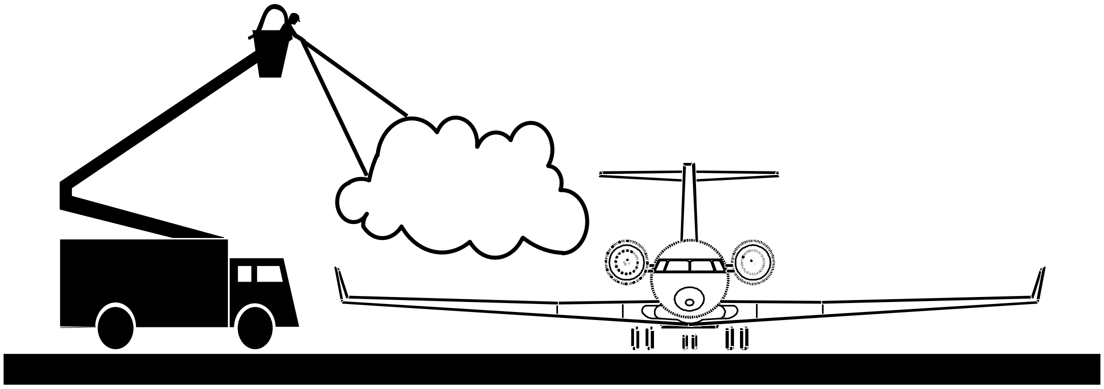
TP 13316E

Contaminated Aircraft Takeoff Test for the 1997/98 Winter



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APS AVIATION INC.

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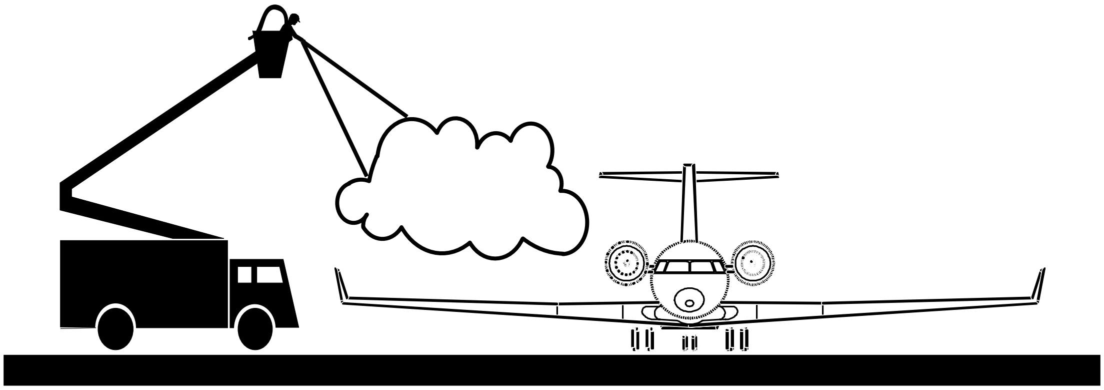

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Un sommaire français se trouve avant la table des matières.

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 APS test program were:

- to develop holdover time tables for new Type IV fluids and to validate *fluid-specific* tables and SAE tables;
- to determine the influence of fluid type, precipitation, and wind on location and time to fluid failure initiation, and also failure progression on the Canadair Regional Jet and on high-wing turboprop commuter aircraft;
- to establish experimental data sufficient to support development of a *deicing only* table to serve as an industry guideline, and to evaluate freeze point temperature limits for fluids used as the first step in such a procedure;
- to establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft when subjected to rotation speeds;
- to document the appearance of fluid failure and the characteristics of the fluid at time of failure, through conduct of a series of trials on standard flat plates; and
- to determine the feasibility of examining the condition of aircraft wings prior to takeoff through use of ice contamination sensor systems.

The research activities of the program conducted on behalf of Transport Canada during the 1997/98 winter season are documented in six separate reports. The titles of these reports are as follows:

TP 13318E	Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1997/98 Winter;
TP 13314E	Research on Deicing Operations for the 1997/98 Winter;
TP 13315E	Aircraft Deicing Fluid Freeze Point Buffer Requirements: *Deicing Only* and First Step of Two-Step Deicing;
TP 13316E	Contaminated Aircraft Takeoff Test for the 1997/98 Winter;
TP 13317E	Characteristics of Aircraft Anti-icing Fluids Subjected to Precipitation;

- TP 13489E Deicing with a Mobile Infrared System.

This report, TP 13316E addresses the following objective:

- to establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft when subjected to speeds up to rotation speed.

This objective was met by conducting simulated takeoff runs with the National Research Council Falcon 20D research aircraft at Montreal International Airport (Mirabel). Aircraft wings were treated with an anti-icing fluid and then subjected to artificial precipitation to cause contamination of varying degrees. Fluid condition was examined and recorded before and after takeoff runs.

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Research has been funded by the Civil Aviation Group, Transport Canada, with support from the Federal Aviation Administration and USAirways Inc. This research program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre, the Federal Aviation Administration, USAirways Inc., the National Research Council Canada, Atmospheric Environment Services, Transport Canada, and the fluid manufacturers for their contributions to and assistance with the program. Special thanks are extended to USAirways Inc., Air Canada, the National Research Council Canada, Canadian Airlines International, Inter-Canadian, AéroMag 2000, Aéroport de Montreal, Union Carbide, RVSI, Cox and Company Inc., KnightHawk, and Shell Aviation for provision of personnel and facilities, and for their co-operation 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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16. Abstract

The primary objective of this study was to establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft when subjected to acceleration up to rotation speed.

Static anti-icing fluid failure tests were conducted on a Falcon 20D aircraft to determine the normal pattern of failure on this aircraft during natural freezing precipitation. These tests determined that the failure pattern on this aircraft's wings is consistent with that observed on other aircraft types, with failures generally initiating on flight control surfaces at the rear of the wing.

Simulated takeoff runs were performed with the NRC Falcon 20D research aircraft to examine the behaviour of different levels of contamination at several spanwise locations. Sections of the aircraft wings were sprayed with anti-icing fluid, which was then subjected to artificial precipitation for various durations to produce several levels of contamination severity. The aircraft was then operated through a simulated takeoff, without rotation. The nature and extent of contamination were examined and recorded before and after the takeoff run without rotation. Failure patterns in takeoff tests were consistent with patterns determined from the static tests.

