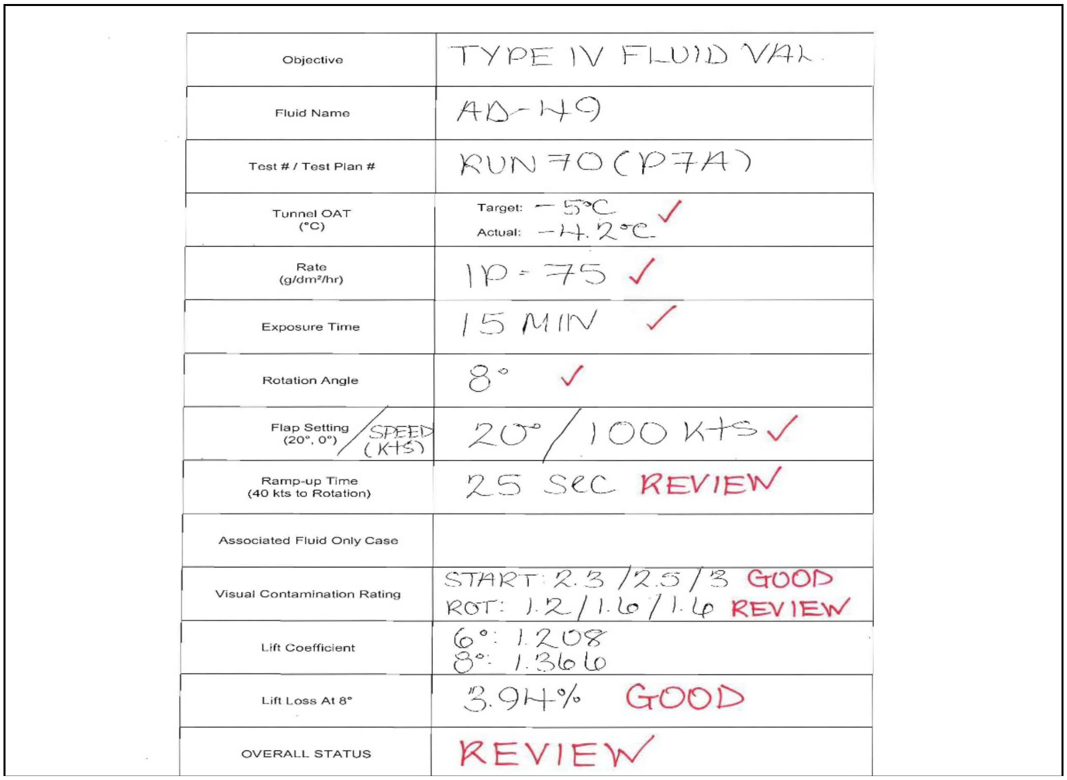
Objective	TYPE IV FLUID VAL.
Fluid Name	AD-49
Test # / Test Plan #	RUN 69 (P7)
Tunnel OAT (°C)	Target: -5°C Actual: -3.6°C ✓
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	25 MIN ✓
Rotation Angle	18° CL MAX
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	23 sec REVIEW
Associated Fluid Only Case	
Visual Contamination Rating	START 3.3/2.8/3.7 ~~GOOD~~ REVIEW ✓ ROT 1.2/1.6/1.6 REVIEW
Lift Coefficient	6° 1.195 8° 1.362
Lift Loss At 8°	4.22% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

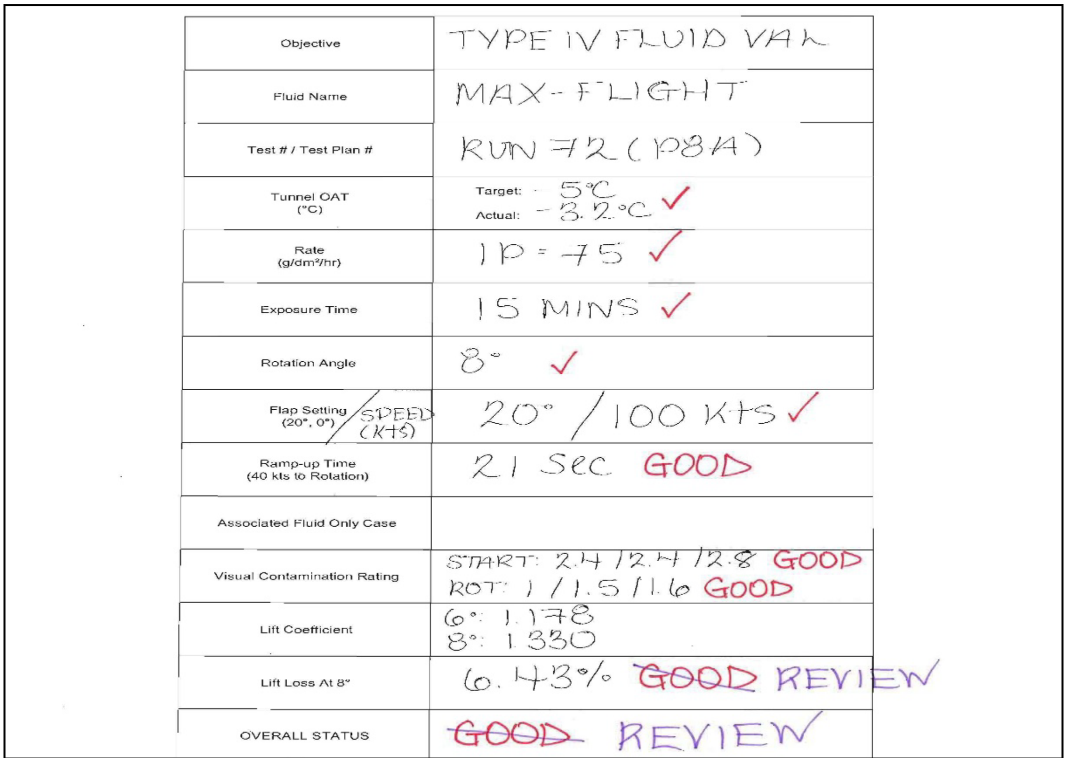
~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~ ~~} 5%~~
~~***** 8° Cl should be >=1.64~~
~~***** 6° Cl should be >=1.40~~ ~~} 8%~~
~~***** 8° Cl should be >=1.59~~

Figure F34: Run #69



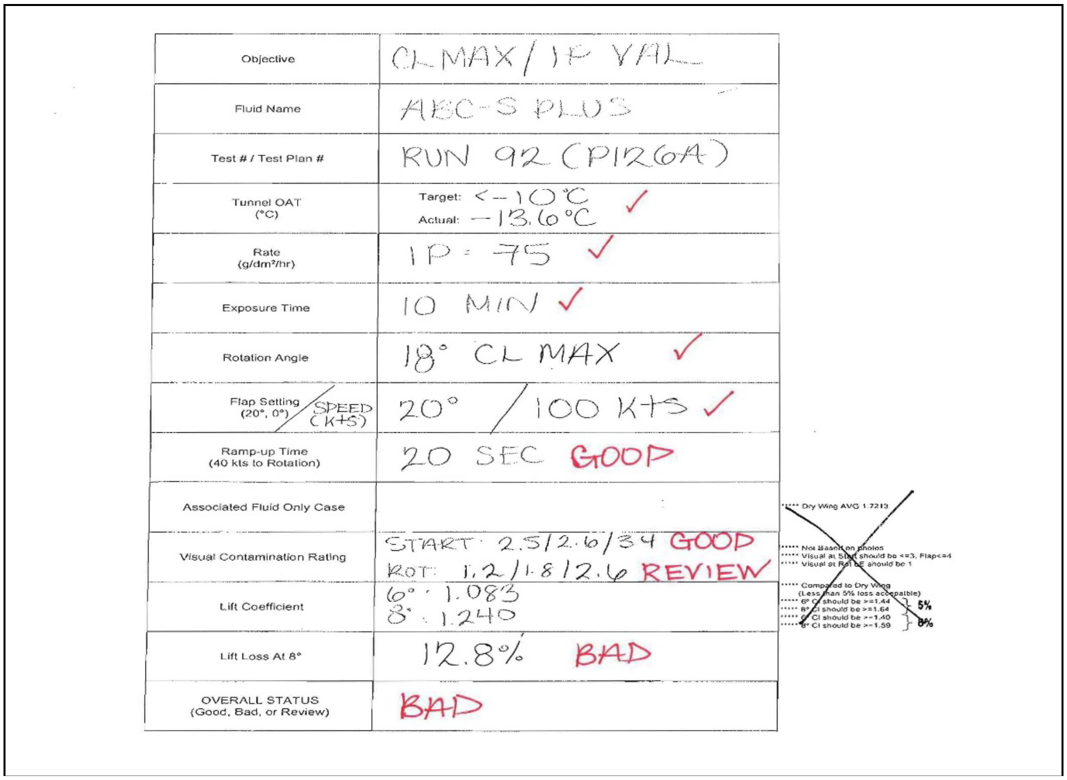
Objective	TYPE IV FLUID VAL.
Fluid Name	AD-49
Test # / Test Plan #	RUN 70 (P7A)
Tunnel OAT (°C)	Target: −5°C Actual: −4.2°C ✓
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	15 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	25 Sec REVIEW
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.3 / 2.5 / 3 GOOD ROT: 1.2 / 1.6 / 1.6 REVIEW
Lift Coefficient	6°: 1.208 8°: 1.366
Lift Loss At 8°	3.94% GOOD
OVERALL STATUS	REVIEW

Figure F35: Run #70



Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 72 (P8A)
Tunnel OAT (°C)	Target: −5°C Actual: −3.2°C ✓
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	15 MINS ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	21 Sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.4 / 2.4 / 2.8 GOOD ROT: 1 / 1.5 / 1.6 GOOD
Lift Coefficient	6°: 1.178 8°: 1.330
Lift Loss At 8°	6.43% ~~GOOD~~ REVIEW
OVERALL STATUS	~~GOOD~~ REVIEW

Figure F36: Run #72



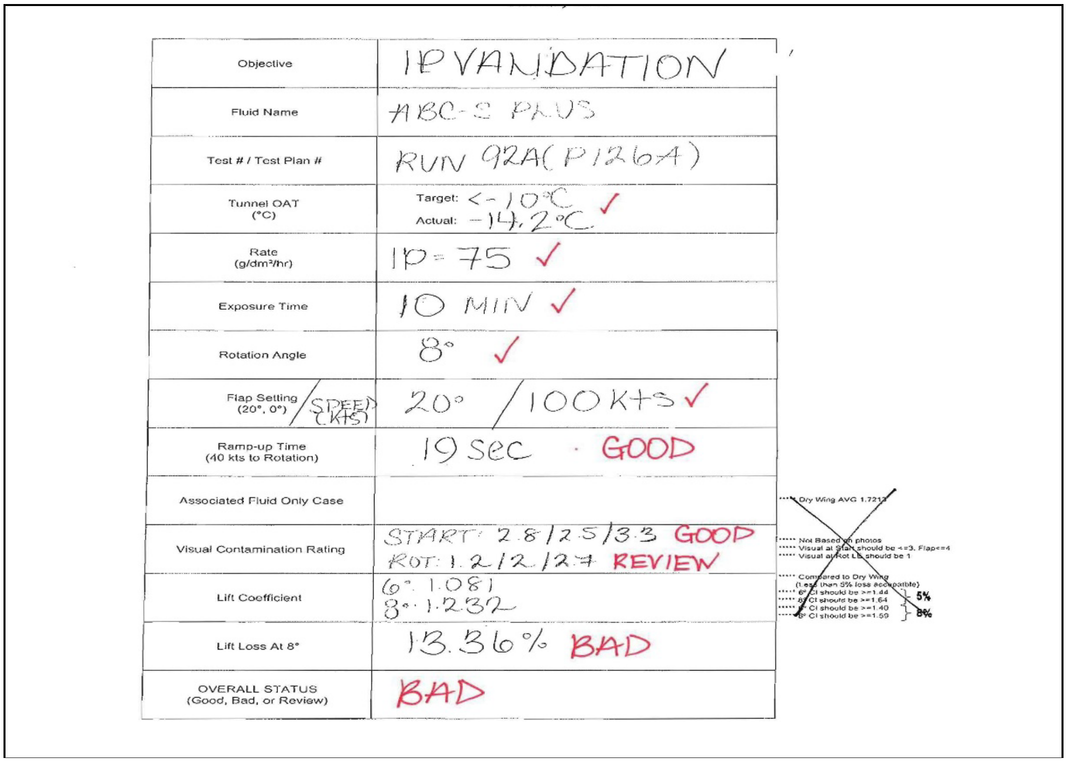
Objective	CL MAX / IP VAL
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 92 (P126A)
Tunnel OAT (°C)	Target: <-10°C Actual: -13.6°C ✓
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	18° CL MAX ✓
Flap Setting (20°, 0°) / SPEED (K+S)	20° / 100 K+S ✓
Ramp-up Time (40 kts to Rotation)	20 SEC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5/2.6/34 GOOD ROT: 1.2/1.8/2.6 REVIEW
Lift Coefficient	6° : 1.083 8° : 1.240
Lift Loss At 8°	12.8% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing~~
~~(Less than 5% loss accepalble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F37: Run #92



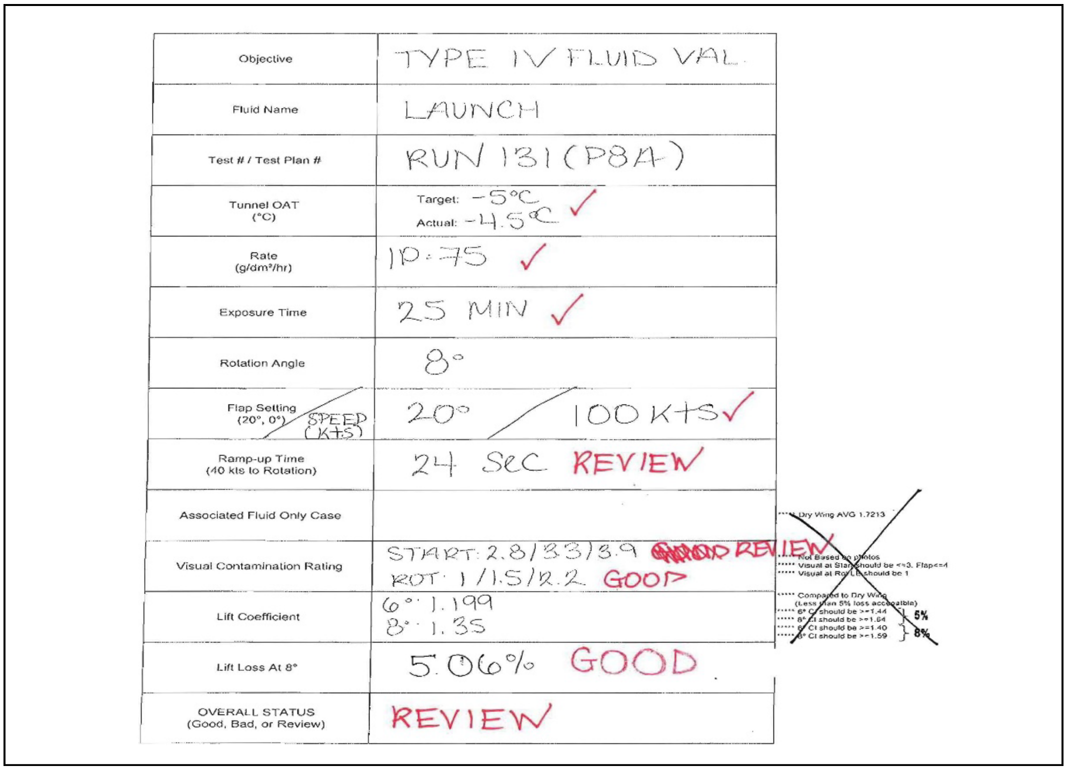
Objective	IP VALIDATION
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 92A (P126A)
Tunnel OAT (°C)	Target: <-10°C ✓ Actual: -14.2°C
Rate (g/dm²/hr)	IP = 75 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (K+S)	20° / 100 K+S ✓
Ramp-up Time (40 kts to Rotation)	19 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.8/2.5/3.3 GOOD ROT: 1.2/2/2.7 REVIEW
Lift Coefficient	6°: 1.081 8°: 1.232
Lift Loss At 8°	13.36% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing~~
~~(Less than 5% loss acceptable)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F38: Run #92A



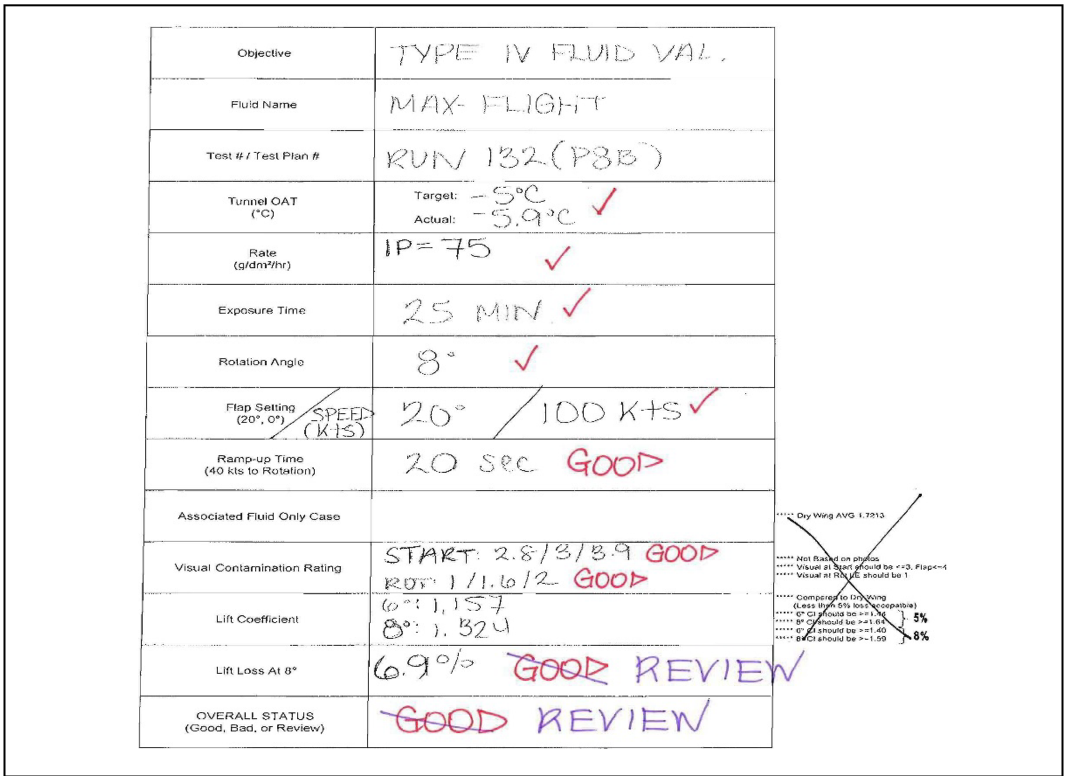
Objective	TYPE IV FLUID VAL.
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 131 (P8A)
Tunnel OAT (°C)	Target: -5°C Actual: -4.5°C ✓
Rate (g/dm²/hr)	IP: 75 ✓
Exposure Time	25 MIN ✓
Rotation Angle	8°
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	24 SEC REVIEW
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.8/3.3/3.9 ~~GOOD~~ REVIEW ROT: 1/1.5/2.2 GOOD
Lift Coefficient	6°: 1.199 8°: 1.35
Lift Loss At 8°	5.06% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW

~~***** Dry Wing AVG 1.7213~~

~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F39: Run # 131



Objective	TYPE IV FLUID VAL.
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 132 (P8B)
Tunnel OAT (°C)	Target: -5°C Actual: -5.9°C ✓
Rate (g/dm²/hr)	IP=75 ✓
Exposure Time	25 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	20 SEC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.8/3/3.9 GOOD ROT: 1/1.6/2 GOOD
Lift Coefficient	6°: 1.157 8°: 1.324
Lift Loss At 8°	6.9% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	~~GOOD~~ REVIEW

