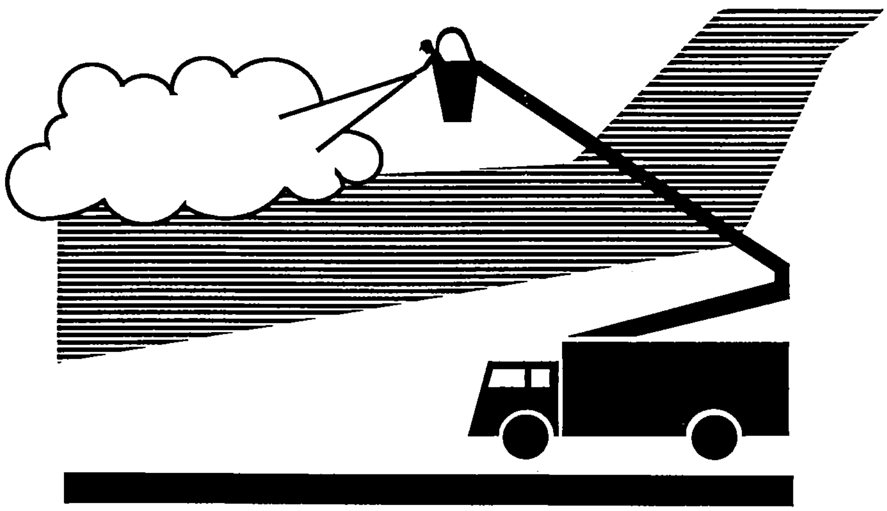
TP 12898E

Feasibility of Enhancing Visibility of Contamination on a Wing

Phase 1



Prepared for

Transportation Development Centre
on behalf of
Civil Aviation

Safety and Security
Transport Canada

by

APS AVIATION INC.

October 1996

Final

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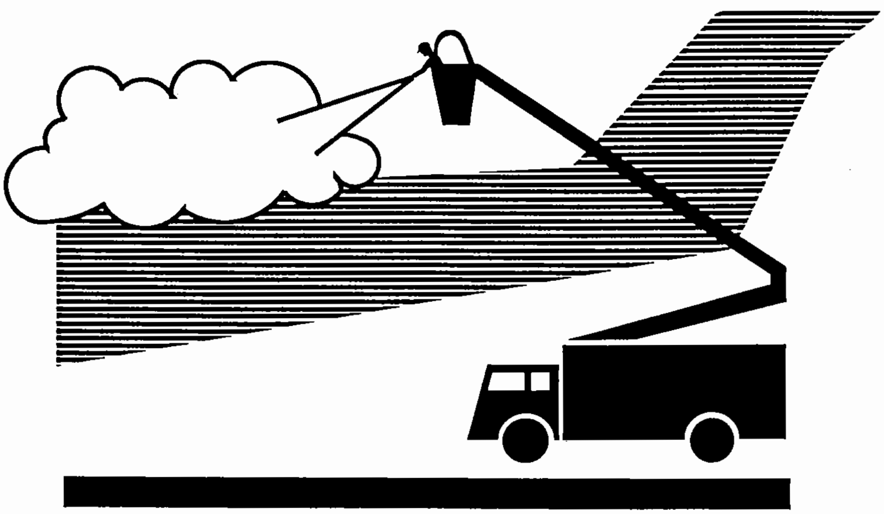

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October 1996

Final

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Un sommaire français se trouve avant la table des matières.

PREFACE

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. has undertaken a research program to further advance aircraft ground deicing/anti-icing technology. Specific objectives of the overall program were:

- To complete the substantiation of the existing Type I and Type II fluid SAE/ISO holdover time tables by conducting cold-soak tests and very low temperature tests;
- To determine the holdover time performance of the proposed Type IV fluids over the range of characteristic conditions and develop a generic Type IV holdover time table;
- To establish the precipitation, wind and temperature values that delimit the holdover times given in the tables;
- To validate that test data on Type IV fluid performance on flat plates used to establish the SAE holdover time tables is representative of Type IV fluid performance on service aircraft under conditions of natural freezing precipitation;
- To document the characteristics of frost deposits occurring naturally during very cold temperatures;
- To validate that fluid performance on cold-soaked boxes used for establishing holdover times is representative of fluid performance on a cold-soaked wing;
- To identify potential solutions to enhance the visibility of failed wing surfaces from inside the aircraft; and
- To identify optimum wing locations to be used as representative surfaces by measuring the wet film thickness profiles of fluid application on aircraft wing surfaces.

The research activities of the program conducted on behalf of Transport Canada during the 1995/96 winter season are documented in six separate reports. The titles of these reports are as follows:

- TP 12896E Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1995/96 Winter;
- TP 12897E Evaluation of Frost Formations at Very Cold Temperatures;
- TP 12898E Feasibility of Enhancing Visibility of Contamination on a Wing, Phase 1;
- TP 12899E Validation of Methodology for Simulating a Cold-Soaked Wing;
- TP 12900E Evaluation of Fluid Thickness to Locate Representative Surfaces; and
- TP 12901E Aircraft Full-Scale Test Program for the 1995/96 Winter.

This report, TP 12898E, addresses the objective of examining the feasibility of enhancing visibility of contamination on a wing.

Funding for the research has come from the Civil Aviation Group, Transport Canada, with support from the Federal Aviation Administration. This program of research could not have been accomplished without the assistance of many organizations. APS would therefore like to thank the Transportation Development Centre, the Federal Aviation Administration, the National Research Council, Atmospheric Environment Services, Transport Canada and the fluid manufacturers for their contribution and assistance in the project. Special thanks are extended to Air Canada for provision of personnel and facilities and for their cooperation on the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data leading to the preparation of this document.

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Research reports produced on behalf of Transport Canada for testing during previous winters are available from TDC. Six reports (including this report) were produced as part of this winter's research program. The subject matter of these reports is provided in the preface. Funding for this project was provided by the Civil Aviation Group, Transport Canada and, in part, by the FAA.

16. Abstract

Identification of deicing and anti-icing fluid failure by visual observation from inside the aircraft cabin can be difficult. Inadequate lighting, wet and glossy surfaces experienced during freezing rain or freezing drizzle, distance from the surface under inspection, the viewing angle dictated by the geometry of the wing and fuselage design, stray light reflections on the viewing window, contaminated windows and the uncertain nature of the appearance of fluid failure, all contribute to the problem. This is of concern because the pilot view of wing surfaces for signs of failure is fundamental to safe winter operations.

Advances in the development of ice detection sensors have not yet reached the stage where sensors can eliminate the need to visually identify fluid failure.

The objective of this study was to examine the problem of limited visibility of fluid failures, to identify methods of enhancing visibility, and to propose an approach to evaluate solutions believed to offer potential for success.

The study recommended that:

- flight crews be provided with photo documentation illustrating the appearance of typical fluid failures;
- an experimental program be developed to evaluate potential solutions to enhance visibility; and
- an activity be conducted to define, for principal aircraft in airline service, the area of the wing that is visible to the flight crew.

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Les rapports sur les recherches effectuées au cours des hivers précédents pour le compte de Transports Canada sont disponibles au CDT. Six rapports, dont le présent, ont été produits dans le cadre des recherches menées cet hiver. L'objet de ces recherches figure dans l'avant-propos. Les recherches ont été financées principalement par le Groupe Aviation civile, Transports Canada et en partie par la FAA.

16. Résumé

Il peut être difficile de se rendre compte visuellement de la perte d'efficacité d'un liquide dégivrant/antigivrant depuis l'intérieur du poste de pilotage d'un aéronef. Le mauvais éclairage, des surfaces qui deviennent mouillées ou brillantes sous la pluie verglaçante ou la bruine verglaçante, la distance qui sépare l'observateur de la surface observée, l'angle de vision imposé par la géométrie de l'aile et du fuselage, les reflets de lumière parasite dans la vitre, un pare-brise contaminé et le caractère incertain des effets visibles de la perte d'efficacité des liquides antigivrants sont autant de facteurs qui contribuent au problème. Or, la capacité du pilote d'observer la voilure de l'aéronef pour y déceler les signes de la perte d'efficacité des liquides antigivrants est une condition essentielle à la sûreté des opérations aériennes en conditions hivernales.

La R&D sur les capteurs de givre n'a pas atteint un stade d'avancement tel que les pilotes puissent s'abstenir de vérifier visuellement l'efficacité des liquides antigivrants.

Cette recherche avait pour objectif d'étudier le problème de la difficulté à percevoir visuellement la cessation d'efficacité des produits dégivrants/antigivrants, de cerner des solutions possibles et de proposer une méthode pour évaluer les plus prometteuses de ces solutions.

L'étude a débouché sur les recommandations suivantes :

- fournir aux équipages de conduite des photographies leur permettant de se familiariser avec les signes visuels caractéristiques de la cessation d'efficacité des produits dégivrants/antigivrants;
- élaborer un programme d'essais pour évaluer les moyens pouvant être pris pour améliorer la visibilité;
- déterminer, pour les principaux types d'aéronefs présentement en service, la zone de l'aile à portée de vue de l'équipage de conduite.

17. Mots clés Visibilité, caractérisation de la perte d'efficacité des liquides de dégivrage/antigivrage, contamination des liquides de dégivrage/antigivrage, perte d'efficacité des liquides de dégivrage/antigivrage	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

Full-scale aircraft deicing/anti-icing fluid tests were conducted during the 1994/95 winter season by APS to substantiate fluid holdover times. These tests led to a number of recommendations, one of which proposed research into methods to enhance the visibility and identification of fluid failures from inside the aircraft.

In actual pre-flight deicing operations, several factors combine to make the identification of fluid failure especially difficult. Shallow angle and low intensity illumination, wing/fuselage geometry, and wet or glossy surfaces observed during conditions of freezing rain or drizzle are some of the factors that generally hinder fluid failure identification. The difficulty is exacerbated by reduced visibility of critical surfaces when viewing is attempted from the aircraft interior.