The simulated takeoff run trials demonstrated that some portion of failed fluid remained on the wing following acceleration to rotation. This was true even for the case of initial failure condition, when only a very small area was covered by contaminated fluid. For higher levels of contamination, a significantly large area remained covered with failed fluid following the takeoff run. Some unfailed fluid also remained on the wing following the takeoff run.

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Les rapports sur les recherches effectuées au cours des hivers précédents pour le compte de Transports Canada sont disponibles au Centre de développement des transports (CDT). Six rapports, dont le présent, ont été produits dans le cadre des recherches menées pendant l'hiver 1997-1998. Leur objet est précisé dans l'avant-propos.

16. Résumé

L'objectif principal de cette étude était d'établir les conditions qui amènent des fluides antigivrage contaminés par des précipitations givrantes à adhérer à la voilure d'un avion de transport à réaction plutôt que de s'en détacher, lorsque celui-ci accélère jusqu'à la vitesse de rotation.

Des essais statiques de durée d'efficacité ont été réalisés au moyen d'un Falcon 20D, afin de déterminer les caractéristiques des fluides antigivrage au cours de leur progression vers la perte d'efficacité, dans des conditions de précipitations givrantes naturelles. Ces essais ont révélé que le comportement des fluides antigivrage sur la voilure d'un Falcon 20D ressemble à celui observé sur celle d'autres types d'avions : c'est généralement sur les gouvernes du bord de fuite que se manifeste d'abord leur perte d'efficacité.

Des décollages simulés ont été exécutés avec le Falcon 20D de recherche du CNRC, afin d'observer le comportement de fluides affichant divers degrés de contamination, à plusieurs emplacements le long de l'envergure de l'aile. Différentes zones des ailes étaient pulvérisées de fluide antigivrage, après quoi l'avion était exposé à des précipitations artificielles pendant des durées diverses, de façon à produire plusieurs degrés de contamination. Le pilote exécutait alors un décollage simulé, amenant l'appareil jusqu'à la vitesse de rotation, mais sans décoller. Les chercheurs observaient et notaient la nature et l'étendue de la contamination, avant et après la course au décollage. Les résultats de ces essais concordaient avec ceux des essais statiques.

Les décollages simulés ont révélé qu'une partie du fluide contaminé demeurait sur la voilure après l'accélération jusqu'à la vitesse de rotation. Cela valait même aux premiers instants de la perte d'efficacité, alors que le fluide était contaminé sur une infime superficie de l'aile seulement. Dans les cas où une plus grande partie de l'aile était contaminée, une grande superficie de l'aile demeurait couverte de fluide contaminé après la course au décollage. Et il restait encore sur l'aile une certaine quantité de fluide encore efficace.

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EXECUTIVE SUMMARY

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation undertook a research program to examine the elimination of failed fluids from aircraft wings during takeoff.

Regulations require that no one attempt a takeoff if ice, frost, snow, or slush is adhering to the critical surfaces of an aircraft. Currently, failure of anti-icing fluid is identified visually, by observing frozen contamination on the fluid surface. However, the observer cannot judge whether the visible frozen contamination is, in fact, adhering to the wing surface.

To date, theoretical analyses and laboratory research to determine whether failed anti-icing fluid remains adhering to a wing at lift-off have produced no tangible results. Direct observation for a typical sample aircraft is an alternative approach to gaining an understanding of adherence.

The primary objective of this study was to establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft when subjected to acceleration up to rotation speed.

Simulated takeoff runs were performed at Montreal International Airport (Mirabel) with the National Research Council Canada Falcon 20D research aircraft. The persistence or adhesional behaviour of different levels of contamination at several spanwise locations was examined. Selected sections of the aircraft wings were sprayed with anti-icing fluid, which was then exposed to artificial freezing precipitation for various durations to produce several levels of contamination severity. The aircraft was then operated through a simulated takeoff, with acceleration to rotation speed but without rotation or lift-off. The nature and extent of contamination were examined and recorded before and after each takeoff run. Principal observations were conducted externally, supplemented by observations from within the aircraft.

Static fluid failure tests were conducted on a Falcon 20D aircraft at Ottawa International Airport, to determine the normal pattern of failure on this aircraft during natural precipitation.

Results and Conclusion

Static tests determined that the pattern of failure on the wings of a Falcon 20D aircraft is consistent with that observed on other aircraft types in past test seasons. Generally, failures initiate on the leading and trailing edges, due to discontinuities caused by the control surfaces in these sections. In the case of

the Falcon 20D, failures initiated on the flight control surfaces of the trailing edge.

Failure patterns in the takeoff tests were consistent with those determined from the static tests.

The results of simulated takeoff run trials demonstrated that some portion of failed fluid remained on the wing following the acceleration to rotation. This was true even for the case of initial failure condition, when only a very small area was covered by contaminated fluid. For higher levels of contamination, a significantly large area remained covered with failed fluid following the takeoff run. Some amount of uncontaminated fluid also remained on the wing following the takeoff run.

The trial offered an opportunity to document the reliability of identifying fluid failure by observation from inside the cabin. Very low levels of contamination appear to be difficult to identify. As the extent of failure increased, the accuracy of calls from inside the cabin improved, although failures on the leading edge were more difficult to identify.

This brief series of trials demonstrated the validity of this test approach for gaining an improved understanding of adherence. Direct observation of wing condition on a typical sample aircraft following a simulated takeoff run can provide reliable information regarding whether failed fluid clears from the wing during the takeoff run. Ground observer documentation with respect to the condition of the wing prior to and following the takeoff run appears to be the simplest and most satisfactory approach to data gathering. Real-time images of contamination, as produced by an ice detection sensor camera, would be a valuable aid during the trial and during subsequent analysis.

In the tests, the aircraft was accelerated to rotation speed without actually rotating. A greater removal of fluid and ice formation may be experienced with actual rotation and this aspect should be considered for any future tests of this nature. The performance of different fluids should also be examined in future trials.

SOMMAIRE

À la demande du Centre de développement des transports (CDT) de Transports Canada, APS Aviation a entrepris un programme de recherche pour approfondir le comportement au décollage de fluides antigivrage déposés sur la voilure d'un avion, une fois qu'ils ont perdu leur efficacité.