~~***** Dry Wing AVG 1.7213~~

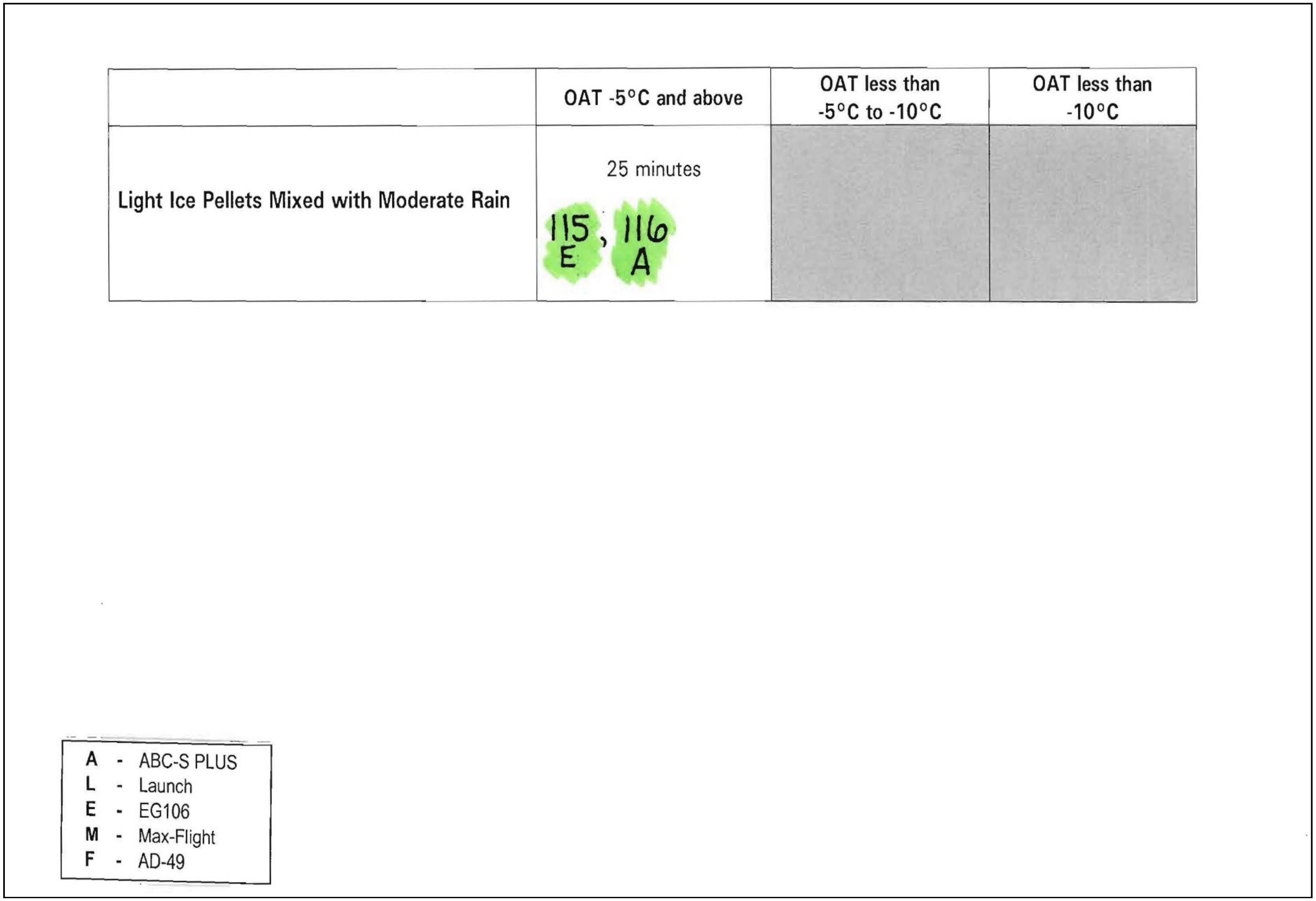
~~***** Not Based on photos~~
~~***** Visual at Start should be <=3, Flap<=4~~
~~***** Visual at Rot LE should be 1~~

~~***** Compared to Dry Wing (Less than 5% loss accepatble)~~
~~***** 6° Cl should be >=1.44~~
~~***** 8° Cl should be >=1.64~~ } 5%
~~***** 6° Cl should be >=1.40~~
~~***** 8° Cl should be >=1.59~~ } 8%

Figure F40: Run # 132

This page intentionally left blank.

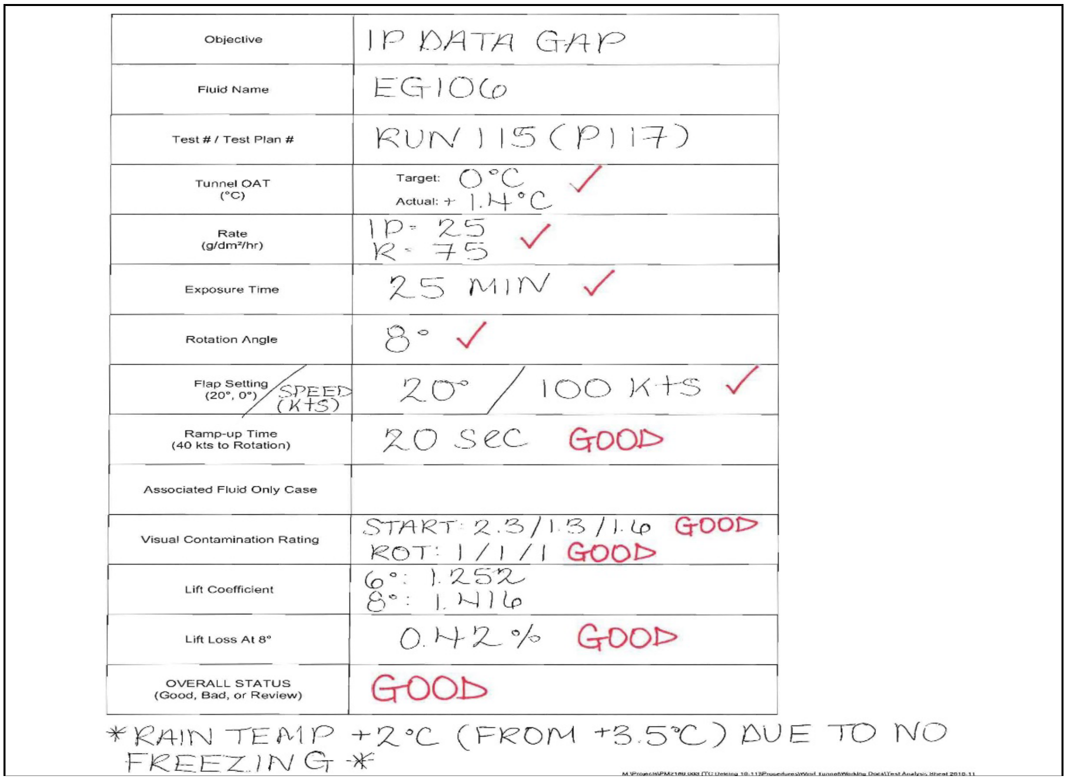
LIGHT ICE PELLETS MIXED WITH MODERATE RAIN



	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets Mixed with Moderate Rain	25 minutes 115, 116 E A		

A - ABC-S PLUS
L - Launch
E - EG106
M - Max-Flight
F - AD-49

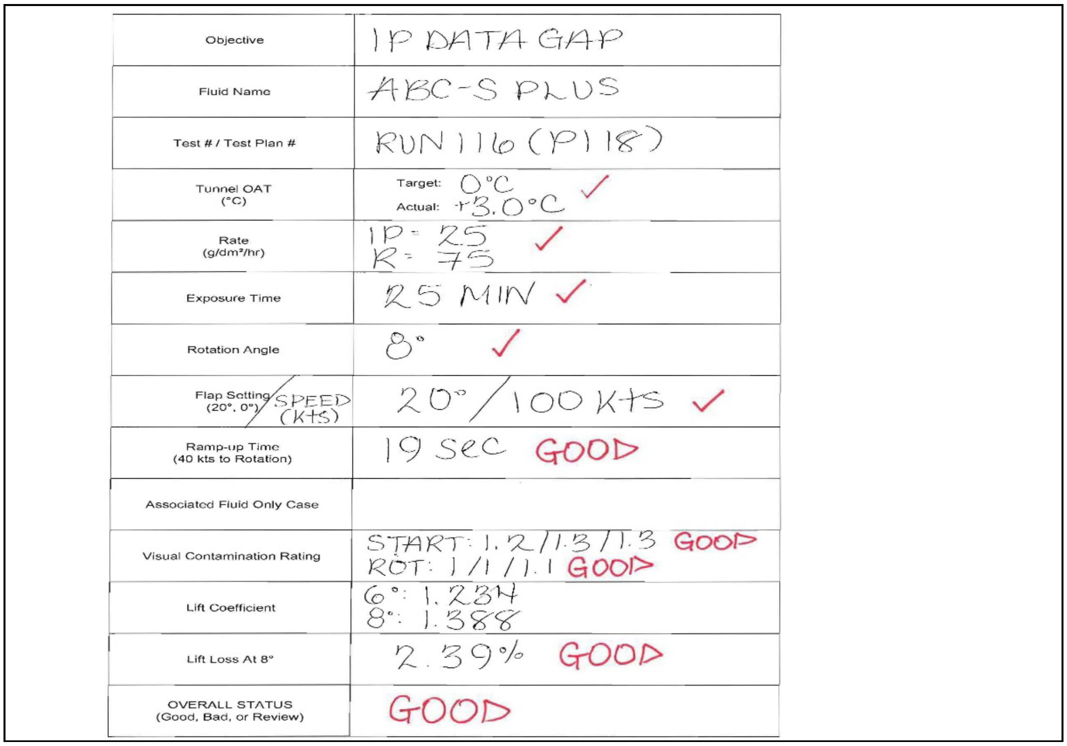
Figure F41: Light Ice Pellets Mixed With Moderate Rain Allowance Table



Objective	IP DATA GAP
Fluid Name	EG106
Test # / Test Plan #	RUN 115 (P117)
Tunnel OAT (°C)	Target: 0°C ✓ Actual: + 1.4°C
Rate (g/dm²/hr)	IP: 25 ✓ R: 75
Exposure Time	25 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	20 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.3/1.3/1.6 GOOD ROT: 1/1/1 GOOD
Lift Coefficient	6°: 1.252 8°: 1.416
Lift Loss At 8°	0.42% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

RAIN TEMP +2°C (FROM +3.5°C) DUE TO NO FREEZING

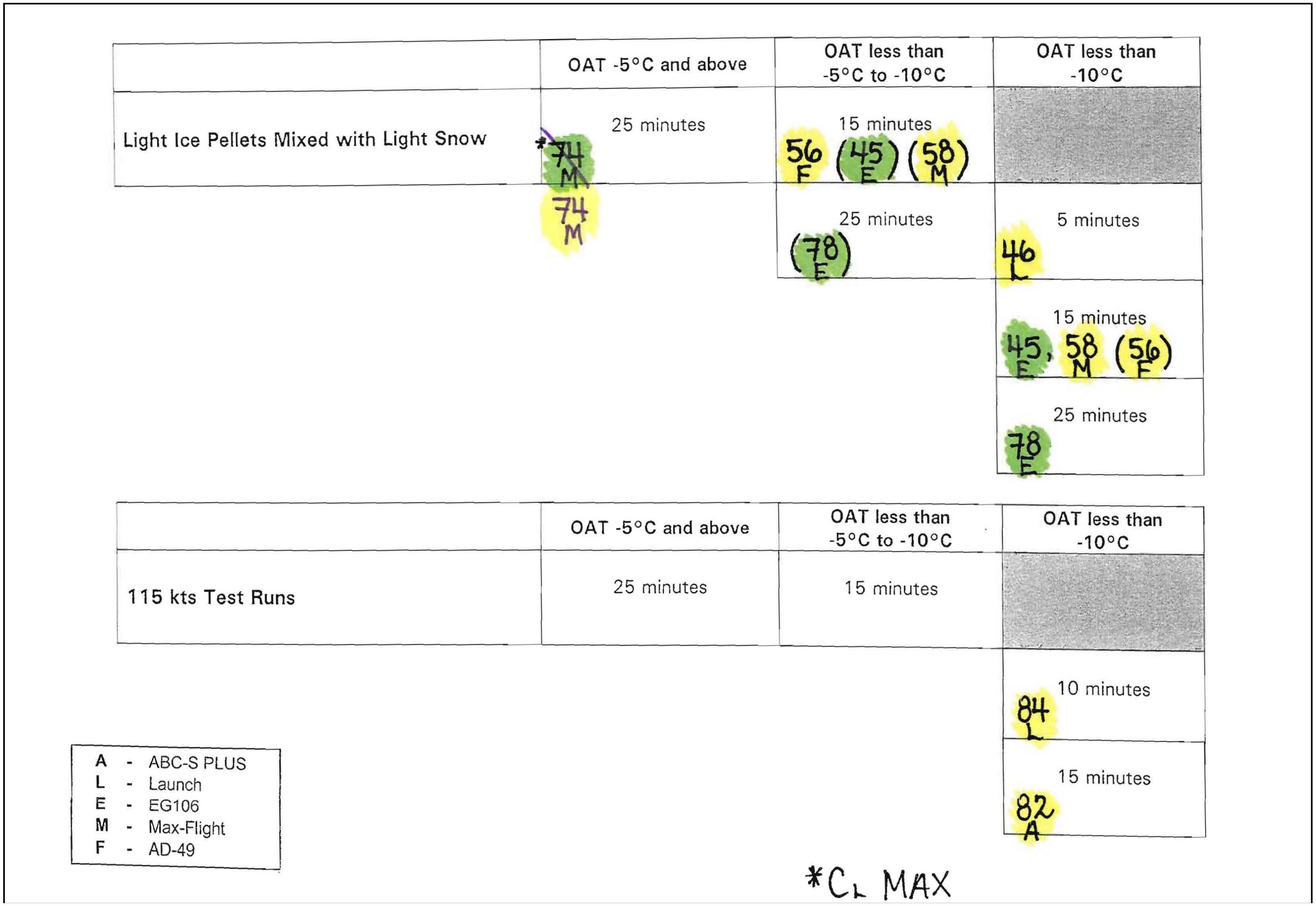
Figure F42: Run #115



Objective	IP DATA GAP
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 116 (P118)
Tunnel OAT (°C)	Target: 0°C ✓ Actual: +3.0°C
Rate (g/dm²/hr)	IP: 25 ✓ R: 75
Exposure Time	25 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	19 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 1.2/1.3/1.3 GOOD ROT: 1/1/1.1 GOOD
Lift Coefficient	6°: 1.234 8°: 1.388
Lift Loss At 8°	2.39% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

Figure F43: Run #116

LIGHT ICE PELLETS MIXED WITH LIGHT SNOW



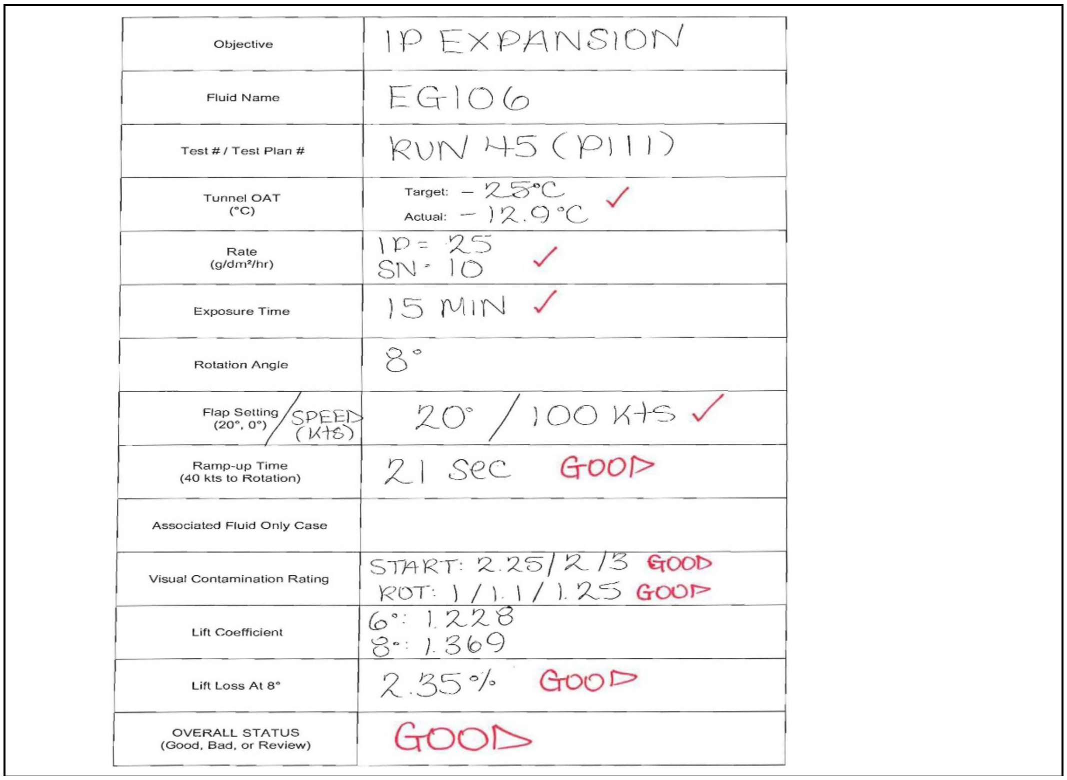
	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets Mixed with Light Snow	25 minutes *74 M	15 minutes 56 F (45 E) (58 M)	
	74 M	25 minutes (78 E)	5 minutes 46 L
			15 minutes 45 E, 58 M (56 F)
			25 minutes 78 E

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
115 kts Test Runs	25 minutes	15 minutes	
			10 minutes 84 L
			15 minutes 82 A

A - ABC-S PLUS
L - Launch
E - EG106
M - Max-Flight
F - AD-49

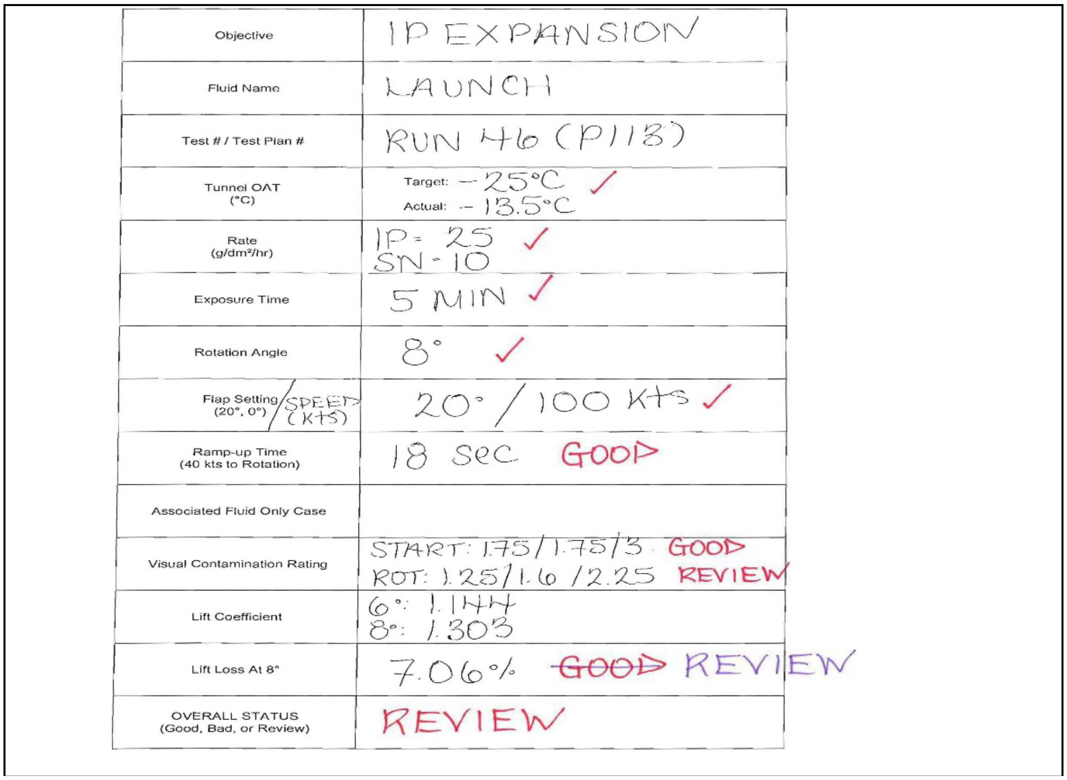
*C_L MAX

Figure F44: Light Ice Pellets Mixed with Light Snow Allowance Table



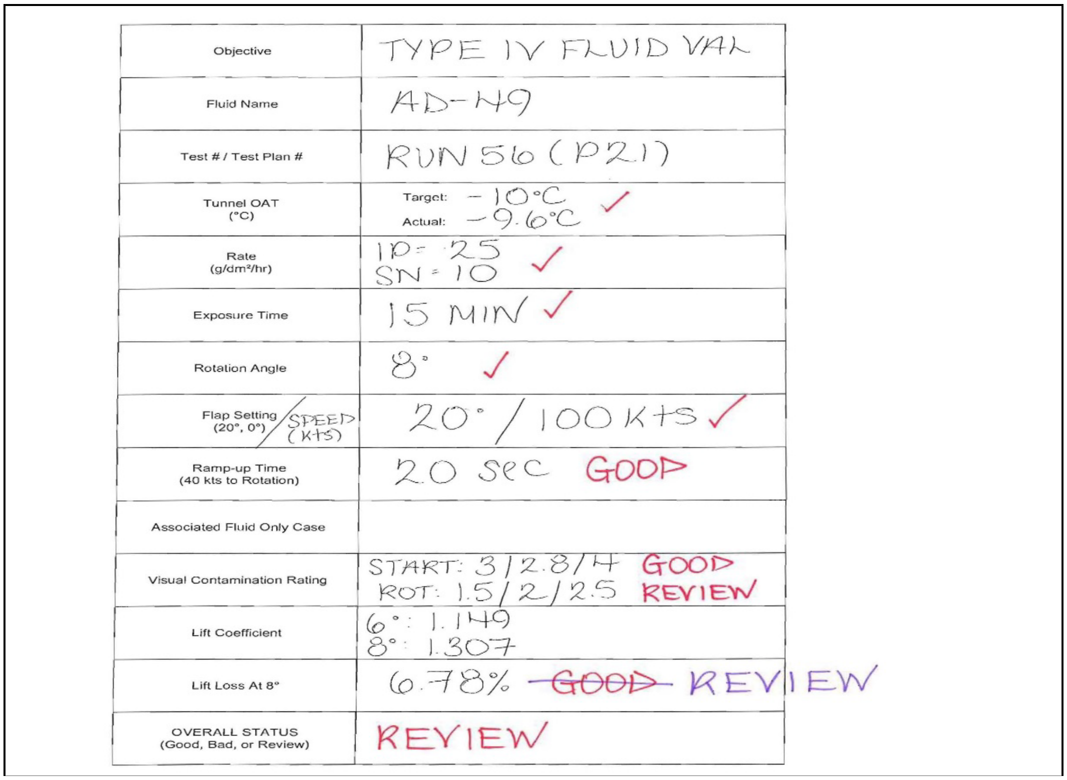
Objective	IP EXPANSION
Fluid Name	EG106
Test # / Test Plan #	RUN 45 (P111)
Tunnel OAT (°C)	Target: -25°C Actual: -12.9°C ✓
Rate (g/dm²/hr)	IP= 25 SN= 10 ✓
Exposure Time	15 MIN ✓
Rotation Angle	8°
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.25/2/3 GOOD ROT: 1/1.1/1.25 GOOD
Lift Coefficient	6°: 1.228 8°: 1.369
Lift Loss At 8°	2.35% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