The distance from the surface under inspection, the viewing angle dictated by the geometry of the wing/fuselage design, stray light reflections from the inner surface of the viewing window, contaminated windows, and the uncertain nature of the appearance of fluid failure, all contribute to the problem. This is of concern because the pilot view of wing surfaces for signs of failure is fundamental to safe winter operations.

Airlines and manufacturers have investigated various approaches to those problems, and individual solutions have been adopted by different operators. However, a common approach has not emerged, and a general solution has not been achieved.

Research and development dedicated to optimization of ice detection sensors have been conducted by several organizations and prototype systems are now in operation on a test basis. Use of sensors has not yet reached a state of development where implementation of sensors can eliminate the need to identify fluid failure by visual means.

This study constitutes the first phase (feasibility study) of a three-phase program. The objective was to examine the problem, to identify and explore various options that may potentially enhance visibility of failed wing surfaces from inside the cabin, and to propose an approach to evaluate solutions believed to offer a reasonable potential for success.

Subject to a decision to proceed, Phase Two of the program would consist of conducting a structured evaluation program to determine and document effectiveness of potential solutions. Phase Three would develop support material to communicate details of the recommended approaches, methodology of use, and guidance on interpretation of visual indications in actual operations.

Feasibility Study

A causal factor analysis was conducted to document the main contributors to the problem, and to examine, for each contributing factor, potential approaches that might diminish its detrimental influence on visibility.

A review of relevant industry literature was conducted to identify past efforts in this area.

Various airline operators were contacted to establish an understanding of attempted and currently employed solutions and of ongoing activities. In addition, the problem was explored with physical science departments at universities to identify interest in the subject and potential solutions.

Attention was given to solutions developed for other applications but potentially appropriate to this requirement. Search preference was given to commonplace solutions involving off-the-shelf materials such as tapes, decals and paints, and simple optical and/or mechanical devices.

Conclusions and Recommendations

The analysis indicated that there is reason to expect a degree of success in alleviating the problem. The study recommended that:

- Flight crews be provided with photo documentation and/or actual field training illustrating the appearance of typical failures for different fluids in various types of precipitation conditions.

- An experimental program be developed and conducted to evaluate potential solutions to enhance visibility.

- A distinct activity in the evaluation program be conducted to define, for principal aircraft in airline service, the area of the wing that is visible to the flight crew.

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SOMMAIRE

APS a réalisé, à l'hiver 1994-1995, des essais de liquides de dégivrage/antigivrage sur des ailes d'avions dans le but de valider les durées d'efficacité des liquides en question. Ces essais ont débouché sur un certain nombre de recommandations, dont l'une proposait d'étudier des méthodes pour améliorer la visibilité et la caractérisation de la perte d'efficacité des liquides de dégivrage/antigivrage depuis l'intérieur du poste de pilotage.

Lors du déglaçage avant le décollage d'un aéronef, divers facteurs se conjuguent pour rendre particulièrement difficile la perception de la perte d'efficacité des liquides de dégivrage/antigivrage. Le faible angle et la faible intensité de l'éclairement, la géométrie de l'aile et du fuselage, et les surfaces devenues mouillées ou brillantes sous la pluie verglaçante ou la bruine verglaçante sont quelques-uns des facteurs qui empêchent généralement de se rendre compte de la perte d'efficacité des liquides de dégivrage/antigivrage. Cette difficulté est accentuée par le fait que les zones critiques de l'aile sont malaisées à observer depuis l'intérieur du poste de pilotage.

La distance qui sépare l'observateur de la voilure, l'angle de vision imposé par la géométrie de l'aile et du fuselage, les reflets de lumière parasite sur la face intérieure de la vitre, un pare-brise contaminé et le caractère incertain des signes visuels associés à la perte d'efficacité des liquides de dégivrage/antigivrage contribuent également au problème. Or, la capacité du pilote d'observer la voilure de l'aéronef pour y déceler des signes de la perte d'efficacité des liquides antigivrants est une condition essentielle à la sûreté des opérations aériennes en conditions hivernales.

Les sociétés aériennes et les fabricants de liquides ont étudié ces problèmes sous divers angles, et quelques solutions ont été mises en oeuvre par différents transporteurs. Mais faute d'une démarche unifiée, aucune solution globale n'a encore été trouvée.

Plusieurs équipes de recherche ont entrepris des travaux de R&D visant l'optimisation des capteurs de givre et des prototypes sont maintenant à l'essai en service réel. Mais ces dispositifs n'ont pas encore atteint un stade de développement où leur adoption pourrait éliminer la nécessité de vérifier visuellement l'efficacité des liquides de dégivrage/antigivrage.

Cette étude constitue la phase I (étude de faisabilité) d'un programme de recherche qui comporte deux autres phases. La présente phase avait pour objet d'étudier le problème, de cerner diverses solutions pour améliorer la perception de la cessation d'efficacité des liquides dégivrants/antigivrants sur la voilure d'un aéronef depuis l'intérieur du poste de pilotage, et de proposer une méthode pour évaluer les plus prometteuses de ces solutions.

Moyennant qu'il soit décidé de poursuivre le programme, la phase II consistera en une évaluation structurée et documentée de l'efficacité des solutions possibles. Quant à la phase III, elle prévoit l'élaboration d'une trousse documentaire qui exposera les méthodes recommandées et leur mode opératoire, et fournira un guide d'interprétation des indices visuels observés en service opérationnel.

Étude de faisabilité

Une analyse des facteurs causaux a fait ressortir les principaux facteurs participant au problème et de cerner, pour chacun de ces facteurs, des méthodes susceptibles de neutraliser leur influence négative sur la visibilité.

Une recherche documentaire dans les bases d'information pertinentes de l'industrie a permis d'inventorier les travaux antérieurs réalisés dans le domaine.

Les chercheurs se sont adressés à diverses sociétés aériennes pour faire un état des lieux : solutions essayées et actuellement mises en oeuvre, pratiques en vigueur. Ils ont également communiqué avec des départements de sciences physiques d'universités pour s'enquérir de leur intérêt à l'égard de la question et des solutions envisageables.

Une attention particulière a été portée à des solutions élaborées en fonction d'autres applications mais pouvant répondre au problème étudié. La préférence a été accordée à des solutions simples, faisant appel à des produits d'emploi courant, comme du ruban, des décalcomanies et de la peinture, conjugués à des dispositifs optiques et/ou mécaniques simples.

Conclusions et recommandations

L'étude de faisabilité a révélé qu'il est raisonnable d'espérer atténuer le problème. Elle a débouché sur les recommandations suivantes :

- fournir aux équipages de conduite des photographies leur permettant de se familiariser avec les signes visuels caractéristiques de la cessation d'efficacité des divers produits dégivrants/antigivrants lors de différentes conditions météorologiques;

- élaborer un programme d'essais pour évaluer les moyens pouvant être pris pour améliorer la visibilité;

- déterminer, pour les principaux types d'aéronefs présentement en service, la zone de l'aile à portée de vue de l'équipage de conduite.

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SECTION NUMBER | PAGE NUMBER

LIST OF ACRONYMS

APS	APS Aviation Inc.
ISO	International Organization for Standardization
SAE	Society of Automotive Engineers
TDC	Transportation Development Centre

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1. INTRODUCTION

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation Inc. undertook a study to explore alternative means of enhancing visibility of failed wing surfaces from inside the cabin and from the flight deck, and to make recommendations for testing the most promising potential solutions for operational suitability.

Aircraft full-scale tests to substantiate fluid holdover times conducted in the winter season 1994/95[(1)] led to the recommendation that research be conducted to find ways to facilitate identification of fluid failures from inside the cabin. Appendix A presents a detailed statement of work for this project.

During the 1994/95 tests, observations made by test personnel working in close proximity to the wing were successful in identifying failures. Proximity to the surface experiencing fluid failure, and adequacy of lighting were the principal factors supporting ability to discern contamination.

In actual ground deicing operations, a myriad of factors contribute to the difficulties encountered in identification of fluid failures. Low intensity and/or shallow angle illumination of flight control surfaces, distance between observer and surface under inspection, and wet, glossy surfaces are three factors which reduce the ability to identify fluid failures, regardless of the point of observation. For the pilot situated inside the cabin some distance from these surfaces, with a viewing angle dictated by the aircraft geometry, and likely subject to stray light reflections from instruments and other interior sources of illumination, identification of contamination poses a particularly daunting challenge. This is of concern as the pilot view of wing surfaces for signs of failure is fundamental to safe winter operations.

Attention has been given to the problem and to the need to improve visibility of contamination on wing surfaces, and airlines and manufacturers have investigated various

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[(1)] Number in brackets denotes reference given at the end of the report.

approaches. Individual solutions have been adopted by different operators, however a common approach has not emerged.

In a related activity, research and development dedicated to ice detection sensors has been conducted by several different organizations. These developments generally address either of two possible approaches; being either a system installed on the aircraft providing information directly to the flight crew, or an external contamination scanning apparatus operated by ground staff. These activities have resulted in development of operating systems which are currently installed on a test basis at a few locations and on some aircraft. Use of sensors has not yet reached a state of development where their installation can eliminate the need to identify fluid failure by visual means.

This present study constitutes the first phase of a three phase program with the objective being: to examine the problem; to identify and explore various options that may potentially enhance visibility of failed wing surfaces from inside the cabin; and to propose an approach to evaluate solutions believed to offer reasonable potential for success.

Subject to a decision to proceed, Phase Two of the program would consist of conducting a structured evaluation program to determine and document effectiveness of potential solutions.

Phase Three deals with development of support material to communicate details of the recommended approaches, methodology of use, and guidance on interpretation of visual indications in actual operations.

2. APPROACH

The obstacles to clear and unobstructed visibility of the wing surface area of interest and the ability to identify indicators of fluid failure or contamination on the wing were examined. A causal factor analysis was conducted to assist in improved understanding of the problem and of the potential approaches and solutions that might be considered.