Les règlements interdisent tout décollage lorsque de la glace, du givre, de la neige ou de la neige fondante adhèrent aux surfaces critiques d'un aéronef. À l'heure actuelle, la perte d'efficacité des fluides antigivrage est constatée visuellement, par l'observation de la présence de contamination solide à la surface du fluide. Mais l'observateur n'est pas en mesure de juger si la contamination solide adhère à la surface de l'aile.

Les études théoriques et les recherches en laboratoire menées à ce jour pour déterminer si un fluide antigivrage contaminé continuera d'adhérer à la voilure au moment du décollage n'ont produit aucun résultat probant. L'observation directe au cours d'expériences mettant en jeu un avion réel constitue une autre façon d'approfondir la question de l'adhérence des fluides contaminés.

L'objectif principal de cette étude était d'établir les conditions qui amènent des fluides antigivrage contaminés par des précipitations givrantes à adhérer aux ailes d'un avion de transport à réaction plutôt que de s'en détacher, lorsque celui-ci accélère jusqu'à la vitesse de rotation.

Des décollages simulés ont été exécutés à l'Aéroport international de Montréal (Mirabel), avec le Falcon 20D de recherche du Conseil national de recherches du Canada. Les chercheurs ont mesuré le degré d'adhérence de fluides affichant divers degrés de contamination et occupant divers emplacements le long de l'envergure de l'aile. Différentes zones des ailes étaient pulvérisées de fluide antigivrage, après quoi l'avion était exposé à des précipitations givrantes artificielles pendant des durées diverses, de façon à produire plusieurs degrés de contamination. Le pilote exécutait alors un décollage simulé, amenant l'appareil jusqu'à la vitesse de rotation, mais sans décoller. La nature et l'étendue de la contamination étaient notées avant et après chaque course au décollage. Les principales observations étaient faites à l'extérieur. Des observations complémentaires étaient également faites depuis le poste de pilotage.

Des essais statiques de durée d'efficacité ont été réalisés à l'Aéroport international d'Ottawa, au moyen d'un Falcon 20D, afin de déterminer les

caractéristiques des fluides antigivrage au cours de leur progression vers la perte d'efficacité, dans des conditions de précipitations naturelles.

Résultats et conclusions

Les essais statiques ont révélé que le comportement des fluides antigivrage sur les ailes d'un Falcon 20D ressemble à celui observé sur la voilure d'autres types d'avions lors d'essais antérieurs. C'est généralement sur les bords d'attaque et de fuite que se manifeste d'abord leur perte d'efficacité, en raison des discontinuités produites par les gouvernes. Dans le cas du Falcon 20D, la perte d'efficacité était d'abord observée sur les gouvernes du bord de fuite.

Les résultats des décollages simulés concordaient avec ceux des essais statiques.

Les décollages simulés ont révélé qu'une partie du fluide contaminé demeurait sur la voilure après l'accélération jusqu'à la vitesse de rotation. Cela valait même aux premiers instants de la perte d'efficacité, alors que le fluide était contaminé sur une infime superficie de l'aile seulement. Dans les cas où une plus grande partie de l'aile était contaminée, une grande superficie de l'aile demeurait couverte de fluide contaminé après la course au décollage. Et il restait encore sur l'aile une certaine quantité de fluide encore efficace.

L'essai a donné l'occasion de documenter la fiabilité de l'observation visuelle depuis le poste de pilotage comme méthode de détection de la perte d'efficacité des fluides. Il semble qu'un degré très faible de contamination soit difficile à reconnaître. Mais plus la perte d'efficacité progressait, plus elle était facile à détecter, sauf pour ce qui est des bords d'attaque, pour lesquels le diagnostic demeurait difficile.

Cette brève série d'essais a confirmé la validité du protocole mis en oeuvre pour approfondir la question de l'adhérence des fluides antigivrage. L'observation directe de l'état de la voilure d'un avion représentatif après un décollage simulé permet en effet de recueillir des données fiables sur la quantité de fluide contaminé qui se détache de la voilure pendant la course au décollage. L'observation au sol de l'état de la voilure avant et après la course au décollage semble la méthode la plus simple et la plus satisfaisante de colliger des données. Des images en temps réel de la contamination, enregistrées par une caméra de détection de givre, constitueraient un atout précieux tant pendant l’essai que pour les analyses subséquentes.

Lors des essais, l’avion accélérait jusqu’à la vitesse de rotation, mais sans décoller. On pourrait penser que si l’avion décollait réellement, une plus grande quantité de fluide et de contamination serait chassée de la voilure. Il serait intéressant d’étudier cette hypothèse lors d’essais futurs. Il serait également souhaitable d’évaluer le comportement de différents fluides.

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GLOSSARY

APS	APS Aviation Inc.
DND	Department of National Defence
ISO	International Organization for Standardization
READAC	Remote Environmental Automatic Data Acquisition Concept
RVSI	Robotic Vision System Inc.
SAE	Society of Automotive Engineers

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1 INTRODUCTION

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation undertook a research program to examine the elimination of failed fluids from aircraft wings during takeoff.

1.1 Background

Current regulations require that no one attempt a takeoff if ice, frost, snow, or slush is adhering to the critical surfaces of an aircraft. Currently, failure of the protection provided by anti-icing fluid is identified visually, by observing frozen contamination on the fluid surface. However, the observer cannot ascertain whether the visible frozen contamination is in fact adhering, and cannot judge at what level of coverage the contamination becomes excessive.

Research directed toward resolving the question of whether failed anti-icing fluid still adheres to a wing at lift-off has produced no conclusive results to date. Literature surveys and discussions with researchers have been unable to identify any validated quantitative data. Relevant theoretical analyses are complicated by the interaction of the rough failed fluid surface with the pertinent airflow so that the applied aerodynamic shear forces are difficult to calculate. Observations in the National Research Council open circuit wind tunnel based on takeoff runs with a wing section show that the contamination frequently, though not always, remains in place through to lower turbo prop commuter rotation speeds. However, testing has been restricted to only one wing section and the tunnel is limited to a maximum velocity of 45m/sec, well below the 65m/sec typical of flow over a jet aircraft wing at rotation speed.