Figure F45: Run #45



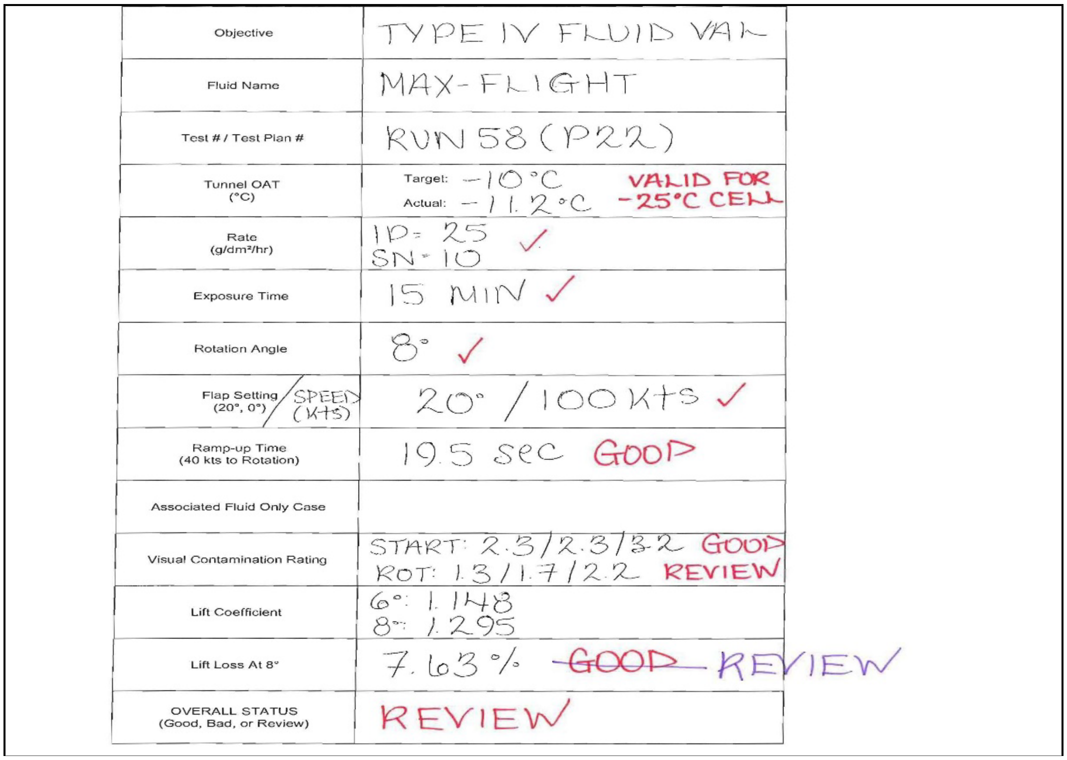
Objective	IP EXPANSION
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 46 (P113)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -13.5°C
Rate (g/dm²/hr)	IP= 25 ✓ SN= 10
Exposure Time	5 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	18 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 1.75/1.75/3 GOOD ROT: 1.25/1.6/2.25 REVIEW
Lift Coefficient	6°: 1.144 8°: 1.303
Lift Loss At 8°	7.06% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F46: Run #46



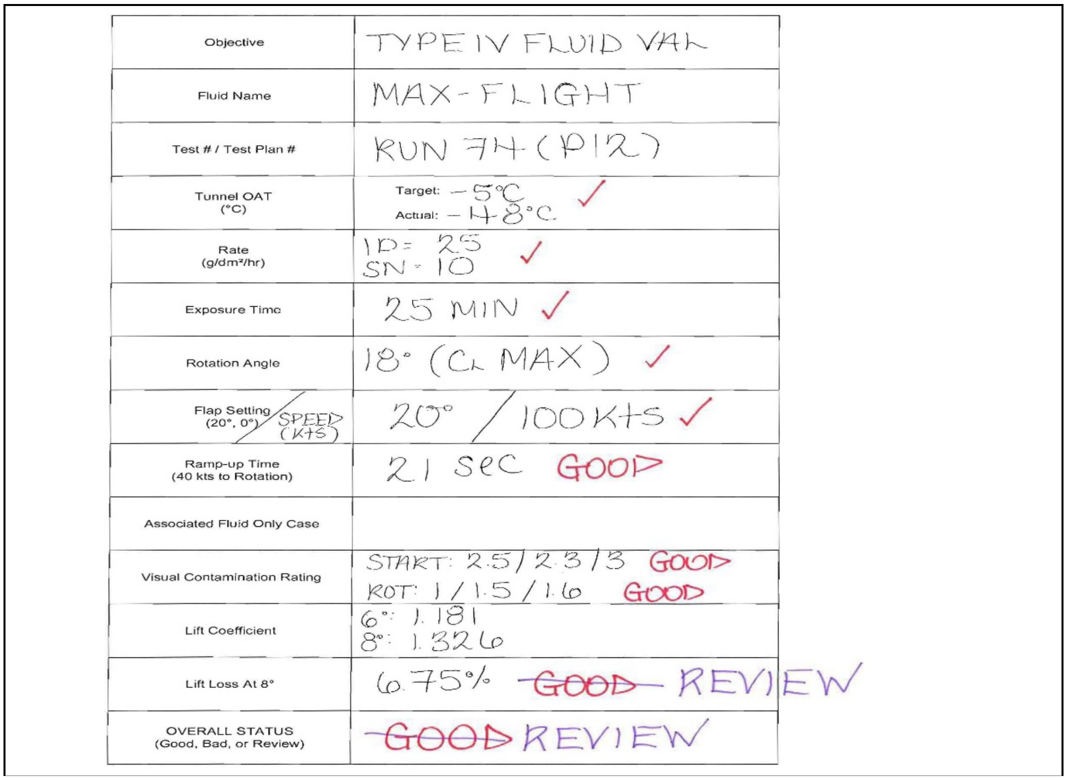
Objective	TYPE IV FLUID VAL
Fluid Name	AD-49
Test # / Test Plan #	RUN 56 (P21)
Tunnel OAT (°C)	Target: -10°C ✓ Actual: -9.6°C
Rate (g/dm²/hr)	IP= 25 SN= 10 ✓
Exposure Time	15 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	20 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/2.8/4 GOOD ROT: 1.5/2/2.5 REVIEW
Lift Coefficient	6°: 1.149 8°: 1.307
Lift Loss At 8°	6.78% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F47: Run #56



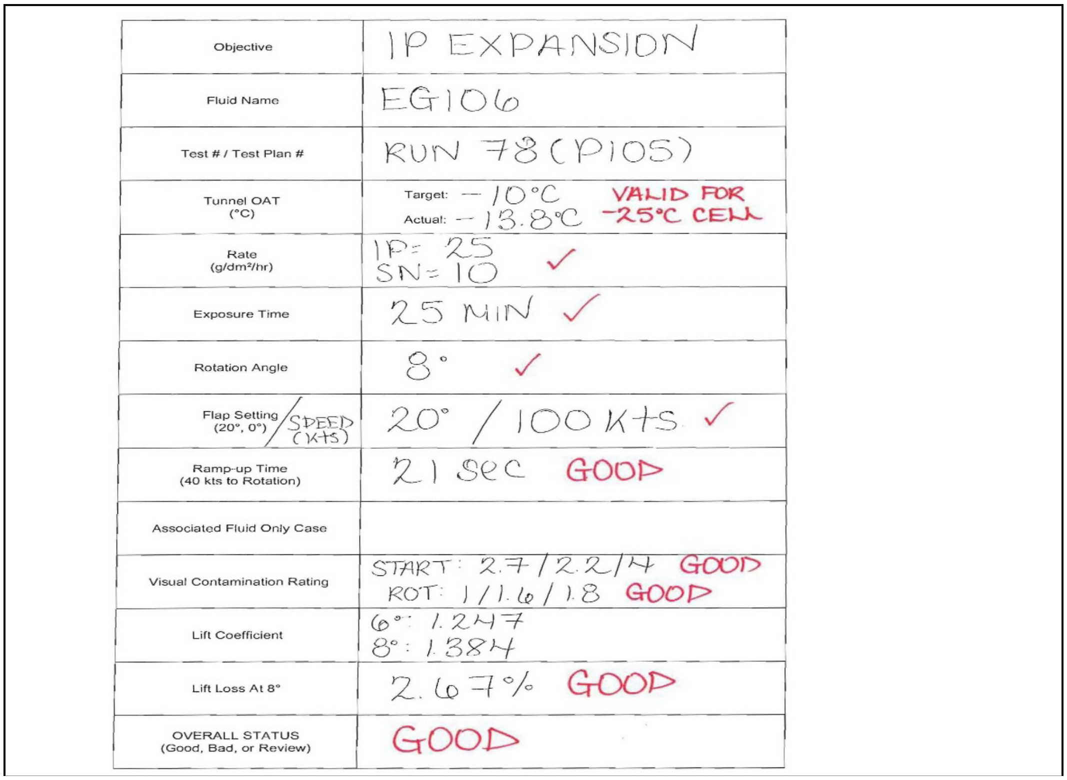
Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 58 (P22)
Tunnel OAT (°C)	Target: -10°C Actual: -11.2°C VALID FOR -25°C CELL
Rate (g/dm²/hr)	IP= 25 SN= 10 ✓
Exposure Time	15 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	19.5 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.3/2.3/3.2 GOOD ROT: 1.3/1.7/2.2 REVIEW
Lift Coefficient	6°: 1.148 8°: 1.295
Lift Loss At 8°	7.63% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F48: Run #58



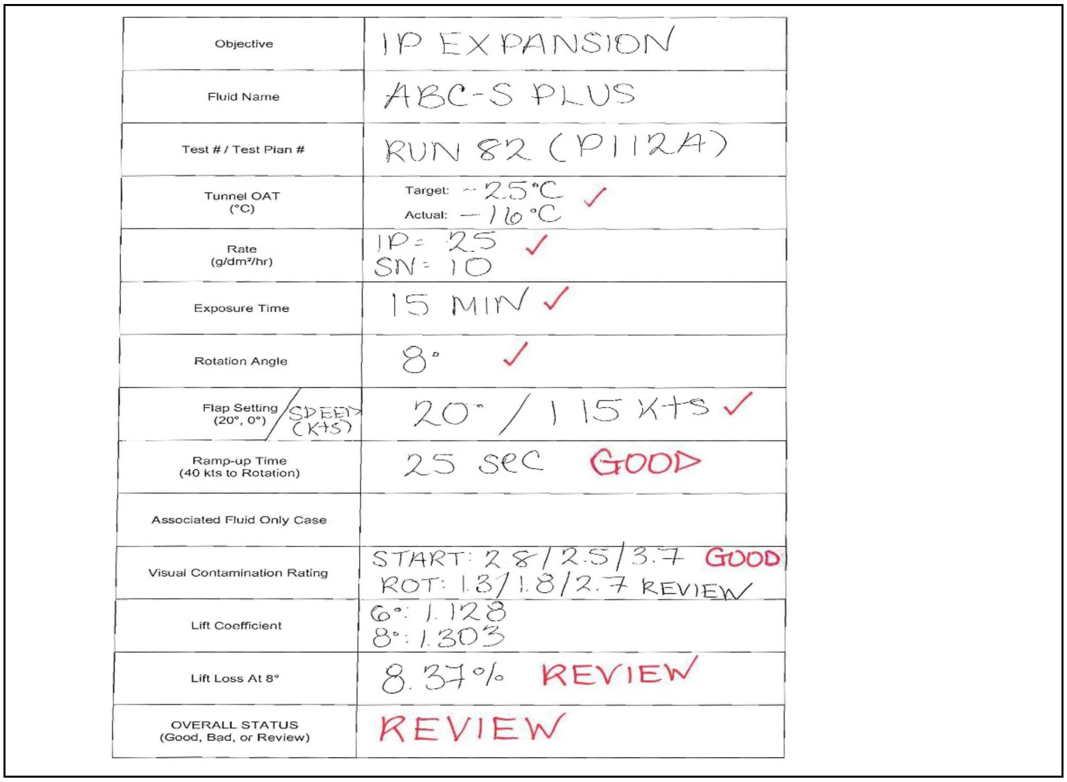
Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 74 (P12)
Tunnel OAT (°C)	Target: -5°C Actual: -4.8°C ✓
Rate (g/dm²/hr)	IP = 25 SN = 10 ✓
Exposure Time	25 MIN ✓
Rotation Angle	18° (CL MAX) ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5/2.3/3 GOOD ROT: 1/1.5/1.6 GOOD
Lift Coefficient	6°: 1.181 8°: 1.326
Lift Loss At 8°	6.75% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	~~GOOD~~ REVIEW

Figure F49: Run #74



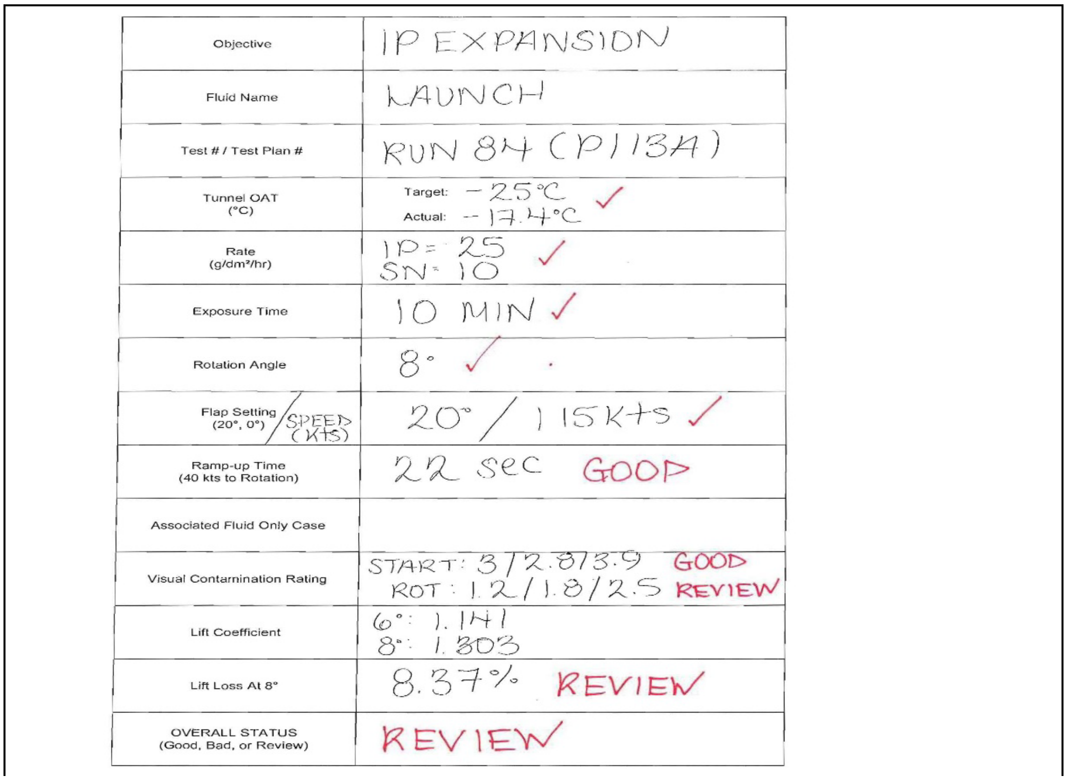
Objective	IP EXPANSION
Fluid Name	EG106
Test # / Test Plan #	RUN 78 (P105)
Tunnel OAT (°C)	Target: -10°C Actual: -13.8°C VALID FOR -25°C CELL
Rate (g/dm²/hr)	IP = 25 SN = 10 ✓
Exposure Time	25 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.7/2.2/4 GOOD ROT: 1/1.6/1.8 GOOD
Lift Coefficient	6°: 1.247 8°: 1.384
Lift Loss At 8°	2.67% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

Figure F50: Run #78



Objective	IP EXPANSION
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 82 (P112A)
Tunnel OAT (°C)	Target: -25°C Actual: -16°C ✓
Rate (g/dm²/hr)	IP= 25 SN= 10 ✓
Exposure Time	15 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	25 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.8/2.5/3.7 GOOD ROT: 1.3/1.8/2.7 REVIEW
Lift Coefficient	6°: 1.128 8°: 1.303
Lift Loss At 8°	8.37% REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F51: Run #82

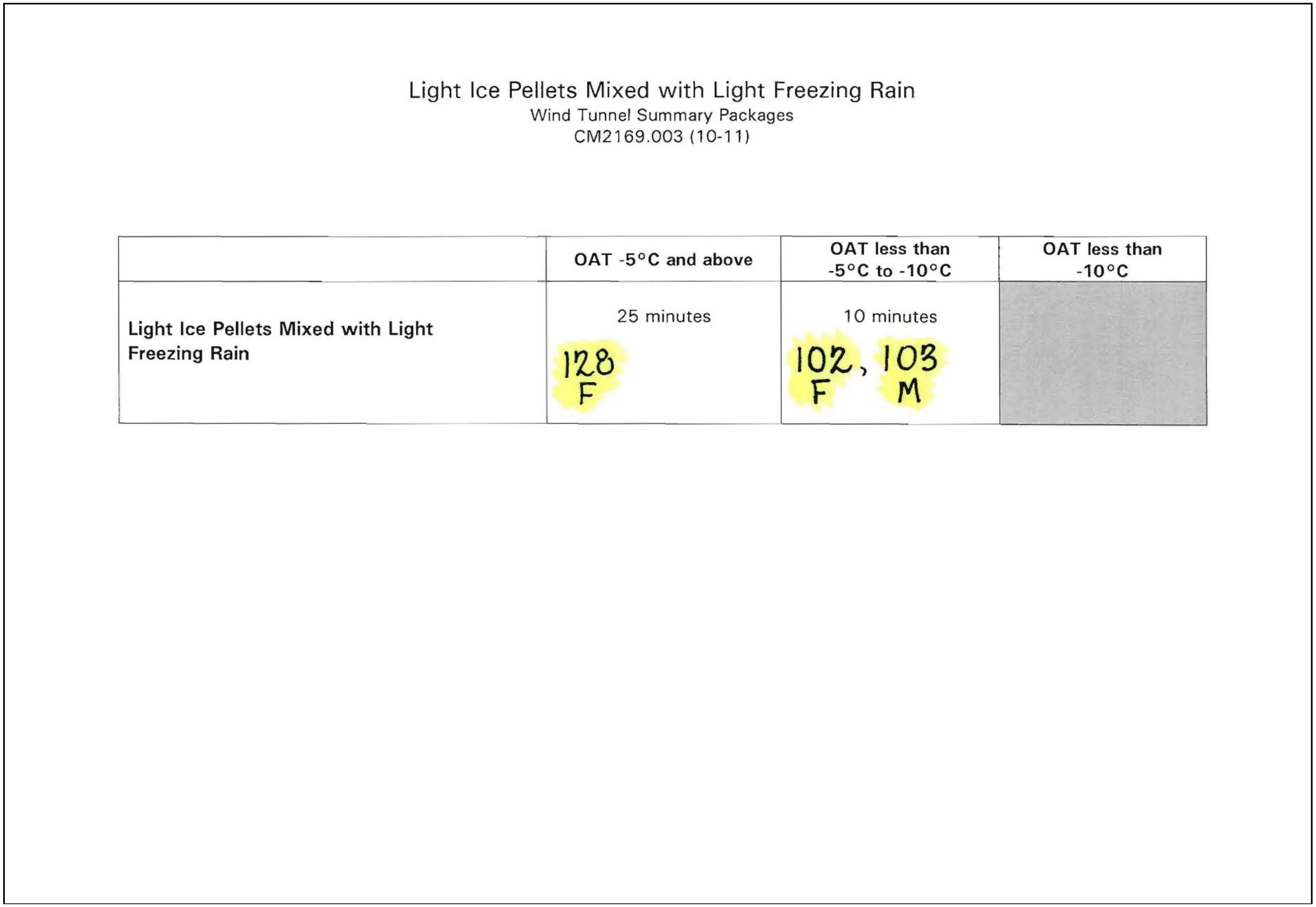


Objective	IP EXPANSION
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 84 (P113A)
Tunnel OAT (°C)	Target: -25°C Actual: -17.4°C ✓
Rate (g/dm²/hr)	IP= 25 SN= 10 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (Kts)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	22 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/2.8/3.9 GOOD ROT: 1.2/1.8/2.5 REVIEW
Lift Coefficient	6°: 1.141 8°: 1.303
Lift Loss At 8°	8.37% REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F52: Run #84

This page intentionally left blank.