A review of pertinent industry literature was conducted to establish an appreciation of past activities. Reports and minutes of industry meetings were reviewed to identify specific past efforts in this area.

Different airline operators were contacted to establish an understanding of their perspective of the situation, of local solutions now in operational use, and of ongoing activities intended to enhance visibility.

The problem was explored with University physical science departments to identify interest in the subject, and to determine whether particular physical attributes of the problem, or physical disciplines may lead to potential solutions.

Attention was given to potential solutions that already exist in physical form, developed for other applications but potentially appropriate to this requirement. Search preference was given to commonplace solutions involving off the shelf materials such as adhesive tapes, decals and paints, and simple optical and/or mechanical devices.

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3. OBSTACLES TO CLEAR VISIBILITY OF FLUID FAILURE

In the process of searching for potential solutions, the problem was first examined to clearly identify the obstacles in current operations. Obstacles appear to be two-fold. The first obstacle is the nature of fluid failure and the variation in visible indicators of failure. The second obstacle is the impediment to clear and unobstructed visibility of those indicators, particularly with respect to viewing the lift surfaces from the aircraft interior.

3.1 The Nature of Fluid Failure

Visual identification of failed fluid is not always a straightforward task and can be challenging even under the controlled conditions associated with laboratory tests. Different conditions of precipitation produce different visual indications of failure.

Procedures for recognizing and calling fluid failure have been developed to provide standardization in the conduct of trials designed to determine fluid holdover times(2). In a snow condition, the specification calls for a visible accumulation of snow (not slush, but white snow) on the fluid when viewed from an appropriate angle relative to the wing/test surface. This indicates that the fluid can no longer absorb the precipitation.

Precipitation conditions involving freezing rain/drizzle, ice pellets or freezing fog, or a mixture of snow with freezing rain/drizzle or ice pellets, produce fluid failures that are more difficult to identify. Visual indications include: a "loss of gloss" (a dulling of the surface reflectivity); a change in dye colour from orange or green to grey or "greyish" appearance; and ice, crusty snow, or ice crystals which have bonded to the wing or test surface.

Transient failures can occur when the precipitate (i.e., large snow flakes, ice pellets) is not initially absorbed by the fluid and gives an appearance leading to a judgment of failure. After a period the contaminant is absorbed and disappears, in effect causing "unfailing" of the fluid. This can occur during natural freezing precipitation and results from a decrease in rate following a period of heavy precipitation or a rise in ambient temperature subsequent to fluid application.

Trials to substantiate fluid holdover times on full-scale aircraft in freezing rain[1] provided good photographic documentation of the visual nature of failure under these more difficult conditions (freezing drizzle, freezing rain). Photos 3.1 to 3.3 portray fluid prior to and subsequent to failure, as well as during the progress of failure. The glossy surface caused by the freezing rain makes it difficult to determine whether the surface is completely uncontaminated (Photo 3.1) or fully failed (Photo 3.3). However, once started, the progress of failure followed clearly defined areas on the wing (Photo 3.2). The resultant contrast in appearance between failed and unfailed fluid is very obvious, and provides a basis sufficient for correct call of fluid failure.

Separate trials were conducted in a laboratory setting to document the nature of fluid failure. These trials, conducted at the National Research Council (NRC) Climatic Engineering Facility in Ottawa, involved exposing a number of fluids, applied on flat plates, to various types and rates of precipitation. An important part of the documentation involved photographing the appearance of the various fluids as they progressed through different stages of failure.

In the process of conducting these trials in freezing rain and freezing drizzle conditions, it was observed that locating the camera (or the observer's eye) in the optimum position relative to the angle of incidence of the photographic lighting was crucial to successful capture of the image of failed fluid. The optimum position was located intuitively simply by moving one's head until the best view of the failure was found, and then positioning the camera accordingly.

A small movement of the angle of vision away from the ideal position resulted in a diminished view of the indications of failure.

Variation of the camera location relative to the source of illumination was seen to produce markedly different images of failure as illustrated in Photo sets 3.4 and 3.5. The photos in each of these sets were taken at the same time, but from different angles of lighting relative to the camera lens. The upper photo shows failed fluid appearing as finger-like dark shadows pointing downwards from the upper end of the plate. With different positioning of the camera, the same failed areas show as white crystalline finger-like formations. What is important in both representations is the contrast between the failed and unfailed fluid, regardless of its actual pattern of formation.

Under test conditions in which "loss of gloss" criteria applied, as in cases of wet precipitation, it was observed that best visibility of failure was achieved when the camera was pointed slightly off 180þ from the light source, with the source of light being somewhat higher (giving a higher angle of incidence) than the camera. Figure 3.1 provides a sketch illustrating this setup. Views of the same failure case by an observer or camera located near the source of light resulted in a quite different result.

3.2 Obstacles to Clear View of Wing Surface

3.2.1 Lighting

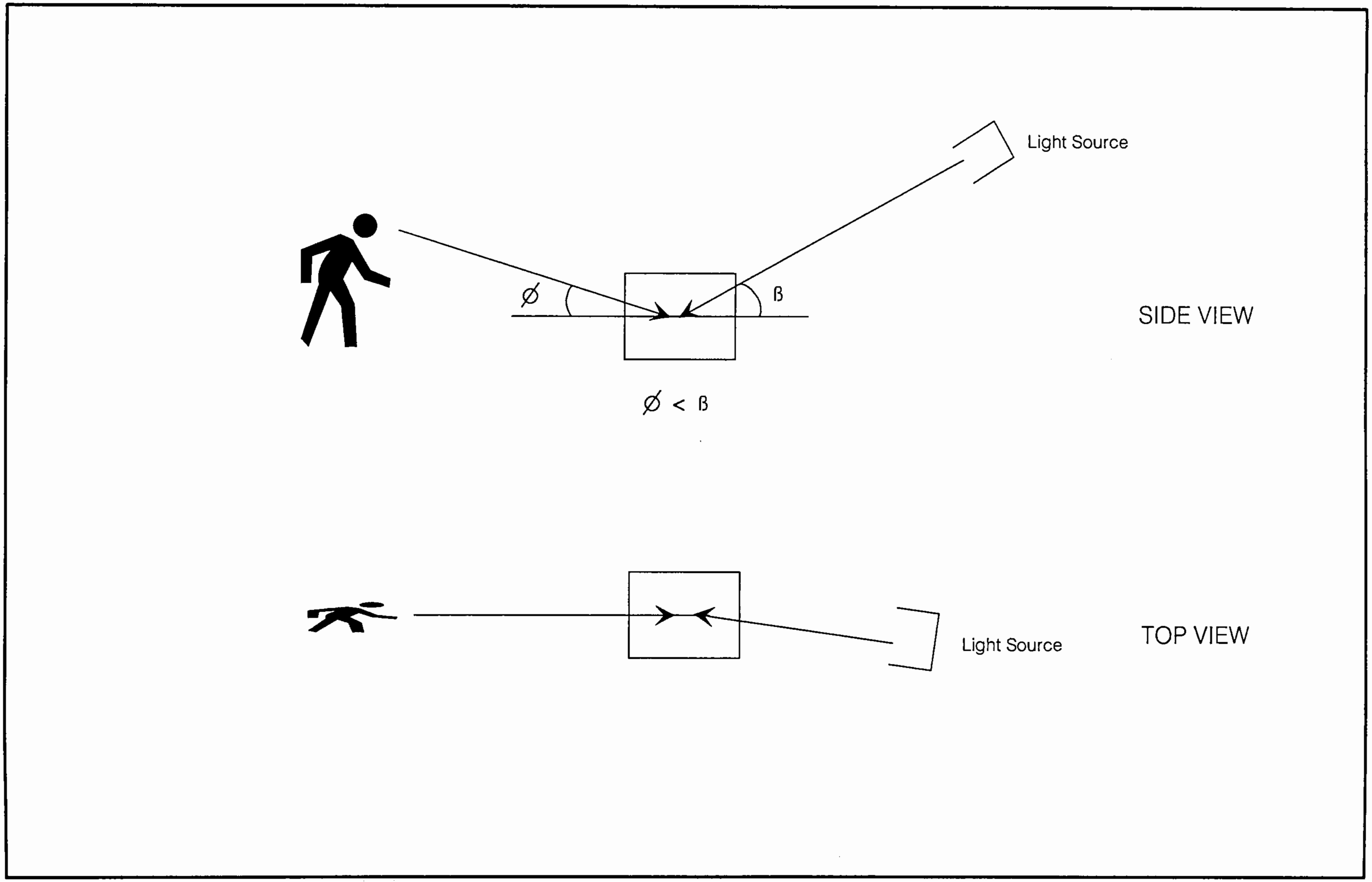
Existing lights may provide insufficient intensity or may interfere with clear viewing of the area under scrutiny:

- At the time the pilot needs to examine the wings for fluid failure, the aircraft will likely be away from terminal buildings and ground equipment, and be completely dependent on aircraft or crew lights.

- Existing on board fixed aircraft lighting may be unsuitable to the observers need. The angle of illumination may be unsuitable with too shallow an angle casting shadows over areas of concern on the wing

FIGURE 3.1

LOCATION OF LIGHT SOURCE FOR BEST VIEW OF LOSS OF GLOSS INDICATION OF FAILURE



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surface, or causing glare. The same shortcoming may be true of portable lighting shone through flight deck or cabin windows.

3.2.2 The Nature of the Wing Surface

The colour or shininess of the wing surface may influence ability to discern fluid failure, or contamination directly on the wing surface.

Snow, ice crystals or frost are difficult to see on a white or light coloured background but may be visible on a dark coloured background.

A glossy painted surface versus a flat painted surface may have different influence on visibility of contaminants or failed fluid.

3.2.3 Type of Precipitation

Falling snow can reduce the ability to see the area of interest on the wing surface. Shining a light through the falling snow may exaggerate the problem with reflected light off the falling flakes.

Freezing precipitation may produce a glossy surface and hide evidence of failure.