Observation of failed fluid behaviour on a typical sample aircraft wing as a direct approach to gaining an understanding of the question of adherence has therefore been pursued.

1.2 Work Statements

Appendix A presents the work statement for the APS Aviation Winter 1997/98 research program. Section 5.11, Provision of Support Services, includes support to this project, *Contaminated Aircraft Takeoff Tests*. Appendix B presents the detailed work statement for this project.

1.3 Objectives

The primary objective was to determine conditions under which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft when subjected to wind shear developed at rotation speeds.

In satisfying this objective, test runs were to be performed with contaminated anti-icing fluid on selected sections of the wing of the National Research Council Falcon 20D research aircraft in a manner so as to not affect aircraft stability. The aircraft was to accelerate to rotation speed but without rotation or lift-off. The behaviour of different levels of contamination at several spanwise locations was observed and recorded both visually and using a remote contamination detection sensor from inside the aircraft. All records were time-stamped to co-ordinate with air speed.

1.4 Test Program

The test program developed to address the objectives comprised static tests of an anti-icing aircraft under conditions of winter precipitation to determine the pattern of failure of the anti-icing fluid, and dynamic tests to observe the behaviour of slush and ice in failed fluid during the takeoff run.

It was recognized that these were the first such tests ever conducted and that only limited results could be anticipated. Follow-on tests are recommended.

2 METHODOLOGY

This section describes the test conditions and test methodologies used, as well as the test equipment and personnel requirements.

2.1 Test Sites

The dynamic tests involving takeoff runs were conducted at Montreal International Airport (Mirabel). This airport offered excellent facilities for the trials: long runways and a central deicing facility, both with very low traffic levels. Runway conditions for the trials were to be clear and dry.

The static tests were conducted at Ottawa International Airport (MacDonald Cartier) at the specified deicing area of a fixed base operator (Shell Aviation).

2.2 Description of Test Procedures

2.2.1 Static Fluid Failure Tests on the Falcon 20D

These tests were intended to provide supplementary information to support the dynamic tests, and to determine the pattern of failure and roughness on wings for this aircraft type.

One session of testing was planned, to be conducted during daylight hours, and to include a set of three tests as follows:

- Two tests with leading edge into the wind; and
- One test with trailing edge into the wind.

Preferred conditions were snow, freezing rain, or freezing drizzle.

Fluids to be used in the tests were Type IV (Ultra+) over Type I (XL54).

The standard procedures used in the program to determine fluid failure patterns on full-scale aircraft were followed, (Transport Canada report, TP 13130E[1]). Briefly, these procedures involved observing the progress of fluid failure on the wing following fluid application, mapping on wing plans the points of failure initiation and patterns of failure progress, and recording times to failure events. Initial film thickness was recorded, including locations at three points on the wing span. Simultaneous tests were conducted on flat plates to provide a common basis of reference to data gathered on other aircraft. Precipitation rates were measured while the trials were underway.

2.2.2 Takeoff Run Trials

Desired weather conditions for the aircraft takeoff run trials were dry, with subfreezing outside air temperature, overcast skies, and relative humidity in excess of 75%. Runway conditions were to be clear and dry. Weather outlook was monitored and the date of testing was selected based on forecast and aircraft availability.

Two areas on the port wing were pre-selected for test purposes. On the Falcon 20D, the wing structure outboard of the fence incorporates an extendable leading edge slat, while the leading edge inboard of the slat is fixed. An area within both of these structural areas was designated for testing to support examination of the influence of the type of leading edge.

For each trial, the entire wing was sprayed following standard procedures for two-step fluid application, and the thickness of the fluid film was then measured. A portable freezing rain sprayer was then used to apply a spray of chilled water to each designated test area in turn. This simulated rain was applied until the treated area reached the desired level of freezing contamination.

The point of initiation and progress of failure was mapped on a wing form by a ground observer, and thickness, adherence and concentration of fluid were measured at points of contamination and at several locations along the wing chord. Failure patterns were also mapped by an experienced observer located within the aircraft cabin, and by the pilot who was given some basic instructions on completing data sheets to record location of failure. The pilot recorded observations only for the "prior to takeoff run" condition.

Location of ice was also recorded using an ice contamination sensor manufactured by Robotic Vision System Inc. (RVSI).

The takeoff run was then performed. Test personnel were situated on board to film the nature of the fluid on the wing during the takeoff run and to film the air speed indicator for reference.

When the aircraft returned and parked at the test location, the wing was examined to identify and document any remnants of fluid or contamination. Any remnants were photographed, and fluid thickness, adherence, and Brix were measured.

The aircraft was then deiced and the test was repeated at a different level of contamination.

One dry run was planned, to check out procedures and to examine the uncontaminated fluid behaviour.

The test plan with defined test parameters is provided as Table 2.1.

Appendix C and Appendix D provide the experimental programs for takeoff run trials and the static tests.

TABLE 2.1

TEST PLAN - REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING TAKEOFF RUN

Run	Trial Type	Location of Tests	Test Area on Wing	Degree of Contamination
1	Failure Pattern	YOW or YUL	Full Wing	Failed Wing
2	Dry Run	YMX	Inboard Area 1 Outboard Area 2	None
3	Takeoff Run 1	YMX	Inboard Area 1 Outboard Area 2	1%
4	Takeoff Run 2	YMX	Inboard Area 1 Outboard Area 2	10%
5	Takeoff Run 3	YMX	Inboard Area 1 Outboard Area 2	25%
6	Takeoff Run 4	YMX	Inboard Area 1 Outboard Area 2	33%

2.3 Data Forms

2.3.1 Static Fluid Failure Tests

Forms used were the same as defined in the program to determine fluid failure patterns on full-scale aircraft[1].

2.3.2 Takeoff Run Trials

Forms for gathering test data included:

- General Form (Once per Session);
- General Form (Every Test);
- De/Anti-icing Form for Aircraft Wing; and
- Fluid Thickness on Aircraft.

Copies of these forms are included in the test procedure (Appendix C). A sample of the form De/Anti-icing Form for Aircraft Wings is shown as Figure 2.1. The locations on the wing designated as test areas are indicated by diagonal hatchmarks.