LIGHT ICE PELLETS MIXED WITH LIGHT FREEZING RAIN



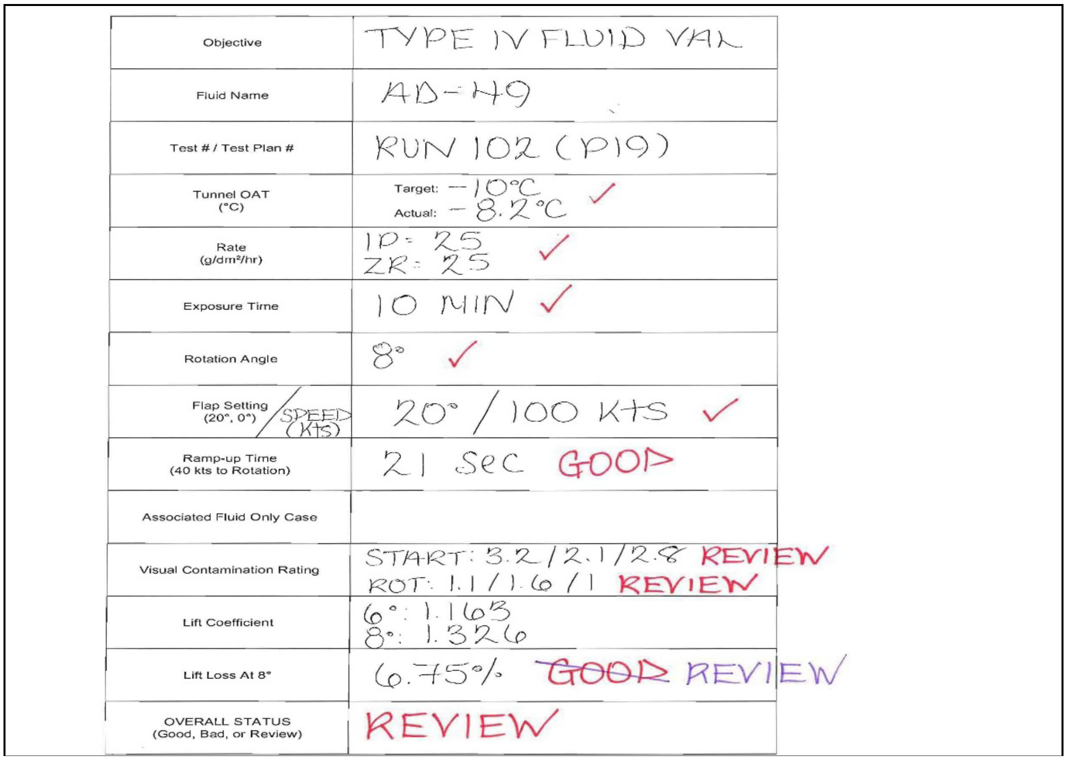
Light Ice Pellets Mixed with Light Freezing Rain

Wind Tunnel Summary Packages

CM2169.003 (10-11)

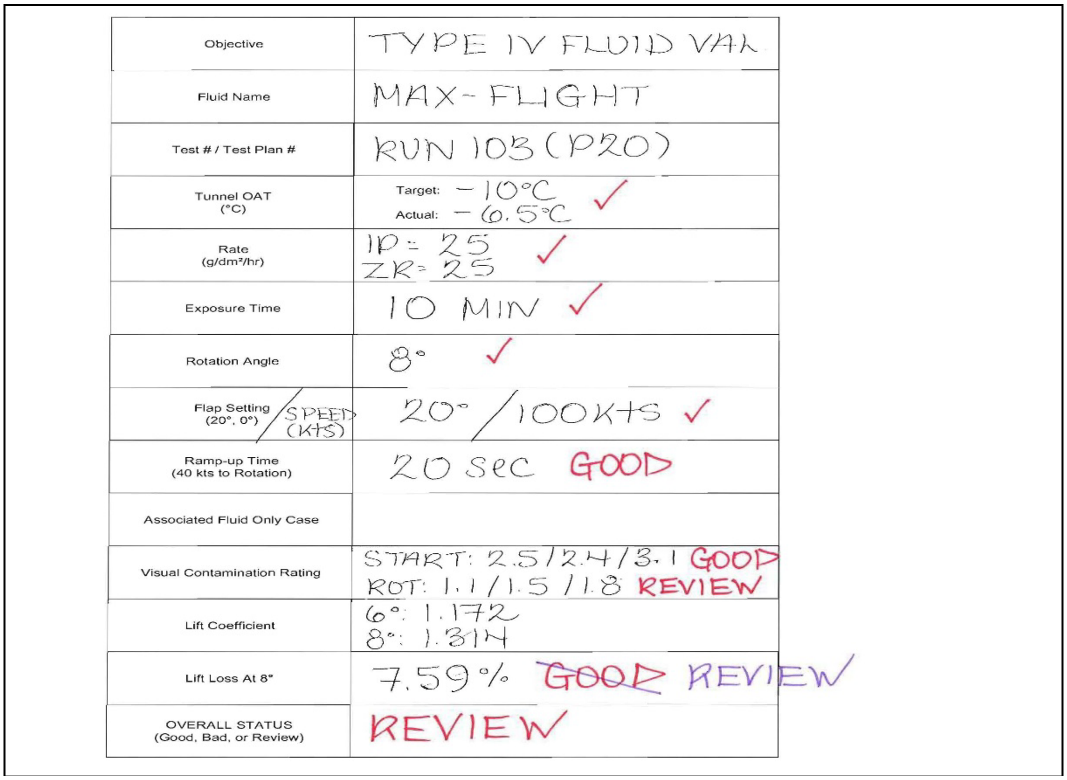
	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes 128 F	10 minutes 102, 103 F M	

Figure F53: Light Ice Pellets Mixed with Light Freezing Rain Allowance Table



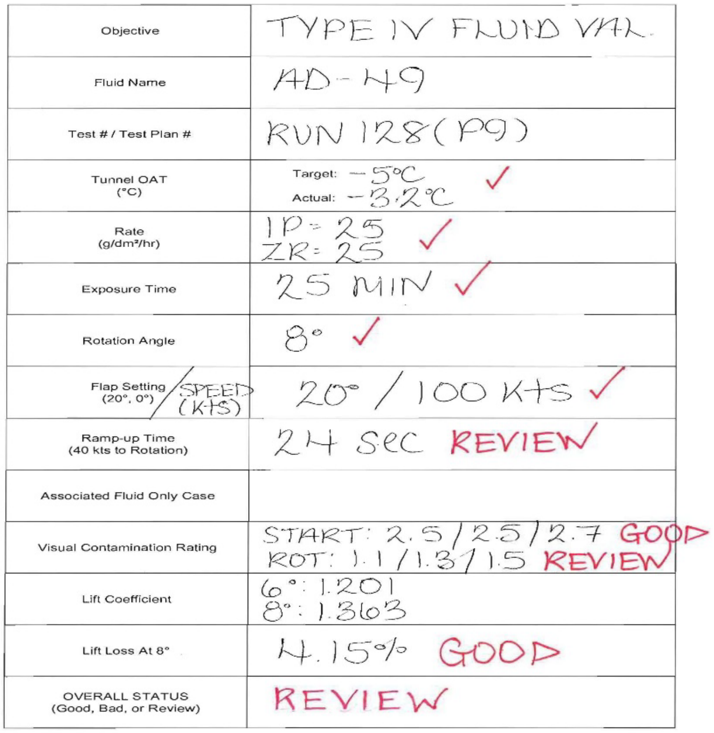
Objective	TYPE IV FLUID VAL
Fluid Name	AD-49
Test # / Test Plan #	RUN 102 (P19)
Tunnel OAT (°C)	Target: -10°C Actual: -8.2°C ✓
Rate (g/dm²/hr)	IP = 25 ZR = 25 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3.2 / 2.1 / 2.8 REVIEW ROT: 1.1 / 1.6 / 1 REVIEW
Lift Coefficient	6°: 1.163 8°: 1.326
Lift Loss At 8°	6.75% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F54: Run #102



Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 103 (P20)
Tunnel OAT (°C)	Target: -10°C Actual: -6.5°C ✓
Rate (g/dm²/hr)	IP = 25 ZR = 25 ✓
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	20 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5 / 2.4 / 3.1 GOOD ROT: 1.1 / 1.5 / 1.8 REVIEW
Lift Coefficient	6°: 1.172 8°: 1.314
Lift Loss At 8°	7.59% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F55: Run #103

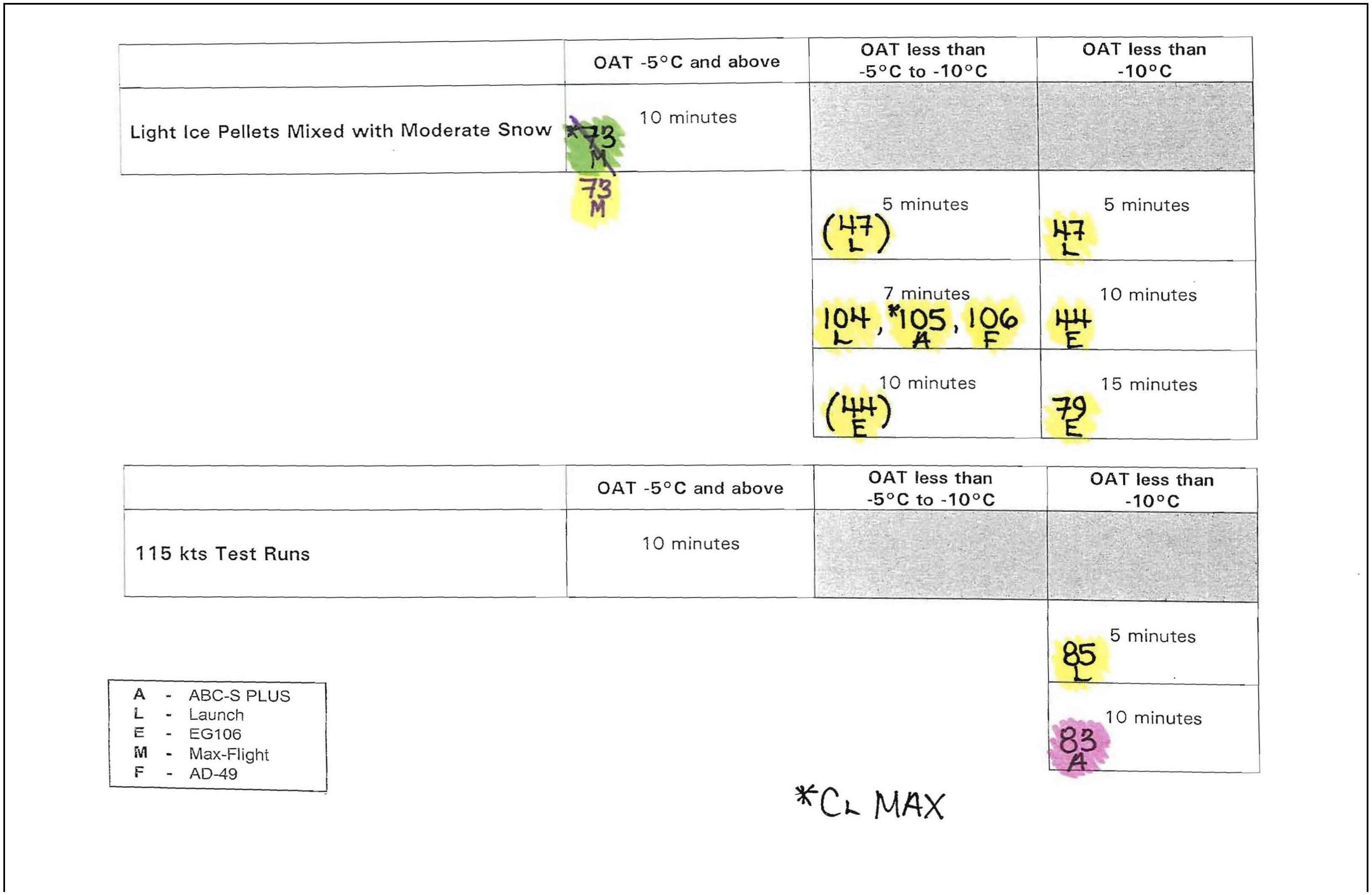


Objective	TYPE IV FLUID VAL.
Fluid Name	AD-49
Test # / Test Plan #	RUN 128(P9)
Tunnel OAT (°C)	Target: -5°C ✓ Actual: -3.2°C
Rate (g/dm²/hr)	IP= 25 ✓ ZR= 25
Exposure Time	25 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	24 SEC REVIEW
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.5/2.5/2.7 GOOD ROT: 1.1/1.3/1.5 REVIEW
Lift Coefficient	6°: 1.201 8°: 1.363
Lift Loss At 8°	4.15% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F56: Run #128

This page intentionally left blank.

LIGHT ICE PELLETS MIXED WITH MODERATE SNOW



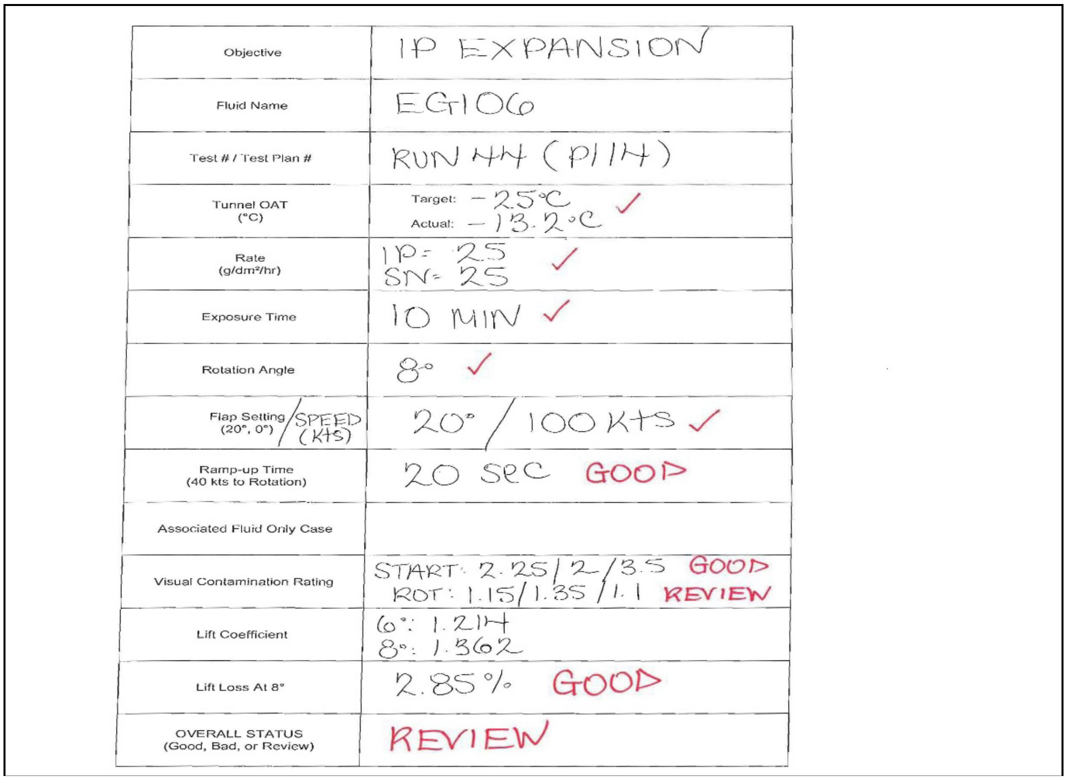
	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets Mixed with Moderate Snow	10 minutes ~~*73 M~~	▨	▨
	73 M	5 minutes (47 L)	5 minutes 47 L
		7 minutes 104 L, *105 A, 106 F	10 minutes 44 E
		10 minutes (44 E)	15 minutes 79 E

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
115 kts Test Runs	10 minutes	▨	▨
			5 minutes 85 L
			10 minutes 83 A

A - ABC-S PLUS
L - Launch
E - EG106
M - Max-Flight
F - AD-49

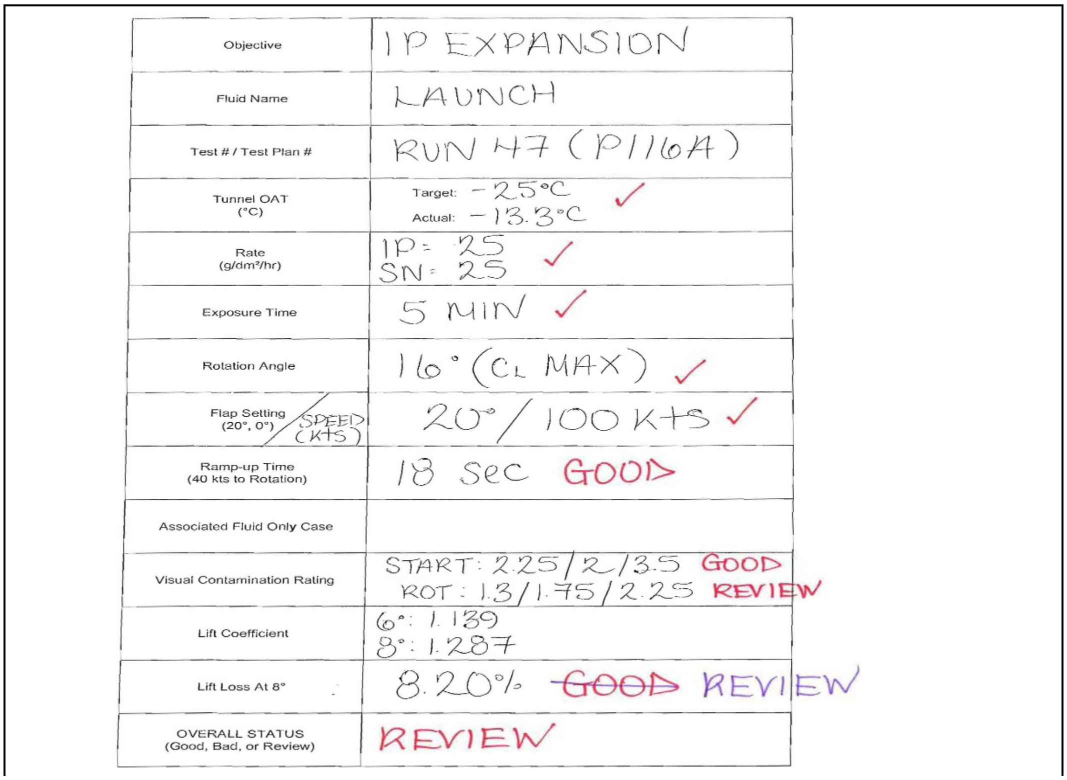
*CL MAX

Figure F57: Light Ice Pellets Mixed with Moderate Snow Allowance Table



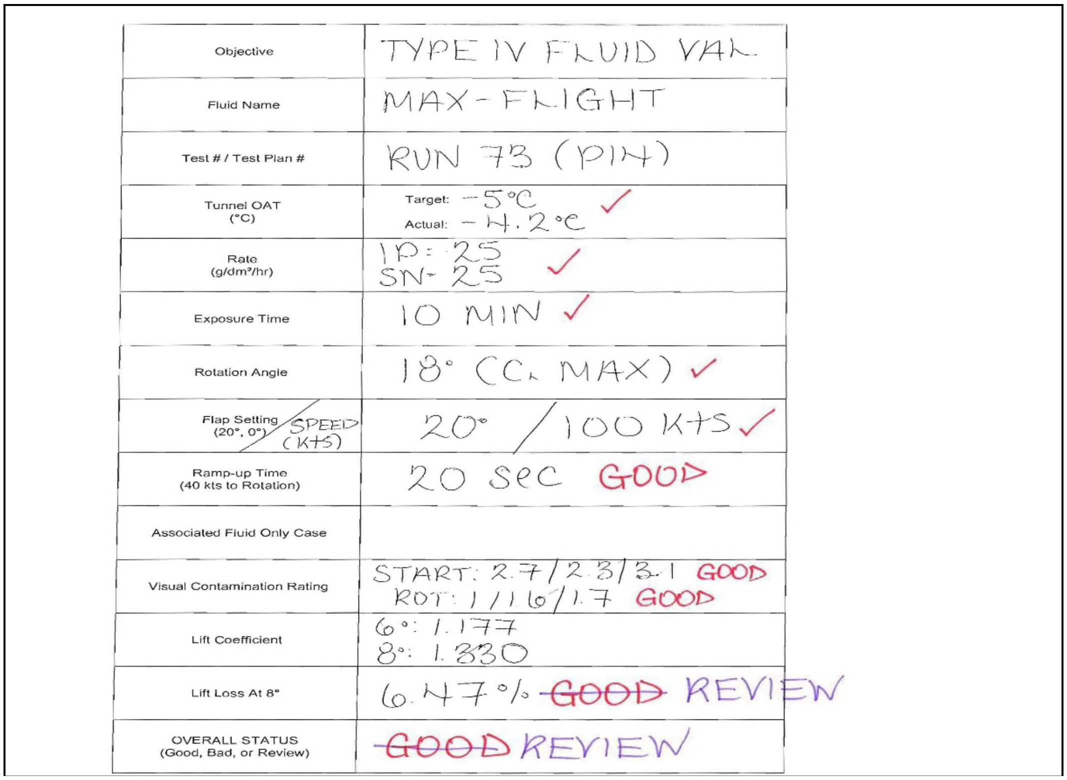
Objective	IP EXPANSION
Fluid Name	EG106
Test # / Test Plan #	RUN 44 (P114)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -13.2°C
Rate (g/dm²/hr)	IP= 25 ✓ SN= 25
Exposure Time	10 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	20 SeC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.25/2/3.5 GOOD ROT: 1.15/1.35/1.1 REVIEW
Lift Coefficient	6°: 1.214 8°: 1.362
Lift Loss At 8°	2.85% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F58: Run #44