Transient failures (unfailures) occur when the snow or ice particles are not immediately absorbed into the fluid giving the impression of failure, but eventually are absorbed. This can be associated with very large snow flakes, or with ice pellets that initially penetrate the fluid surface.

3.2.4 Distance to the Wing Surface Area of Interest

The area of interest may be quite far out on the wing. Limitations of unaided vision may constrain ability to distinguish evidence of fluid failure. An obvious factor further increasing the difficulty of failure identification would be observed on very large aircraft in which the vast surface areas and long distance from root to wing tip come into play.

3.2.5 Area of the Wing Visible to Flight Crew

The physical geometry of the plane of the wing surface versus the location of the observers viewpoint within the cabin can result in viewing angles that are very shallow. Portions of the wing including points of interest like flaps and trim tabs may be entirely out of view of the observer.

3.2.6 Interference of the Window Material

Clear and unobstructed viewing may be hindered by a window that is dirty either on the inside or outside surface. In the weather conditions of interest, the outside surface typically could be covered with precipitation, either frozen or melted, and possibly with deicing and anti-icing fluid.

Light from inside the cabin may cause reflection on the inner window surface interfering with visibility of the wing surface.

3.2.7 Colour of Fluid Dye

An indicator of fluid failure is a change in fluid colour (dye) to grey or greyish appearance. Such a change in colour may be difficult to distinguish under actual operating conditions.

PHOTO 3.1
DC-9 WING SURFACE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)
PRIOR TO FAILURE

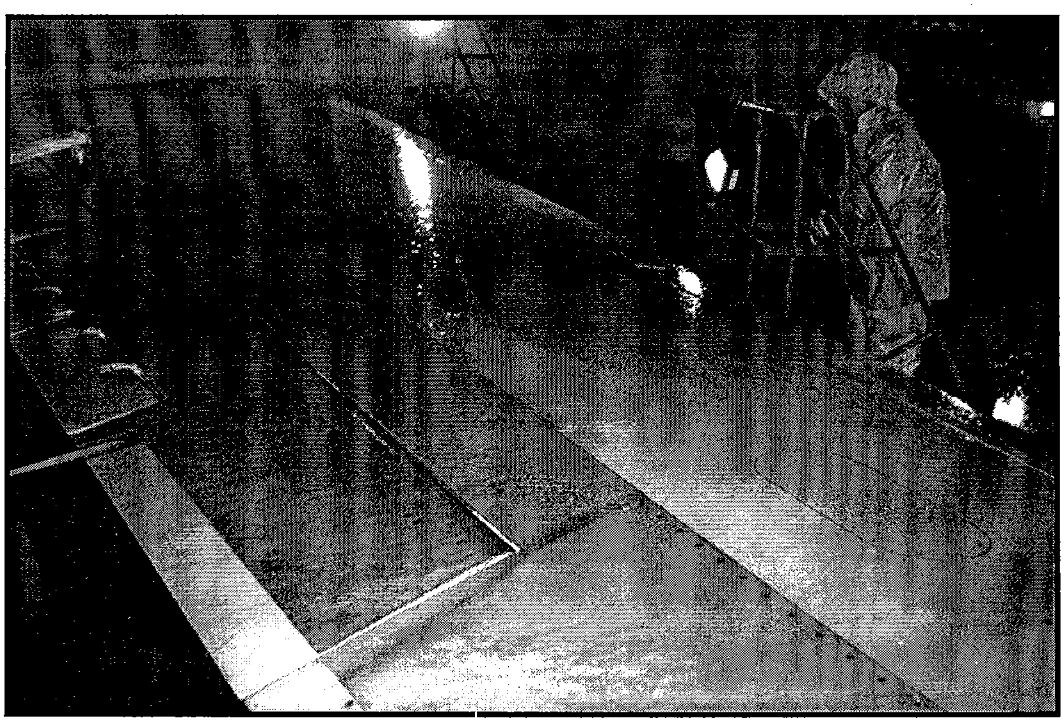


PHOTO 3.2
DC-9 WING SURFACE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)

DURING FAILURE

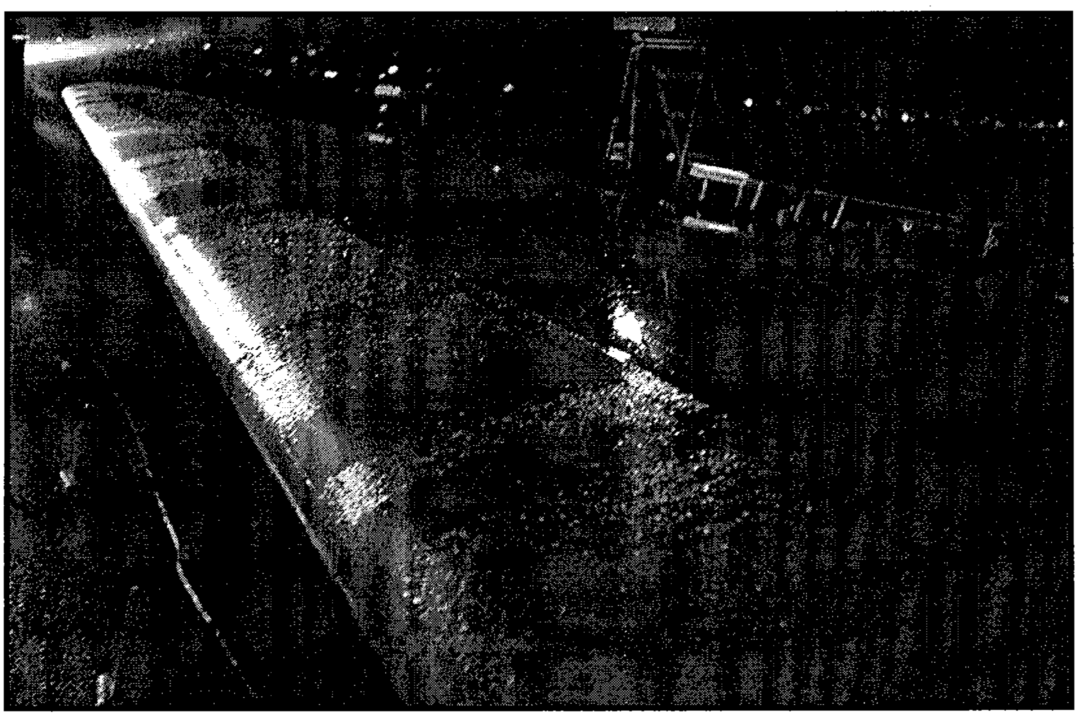
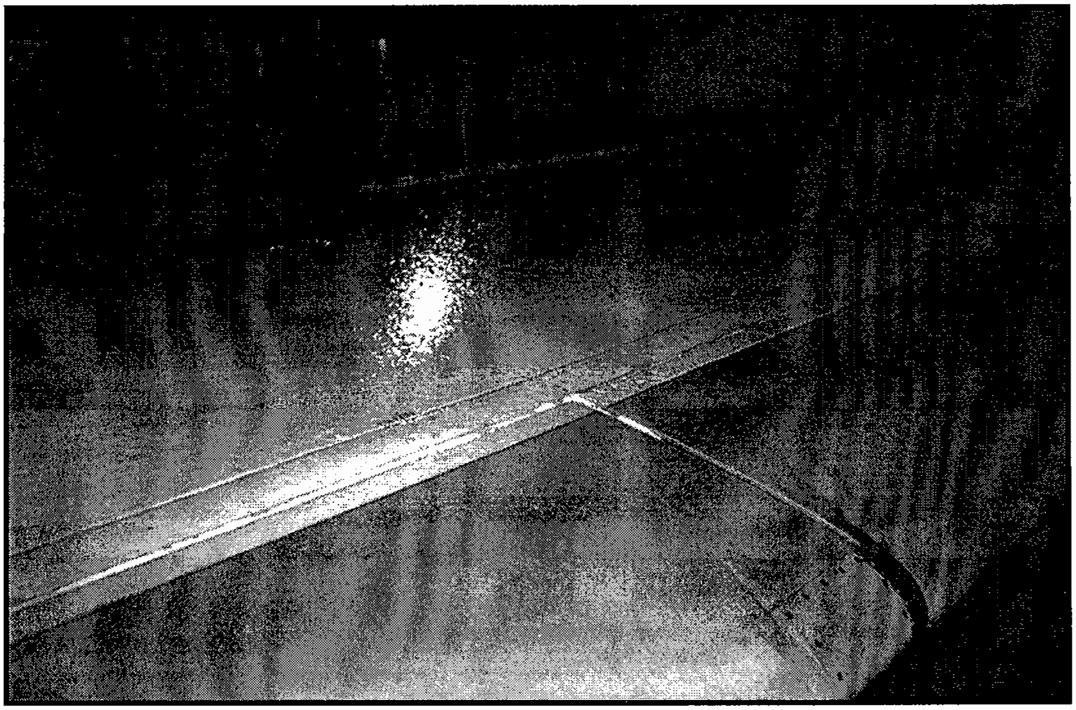


PHOTO 3.3
DC-9 WING SURFACE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)