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[1] 1. D'Avirro, J., *Aircraft Full-Scale Test Program for the 1996-1997 Winter*, APS Aviation Inc., Montreal, December 1997, Transportation Development Centre, TP 13130E, 179.

FIGURE 2.1

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Winter 97/98

DATE: **RUN NUMBER:**

FAILURES CALLED BY:

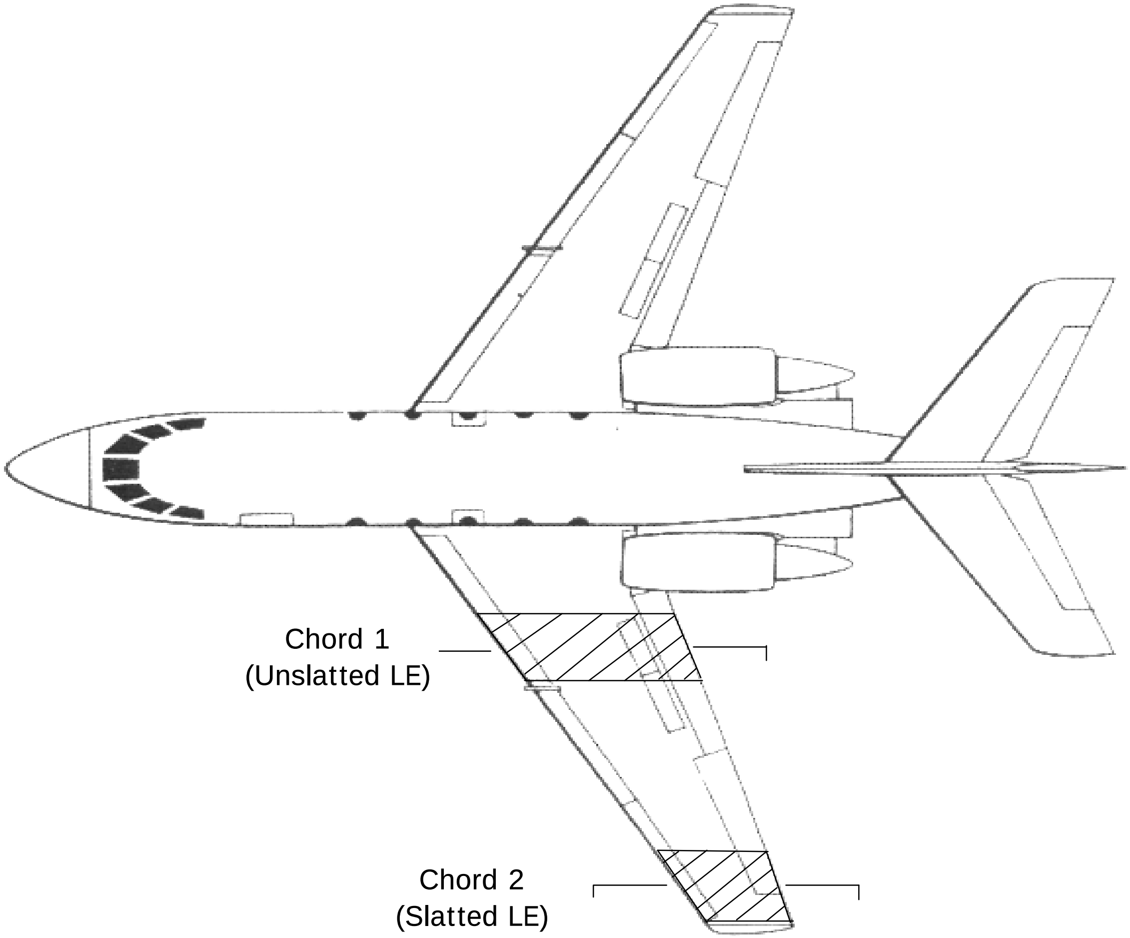
HANDWRITTEN BY:

ASSISTED BY:

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

FALCON 20



Cross-hatched area = Area of wing to be tested

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2.4 Equipment

2.4.1 Static Fluid Failure Tests on the Falcon 20D

Trials were conducted on a Falcon 20D aircraft owned and operated by KnightHawk (Photo 2.1), at Ottawa International Airport. The aircraft was cold-soaked prior to the trials.

Equipment used was the same as defined in the program to determine fluid failure patterns on full-scale aircraft[1]. A portable plate-stand (Photo 2.2) was used for simultaneous flat plate tests.

Type I spray was applied from a Shell Aviation deicing vehicle at the Shell Aviation deicing pad, and Type IV anti-icing fluid was applied with a garden sprayer (Photo 2.3). The operator's standard procedure was to apply

Type IV fluid with the garden sprayer to the aircraft while still in the hangar.

2.4.2 Takeoff Run Trials

The NRC Falcon 20D aircraft was flown to Mirabel Airport early in the morning from the National Research Council Flight Test Facility at Ottawa International Airport. On arrival, a brake line unserviceability was discovered. A replacement part was flown in by helicopter and the aircraft was made serviceable for tests by mid-day.

Photos 2.4 and 2.5 show the aircraft being prepared for test, and the location of the fence on the wing.

In addition to standard test equipment as employed during other test programs on aircraft, some special equipment was employed for these trials as follows.

2.4.2.1 Freezing rain sprayer

A water sprayer to simulate freezing rain was specifically designed and assembled for this project. The principal elements of the sprayer system included:

- A pumping unit (off-the-shelf residential car wash unit);

- An air compressor;
- A portable generator;
- An ice bath water reservoir; and
- A hand-held spray bar.

The spray bar was made available by the National Research Council who had previously used it for production of freezing rain at the Climate Engineering Facility. The unit was equipped with two spray heads that accepted hypodermic needles of various gauges as used at the National Research Council Climatic Engineering Facility to produce different droplet sizes. In this application, 20 gauge hypodermic needles were installed to produce droplet sizes appropriate to freezing rain.

In the process of designing the sprayer system, a similar system assembled previously by AlliedSignal was examined, and advantage was taken of their experience.

Evaluation trials conducted at the APS test site prior to the aircraft tests demonstrated that rates typical of freezing rain could be achieved using the portable unit. As the spray bar was hand-held and manipulated by an operator to provide coverage over the desired area, rates and consistency of coverage were operator dependent. For these trials, a single operator was used who developed a satisfactory level of skill. Calm wind conditions were necessary in order to achieve satisfactory coverage.