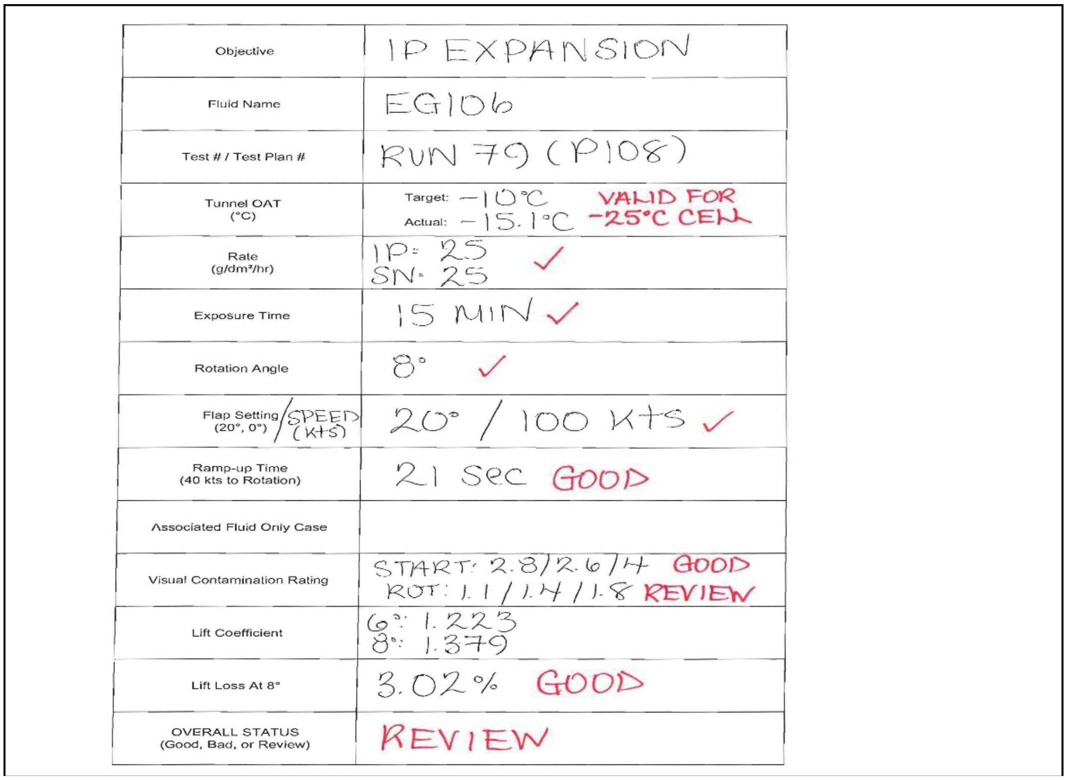
Objective	IP EXPANSION
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 47 (P116A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -13.3°C
Rate (g/dm²/hr)	IP= 25 ✓ SN= 25
Exposure Time	5 MIN ✓
Rotation Angle	16° (CL MAX) ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	18 SeC GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.25/2/3.5 GOOD ROT: 1.3/1.75/2.25 REVIEW
Lift Coefficient	6°: 1.139 8°: 1.287
Lift Loss At 8°	8.20% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F59: Run #47



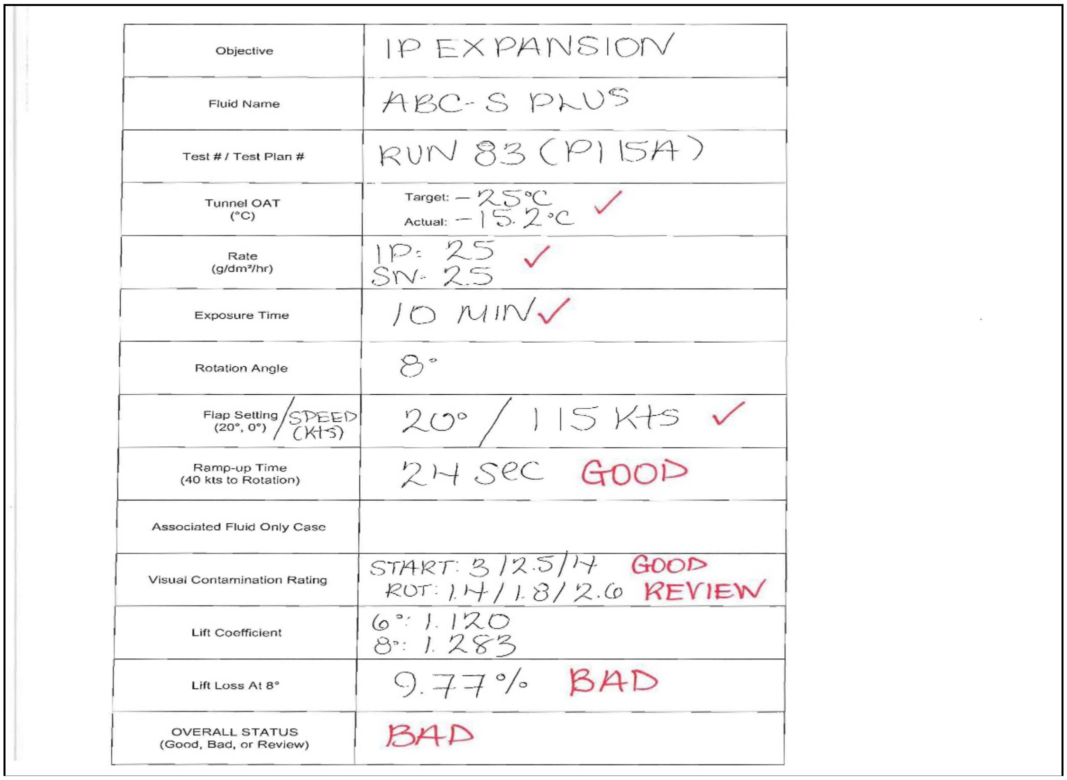
Objective	TYPE IV FLUID VAL
Fluid Name	MAX-FLIGHT
Test # / Test Plan #	RUN 73 (P14)
Tunnel OAT (°C)	Target: −5°C Actual: −4.2°C ✓
Rate ($g/dm^2/hr$)	IP: 25 SN- 25 ✓
Exposure Time	10 MIN ✓
Rotation Angle	18° (CL MAX) ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	20 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.7/2.3/3.1 GOOD ROT: 1/1.6/1.7 GOOD
Lift Coefficient	6°: 1.177 8°: 1.330
Lift Loss At 8°	6.47% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	~~GOOD~~ REVIEW

Figure F60: Run #73



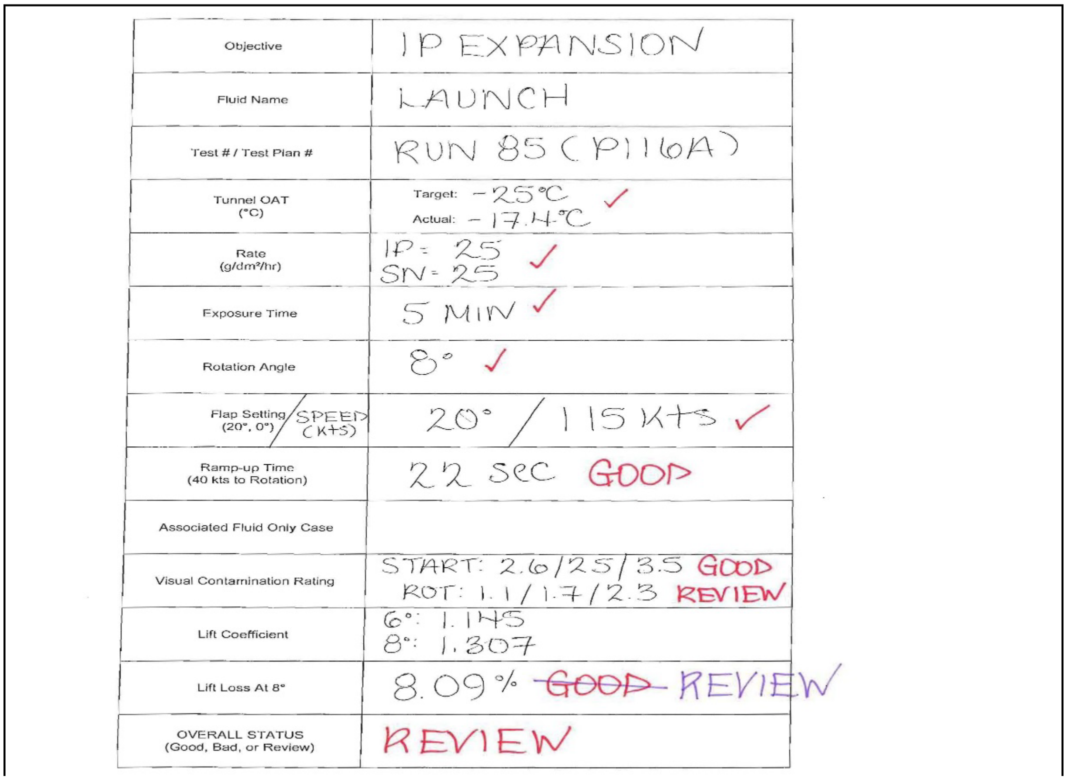
Objective	IP EXPANSION
Fluid Name	EG106
Test # / Test Plan #	RUN 79 (P108)
Tunnel OAT (°C)	Target: −10°C Actual: −15.1°C VALID FOR −25°C CELL
Rate ($g/dm^2/hr$)	IP: 25 SN: 25 ✓
Exposure Time	15 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KtS)	20° / 100 KtS ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.8/2.6/4 GOOD ROT: 1.1/1.4/1.8 REVIEW
Lift Coefficient	6°: 1.223 8°: 1.379
Lift Loss At 8°	3.02% GOOD
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F61: Run #79



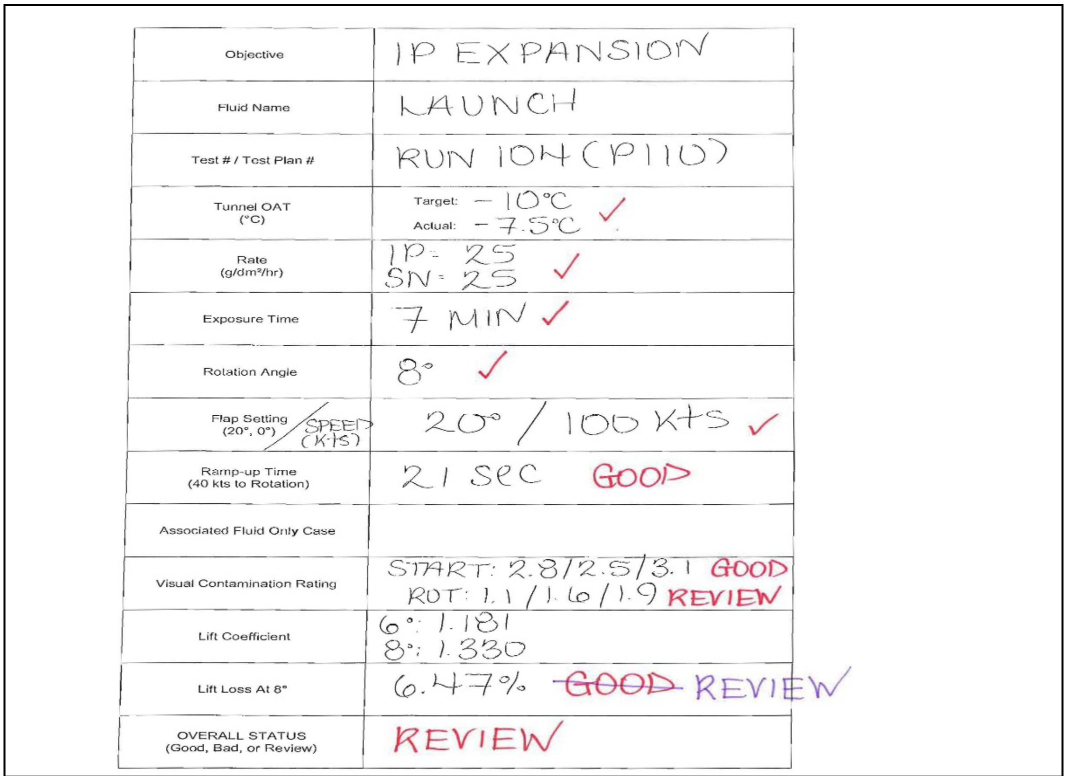
Objective	IP EXPANSION
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 83 (P115A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -15.2°C
Rate (g/dm²/hr)	IP: 25 ✓ SN: 25
Exposure Time	10 MIN ✓
Rotation Angle	8°
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	24 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 3/2.5/4 GOOD ROT: 1.4/1.8/2.6 REVIEW
Lift Coefficient	6°: 1.120 8°: 1.283
Lift Loss At 8°	9.77% BAD
OVERALL STATUS (Good, Bad, or Review)	BAD

Figure F62: Run #83



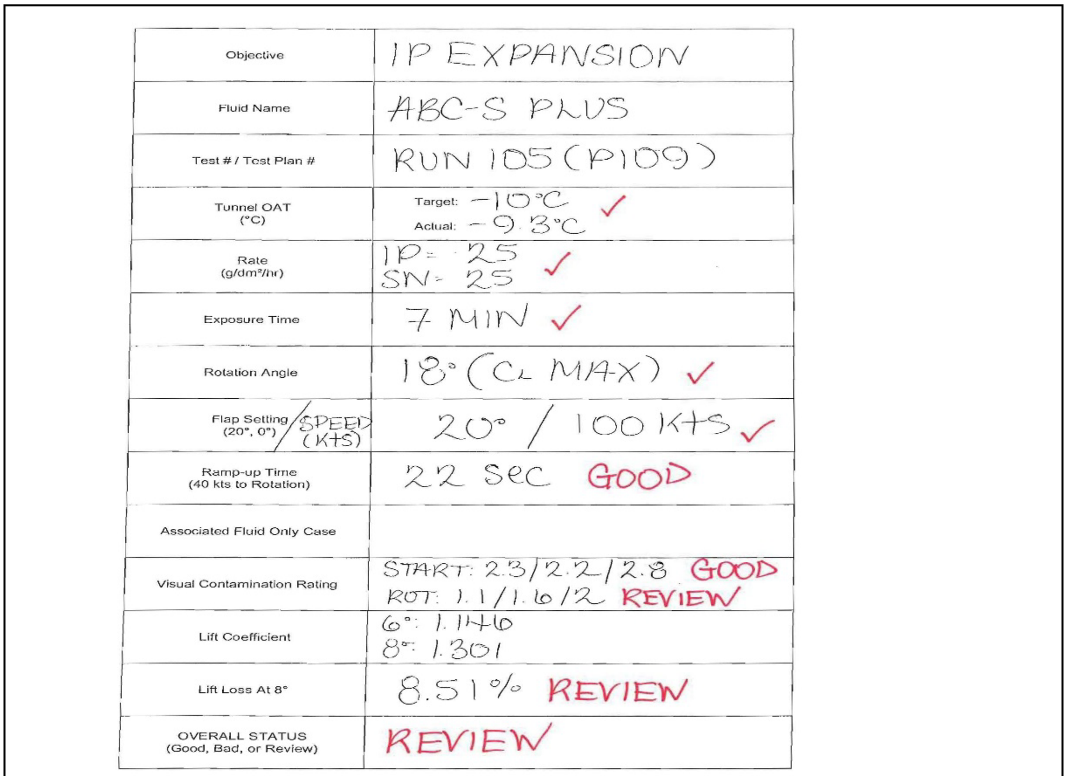
Objective	IP EXPANSION
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 85 (P116A)
Tunnel OAT (°C)	Target: -25°C ✓ Actual: -17.4°C
Rate (g/dm²/hr)	IP = 25 ✓ SN = 25
Exposure Time	5 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 115 Kts ✓
Ramp-up Time (40 kts to Rotation)	22 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.6/25/3.5 GOOD ROT: 1.1/1.7/2.3 REVIEW
Lift Coefficient	6°: 1.145 8°: 1.307
Lift Loss At 8°	8.09% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F63: Run #85



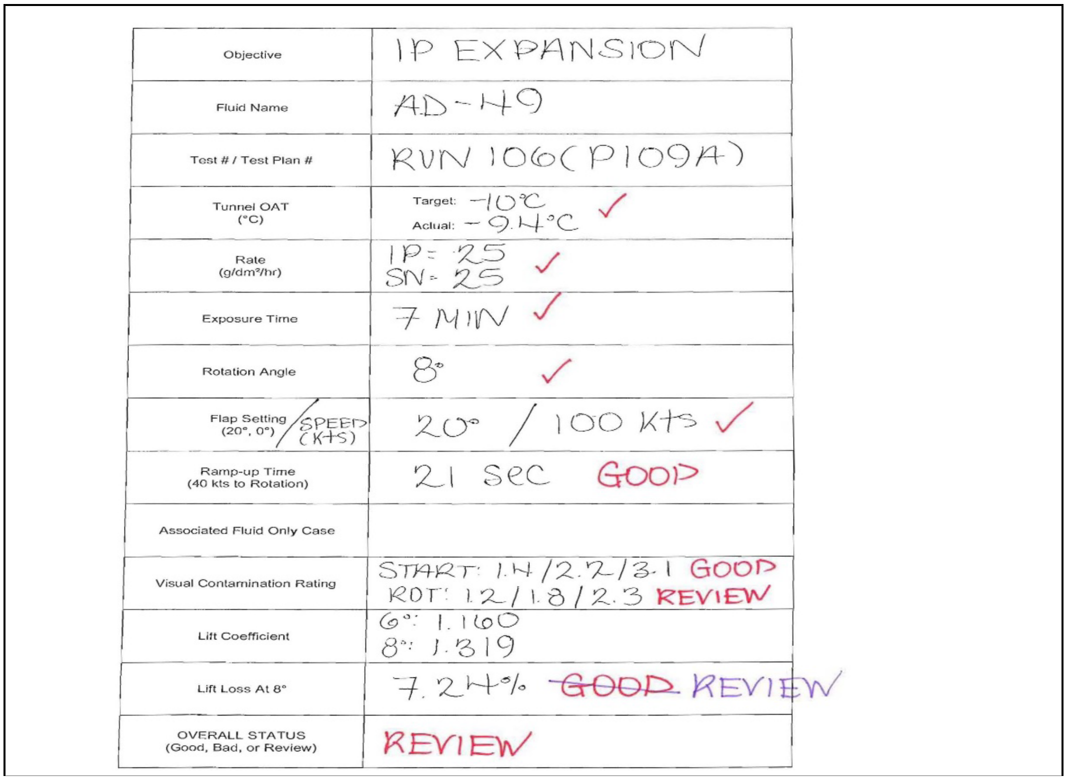
Objective	IP EXPANSION
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 104 (P110)
Tunnel OAT (°C)	Target: −10°C ✓ Actual: −7.5°C
Rate (g/dm²/hr)	IP = 25 SN = 25 ✓
Exposure Time	7 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.8/2.5/3.1 GOOD ROT: 1.1/1.6/1.9 REVIEW
Lift Coefficient	6°: 1.181 8°: 1.330
Lift Loss At 8°	6.47% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F64: Run #104



Objective	IP EXPANSION
Fluid Name	ABC-S PLUS
Test # / Test Plan #	RUN 105 (P109)
Tunnel OAT (°C)	Target: −10°C ✓ Actual: −9.3°C
Rate (g/dm²/hr)	IP = 25 SN = 25 ✓
Exposure Time	7 MIN ✓
Rotation Angle	18° (C_L MAX) ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	22 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.3/2.2/2.8 GOOD ROT: 1.1/1.6/2 REVIEW
Lift Coefficient	6°: 1.146 8°: 1.301
Lift Loss At 8°	8.51% REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