AFTER FAILURE



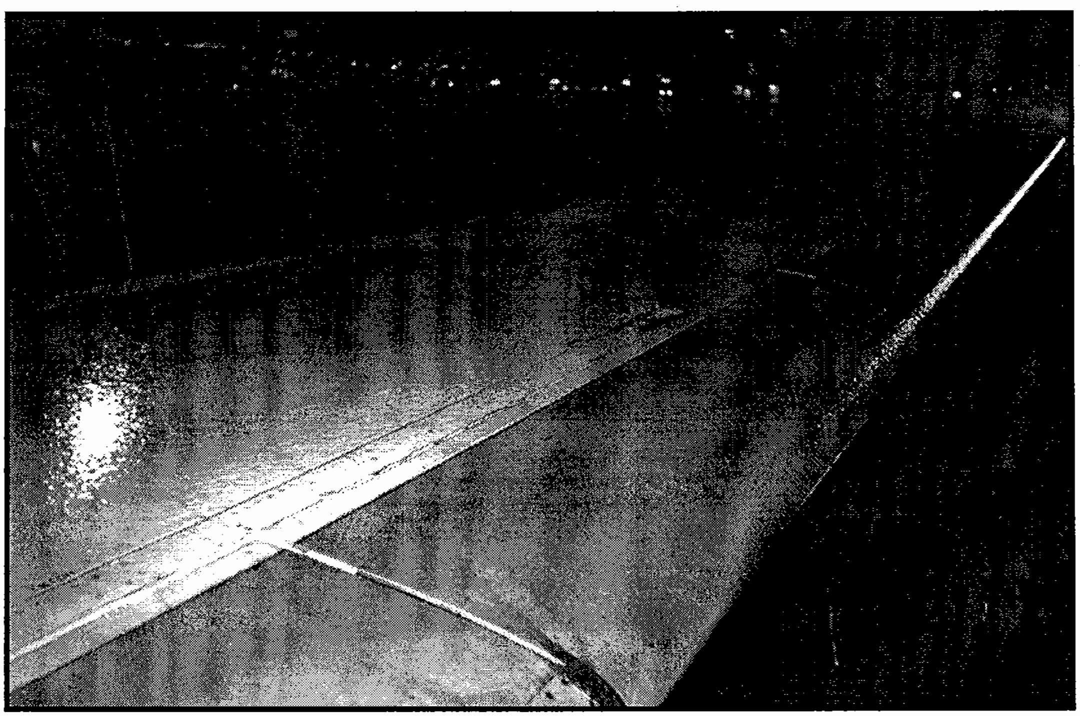
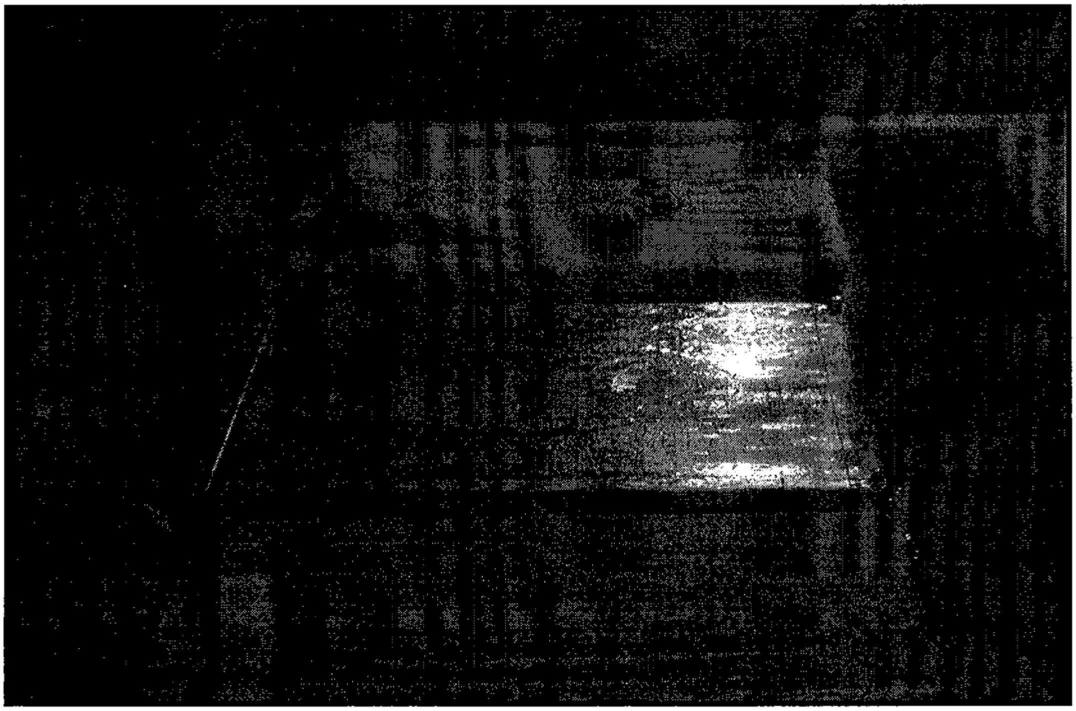
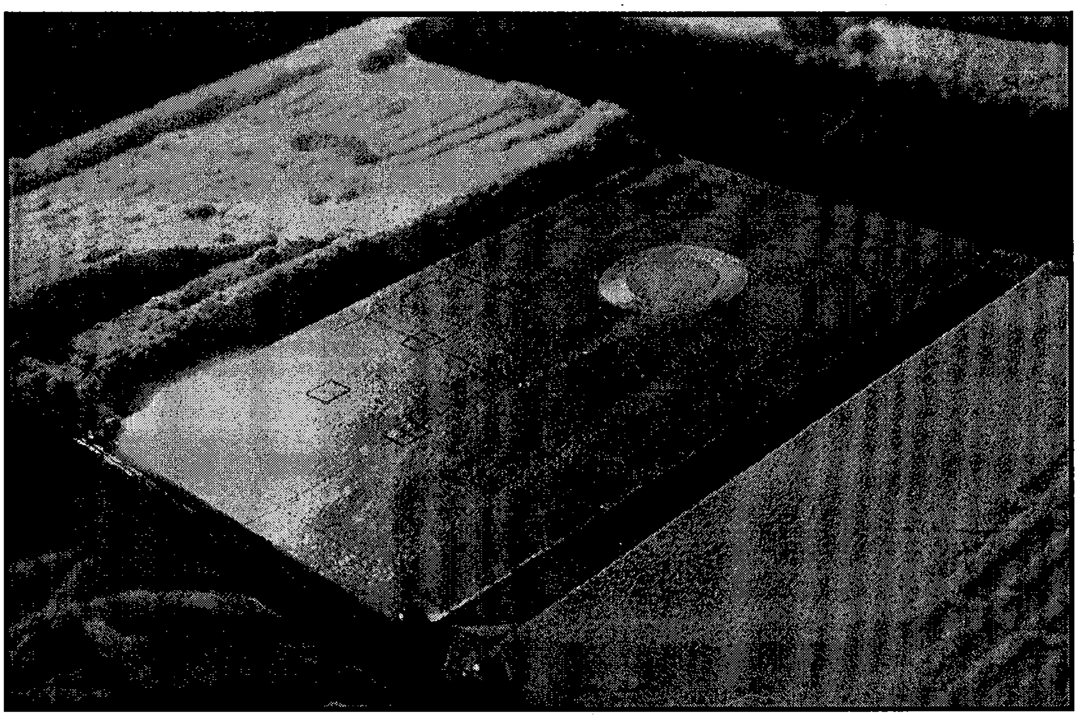


PHOTO 3.4 DOCUMENTATION OF NATURE OF FLUID FAILURE

Test Condition: Freezing Fog Temperature: -10°C Test Fluid: Ultra+ Neat



First Failure (Dark Shadow) - Appearance with Light Shining Toward Camera



First Failure (White Finger - Like Formations) - Appearance with Light Shining from Different Angle