During preliminary trials on the day of aircraft trials, the sprayer nozzles experienced freezing during operation. The water reservoir had been prepared with a large amount of ice to maintain a low water temperature, just above freezing, and this was exchanged for water only. No further nozzle freezing was encountered, and the outside air temperature was low enough to compensate. Photo 2.6 shows the water spray equipment positioned in a boom truck, and Photo 2.7 shows the spray bar.

Photo 2.8 shows an operator located in the bucket manipulating the water spray bar.

2.4.2.2 Other equipment

An RVSI ice contamination sensor and an RVSI representative was made available for these trials. Because the aircraft wing surfaces were coated with a polyurethane finish, the sensor was not able to identify fluid failures during the trial sessions. Nevertheless, the test areas were scanned, and the collected data is available for interpretation if needed.

Deicing vehicles were provided by AéroMag 2000 Inc. Access to the deicing facility was arranged with AéroMag and Aéroports de Montréal staff. Photo 2.9 shows an AéroMag technician applying Type IV fluid from the bucket of an AéroMag deicing truck.

Currently, there is no single accepted method to determine whether failed fluid has adhered to the wing surface. Different observers follow different routines to assess possible adherence: some blow on the failed fluid to determine whether it will move, while others probe with a pencil tip to see if the ice has adhered. In an attempt to remove the subjective nature of observations on adherence, APS developed an instrument to determine adherence. Essentially, the instrument was composed of a brush installed between two legs that hold the bristles at a fixed distance above the surface. The user allows the legs to penetrate through the failed fluid to the wing surface, and then moves the apparatus forward while observing if the fluid is dislodged by the bristles, or if the bristles ride over the failed fluid. In the latter case, the fluid would be considered to have adhered to the surface. The apparatus is shown in Photo 2.10.

A complete list of equipment is included in Appendix C.

2.5 Fluids

Fluids used in the takeoff run trials were Union Carbide XL54 Type I fluid followed by Union Carbide Ultra+Type IV fluid. Fluids were supplied from the local AéroMag fluid inventory.

Fluids used in the static tests included Union Carbide XL54 provided by the spray operator (Shell Aviation) and Ultra+ provided by KnightHawk. The Ultra+ fluid was applied with a garden sprayer (Photo 2.3).

2.6 Personnel

For the takeoff run trials, the Falcon 20D aircraft was operated by a National Research Council crew.

AéroMag conducted aircraft spray operations in conformance with their standard procedures.

An RVSI representative was present to operate the ice contamination sensor.

APS staff co-ordinated trials and gathered test data. Individual task assignments are shown in the procedure in Appendix C.

Representatives from Transport Canada Transportation Development Centre and De Havilland/Bombardier participated as observers.

Shell Aviation and KnightHawk staff participated in static tests conducted at Ottawa airport.

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Photo 2.1

KnightHawk Falcon 20D

Photo 2.2

Falcon 20D Static Test Setup

Photo 2.3

Falcon 20D Static Test Spray Equipment

Photo 2.4

Preparing NRC Falcon 20D for Dynamic Testing

Photo 2.5

NRC Falcon 20D Fluid Thickness Measuring (Wing Fence at Right)

Photo 2.6

Boom Truck with Water Spray Equipment

Photo 2.7

Water Spray Bar

Photo 2.8

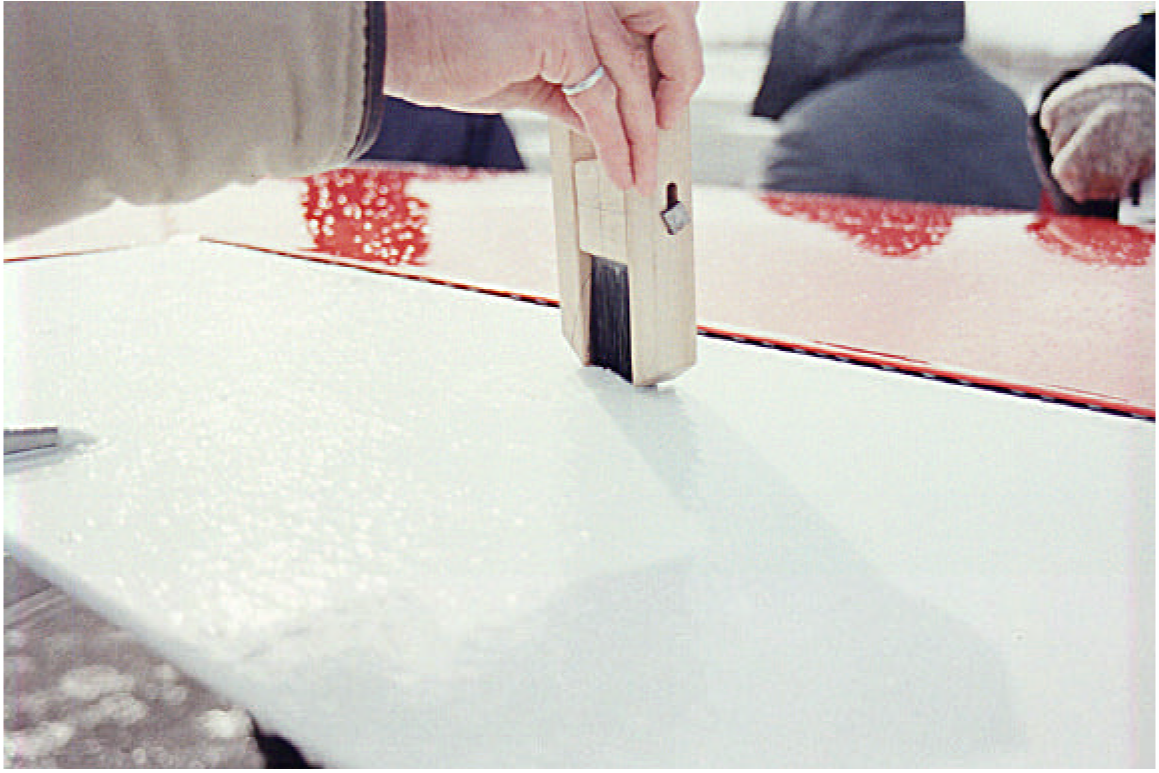
Applying Water Spray from Bucket

Photo 2.9

Spraying Type IV Fluid

Photo 2.10

Testing Adherence of Failed Fluid



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3 DESCRIPTION AND PROCESSING OF DATA

3.1 Overview of Tests

3.1.1 Static Tests

Two tests were conducted, one with a Type I fluid only, and the second with a Type I fluid oversprayed with a Type IV fluid.