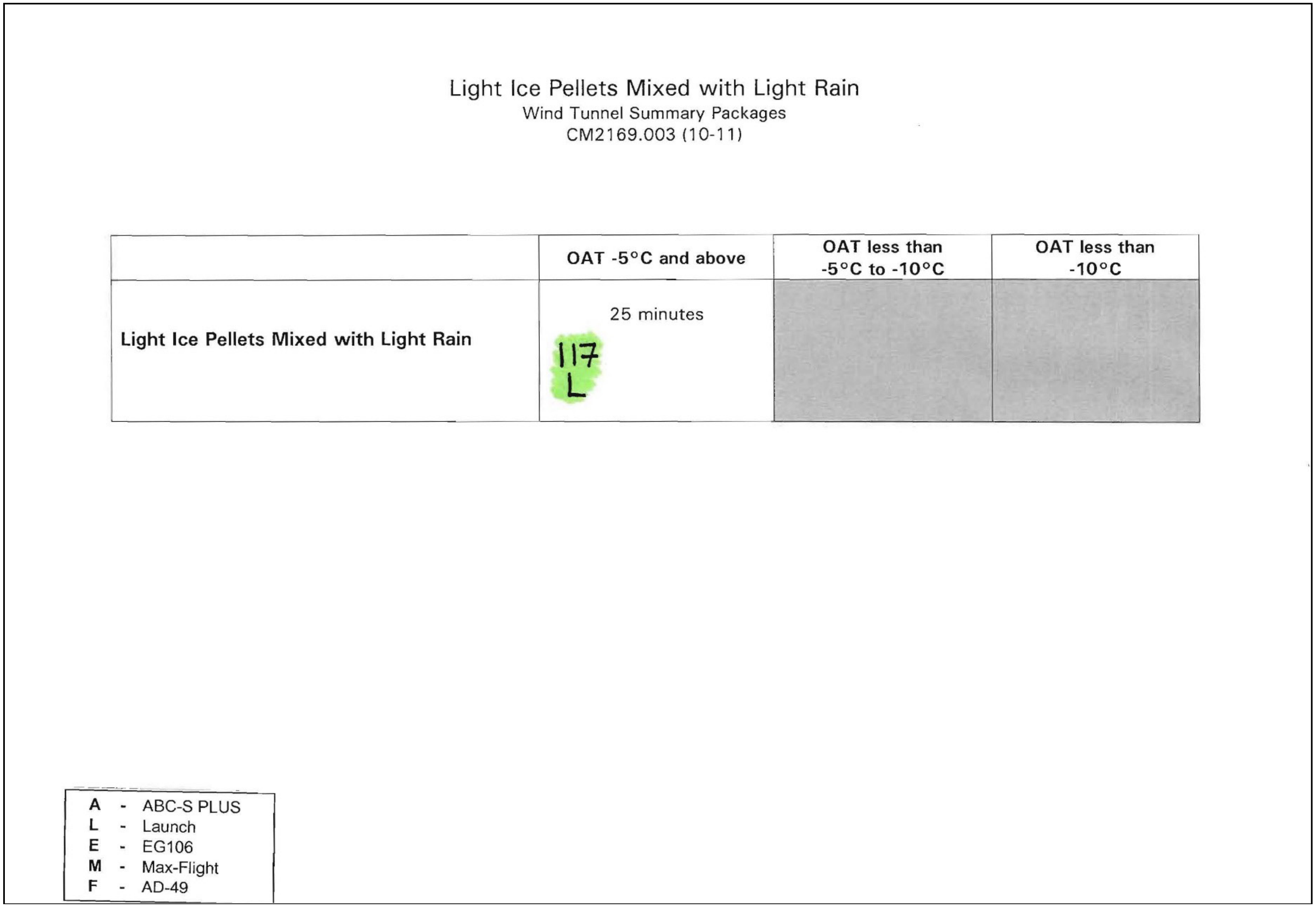
Figure F65: Run #105



Objective	IP EXPANSION
Fluid Name	AD-49
Test # / Test Plan #	RUN 106(P109A)
Tunnel OAT (°C)	Target: -10°C Actual: -9.4°C ✓
Rate (g/dm²/hr)	IP= 25 SN= 25 ✓
Exposure Time	7 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 Kts ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 1.4/2.2/3.1 GOOD ROT: 1.2/1.8/2.3 REVIEW
Lift Coefficient	6°: 1.160 8°: 1.319
Lift Loss At 8°	7.24% ~~GOOD~~ REVIEW
OVERALL STATUS (Good, Bad, or Review)	REVIEW

Figure F66: Run #106

LIGHT ICE PELLETS MIXED WITH LIGHT RAIN



Light Ice Pellets Mixed with Light Rain

Wind Tunnel Summary Packages
CM2169.003 (10-11)

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets Mixed with Light Rain	25 minutes 117 L		

A - ABC-S PLUS
L - Launch
E - EG106
M - Max-Flight
F - AD-49

Figure E67: Light Ice Pellets Mixed with Light Rain Allowance Table

Objective	IP DATA GAP
Fluid Name	LAUNCH
Test # / Test Plan #	RUN 117 (P119A)
Tunnel OAT (°C)	Target: 0°C Actual: +2.3°C ✓
Rate (g/dm^2/hr)	IP = 25 R = 25 ✓
Exposure Time	25 MIN ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	21 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 1.3/1.3/1.3 GOOD ROT: 1/1/1 GOOD
Lift Coefficient	6°: 1.227 8°: 1.381
Lift Loss At 8°	2.88% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

Figure F68: Run #117

APPENDIX G

FLUID THICKNESS DATA

Test 5A: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -10.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	1.5	N/A	0.0
2	1.9	N/A	0.1
3	2.2	N/A	0.1
4	2.5	N/A	0.2
5	2.9	N/A	0.2
6	3.1	N/A	0.1
7	3.1	N/A	0.1
8	2.5	N/A	0.1
Flap	0.7	N/A	0.1

Test 6: Dow FlightGuard AD-49, IP-, Tunnel OAT -10.9°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	2.5	0.0
2	1.7	2.2	0.1
3	2.2	2.2	0.1
4	2.7	3.3	0.2
5	2.7	3.7	0.2
6	2.9	3.3	0.2
7	3.1	3.5	0.1
8	2.2	3.1	0.1
Flap	1.0	1.3	0.3

Test 7: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -10.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	1.2	2.2	0.1
2	1.7	2.2	0.2
3	2.2	2.2	0.2
4	2.7	3.3	0.2
5	3.1	4.5	0.2
6	3.5	4.5	0.2
7	3.5	4.5	0.1
8	2.5	3.3	0.1
Flap	0.7	1.3	0.2

Test 8: Dow FlightGuard AD-49, IP-, Tunnel OAT -8.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	1.6	2.5	N/A
2	1.9	2.9	0.1
3	2.2	3.3	N/A
4	2.5	3.5	N/A
5	2.5	3.9	0.1
6	3.1	4.5	0.2
7	3.1	3.5	0.2
8	2.5	3.3	0.2
Flap	0.6	2.2	0.3

Test 9: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -6.7°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	0.0
2	1.3	N/A	0.1
3	N/A	N/A	0.1
4	N/A	N/A	0.1
5	2.9	N/A	0.1
6	N/A	N/A	0.2
7	N/A	N/A	0.2
8	2.2	N/A	0.2
Flap	0.7	N/A	0.1

Test 10: Octagon Max Flight 04, IP Mod, Tunnel OAT -6.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	2.2	2.5	N/A
2	3.3	3.5	N/A
3	3.9	4.5	N/A
4	4.5	5.7	N/A
5	4.5	5.7	N/A
6	5.7	7.0	N/A
7	4.5	7.0	N/A
8	3.7	5.7	N/A
Flap	1.6	1.2	N/A

Test 12: Octagon Max Flight 04, Fluid Only, Tunnel OAT -14.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	2.2	N/A	0.0
2	3.1	N/A	0.1
3	3.3	N/A	0.1
4	4.5	N/A	0.2
5	3.9	N/A	0.2
6	4.5	N/A	0.2
7	3.9	N/A	0.2
8	2.2	N/A	0.3
Flap	1.3	N/A	0.3

Test 13: Octagon Max Flight 04, IP Mod, Tunnel OAT -12.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.1	3.3	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.7	4.5	0.3
Flap	1.6	1.1	0.2

Test 14: Octagon Max Flight 04, IP Mod, Tunnel OAT -12.3°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.3	3.7	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	4.5	0.3
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.9	5.7	0.2
Flap	1.6	1.6	0.1

Test 15: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.1	4.5	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.7	5.7	0.3
Flap	1.3	2.2	0.2

Test 15A: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.1	3.7	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	4.5	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	4.5	4.5	N/A
Flap	1.7	1.7	N/A

Test 15B: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.3	3.3	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	5.7	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	4.5	5.7	0.3
Flap	1.2	1.9	0.2

Test 20: ABC-S Plus, IP-, Tunnel OAT -17.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	1.2	1.7	0.1
2	1.9	3.1	0.2
3	2.2	3.3	0.2
4	2.9	3.5	0.1
5	2.9	3.5	0.1
6	2.9	3.3	0.1
7	1.7	3.3	0.1
8	1.7	3.5	0.2
Flap	0.7	slush	0.2

Test 21: ABC-S Plus, Fluid Only, Tunnel OAT -18.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	1.7	N/A	0.1
2	1.9	N/A	0.2
3	2.2	N/A	0.2
4	2.7	N/A	0.2
5	2.7	N/A	0.2
6	2.5	N/A	0.2
7	2.2	N/A	0.2
8	N/A	N/A	0.2
Flap	0.6	N/A	0.1

Test 22: ABC-S Plus, IP-, Tunnel OAT -19.3°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	1.6	1.3	0.1
2	1.9	1.7	0.1
3	2.2	3.7	0.2
4	2.5	2.9	0.1
5	2.5	3.1	0.2
6	2.5	3.3	0.1
7	2.2	3.3	0.2
8	1.7	2.5	0.2
Flap	0.5	slush	0.2

Test 23: Clariant MP IV Launch, IP-, Tunnel OAT -21.5°C

FLUID THICKNESS (mm)

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1	1.2	1.6	0.1
2	1.7	1.7	0.1
3	1.7	1.7	0.1
4	1.9	3.5	0.1
5	1.9	2.9	0.1
6	1.9	3.1	0.1
7	1.6	2.9	0.2
8	1.3	2.5	0.3
Flap	0.5	slush	0.2

Test 24: Clariant MP IV Launch, IP-, Tunnel OAT -22.5°C

FLUID THICKNESS (mm)

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1	1.1	1.6	N/A
2	1.5	1.9	0.1
3	1.7	1.9	N/A
4	1.9	2.2	N/A
5	2.2	2.5	0.1
6	1.9	3.5	N/A
7	1.7	2.7	N/A
8	1.3	2.5	0.2
Flap	0.5	slush	0.2

Test 25: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -22.3°C

FLUID THICKNESS (mm)

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1	N/A	N/A	N/A
2	1.6	1.9	0.3
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	2.2	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.3	1.7	0.3
Flap	0.5	1.5	0.3

Test 26: Dow EG 106, IP Mod, Tunnel OAT -21.0°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.1	3.1	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.3	4.5	0.3
Flap	1.1	1.5	0.2

Test 27: Dow EG 106, IP-, Tunnel OAT -22.6°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.5	3.5	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.7	4.5	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.3	4.5	0.3
Flap	1.0	1.7	0.1

Test 28: Clariant MP IV Launch, IP Mod, Tunnel OAT -24.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.6	1.7	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	1.7	2.2	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.1	1.9	0.1
Flap	0.4	slush	0.2

Test 29: Clariant MP IV Launch, Fluid Only, Tunnel OAT -23.9°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.3	N/A	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	1.9	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.1	N/A	0.2
Flap	0.4	N/A	0.1

Test 30: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -23.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	N/A	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.5	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.5	N/A	0.2
Flap	0.5	N/A	0.3

Test 31: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -22.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.7	3.1	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.6	3.1	0.1
Flap	0.5	slush	0.2

Test 34: Dow EG 106, Fluid Only, Tunnel OAT -23.3°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.1	N/A	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.7	N/A	0.3
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.9	N/A	0.3
Flap	0.1	N/A	0.3

Test 35: Dow FlightGuard AD-49, IP-, Tunnel OAT -23.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	0.8	slush	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	1.0	1.9	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.7	slush	0.2
Flap	0.3	slush	0.3

Test 37: Octagon Max Flight 04, IP Mod, Tunnel OAT -24.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.7	2.5	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	3.1	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.7	3.1	0.2
Flap	0.4	slush	0.3

Test 38: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -24.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.7	3.1	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.9	2.5	0.2
Flap	0.5	slush	0.2

Test 40: Octagon Max Flight 04, IP-, Tunnel OAT -15.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	2.7	5-11
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.7	3.7	5-12
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.5	3.7	5-12
Flap	1.0	1.7	6-12

Test 41: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -16.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	0.8	0.5	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	1.1	1.5	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.8	0.4	N/A
Flap	0.2	slush	N/A

Test 41A: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -15.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	0.7	0.2	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	0.8	0.3	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.5	0.2	0.2
Flap	0.2	slush	0.2

Test 43: Dow EG 106, Fluid Only, Tunnel OAT -15.0°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.7	N/A	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	N/A	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.7	N/A	0.2
9 (flap)	1.2	N/A	0.2

Test 44: Dow EG 106, IP-/SN, Tunnel OAT -13.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.5	2.2	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.3	3.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.7	3.3	0.1
Flap	1.0	1.2	0.1

Test 45: Dow EG 106, IP-/SN-, Tunnel OAT -12.9°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.5	0.8	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.3	3.9	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.1	3.7	0.3
Flap	1.1	0.7	0.2

Test 46: Clariant MP IV Launch, IP-/SN-, Tunnel OAT -13.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.7	0.8	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	1.9	1.2	0.3
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.3	1.0	0.3
Flap	0.5	0.6	0.3

Test 47: Clariant MP IV Launch, IP-/SN, Tunnel OAT -13.3°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.3	1.5	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	1.6	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.5	1.7	0.1
Flap	0.5	1.0	0.2

Test 51: Dow EG 106, IP-, Tunnel OAT -11.1°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.1	2.2	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	3.9	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.3	3.3	0.1
Flap	1.2	1.5	0.1

Test 52: Dow EG 106, Fluid Only, Tunnel OAT -13.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	N/A	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.7	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.7	N/A	0.3
Flap	1.1	N/A	0.3

Test 53: Kilfrost ABC-S Plus, IP-, Tunnel OAT -12.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	2.5	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.1	3.5	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	3.1	0.3
Flap	0.8	0.1	0.3

Test 54: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -12.1°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	N/A	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.9	N/A	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	N/A	0.2
Flap	0.7	N/A	0.2

Test 54 (09-10): Launch, Fluid Only, Tunnel OAT -2.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Test**
1	1.2	N/A	0.0
2	1.7	N/A	0.1
3	1.8	N/A	0.1
4	2.2	N/A	0.2
5	2.7	N/A	0.1
6	2.7	N/A	0.1
7	2.5	N/A	0.1
8	2.2	N/A	0.1
Flap	0.7	N/A	0.1

Test 56: Dow FlightGuard AD-49, IP-/SN-, Tunnel OAT -9.6°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	0.7	1.1	0.3
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	1.0	1.2	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.6	1.5	0.1
Flap	0.2	slush	0.2

Test 57: Octagon Max Flight 04, Fluid Only, Tunnel OAT -9.9°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1	N/A	N/A	N/A
2	2.7	N/A	0.3
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.5	N/A	0.3
Flap	1.5	N/A	0.2

Test 58: Octagon Max Flight 04, IP-/SN-, Tunnel OAT -11.2°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1	N/A	N/A	N/A
2	2.9	3.3	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	4.5	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.5	3.9	0.4
Flap	1.0	1.6	0.2

Test 59: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.9°C			
FLUID THICKNESS (mm)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1	N/A	N/A	N/A
2	3.1	3.3	0.3
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	4.5	0.3
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.9	3.9	0.4
Flap	1.3	1.0	0.3

Test 59A: Octagon Max Flight 04, IP Mod, Tunnel OAT -9.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.7	3.1	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.3	4.5	0.3
Flap	1.0	slush	0.3

Test 63: Clariant MP IV Launch, Fluid Only, Tunnel OAT -4.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	N/A	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.9	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.9	N/A	0.2
Flap	0.7	N/A	0.2

Test 68: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -1.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.7	N/A	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	N/A	0.2
9 (flap)	0.5	N/A	0.2

Test 69: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -3.6°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	2.2	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.5	4.5	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	3.3	0.2
9 (flap)	0.6	0.1	0.3

Test 70: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -4.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	3.1	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.7	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	3.3	0.2
9 (flap)	0.7	1.5	0.1

Test 70 (09-10): Launch, Fluid-only, Tunnel OAT -17.9°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Test**
1	1.1	N/A	0.0
2	1.5	N/A	0.1
3	1.8	N/A	0.1
4	2.2	N/A	0.2
5	2.2	N/A	0.2
6	1.6	N/A	0.2
7	1.8	N/A	0.2
8	2.2	N/A	0.2
Flap	0.5	N/A	0.1

Test 71: Octagon Max Flight 04, Tunnel OAT -3.7°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.3	N/A	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.3	N/A	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	4.5	N/A	0.1
9 (flap)	1.6	N/A	0.1

Test 72: Octagon Max Flight 04, IP Mod, Tunnel OAT -3.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.7	3.5	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	5.7	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.7	4.5	0.3
9 (flap)	1.5	1.7	0.2

Test 73: Octagon Max Flight 04, IP-/SN, Tunnel OAT -4.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.7	3.3	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	3.9	0.2
6	N/A	N/A	N/A
7	N/A	N/A	#N/A
8	4.5	4.5	0.3
9 (flap)	1.1	1.7	0.2

Test 74: Octagon Max Flight 04, IP-/SN-, Tunnel OAT -4.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.7	3.5	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	5.7	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	4.5	4.5	0.3
9 (flap)	1.6	1.7	0.2

Test 75: Octagon Max Flight 04, Fluid Only, Tunnel OAT -5.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	**3.9**	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	**3.9**	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	**3.9**	N/A	N/A
9 (flap)	**1.5**	N/A	N/A

Test 76: Octagon Max Flight 04, Fluid Only, Tunnel OAT -5.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	3.9, 2.9	N/A	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5, 2.2	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.5, 5.7	N/A	0.2
9 (flap)	1.6	N/A	0.1

Test 78: Dow EG 106, IP-/SN-, Tunnel OAT -13.8°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.7	2.5	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	4.5	0.0
6	N/A	N/A	N/A
7	/A	N/A	N/A
8	3.1	3.3	0.1
9 (flap)	1.1	0.3	0.2

Test 79: Dow EG 106, IP-/SN, Tunnel OAT -15.1°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.7	1.9	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	4.5	3.9	0.0
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.1	3.9	0.1
9 (flap)	1.0	0.3	0.1

Test 80: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -15.1°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	N/A	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.1	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	N/A	0.1
9 (flap)	0.6	N/A	0.2

Test 81: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -14.7°C

FLUID THICKNESS (mm)

Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	**#N/A**	**#N/A**	**#N/A**
2	**2.2**	**#N/A**	**0.1**
3	**#N/A**	**#N/A**	**#N/A**
4	**#N/A**	**#N/A**	**#N/A**
5	**3.9**	**#N/A**	**0.1**
6	**#N/A**	**#N/A**	**#N/A**
7	**#N/A**	**#N/A**	**#N/A**
8	**2.5**	**#N/A**	**0.2**
9 (flap)	**0.6**	**#N/A**	**0.2**

Test 82: Kilfrost ABC-S Plus, IP-/SN-, Tunnel OAT -16.0°C

FLUID THICKNESS (mm)

Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	1.9	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.3	3.9	0.1
6	N/A	N/A	N/A
7	N/A	N/A	#N/A
8	2.2	3.1	0.2
9 (flap)	0.8	slush	0.1

Test 83: Kilfrost ABC-S Plus, IP-/SN, Tunnel OAT -15.2°C

FLUID THICKNESS (mm)

Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	1.9	4.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.1	3.5	4.0
6	N/A	N/A	N/A
7	N/A	#N/A	N/A
8	2.2	2.7	6.0
9 (flap)	0.6	0.1 (slush)	4.0

Test 84: Clariant MP IV Launch, IP-/SN-, Tunnel OAT -17.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.7	1.9	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	2.7	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.7	2.5	0.1
9 (flap)	0.5	slush	0.2

Test 85: Clariant MP IV Launch, IP-/SN, Tunnel OAT -17.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.5	1.5	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	2.2	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.6	1.3	N/A
9 (flap)	0.5	0.5	N/A

Test 92: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -13.6°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.6	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.5	4.5	0.0
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.9	2.5	0.2
9 (flap)	0.7	slush	0.1

Test 92A: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -14.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.1	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	3.3	0.2
9 (flap)	0.6	1.3	0.1

Test 93: Kilfrost ABC-S Plus, IP, Tunnel OAT -12.0°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.9	3.5	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.9	2.7	0.2
9 (flap)	0.6	0.3	0.2