PHOTO 3.5 DOCUMENTATION OF NATURE OF FLUID FAILURE

Test Condition: Freezing Fog Temperature: -10°C Test Fluid: Ultra+ Neat

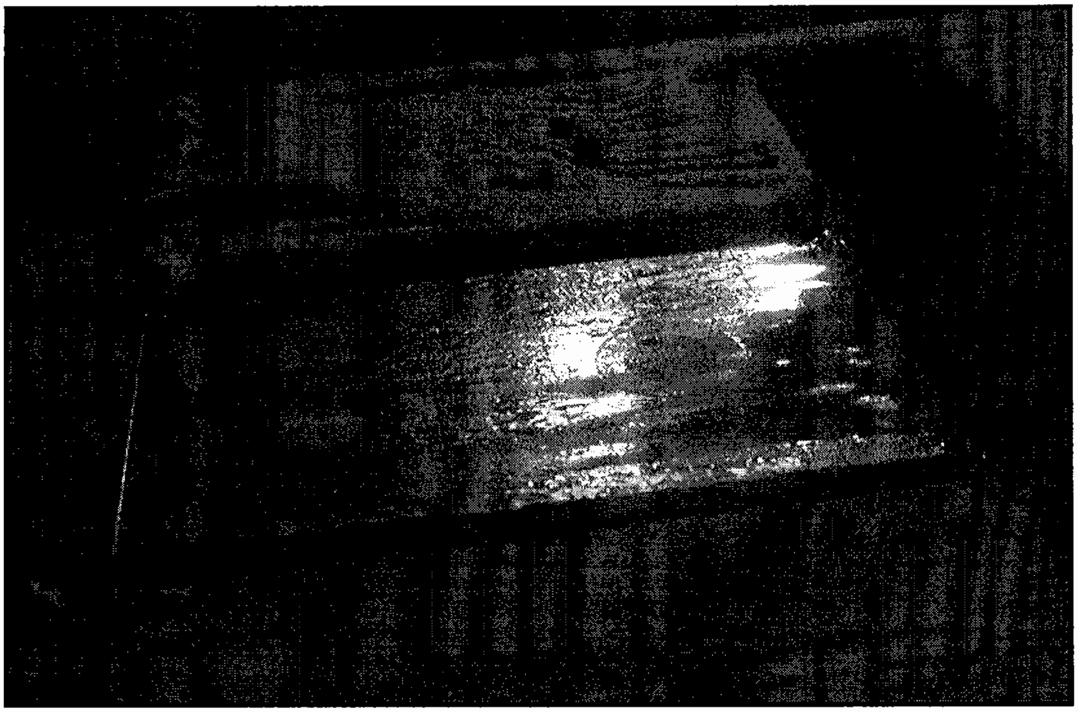


Plate Failure (Dark Shadow) - Appearance with Light Shining Toward Camera

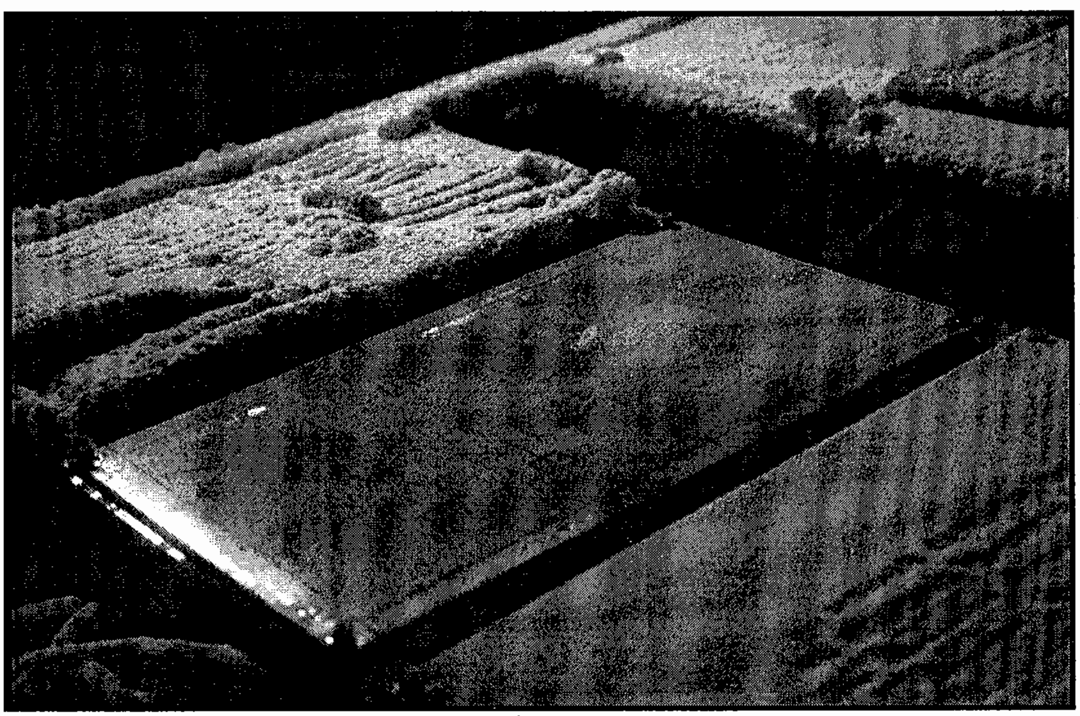


Plate Failure (White Finger - Like Formations) - Appearance with Light Shining from Different Angle

4. REPORTS ON PREVIOUS ACTIVITIES

Research of industry literature met with little success in locating reports on the subject of improving visibility of failed fluid on wing surfaces.

4.1 Fokker Aircraft

At the SAE Aircraft Ground Deicing Conference, June 1993, Fokker Aircraft representative, J. van Hengst, reported[3] on different approaches to improve visibility of ice contamination on wing surfaces:

- Coloured stripes have been tested. A black decal was found to be useful in visibility tests on an aircraft wing, enabling visibility of small particles of ice. In the same tests, ice particles were not visible on a white decal or on the grey painted aircraft wing.

- Ultraviolet light did not illuminate the white ice crystals.

- Fluorescent tape shone brightly to a degree that caused small ice formations to be invisible.

- A light installed on a flap track fairing projecting white light at a shallow angle identified contamination through the shadow effect of particles. Unfortunately it produced the same results for water droplets.

- Retroflective tape performed well. The ability of the material to reflect light directly back to the source was diminished significantly by the refractive properties of ice crystals deposited over the tape. Water or Type II anti-icing fluid did not interfere with the tapes reflecting strength.

4.2 Current Airlines Activities

Currently United Airlines and USAir are investigating the utility of a light mounted in an over wing emergency exit door, evaluating effectiveness in simulated conditions of freezing rain and drizzle on an operational aircraft.

4.3 Other Industry Solutions

Black decals or stripes are now in operational use as contaminant indicators on wing surface areas subject to cold-soaking and clear ice formation. Stripes are also used by some airlines to identify the representative surface area.

Black tapes with rough textures normally appear dull or rough, but become glossy when the textured surface is covered with clear ice.

Tuft and decal devices are used to assist in determination of clear ice contamination. The decal serves the purpose of identifying the location of installation on the aircraft wing, and free movement of the tuft indicates lack of ice.

5. POTENTIAL AREAS FOR INVESTIGATION

Consideration of the nature of the various obstacles to clear viewing and determination of fluid failure on the wing leads to a number of possible avenues for investigation.

5.1 Nature of Indicators of Failure

The obstacles to clear vision of the aircraft wing surface constitute only part of the challenge in providing an enhanced ability to distinguish fluid failure on the wing. A common perception and mental image of the appearance of indicators of fluid failure is necessary on the part of the crew member.

Knowing what to look for when attempting to ascertain fluid failure is a basic prerequisite to successful identification. Providing flight crews with photos or videos of typical fluid failures experienced during fluid testing programs and deicing trials would assist in instilling a common mental image of the appearance of failure under different conditions. A number of operators and regulatory offices have requested and been provided with this type of material for flight crew information.

Subjecting flight crew personnel to field training on fluid failure recognition is another approach.

5.2 Illumination

As discussed, the angle of incidence of lighting relative to the viewer's line of vision is important, and inappropriate lighting may simply serve to mask indications of failure. Location of sources of lighting for operational aircraft is restricted, and is generally limited to a choice of:

a) hand-held;

b) fuselage mounted; and

c) tail mounted.

Of these, the combination of a tail mounted light source in conjunction with an observer view from as far forward as possible in the cabin comes closest to the optimum configuration noted in the laboratory experience for freezing precipitation conditions where "loss of gloss" is the indicator of fluid failure. A light mounted in the winglet of a wing could be a solution.

A light located at the optimal position for identifying "loss of gloss" type failures may not be appropriate for identifying failures in snow conditions.

Different light sources may be considered, as example:

- continuous (incandescent or halogen);
- strobes (flashlamps);
- select wavelengths (laser, ultraviolet); and
- polarizing techniques.

The reflected light problem caused by snow precipitation is familiar to winter drivers, where increased intensity of headlights results in greater light reflection from the snow flakes and leads to diminished visibility. There is an opinion that strobe lighting may reduce this problem and enhance visibility through falling snow.

5.3 Optical Assists

Visual detection of the failed fluid may be performed with the naked eye or with the use of assists such as colour filters or polarized filters.

Based on the experience of full-scale aircraft testing, where close proximity to the wing surface influenced the success of test observers' ability to identify fluid failures, optical devices such as binoculars or refractive telescopes may be appropriate.

A compact lens telescope allows expected failure points to be inspected in which image magnification allows views of surface detail as large as if the viewer was located at the wing edge. Binoculars provide a wider angle of vision as well as depth perception, but generally at lower levels of magnification.

5.4 Light Shield

Provision of a viewing device to eliminate the problem of stray light reflection from the inside surface of the viewing window could be a partial solution.

This could take the form of a flexible light shield that could be pressed up against the window surface by the observer, or could be mounted in place dependent on window location and interference with other functions. It could be designed with a mount for optical equipment and/or light source.

5.5 Retroflective Tape

As noted in the Fokker Aircraft report[(3)], retroflective tape appears to offer potential. The diminishment of the normal levels of reflected light from the tape caused by deposits of ice crystals may make this approach particularly effective and suitable for some types of precipitation, but perhaps not all.

The greatest effectiveness of the tape is achieved in conditions where the angle of incidence of lighting is near normal to the surface and with the light source close to the observer or in line with the observers line of vision. However, some of these products are less constricting in terms of angular reflectivity and may provide adequate indication of contamination at shallow angles of illumination.

Discussions with the retroflective tape manufacturer have suggested another avenue for consideration which is to imprint a pattern on the tape with the expectation that contamination would reduce visibility of the pattern, and perhaps even indicate the degree of solid contamination over the tape.

5.6 Other Tapes and Decals

Although a variation of other types and colours of tapes and decals have been tried by various operators, there is little documentation on success. Some of these may be acceptable as partial solutions, and there may be merit in developing an objective and well documented evaluation of typical applications for the use of all members of the industry.

5.7 Selection of Fluid Dyes

This may be most efficiently performed in conjunction with a selected fluid manufacturer. The objective would be to test visibility properties of various dyes in a simulated operational condition, in combination with various sources of light.

5.8 Exploit Contrasting Appearance when Failed and Non-failed Fluid are Side by Side

The useful role played by the contrast in appearance between failed and non-failed fluid when they are side by side as noted in the discussion on the nature of fluid failure may point out a potential avenue for exploration. If a small defined area of the wing was known to be in an unfailed condition then that area could serve as a visual reference point providing the contrast in appearance as portrayed in the photos. It might be that the structural design of individual aircraft types produce natural and well defined patterns of progression of failure that, if known and documented for the flight crew, could be used to provide the contrast needed to support fluid failure recognition.

5.9 Evaluating Potential Solutions

The effectiveness of potential solutions must be evaluated under conditions reflecting the actual operation. During initial stages of evaluation, simulated conditions may be employed to provide a first indication of effectiveness of potential solutions. Test setups to accomplish this may involve viewing of test surfaces behind an appropriately positioned window surface. Use of the NRC Climatic Engineering Facility may be considered. Provision of ambient lighting typical of the actual operation will be vital to attainment of valid results.

At the final evaluation stage of the most promising solutions, testing on an aircraft will provide the most satisfactory and reliable test results.

In addition to effectiveness in enhancing visibility, criteria for success would include considerations such as economic implications, weight and stowage requirements, user implications, operator image and impact on the passenger.

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6. CONCLUSIONS AND RECOMMENDATIONS

The analysis of the causal factors contributing to the difficulty in visually detecting and recognizing fluid failure or contamination on wings from inside the aircraft cabin indicates that there is a reasonable potential of achieving some success in improving visibility of fluid failure.