Conditions were outside air temperature at -3°C with light snow. The aircraft was positioned nose into the wind for both tests, with wind speed varying from 15 to 20 kph. Tests were conducted during daylight hours.

3.1.2 Takeoff Run Tests

Three aircraft test runs were conducted, starting at mid-day (Table 3.1). The first test run made use of both wings; one tested with uncontaminated fluid and the other with fluid contaminated to initial failure (about 1% of the area designated for testing was covered with failed fluid). The two subsequent runs made use of one wing only, with levels of failure at 10% and 33%. Table 3.1 represents the actual tests performed.

Conditions during the trials were dry with an overcast sky clearing in late afternoon, relative humidity at 68%, outside air temperature at -13°C, and wind at 29 kph. The aircraft was parked nose into the wind for the deicing operation.

Due to wind direction, takeoff runs were conducted on Runway 24 (see airport diagram, Figure 3.1) involving a lengthy taxi run to the runway button. In the airport diagram, the deicing centre is located in the oval between AB-3 and AB-4. During the takeoff run, the aircraft accelerated to 125 kts, representing normal rotation speed, and then decelerated using flight control surfaces for drag. With the long runway, little braking was required and there was no requirement for special brake cooling procedures during the test session.

Examining Run 2 as a typical test, the time required to achieve the desired level of failure within the two test areas following fluid application was about 20 minutes, and the subsequent aircraft taxi, takeoff run, and return to the deicing centre required about 23 minutes.

TABLE 3.1

TAKEOFF RUN TESTS PERFORMED

March 12, 1998
Montreal International Airport (Mirabel)

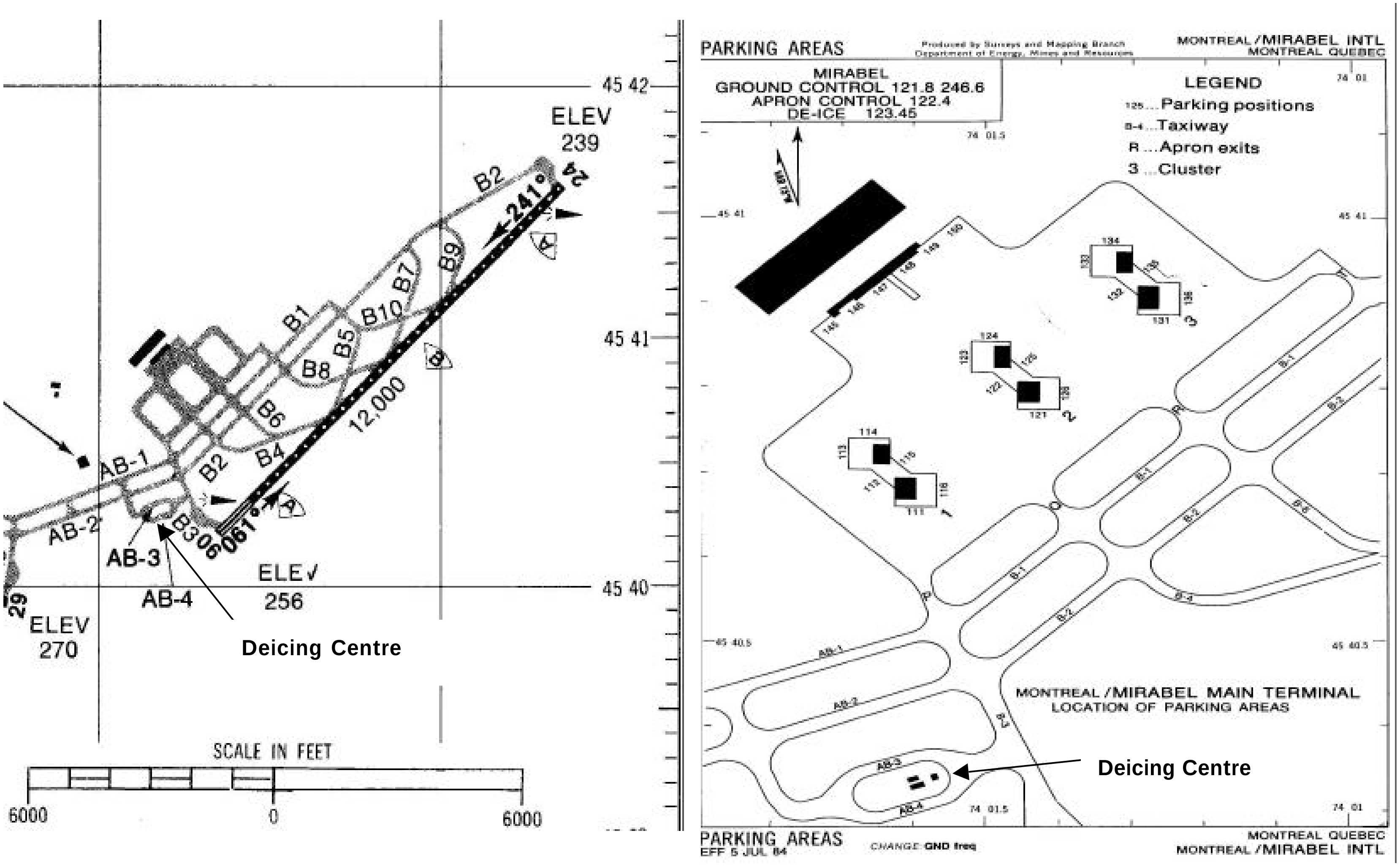
OAT: -13°C
Wind: 29 kph
RH: 68%

Run	**Wing**	**Fluid Condition***	**Max. Speed during Takeoff Run (kts)**	**Vr**
1	Port Starboard	1% Failed Uncontaminated	125	120
2	Port	10% Failed	128	120
3	Port	33% Failed	128	120

* Fluid application: UCAR XL54 (type I) followed by UCAR Ultra+ (Type IV).