Test 97: Clariant MP IV Launch, Fluid Only Tunnel OAT -11.9°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	N/A	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.1	N/A	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	N/A	0.2
9 (flap)	0.8	N/A	0.2

Test 101 (09-10): Launch, Fluid Only, Tunnel OAT -7.6°C			
WING TEMPERATURE (°C)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Test**
T2	-8.9	N/A	-8.3
T5	-8.8	N/A	-7.7
TU	-7.5	N/A	-8.6

Test 102: Dow FlightGuard AD-49, -IP/-ZR, Tunnel OAT -6.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.5	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.3	3.7	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.5	3.1	0.4
9 (flap)	1.1	0.8	0.3

Test 103: Octagon Max Flight 04, -IP/-ZR, Tunnel OAT -6.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.5	2.7	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.3	3.9	0.3
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.7	2.9	0.3
9 (flap)	1.0	1.7	0.2

Test 104: Clariant MP IV Launch, IP-/SN, Tunnel OAT -7.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.6	1.3	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	2.2	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.7	2.2	0.2
9 (flap)	0.6	1.5	0.3

Test 105: Kilfrost ABC-S Plus, IP-/SN, Tunnel OAT -9.3°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.5	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.5	3.9	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.7	2.7	0.2
9 (flap)	0.8	1.5	0.2

Test 106: Dow FlightGuard AD-49, IP-/SN, Tunnel OAT -9.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.6	2.2	0.2
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.9	2.9	0.3
6	N/A	N/A	N/A
7	N/A	N/A	#N/A
8	2.5	2.9	0.3
9 (flap)	0.8	0.5	0.2

Test 115: Dow EG 106, IP-/R Mod, Tunnel OAT 1.4°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.7	0.6	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.5	1.1	0.0
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.7	0.5	0.0
9 (flap)	1.0	0.1	0.0

Test 116: Kilfrost ABC-S Plus, IP-/R Mod, Tunnel OAT 3.0°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.5	1.2	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	3.9	4.5	0.0
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.5	1.7	0.2
9 (flap)	1.0	0.2	0.2

Test 117: Clariant MP IV Launch, IP-/R-, Tunnel OAT 2.3°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.6	2.2	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.2	3.9	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	1.5	2.9	0.2
9 (flap)	0.5	0.1	0.2

Test 121: Octagon Max Flight 04, IP-, Tunnel OAT -12.9°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.2	2.5	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.5	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	3.3	3.7	0.2
9 (flap)	1.2	1.6	0.1

Test 128: Dow FlightGuard AD-49, IP-/ZR-, Tunnel OAT -3.2°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	3.1	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.9	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	3.1	0.2
9 (flap)	0.5	0.8	0.3

Test 129: Dow FlightGuard AD-49, IP-, Tunnel OAT -3.6°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	3.1	0.0
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.9	4.5	0.1
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.5	3.9	0.2
9 (flap)	0.7	0.5	0.3

Test 131: Clariant MP IV Launch, IP Mod, Tunnel OAT -4.5°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	1.9	3.3	0.1
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	2.7	4.5	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	2.2	4.5	0.2
9 (flap)	0.7	slush	0.3

Test 132: Octagon Max Flight 04, IP Mod, Tunnel OAT -5.9°C			
FLUID THICKNESS (mm)			
Wing Position	**After Fluid Application**	**After Precip Application**	**After Takeoff Run**
1	N/A	N/A	N/A
2	2.5	3.7	0.1
3	N/A	N/A	N/A
4	/A	N/A	N/A
5	3.3	5.7	0.2
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	4.5	5.7	0.3
9 (flap)	1.5	slush	0.2

APPENDIX H

TEMPERATURE DATA

Test 5A: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -10.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.0	-7.7	N/A	-8.7
T5	-8.3	-7.9	N/A	-8.9
TU	-9.1	-8.9	N/A	-9.2

Test 6: Dow FlightGuard AD-49, IP-, Tunnel OAT -10.9°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.3	-7.7	-12.4	-9.4
T5	-8.6	-7.8	-12.0	-8.9
TU	-9.4	-9.7	-11.0	-10.0

Test 7: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -10.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-9.1	-8.1	-12.2	-8.5
T5	-9.3	-8.2	-11.6	-8.8
TU	-10.1	-10.1	-10.0	-9.8

Test 8: Dow FlightGuard AD-49, IP-, Tunnel OAT -8.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.0	-7.7	-11.2	-8.4
T5	-8.2	-7.4	-11.1	-7.7
TU	-9.5	-9.3	-9.2	-9.5

Test 9: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -6.7°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-6.9	-5.7	N/A	-5.2
T5	-7.2	-5.7	N/A	-4.9
TU	-7.8	-6.9	N/A	-6.7

Test 12: Octagon Max Flight 04, Fluid Only, Tunnel OAT -14.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-12.2	-11.9	N/A	-12.1
T5	-11.2	-11.3	N/A	-11.5
TU	-14.0	-13.8	N/A	-13.9

Test 13: Octagon Max Flight 04, IP Mod, Tunnel OAT -12.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-11.6	-12.2	-14.5	-12.3
T5	-10.5	-11.5	-14.4	-11.1
TU	-13.3	-13.3	-12.9	-13.5

Test 14: Octagon Max Flight 04, IP Mod, Tunnel OAT -12.3°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-11.6	-12.3	-14.4	-11.8
T5	-10.7	-11.9	-14.2	-11.2
TU	-13.2	-13.3	-12.7	-13.5

Test 15: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.8°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-10.8	-11.6	-13.8	-10.4
T5	-9.9	-11.3	-13.6	-9.8
TU	-12.5	-12.5	-12.4	-12.4

Test 15A: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-10.2	-11.6	-13.3	-10.3
T5	-9.8	-11.7	-13.0	-9.7
TU	-12.0	-11.6	-11.3	-11.8

Test 15B: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.8°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-9.5	-11.2	-12.9	-10.3
T5	-8.9	-10.9	-12.6	-9.2
TU	-11.1	-10.8	-10.8	-11.6

Test 20: ABC-S Plus, IP-, Tunnel OAT -17.5°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.7	-13.1	-16.4	-14.6
T5	-9.1	-13.3	-15.5	-14.5
TU	-8.4	-11.7	-15.9	-17.2

Test 21: ABC-S Plus, Fluid Only, Tunnel OAT -18.2°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-14.6	-16.3	N/A	-14.8
T5	-15.6	-15.7	N/A	-14.9
TU	-17.2	-17.2	N/A	-17.7

Test 22: ABC-S Plus, IP-, Tunnel OAT -19.3°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-15.2	-16.5	-17.7	-16.5
T5	-15.3	-16.5	-17.2	-16.5
TU	-17.9	-17.9	-18.2	-19.4

Test 23: Clariant MP IV Launch, IP-, Tunnel OAT -21.5°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-18.5	-17.0	-19.6	-18.8
T5	-18.7	-17.1	-20.0	-18.9
TU	-20.1	-20.1	-20.3	-21.3

Test 24: Clariant MP IV Launch, IP-, Tunnel OAT -22.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-19.2	-17.4	-21.1	-19.8
T5	-19.9	-17.9	-21.1	-19.8
TU	-21.3	-21.1	-21.4	-22.3

Test 25: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -22.3°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-19.6	N/A	-21.9	-22.4
T5	-20.0	N/A	-20.8	-21.9
TU	-21.1	N/A	-20.9	-23.8

Test 26: Dow EG 106, IP Mod, Tunnel OAT -21.0°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-20.1	-20.3	-20.9	-21.0
T5	-20.6	-20.8	-21.2	-20.4
TU	-22.4	-22.0	-20.8	-23.4

Test 27: Dow EG 106, IP-, Tunnel OAT -22.6°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-19.8	-21.9	-21.5	-22.1
T5	-19.3	-21.4	-21.0	-22.0
TU	-22.3	-21.8	-21.3	-24.3

Test 28: Clariant MP IV Launch, IP Mod, Tunnel OAT -24.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-20.9	-20.7	-22.1	-23.2
T5	-20.8	-20.5	-21.8	-22.7
TU	-23.8	-23.7	-23.7	-25.4

Test 29: Clariant MP IV Launch, Fluid Only, Tunnel OAT -23.9°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-21.5	-19.7	N/A	-23.6
T5	-21.3	-19.7	N/A	-23.1
TU	-24.6	-23.8	N/A	-25.4

Test 30: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -23.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-21.8	-22.3	N/A	-22.5
T5	-21.1	-21.8	N/A	-22.4
TU	-23.5	-23.2	N/A	-25.2

Test 31: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -22.8°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-21.4	-18.3	-22.1	-23.1
T5	-21.3	-17.5	-21.1	-21.2
TU	-24.0	-23.0	-22.4	-21.3

Test 34: Dow EG 106, Fluid Only, Tunnel OAT -23.3°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-22.6	-22.8	N/A	-24.2
T5	-21.0	-21.8	N/A	-22.8
TU	-23.7	-23.4	N/A	-25.5

Test 35: Dow FlightGuard AD-49, IP-, Tunnel OAT -23.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-22.5	-23.1	-21.3	-22.6
T5	-21.0	-22.5	-20.5	-21.0
TU	-24.3	-23.5	-22.6	N/A

Test 37: Octagon Max Flight 04, IP Mod, Tunnel OAT -24.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-22.5	-24.1	-23.4	-24.5
T5	-21.6	-23.7	-22.7	-23.4
TU	-24.4	-24.1	-23.4	-26.0

Test 38: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -24.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-23.7	-24.1	-23.5	-25.1
T5	-22.8	-23.7	-22.6	-23.9
TU	-25.5	-25.1	-23.5	-26.8

Test 40: Octagon Max Flight 04, IP-, Tunnel OAT -15.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-13.3	-18.6	-15.6	-14.4
T5	-12.5	-18.9	-15.4	-13.4
TU	-14.7	-14.5	-14.1	-16.0

Test 41: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -16.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-14.3	-17.5	-16.4	N/A
T5	-13.5	-17.0	-16.4	N/A
TU	-15.1	-15.1	-15.6	N/A

Test 41A: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -15.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-14.2	-17.6	-16.7	-14.8
T5	-13.4	-18.0	-16.7	-13.5
TU	-15.9	-15.6	-15.1	-16.3

Test 43: Dow EG 106, Fluid Only, Tunnel OAT -15.0°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-13.5	-16.4	N/A	-14.2
T5	-13.0	-16.7	N/A	-13.2
TU	-14.7	-15.0	N/A	-15.7

Test 44: Dow EG 106, IP-/SN, Tunnel OAT -13.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-13.4	-17.2	-16.9	-14.9
T5	-12.8	-16.4	-15.7	-13.7
TU	-14.2	-14.0	-13.7	-16.0

Test 45: Dow EG 106, IP-/SN-, Tunnel OAT -12.9°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-14.0	-17.1	-17.0	-13.6
T5	-13.2	-15.7	-15.6	-12.3
TU	-13.0	-14.3	-14.5	-14.8

Test 46: Clariant MP IV Launch, IP-/SN-, Tunnel OAT -13.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-13.2	-15.2	-13.7	-14.5
T5	-12.5	-15.5	-13.1	-13.6
TU	-13.8	-13.4	-13.1	-15.6

Test 47: Clariant MP IV Launch, IP-/SN, Tunnel OAT -13.3°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-13.0	-16.4	-15.9	-13.5
T5	-11.7	-16.4	-14.4	-12.4
TU	-14.4	-14.2	-14.3	-15.0

Test 51: Dow EG 106, IP-, Tunnel OAT -11.1°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-7.6	-12.2	-14.7	-13.1
T5	-8.3	-12.1	-13.2	-12.5
TU	-8.1	-8.5	-10.9	-13.6

Test 52: Dow EG 106, Fluid Only, Tunnel OAT -13.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-10.7	-12.9	N/A	-11.5
T5	-9.9	-12.5	N/A	-11.0
TU	-12.3	-12.5	N/A	-12.3

Test 53: Kilfrost ABC-S Plus, IP-, Tunnel OAT -12.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-9.9	-13.1	-13.1	-10.2
T5	-9.4	-13.1	-12.8	-9.3
TU	-11.7	-12.0	-12.5	-12.1

Test 54: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -12.1°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-9.4	-14.1	N/A	-9.8
T5	-8.6	-14.0	N/A	-9.0
TU	-11.7	-11.8	N/A	-11.3

Test 56: Dow FlightGuard AD-49, IP-/SN-, Tunnel OAT -9.6°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.5	-10.1	N/A	-9.0
T5	-7.5	-10.0	N/A	-8.1
TU	-9.5	-9.4	N/A	-10.4

<table>
<tr><th colspan="5">Test 57: Octagon Max Flight 04, Fluid Only, Tunnel OAT -9.9°C</th></tr>
<tr><th colspan="5">WING TEMPERATURE (°C)</th></tr>
<tr><th>Wing Position</th><th>BEFORE FLUID APPLICATION</th><th>AFTER FLUID APPLICATION</th><th>AFTER PRECIP APPLICATION</th><th>AFTER TAKEOFF RUN</th></tr>
<tr><td>T2</td><td>-8.5</td><td>-12.1</td><td>N/A</td><td>-9.0</td></tr>
<tr><td>T5</td><td>-8.4</td><td>-11.7</td><td>N/A</td><td>-9.7</td></tr>
<tr><td>TU</td><td>-9.2</td><td>-9.3</td><td>N/A</td><td>-10.7</td></tr>
</table>

<table>
<tr><th colspan="5">Test 58: Octagon Max Flight 04, IP-/SN-, Tunnel OAT -11.2°C</th></tr>
<tr><th colspan="5">WING TEMPERATURE (°C)</th></tr>
<tr><td>Wing Position</td><td>BEFORE FLUID APPLICATION</td><td>AFTER FLUID APPLICATION</td><td>AFTER PRECIP APPLICATION</td><td>AFTER TAKEOFF RUN</td></tr>
<tr><td>T2</td><td>-8.7</td><td>-12.0</td><td>-11.6</td><td>-7.5</td></tr>
<tr><td>T5</td><td>-7.7</td><td>-12.2</td><td>-11.5</td><td>-6.7</td></tr>
<tr><td>TU</td><td>-9.7</td><td>-9.6</td><td>-9.6</td><td>-9.3</td></tr>
</table>

<table>
<tr><th colspan="5">Test 59: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.9°C</th></tr>
<tr><th colspan="5">WING TEMPERATURE (°C)</th></tr>
<tr><td>Wing Position</td><td>BEFORE FLUID APPLICATION</td><td>AFTER FLUID APPLICATION</td><td>AFTER PRECIP APPLICATION</td><td>AFTER TAKEOFF RUN</td></tr>
<tr><td>T2</td><td>-7.9</td><td>-11.3</td><td>-13.6</td><td>-8.0</td></tr>
<tr><td>T5</td><td>-7.4</td><td>-11.6</td><td>-13.5</td><td>-7.2</td></tr>
<tr><td>TU</td><td>-9.5</td><td>-10.0</td><td>-10.4</td><td>-10.5</td></tr>
</table>

<table>
<tr><th colspan="5">Test 59A: Octagon Max Flight 04, IP Mod, Tunnel OAT -9.4°C</th></tr>
<tr><th colspan="5">WING TEMPERATURE (°C)</th></tr>
<tr><td>Wing Position</td><td>BEFORE FLUID APPLICATION</td><td>AFTER FLUID APPLICATION</td><td>AFTER PRECIP APPLICATION</td><td>AFTER TAKEOFF RUN</td></tr>
<tr><td>T2</td><td>-8.0</td><td>-11.9</td><td>-13.5</td><td>-10.1</td></tr>
<tr><td>T5</td><td>-7.1</td><td>-11.7</td><td>-13.3</td><td>-9.4</td></tr>
<tr><td>TU</td><td>-10.0</td><td>-9.9</td><td>-10.3</td><td>-10.6</td></tr>
</table>

<table>
<tr><th colspan="5">Test 63: Clariant MP IV Launch, Fluid Only, Tunnel OAT -4.5°C</th></tr>
<tr><th colspan="5">WING TEMPERATURE (°C)</th></tr>
<tr><td>Wing Position</td><td>BEFORE FLUID APPLICATION</td><td>AFTER FLUID APPLICATION</td><td>AFTER PRECIP APPLICATION</td><td>AFTER TAKEOFF RUN</td></tr>
<tr><td>T2</td><td>-2.5</td><td>-4.6</td><td>N/A</td><td>-2.9</td></tr>
<tr><td>T5</td><td>-1.6</td><td>-5.1</td><td>N/A</td><td>-2.2</td></tr>
<tr><td>TU</td><td>-3.2</td><td>-2.9</td><td>N/A</td><td>-3.6</td></tr>
</table>

Test 68: DOW FlightGuard AD-49, Fluid Only, Tunnel OAT -1.8°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	N/A	-1.2	N/A	-1.9
T5	N/A	-0.9	N/A	-0.8
TU	N/A	-0.8	N/A	-2.8

Test 69: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -3.6°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-0.4	-2.3	-10.4	-3.5
T5	0.1	-2.2	-9.2	-2.2
TU	-1.4	-1.3	-4.9	-4.3

Test 70: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -4.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-2.5	-3.0	-9.6	-2.8
T5	-1.9	-3.0	-9.2	-1.6
TU	-3.4	-3.3	-4.7	-4.2

Test 71: Octagon Max Flight 04, Fluid Only, Tunnel OAT -3.7°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-2.2	-2.4	N/A	-3.0
T5	-1.7	-1.7	N/A	-2.1
TU	-3.4	-2.9	N/A	-3.6

Test 72: Octagon Max Flight 04, IP Mod, Tunnel OAT -3.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-1.1	-2.8	-8.2	-3.0
T5	-0.5	-2.7	-8.2	-1.9
TU	-2.5	-2.4	-3.1	-4.2

Test 73: Octagon Max Flight 04, IP-/SN, Tunnel OAT -4.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-2.8	-3.7	N/A	-4.3
T5	-1.6	-3.3	N/A	-3.2
TU	-3.2	-3.0	N/A	-4.9

Test 74: Octagon Max Flight 04, IP-/SN-, Tunnel OAT -4.8°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-2.1	-3.6	-8.2	-4.1
T5	-1.0	-3.6	-7.6	-3.2
TU	-2.8	-2.6	-4.7	-5.4

Test 75: Octagon Max Flight 04, Fluid Only, Tunnel OAT -5.8°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-3.9	-4.5	N/A	N/A
T5	-3.3	-4.3	N/A	N/A
TU	-4.7	-3.7	N/A	N/A

Test 76: Octagon Max Flight 04, Fluid Only, Tunnel OAT -5.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	N/A	-3.2	N/A	-4.0
T5	N/A	-3.1	N/A	-3.2
TU	N/A	-4.0	N/A	-4.8

Test 78: Dow EG 106, IP-/SN-, Tunnel OAT -13.8°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-10.3	-9.7	-16.3	-12.2
T5	-9.8	-9.5	-14.4	-11.3
TU	-11.9	-11.6	-12.0	-13.4

Test 79: Dow EG 106, IP-/SN-, Tunnel OAT -15.1°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-12.3	-10.9	-17.2	-12.6
T5	-11.9	-11.0	-15.6	-11.5
TU	-13.7	-13.7	-14.3	-14.6

Test 80: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -15.1°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-12.7	-11.5	N/A	-11.8
T5	-11.6	-11.5	N/A	-10.7
TU	-14.2	-14.0	N/A	-14.4

Test 81: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -14.7°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-12.0	-12.1	N/A	-12.2
T5	-10.9	-11.8	N/A	-11.2
TU	-14.0	-13.4	N/A	-14.6

Test 82: Kilfrost ABC-S Plus, IP-/SN-, Tunnel OAT -16.0°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-12.5	-11.7	-14.3	-13.1
T5	-11.7	-11.5	-13.4	-11.7
TU	-14.6	-13.8	-13.7	-15.2

Test 83: Kilfrost ABC-S Plus, IP-/SN, Tunnel OAT -15.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-12.8	-12.4	-10.0	-14.4
T5	-11.6	-12.4	-13.4	-13.4
TU	-15.1	-14.9	-16.5	-16.6

Test 84:Clariant MP IV Launch, IP-/SN-, Tunnel OAT -17.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-13.2	-12.9	-15.5	-14.7
T5	-12.2	-12.6	-14.5	-13.5
TU	-16.1	-16.0	-15.3	-17.3

Test 85: Clariant MP IV Launch, IP-/SN, Tunnel OAT -17.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-14.0	-13.0	-15.8	N/A
T5	-12.9	-12.9	-14.3	N/A
TU	-16.4	-16.0	-15.9	N/A

Test 92: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -13.6°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-10.5	-11.8	-14.1	-11.2
T5	-10.9	-11.4	-13.4	-9.6
TU	-12.5	-12.4	-11.7	-13.3

Test 92A: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -14.2°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-11.0	-12.9	-14.6	-10.7
T5	-9.1	-13.1	-14.4	-9.7
TU	-12.4	-12.6	-13.0	-13.4

Test 93: Kilfrost ABC-S Plus, IP, Tunnel OAT -12.0°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-11.9	-13.5	-13.5	-11.7
T5	-10.7	-13.4	-12.6	-10.4
TU	-13.0	-13.0	-12.2	-13.6