Knowing what to look for when attempting to ascertain fluid failure is a fundamental aircrew need. Providing flight crews with photos or videos of typical actual fluid failures would assist in instilling a common mental image of the appearance of failure under different conditions. A number of operators and regulatory offices have been provided with this type of material for flight crew information.

Conduct of a well structured program to evaluate some simple, easily available and relatively inexpensive tools and solutions to enhance visibility is recommended. Examination of potential solutions for acceptability would include considerations such as economic implications, weight and stowage requirements, user implications, operator image and impact on passengers in the cabin. Such a program would provide the airline industry with an objective measure of effectiveness using different approaches, and potentially, may substantiate an approach or combination of approaches that significantly enhances flight crew ability to visually determine failure. In conducting such a program, close cooperation and coordination with other organizations, such as United Airlines and USAir, who are also evaluating potential solutions is important.

It is proposed that an evaluation program would, at least for initial evaluation, be based on a simulated aircraft configuration. This might consist of the use of flat plates or wing sections mounted at various, well-specified distances and angles from the viewer in order to represent typical wing/aircraft window geometries. The aircraft window could be simulated by suitable window material, with precipitation contaminants and/or deicing/anti-icing fluid spread on it as desired.

A phase of the evaluation should define the area of the wing that is visible to the flight crew, either from the flight deck or from the passenger cabin. This information should be gathered for principal aircraft in airline service.

Final testing on an operational aircraft of those solutions deemed to offer the greatest benefit would be required for realistic and valid evaluation under actual operating conditions.

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2. D'Avirro, J., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Test Program for the 1995-1996 Winter*, APS Aviation Inc., Montreal, November 1996, TP 12896E.

3. Society of Automotive Engineers, Inc., *1993 SAE Aircraft Ground Deicing Conference, A Transcription of the Presentations*, PA, USA, 1993.

APPENDIX A

TERMS OF REFERENCE - WORK STATEMENT

TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT
(revised* November 96)

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 95/96
(Short Title: Winter Tests 95/96)

1 INTRODUCTION

In the last decade, a number of fatal aircraft accidents have occurred in the winter at take-off during periods of precipitation that could contaminate aerodynamic surfaces; in several of these accidents the effectiveness of aircraft ground anti-icing has been suspect. Of particular importance to Canada was the crash of an Air Ontario F-28 at Dryden, Ontario on 10th March 1989, which led to a Commission of Inquiry led by Justice Moshansky.

The deicing fluids used on aircraft were originally expected to provide protection for the surfaces during only brief taxi and take-off periods. As traffic demand has grown, operations under more extreme weather conditions have increased, and traffic congestion on the airports has introduced lengthy line-ups for take off with the accompanying longer anti-icing protection requirement. This led to the development of the Type II anti-icing fluids for the jet aircraft and the Type III fluids for turboprops, both of which provide longer protection time (known as Holdover Time) following application. The times given in the official Holdover Time Tables were originally established by the Association of European Airlines (AEA) based on assumptions of fluid properties, and anecdotal data all related to operations in the European environment. These tables are published by the AEA, the Society of Automotive Engineers (SAE) and the International Standards Organization (ISO).

In a series of meetings on holdover time sponsored by the SAE Committee on Aircraft Ground Anti-icing involving the major airlines, aircraft manufacturers and anti-icing fluid producers, a program for field testing Type II fluids to establish holdover times in representative weather conditions was proposed. TDC took the lead in accepting to coordinate these activities for the 90/91 winter season with the participation of a number of carriers, deicing fluid manufacturers, the University of Quebec at Chicoutimi (UQAC), the National Research Council (NRC), and the Federal Aviation Administration (FAA). TDC undertook to prepare the test procedures and analyze and distribute all test results.

During the 90/91 season the methods of testing were developed and Type II and Type III fluids were tested. The Type II fluid results indicated that the times in the holdover tables were excessively long under normal winter snow conditions in North America. This led to the introduction of a range of time values for each condition (except frost) in the AEA/SAE/ISO tables,, the original AEA value being retained for the high time and a new lower time from the TDC tests for the "worst" conditions.

For the 91/92 winter season TDC tests were made on Type III fluids exclusively because of the importance of this fluid to commuter operators.

With the release of the recommendations of the Dryden Inquiry in March, 1992 and the setting up of the Dryden Commission Implementation Project Office (DCIP), even greater support for these holdover tests was generated in Canada. Almost simultaneously the La Guardia crash of a F-28, also in March 1992 spurred the FAA to introduce Holdover Time regulations and to request that the SAE Committee on Aircraft Ground Deicing spearhead work on establishing holdover guidelines. This led to the formation of the holdover time working group, co-chaired by DCIP and FAA/ARC. Building on the earlier work initiated by TDC for the 90/91 and 91/92 winter seasons, a major test program was initiated to substantiate the existing holdover time tables. DCIP undertook to coordinate the expanded test program as part of its fulfilment of the recommendations of the Dryden Commission.

The 92/93 series of outdoor winter tests were in Montreal and involved revision of the test protocol, tests in both natural and artificial snow on flat plates, on simulated wings and on wing leading edges, and used a sensor to confirm fluid failure criteria. Type I, Type II and Type III fluids were tested. Simulated frosting, freezing fog and freezing rain conditions were tested at the NRC facilities in Ottawa. As a result of these tests large parts of the Type I and Type II tables were substantiated

For the 93/94 testing season, efforts were aimed at continuing the substantiation of the holdover tables and mostly involved testing diluted Type II fluids. All natural snow tests were made at Dorval, freezing fog at the NRC Helicopter Icing Facility and Freezing drizzle and freezing rain at the NRC Cold Environment Facility (CEF). In addition to the Instrumar sensor the RVSI remote sensor was also used to assist in collecting data. UCAR provided a new long lasting Type II fluid for preliminary testing.

An important effort was made in the 94/95 season to verify that the flat plate data were representative of aircraft wings. Air Canada cooperated with DCIP by making aircraft and limited ground support staff available at night to facilitate the correlation testing of flat plates with performance of fluids on aircraft. The new UCAR ULTRA fluid was extensively tested and resulted in a new TC/FAA holdover table providing 50% longer holdover times for use during the 95/96 winter season. Additional testing was undertaken to evaluate the suitability of hot air for de-icing as an alternative to heated de-icing fluids at low (e.g. -30^{0}C and below) ambient temperatures or wet snow. Tests were also performed to assess the potential for extending the use of hot water for de-icing from the current -3^{0}C limitation down to -7^{0}C or lower, where past experience has shown it feasible.

The winter 94/95 season testing was very restricted by the paucity of snow conditions and therefore much of the planned testing was not completed. Substantiation of the Type I and Type II tables needs certain special conditions hard to find in the field such as low temperatures with precipitation, and rain or other precipitation on cold soaked surfaces. The development of ULTRA by Union Carbide has stimulated all the manufacturers to produce new long lasting anti-icing fluids that will be defined as Type IV; all these fluids will contribute to the definition of the performance requirements for a generic Type IV. Although the Holdover tables are widely used in the industry as guides to operating aircraft in winter precipitation the significance of the range of time values given in each cell of the table is obscure; there is a clear need to improve the understanding of the limiting weather conditions to which these values relate. The few aircraft tests made to validate the flat plate tests were inconclusive and more such tests are needed. The testing with hot water and with hot air for special deicing conditions have not been completed. All these areas are the subjects for the further research that is planned for the 95/96 winter.

2 PROGRAM OBJECTIVE (MCR 16)

Take an active and participatory role to advance aircraft ground de-icing/anti-icing technology. Develop international standards, guidance material for remote and runway-end de-icing facilities, and more reliable methods of predicting de-icing/anti-icing hold-over times.

3 PROGRAM SUB-OBJECTIVES

3.1 Substantiate the guideline values in the existing holdover time (HOT) tables for type IV fluids that have been qualified as acceptable on the basis of their impact on aircraft take-off performance.

3.2 Perform tests to establish relationships between laboratory testing and real world experience in protecting aircraft surfaces.

3.3 Develop reliable holdover time (HOT) guideline material based on test information for a wide range of winter weather operating conditions.

3.4 Support development of improved approaches to protecting aircraft surfaces from winter precipitation.

4 PROJECT OBJECTIVES

4.1 To complete the substantiation of the existing Type I and Type II SAE holdover time Tables by conducting cold soak tests and very low temperature tests.

4.2 To determine the holdover time performance of the proposed Type IV fluids over the range of characteristic conditions and create a generic Type IV holdover time table.

4.3 To establish the precipitation, wind and temperature values that delimit the holdover times given in the tables.

4.4 To validate that flat plate test data used to establish the SAE Type IV holdover time tables is representative of Type IV performance on service aircraft. under conditions of natural freezing precipitation.

4.5 To evaluate hot air de-icing as an alternative to heated de-icing fluids for frost removal at low ambient temperatures.

4.6 To undertake special tests of Type IV fluids in comparison with a Type II fluid at high rates of precipitation.

5. DETAILED STATEMENT OF WORK

The work shall be broken down into the several distinct areas of activity consistent with the project objectives, together with activities for presentations and reporting at the completion of work. A detailed workplan, activity schedule, cash flow projection, project management control and documentation procedure shall be developed and delivered to the TDC project officer for approval within one week of effective start date.

5.1 Substantiation of Type I and Type II Tables

5.1A Laboratory "Cold soak" Test Program

Tests will be conducted at the Climatic Engineering Facility (CEF), of the National Research Council, Ottawa. APS will supply all necessary equipment and fluids for the conduct of the tests. Laboratory test should be performed after the field tests so that some temperatures can be chosen to match the field tests.

5.1.1 Develop an experimental plan to conduct tests, analyze results and prepare a report to provide values given for the SAE/ISO Holdover Time Tables for Type I. Type II and Type IV fluids using cold soaked boxes to simulate cold soaked wing conditions for a range of precipitation rates above and below freezing.

5.1.2 Include tests at +2°C and -7°C and at temperatures corresponding to selected field tests and cover a range of box temperatures from 0°C to -15°C and a range of precipitation rates, simulating rain, freezing drizzle and snow. These rates should be determined in consultation with personnel from AES and NRC. APS will use their own cold box designs.

5.1.3 Present the test plan to TDC Project Office for review Comment and approval.

5.1.4 Schedule tests with NRC and give advance notice of all intended tests to the TDC project officer.

5.1.5 Conduct tests in the NRC cold chamber using flat plates as benchmark

5.1.6 Analyze results from cold boxes and compare with the flat plate results

5.1B ***Field "Cold soak" Test Program***

Conduct full scale aircraft cold soak experiments with the cooperation of local airlines. Use thermistors to measure temperatures on cold soak box and aircraft wing.

5.1C **Low Temperature Test**

Test Type I and Type II fluids on flat plates to establish holdover times at the lowest temperatures encountered in the winter. These test will be similar to those in the program of Type IV testing and will run concurrently with the Type IV tests

5.2 Program of Type IV

This program will test new "long-life" Type IV fluids over the entire range of conditions covered by the HOT Tables and will include outside testing under conditions of natural precipitation, and laboratory testing in the NRC CEF for tests involving freezing fog, freezing drizzle and light freezing rain.

5.2.1 Develop a program to test samples of the new Type IV fluids to establish holdover times over the full range of HOT table conditions.

5.2.2 Obtain samples from producers of qualified Type IV fluids

5.2.3 Establish a test site for the conduct of outside tests at Montreal, Dorval Airport

5.2.4 Arrange for support services and appropriate facilities.
5.2.5 Recruit and train local personnel .
5.2.6 Repair and replace TDC supplied equipment used for testing in previous years as necessary.
5.2.7 In consultation with TDC, devise a method to evaluate the precipitation type in order to assess the effects of wet and dry snow on visibility in precipitation.
5.2.8 Install an ETI precipitation gauge at Dorval to study its correlation with the READAC gauge and the plate pans.
5.2.9 Acquire data from the READAC station at Dorval on a minute-by-minute basis.
5.2.10 Give advance notice of all intended tests to the TDC project officer.
5.2.11 Conduct tests during periods of freezing precipitation concurrent with HOT Table substantiation tests of conventional fluids. For Type I,II and IV fluids, frequent testing should be conducted under natural precipitation conditions when temperatures are below -14°C.
5.2.12 Coordinate scheduling of the indoor tests with the NRC.
5.2.13 Install Instrumar's C/FIMS on at least one plate, if available RVSI's and SPAR remote sensor will be set up to view the stand holding six standard test plates. All sensors will be used for both the chamber tests and all the field tests where feasible. Determine fluid failure by visual observation
5.2.14 Conduct tests with simulated freezing fog, freezing drizzle and light freezing rain in the NRC CEF facility, Ottawa, supplying the necessary materials and equipment for tests.
5.2.15 Conduct ancillary tests at Dorval and the NRC Chamber to study the effect of HOT's of successive application of new and conventional Type II fluids on clear and contaminated Type I's.
5.2.16 Collect visibility data during periods of freezing precipitation at Dorval and correlated with concurrent meteorological data, including precipitation rate, precipitation type, temperature, wind velocity and direction as appropriate.
5.2.17 Present program results and plans for completion for a "mid-term" review to be called by TDC.
5.2.18 Video tape the tests for archival purposes
5.2.19 Test results will be collected, analyzed and a report produced.

5.3 Weather

The significance of weather conditions in the holdover time tables needs to be defined; the high time value represents "light"" conditions and the shortest time is the boundary for a "heavy" condition. Some evaluation of these terms shall be developed on the basis of existing and current data.

5.3.1 Review weather conditions for test data from all years and all sites for the cases where failure time lay outside the range in the tables for Type I and Type II fluids

5.3.2 Study extreme weather conditions during the 1995/96 winter tests at Dorval using a Type 1 fluid to evaluate "Light" conditions and a Type II to evaluate "heavy" conditions

5.3.3 Analyze the data with respect to the parameters of experimental site, weather conditions, fluid type and fluid manufacturer to establish relationships between weather parameters and holdover time values

5.3.4 Recommend caution statements to go into the holdover time tables

5.3.5 Recommend revisions to the fluid performance tests.

5.4 Performance of Ultra Fluids on Flat Plates Versus Aircraft Surfaces

This test program will be conducted at Dorval International Airport, using aircraft made available by an airline, and, subject to weather conditions, will include three (3) all night test sessions. In general, aircraft will be made available for testing outside regular service hours, i.e. available between 23:00 hrs. and 06:00 hrs. Tests will be conducted to verify that fluid failures on the flat plates used to develop HOT guidelines for the new fluid occurred before failure on the aircraft wings. Depending on the site selected for these tests, it is expected that Air Canada will be providing ancillary equipment and services as stipulated in their agreement with Transport Canada for the 1994/95 winter; this equipment will include lighting fixtures as necessary, observation platforms, vehicles, storage facilities, office facilities and personnel rest accommodation. Additional tests, if required, may be requested subject to agreement by all parties involved.

5.4.1 Develop an experimental program for concurrent comparison testing of fluids under conditions of natural freezing precipitation on flat plates and on aircraft.

5.4.2 ***Prepare the following test plan features, plans and procedures:***

a) A detailed statement of work for each of the participants;

b) A specific test plan, for review by all parties, which will include as a minimum:

- Schedule and sequence of activities;
- Detailed list of responsibilities;
- Complete equipment list;
- List of data, measurements and observations to be recorded; and
- Test procedures.

c) Activities including:

- Visual and Instrumented Data Logging;
- Monitoring and recording environmental conditions, including:
  - Air temperature,
  - Wing surface temperature at selected locations,
  - Wind velocity and direction, and
  - Precipitation type and rate;
- Record of aircraft and plate orientation to the wind; and
- Use of instrumentation to determine the condition of the fluid.

d) Acquisition of data from the tests will address:

- Identification of fluid failure criteria;
- Location of first point of fluid failure on the wing, and subsequent failure progression;
- Correlation of fluid failure time to environmental conditions;
- Correlation of fluid failure times on flat plates and aircraft; and
- Behaviour of fluid on the "representative" surface.

5.4.3 Present the experimental programs for review and approval by the TDC project officer.

5.4.4 Arrange (with the cooperation of TDC) for deicing equipment and aircraft representative of those in common use by airlines in Canada to be made available for the tests .

5.4.5 Present the approved program to the airline involved prior to the start of field tests.

5.4.6 Recruit and train local personnel who will conduct test work.

5.4.7 Provide all equipment and all other instrumentation necessary for conduct of tests and recording of data.

5.4.8 Arrange for the provision of fluids by UCAR for spraying an aircraft.

5.4.9 Secure necessary approvals and passes for personnel and vehicle access for operation on airport airside property

5.4.10 Schedule tests on the basis of forecast significant-duration night-time periods of freezing precipitation;

5.4.11 Provide advance notice to Air Canada of the desired test set-up, including aircraft orientation with respect to the forecast wind direction, sequence of fluid applications, and any additional services requested.

5.4.12 Confirm that the de-icing equipment used for the tests is equipped with a nozzle suitable for the application of Ultra fluids. Application of fluids will be by airline personnel.

5.4.13 Arrange for spray application during the initial tests to be observed by the fluid manufacturer's representative for endorsement.

5.4.14 Orient the aircraft with leading edge into the wind on two occasions and trailing edge into the wind on the third occasion.

5.4.15 Conduct tests of Type II Ultra plus fluid on standard flat plates and aircraft, using Ultra on the plates as a benchmark fluid along with a standard Type II when available.

5.4.16 Record the progression of fluid failure on the wing over the series of tests conducted.

5.4.17 Videotape records of all tests will be made.

5.4.18 Return any equipment obtained from airlines for use during the tests to its original condition at the end of the test program.

5.4.19 Assemble and analyze all results

5.5 Frost Removal

Frost alleviation and removal by "sweep and shine" and hot air shall be explored.

5.5.1 Sweep and Shine
Tests shall be conducted at very low temperatures to evaluate the efficacy of sweep and shine. Micromeasurements of frost shall be made prior to tests and following various amounts of sweeping. Numbers of crystals per area will be noted along with their height and shape to indicate roughness level

5.5.2 Hot Air
Successful application of hot air for frost removal is dependent on provision of a well designed air application tool; one that is user friendly and will provide speedy and effective results. Provision will be made to evaluate prototype equipment in conjunction with an airline and a manufacturer.

5.6 Wing Surface Visibility Study

Examine various options to enhance visibility of failed wing surfaces from inside the cabin and flight deck and make recommendations.

5.7 Representative Surfaces Guidelines Study

5.7.1 Study the optimum locations for representative surfaces on specific test aircraft wings.

5.7.2 Develop generic guidelines for defining the optimum locations for representative surfaces on any aircraft and for installation of wing contamination sensors.

5.8 *Heavy Precipitation Type IV Tests*

Using the NRC CEF, test all qualified Type IV fluids at 100% concentration along with a standard Type II fluid as a benchmark at simulated high precipitation rates of 25gm/dm2/hr and at low temperatures close to -7C.

5.9 Presentations of test program results

5.9.1 Prepare and present preliminary findings of test programs involving field tests with aircraft to representatives of Transport Canada and the Airlines involved at end of the test season, but no later than April 30 1995.

5.9.2 Prepare and present, in conjunction with Transport Canada personnel, winter test program results at SAE G-12 Committee meetings in Chicago, and London, England.

5.10 Reporting

Reporting shall be in accordance with section 10 "Reporting", below.

5.10.1 Substantiation of HoldOver Time Tables
A final report shall be prepared covering all winter testing sponsored by TDC and DCIP, including that from previous winters, conducted to substantiate the SAE HOT Tables.

5.10.2 Reporting of Other Testing
Separate final reports shall be issued for each area of activity consistent with the project objectives.