Test 97: Clariant MP IV Launch, Fluid Only, Tunnel OAT -11.9°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.3	-10.5	N/A	-9.6
T5	-7.8	-10.4	N/A	-8.8
TU	-10.4	-10.4	N/A	-10.4

Test 102: Dow FlightGuard AD-49, IP-/ZR-, Tunnel OAT -6.2°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.1	-8.7	-7.3	-6.7
T5	-7.3	-8.9	-6.3	-5.7
TU	-8.1	-8.0	-7.6	-8.6

Test 103: Octagon Max Flight 04, IP-/ZR-, Tunnel OAT -6.5°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.2	-8.3	-7.6	-8.6
T5	-8.0	-8.3	-7.0	-7.6
TU	-9.3	-8.9	-7.8	-9.6

Test 104: Clariant Mp IV Launch, IP-/SN, Tunnel OAT -7.5°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-8.4	-6.8	-10.3	-5.8
T5	-7.5	-6.7	-8.4	-5.0
TU	-9.0	-8.6	-7.5	-8.6

Test 105: Kilfrost ABC-S Plus, IP-/SN, Tunnel OAT -9.3°C

WING TEMPERATURE (°C)

Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-7.5	-8.4	-11.0	-6.9
T5	-7.0	-8.7	-9.7	-6.0
TU	-9.1	-9.1	-8.1	-9.5

Test 106: Dow FlightGuard AD-49, IP-/SN, Tunnel OAT -9.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-6.8	-7.9	-10.4	-8.6
T5	-6.1	-7.7	-9.0	-7.6
TU	-8.5	-8.8	-8.1	-10.2

Test 115: Dow EG 106, Ip-/R Mod, Tunnel OAT 1.4°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	+3.5	+4.3	+0.7	N/A
T5	+4.0	+4.4	+0.7	N/A
TU	+2.7	+3.5	+3.0	N/A

Test 116: Kilfrost ABC-S Plus, IP-/R Mod, Tunnel OAT 3.0°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	+3.4	+2.9	+1.7	+3.5
T5	+4.0	+2.9	+2.7	+4.5
TU	+3.2	+3.4	+4.2	+3.0

Test 117: Clariant MP IV Launch, IP-/R Mod, Tunnel OAT 2.3°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	+4.6	+3.7	-0.9	+2.9
T5	+5.3	+4.0	-1.2	+3.6
TU	+4.0	+4.0	+2.8	+2.5

Test 121: Octagon Max Flight 04, IP-, Tunnel OAT -12.9°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-13.6	-11.3	-14.7	-12.4
T5	-13.0	-10.7	-14.2	-12.0
TU	-13.4	-13.1	-13.5	-13.4

Test 128: Dow FlightGuard AD-49, IP-/ZR, Tunnel OAT -3.2°				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-6.9	-7.6	-4.6	-4.6
T5	-6.2	-7.3	-4.2	-3.9
TU	-6.4	-6.4	-2.7	-5.4

Test 129: Dow FlightGuard AD-49, IP-, Tunnel OAT -3.6°				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-4.8	-6.7	-6.4	-3.7
T5	-4.4	-6.1	-6.4	-3.2
TU	-5.3	-5.2	-2.7	-4.2

Test 131: Clariant MP IV Launch, IP Mod, Tunnel OAT -4.5°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-3.6	-4.1	-10.3	-4.5
T5	-3.3	-4.2	-10.3	-3.8
TU	-4.0	-4.0	-5.0	-4.9

Test 132: Octagon Max Flight 04, IP Mod, Tunnel OAT -5.9°C				
WING TEMPERATURE (°C)				
Wing Position	BEFORE FLUID APPLICATION	AFTER FLUID APPLICATION	AFTER PRECIP APPLICATION	AFTER TAKEOFF RUN
T2	-2.9	-3.9	-10.3	-5.6
T5	-2.8	-3.7	-10.0	-4.6
TU	-3.4	-3.5	-5.3	-6.0

APPENDIX I

BRIX DATA

Test 5A: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -10.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.25	N/A	38.25
8	N/A	N/A	38.25
Flap	N/A	N/A	38.25

Test 6: Dow FlightGuard AD-49, IP-, Tunnel OAT -10.9°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.25	35.25	26.75
8	N/A	31.50	25.00
Flap	N/A	32.00	29.00

Test 7: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -10.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.25	30.50	29.50
8	N/A	31.50	31.00
Flap	N/A	32.00	33.00

Test 8: Dow FlightGuard AD-49, IP-, Tunnel OAT -8.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.75	21.00	29.50
8	N/A	33.50	31.00
Flap	N/A	22.50	33.00

Test 9: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -6.7°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.00	N/A	40.25
8	N/A	N/A	39.50
Flap	N/A	N/A	39.00

Test 10: Octagon Max Flight 04, IP Mod, Tunnel OAT -6.8°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.25	25.00	N/A
8	N/A	21.75	N/A
Flap	N/A	17.75	N/A

Test 12: Octagon Max Flight 04, Fluid Only, Tunnel OAT -14.2°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.50	N/A	37.50
8	N/A	N/A	38.00
Flap	N/A	N/A	38.00

Test 13: Octagon Max Flight 04, IP Mod, Tunnel OAT -12.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.75	32.25	34.75
8	N/A	31.00	34.25
Flap	N/A	29.75	35.00

Test 14: Octagon Max Flight 04, IP Mod, Tunnel OAT -12.3°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.00	36.00	35.25
8	N/A	38.00	34.25
Flap	N/A	31.50	33.00

Test 15: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.8°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.25	30.25	35.75
8	N/A	39.75	34.50
Flap	N/A	37.25	35.00

Test 15A: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.75	31.25	N/A
8	N/A	37.00	N/A
Flap	N/A	27.00	N/A

Test 15B: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.8°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	32.50	35.50	37.25
8	N/A	32.50	36.50
Flap	N/A	30.75	35.25

Test 20: ABC-S Plus, IP-, Tunnel OAT -17.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.75	29.00	29.25
8	N/A	17.50	31.50
Flap	N/A	16.50	31.50

Test 21: ABC-S Plus, Fluid Only, Tunnel OAT -18.2°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	N/A	38.00
8	N/A	N/A	38.25
Flap	N/A	N/A	37.50

Test 22: ABC-S Plus, IP-, Tunnel OAT -19.3°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.75	29.50	31.25
8	N/A	29.00	33.25
Flap	N/A	29.75	33.50

Test 23: Clariant MP IV Launch, IP-, Tunnel OAT -21.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.00	28.50	32.25
8	N/A	29.25	33.50
Flap	N/A	28.00	35.50

Test 24: Clariant MP IV Launch, IP-, Tunnel OAT -22.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	39.50	32.25
8	N/A	34.00	34.00
Flap	N/A	27.50	35.25

Test 25: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -22.3°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.00	36.50	34.25
8	N/A	27.50	34.50
Flap	N/A	21.50	34.00

Test 26: Dow EG 106, IP Mod, Tunnel OAT -21.0°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	32.50	33.25	33.00
8	N/A	32.00	33.00
Flap	N/A	24.50	33.25

Test 27: Dow EG 106, IP-, Tunnel OAT -22.6°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	32.50	29.00	31.50
8	N/A	28.75	32.25
Flap	N/A	30.00	32.75

Test 28: Clariant MP IV Launch, IP Mod, Tunnel OAT -24.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	36.00	36.25
8	N/A	32.75	35.25
Flap	N/A	31.00	36.75

Test 29: Clariant MP IV Launch, Fluid Only, Tunnel OAT -23.9°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	N/A	38.75
8	N/A	N/A	38.25
Flap	N/A	N/A	38.50

Test 30: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -23.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.50	N/A	38.50
8	N/A	N/A	37.50
Flap	N/A	N/A	38.25

Test 31: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -22.8°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	34.50	35.50
8	N/A	20.00	34.75
Flap	N/A	26.00	32.50

Test 34: Dow EG 106, Fluid Only, Tunnel OAT -23.3°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	34.25	N/A	34.25
8	N/A	N/A	35.00
Flap	N/A	N/A	34.75

<table>
<tr><th colspan="4">Test 35: Dow FlightGuard AD-49, IP-, Tunnel OAT -23.2°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>37.50</td><td>25.25</td><td>35.00</td></tr>
<tr><td>8</td><td>N/A</td><td>32.50</td><td>34.50</td></tr>
<tr><td>Flap</td><td>N/A</td><td>31.00</td><td>36.25</td></tr>
</table>

<table>
<tr><th colspan="4">Test 36: Clariant MP III 2031, Fluid Only, Tunnel OAT -24.5°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>37.75</td><td>N/A</td><td>38.50</td></tr>
<tr><td>8</td><td>N/A</td><td>N/A</td><td>34.00</td></tr>
<tr><td>Flap</td><td>N/A</td><td>N/A</td><td>37.50</td></tr>
</table>

<table>
<tr><th colspan="4">Test 37: Octagon Max Flight 04, IP Mod, Tunnel OAT -24.5°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>38.00</td><td>34.50</td><td>36.75</td></tr>
<tr><td>8</td><td>N/A</td><td>35.00</td><td>35.00</td></tr>
<tr><td>Flap</td><td>N/A</td><td>34.00</td><td>35.50</td></tr>
</table>

<table>
<tr><th colspan="4">Test 38: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -24.2°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>38.00</td><td>37.25</td><td>34.75</td></tr>
<tr><td>8</td><td>N/A</td><td>35.50</td><td>34.25</td></tr>
<tr><td>Flap</td><td>N/A</td><td>35.00</td><td>34.50</td></tr>
</table>

<table>
<tr><th colspan="4">Test 40: Octagon Max Flight 04, IP-, Tunnel OAT -15.2°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>37.25</td><td>36.00</td><td>25.50</td></tr>
<tr><td>8</td><td>N/A</td><td>N/A</td><td>32.50</td></tr>
<tr><td>Flap</td><td>N/A</td><td>N/A</td><td>35.00</td></tr>
</table>

Test 41: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -16.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.25	36.50	N/A
8	N/A	37.25	N/A
Flap	N/A	38.50	N/A

Test 41A: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -15.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.25	30.00	37.00
8	N/A	26.25	33.00
Flap	N/A	21.50	34.25

Test 43: Dow EG 106, Fluid Only, Tunnel OAT -°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	33.75	N/A	34.25
8	N/A	N/A	34.25
Flap	N/A	N/A	34.25

Test 44: Dow EG 106, IP-/SN, Tunnel OAT -13.2°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	34.50	32.50	29.00
8	N/A	29.50	39.00
Flap	N/A	29.75	32.50

Test 45: Dow EG 106, IP-/SN-, Tunnel OAT -12.9°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	32.50	31.00	31.50
8	N/A	29.50	32.50
Flap	N/A	25.25	33.50

Test 46: Clariant MP IV Launch, IP-/SN-, Tunnel OAT -13.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	37.00	36.25
8	N/A	36.75	36.25
Flap	N/A	36.50	34.50

Test 47: Clariant MP IV Launch, IP-/SN, Tunnel OAT -13.3°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	36.50	36.00
8	N/A	34.50	35.50
Flap	N/A	29.75	32.25

Test 51: Dow EG 106, IP-, Tunnel OAT -11.1°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	32.50	27.25	26.25
8	N/A	29.00	29.75
Flap	N/A	19.25	27.25

Test 52: Dow EG 106, Fluid Only, Tunnel OAT -13.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	33.50	N/A	33.50
8	N/A	N/A	33.50
Flap	N/A	N/A	33.25

Test 53: Kilfrost ABC-S Plus, IP-, Tunnel OAT -12.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	34.50	30.25
8	N/A	32.50	28.25
Flap	N/A	34.00	29.25

<table>
<tr><th colspan="4">Test 54: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -12.1°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>38.25</td><td>N/A</td><td>36.75</td></tr>
<tr><td>8</td><td>N/A</td><td>N/A</td><td>37.00</td></tr>
<tr><td>Flap</td><td>N/A</td><td>N/A</td><td>37.00</td></tr>
</table>

<table>
<tr><th colspan="4">Test 55: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -11.4°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>38.50</td><td>N/A</td><td>38.50</td></tr>
<tr><td>8</td><td>N/A</td><td>N/A</td><td>38.00</td></tr>
<tr><td>Flap</td><td>N/A</td><td>N/A</td><td>37.50</td></tr>
</table>

<table>
<tr><th colspan="4">Test 56: Dow FlightGuard AD-49, IP-/SN-, Tunnel OAT -9.6°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>38.25</td><td>26.50</td><td>30.75</td></tr>
<tr><td>8</td><td>N/A</td><td>N/A</td><td>26.00</td></tr>
<tr><td>Flap</td><td>N/A</td><td>N/A</td><td>26.00</td></tr>
</table>

<table>
<tr><th colspan="4">Test 57: Octagon Max Flight 04, Fluid Only, Tunnel OAT -9.9°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>37.25</td><td>N/A</td><td>38.25</td></tr>
<tr><td>8</td><td>N/A</td><td>N/A</td><td>37.50</td></tr>
<tr><td>Flap</td><td>N/A</td><td>N/A</td><td>37.25</td></tr>
</table>

<table>
<tr><th colspan="4">Test 58: Octagon Max Flight 04, IP-/SN-, Tunnel OAT -11.2°C</th></tr>
<tr><th colspan="4">FLUID BRIX (°)</th></tr>
<tr><th>Wing Position</th><th>After Fluid Application</th><th>After Precip. Application</th><th>After Takeoff Run</th></tr>
<tr><td>2</td><td>38.00</td><td>31.50</td><td>25.50</td></tr>
<tr><td>8</td><td>N/A</td><td>29.00</td><td>35.50</td></tr>
<tr><td>Flap</td><td>N/A</td><td>29.75</td><td>33.75</td></tr>
</table>

Test 59: Octagon Max Flight 04, IP Mod, Tunnel OAT -10.9°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.50	27.25	33.75
8	N/A	27.50	32.50
Flap	N/A	25.00	32.50

Test 59A: Octagon Max Flight 04, IP Mod, Tunnel OAT -9.4°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.00	32.75	34.00
8	N/A	30.00	32.50
Flap	N/A	29.75	32.75

Test 63: Clariant MP IV Launch, Fluid Only, Tunnel OAT -4.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.75	N/A	37.00
8	N/A	N/A	37.00
Flap	N/A	N/A	36.00

Test 68: Dow FlightGuard AD-49, Fluid Only, Tunnel OAT -1.8°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.25	N/A	38.50
8	N/A	N/A	39.25
Flap	N/A	N/A	39.50

Test 69: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -3.6°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	13.50	28.50
8	N/A	17.00	27.00
Flap	N/A	10.00	27.00

Test 70: Dow FlightGuard AD-49, IP Mod, Tunnel OAT -4.2°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.75	19.50	28.75
8	N/A	15.00	28.25
Flap	N/A	15.00	33.50

Test 71: Octagpm Max Flight 04, Fluid Only, Tunnel OAT -3.7°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	N/A	39.50
8	N/A	N/A	38.75
Flap	N/A	N/A	39.00

Test 72: Octagon Max Flight 0, IP Mod, Tunnel OAT -3.2°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.75	25.50	35.00
8	N/A	19.00	33.75
Flap	N/A	17.00	34.00

Test 73: Octagon Max Flight 04, IP-/SN, Tunnel OAT -4.2°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.75	32.50	34.50
8	N/A	29.50	34.50
Flap	N/A	23.00	34.50

Test 74: Octagon Max Flight 04, IP-/SN, Tunnel OAT -4.8°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.75	32.00	35.00
8	N/A	19.75	35.25
Flap	N/A	19.50	30.50

Test 75: Octagon Max Fligh 04, Fluid Only, Tunnel OAT -5.8°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	36.75	N/A	N/A
8	N/A	N/A	N/A
Flap	N/A	N/A	N/A

Test 76: Octagon Max Flight 04, Fluid Only, Tunnel OAT -5.5°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	36.75	N/A	38.50
8	N/A	N/A	38.50
Flap	N/A	N/A	37.50

Test 78: Dow EG 106, IP-/SN, Tunnel OAT -13.8°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	34.25	23.75	35.50
8	N/A	19.00	33.50
Flap	N/A	20.25	33.75

Test 79: Dow EG 106, IP-/SN, Tunnel OAT -15.1°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	34.75	32.00	34.25
8	N/A	26.25	31.00
Flap	N/A	15.50	31.25

Test 80: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -15.1°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	37.75	N/A	41.00
8	N/A	N/A	39.25
Flap	N/A	N/A	39.00

Test 81: Kilfrost ABC-S Plus, Fluid Only, Tunnel OAT -14.7°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.75	N/A	39.00
8	N/A	N/A	41.50
Flap	N/A	N/A	38.00

Test 82: Kilfrost ABC-S Plus, IP-/SN, Tunnel OAT -16.0°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.75	32.50	32.75
8	N/A	33.00	37.25
Flap	N/A	27.75	31.50

Test 83: Kilfrost ABC-S Plus IP-/SN, Tunnel OAT -15.2°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.25	20.50	34.00
8	N/A	28.00	34.75
Flap	N/A	28.25	33.50

Test 84: Clariant MP IV Launch, IP-/SN-, Tunnel OAT -17.4°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.75	24.50	33.75
8	N/A	27.50	30.25
Flap	N/A	23.00	35.25

Test 85: Clariant MP IV Launch, IP-/SN, Tunnel OAT -17.4°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.25	33.75	N/A
8	N/A	33.25	N/A
Flap	N/A	30.00	N/A

Test 92: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -13.6°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.50	33.50	34.00
8	N/A	28.75	33.50
Flap	N/A	28.75	32.25

Test 92A: Kilfrost ABC-S Plus, IP Mod, Tunnel OAT -14.2°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.50	35.25	33.25
8	N/A	33.25	34.00
Flap	N/A	17.50	32.25

Test 93: Kilfrost ABC-S Plus, IP, Tunnel OAT 12.0°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	37.75	28.25	31.00
8	N/A	24.00	29.75
Flap	N/A	22.00	30.25

Test 97: Clariant Mp IV Launch, Fluid Only, Tunnel OAT -11.9°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.25	N/A	N/A
8	N/A	N/A	38.00
Flap	N/A	N/A	38.00

Test 102: Dow FlightGuard AD-49, IP-/ZR-, Tunnel OAT -6.2°C

FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	38.00	33.25	33.50
8	N/A	27.50	35.50
Flap	N/A	27.75	34.50

Test 103: Octagon Max Flight 04, IP-/ZR-, Tunnel OAT -6.5°C

FLUID BRIX (°)

Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	38.50	33.25	27.50
8	N/A	29.75	34.25
Flap	N/A	26.00	33.00

Test 104: Clariant MP IV Launch, IP-/SN, Tunnel OAT -7.5°C

FLUID BRIX (°)

Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	36.50	35.50	34.50
8	N/A	24.00	36.50
Flap	N/A	N/A	N/A

Test 105: Kilfrost ABC-S Plus, IP-/SN, Tunnel OAT -9.3°C

FLUID BRIX (°)

Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	38.25	37.00	33.75
8	N/A	36.00	36.50
Flap	N/A	28.50	32.50

Test 106: Dow FlightGuard AD-49, IP-/SN, Tunnel OAT 9.4°C

FLUID BRIX (°)

Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	38.50	33.50	35.25
8	N/A	33.00	35.00
Flap	N/A	20.50	34.50

Test 115: Dow EG 106, Ip-/R Mod, Tunnel OAT 1.4°c

FLUID BRIX (°)

Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	33.25	9.50	29.75
8	N/A	10.25	25.50
Flap	N/A	3.00	29.50

Test 116: Kilfrost ABC-S Plus, IP-/R Mod, Tunnel OAT 3.0°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	36.75	14.00	26.75
8	N/A	15.25	25.25
Flap	N/A	5.50	21.50

Test 117: Clariant MP IV Launch, IP-/R-, Tunnel OAT 2.3°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	36.75	15.50	27.50
8	N/A	15.50	28.25
Flap	N/A	8.00	22.25

Test 121: Octagon Max Flight 04, IP-, Tunnel OAT -12.9°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	37.00	24.00	36.00
8	N/A	28.75	35.00
Flap	N/A	26.00	35.00

Test 128: Dow FlightGuard AD-49. IP-/ZR-, Tunnel OAT -3.2°C			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip. Application	After Takeoff Run
2	37.25	22.00	29.50
8	N/A	14.00	31.50
Flap	N/A	12.50	28.50

Test 129: Dow FlightGuard AD-49, IP-, Tunnel OAT -3.6°			
FLUID BRIX (°)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	21.25	31.25
8	N/A	17.25	30.25
flap	N/A	13.25	33.00

Test 131: Clarian MP IV Launch, IP Mod, Tunnel Oat -4.5°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.25	18.50	24.25
8	N/A	18.50	25.75
Flap	N/A	7.50	23.25

Test 132: Octagon Max Flight 04, IP Mod, Tunnel OAT -5.9°C			
FLUID BRIX (°)			
Wing Position	**After Fluid Application**	**After Precip. Application**	**After Takeoff Run**
2	36.75	26.50	29.00
8	N/A	16.00	31.25
Flap	N/A	16.50	30.50

This page intentionally left blank.