Figure 3.1

Montreal International Airport (Mirabel) Deicing Centre



3.2 Description of Data Collected and Analysis

3.2.1 Static Tests

Data collection included mapping of wing failure patterns, measurement of failure times on wings and plates, and measurement of precipitation rate. Shortly after application, the thickness of Type IV fluid was measured along a selected chord of the wing.

3.2.2 Takeoff Run Tests

Data collection included measurement of thickness of fluid applied, prior to application of simulated freezing rain. The specific areas of failure within the designated test areas were mapped on wing plans, and videotaped and photographed, both before and following the takeoff run. The thickness of the unfailed fluid, and of any patches of frozen fluid, was measured before and after takeoff runs.

Completed data forms are discussed in the following section, and a complete set of data forms is provided in Appendix C.

During the takeoff run, attempts were made to videotape the behaviour of fluid and failed patches on the wing, through cabin windows. This was largely unsuccessful, affected by movement during the run, the foggy condition of the window, and the short duration of the run.

Due to the combination of the direction of the takeoff run and the port wing being used for testing, it was not possible to place an observer in a position suitable for observing the takeoff run from the ground.

4 ANALYSIS AND OBSERVATIONS

4.1 Static Tests

The initiation of failure and pattern of progression on the Falcon 20D aircraft were was similar to those observed on other aircraft types in previous tests[1]. In both of these two tests involving Type I fluid only and Type IV over Type I, first failures occurred on control surfaces at the rear of the wing, either on the aileron or on the flap.

In the test involving Type I fluid only, the second area to fail was the leading edge, followed by the top of the wing.

In the test using Type IV over Type I fluid, the leading edge was last to fail. The very light snowfall appeared to accumulate on the flatter areas of the wing, eventually causing failure, but flowed off the leading edge area, leaving it clean for an extended period.

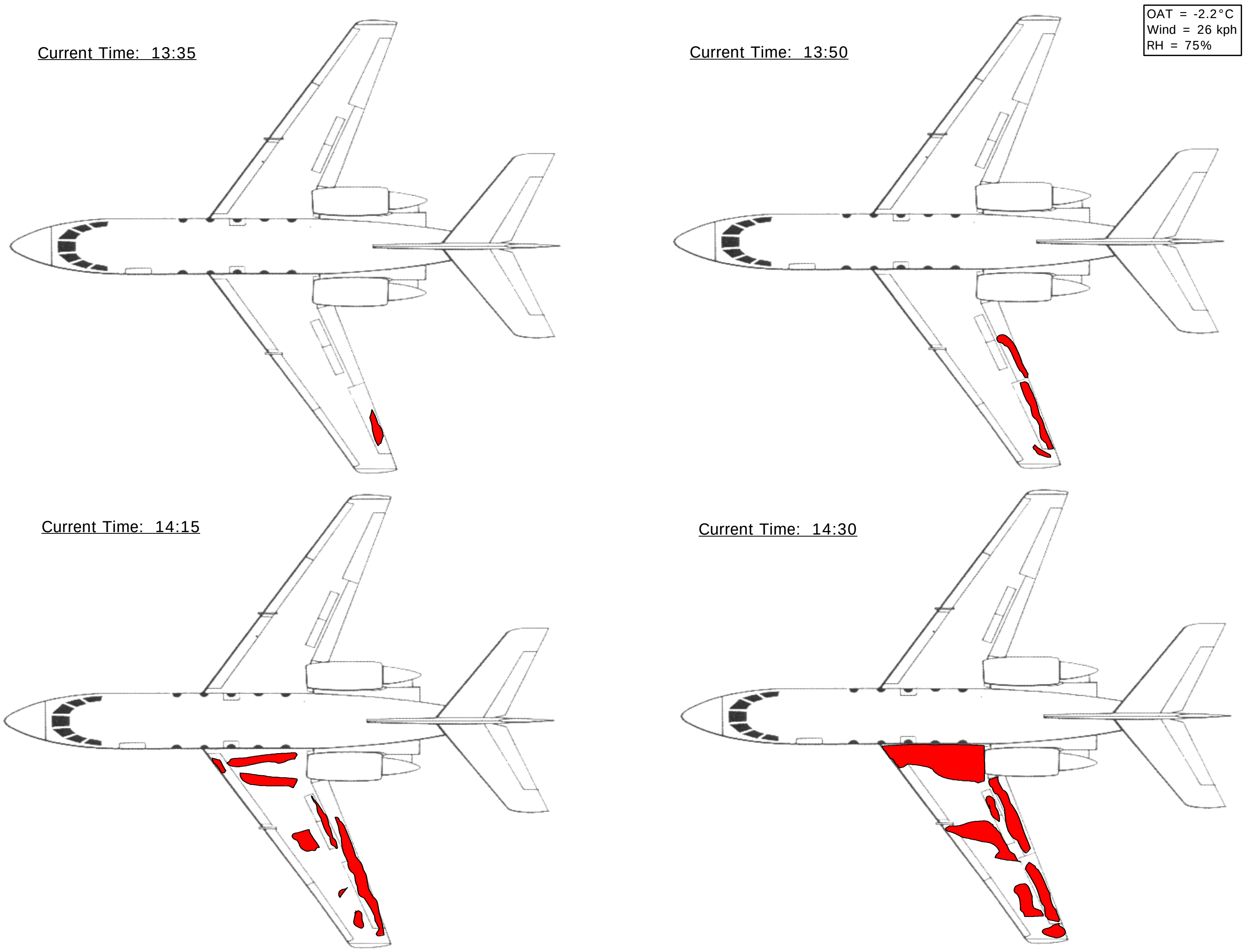
The pattern of failure for the Type IV fluid is shown in Figure 4.1. This is compared to typical results observed on a Boeing 737 aircraft from previous tests (see Figure 4.2). The resulting pattern of failure for the Type I fluid test is shown in Figure 4.3.

FIGURE 4.1

PROGRESSION OF FAILURE - STATIC TEST
Ucar Ultra + over XL54

Run 2 - March 14, 1998

Start Time: 10:47



Current Time: 13:35

Current Time: 13:50

OAT = -2.2°C
Wind = 26 kph
RH = 75%

Current Time: 14:15

Current Time: 14:30

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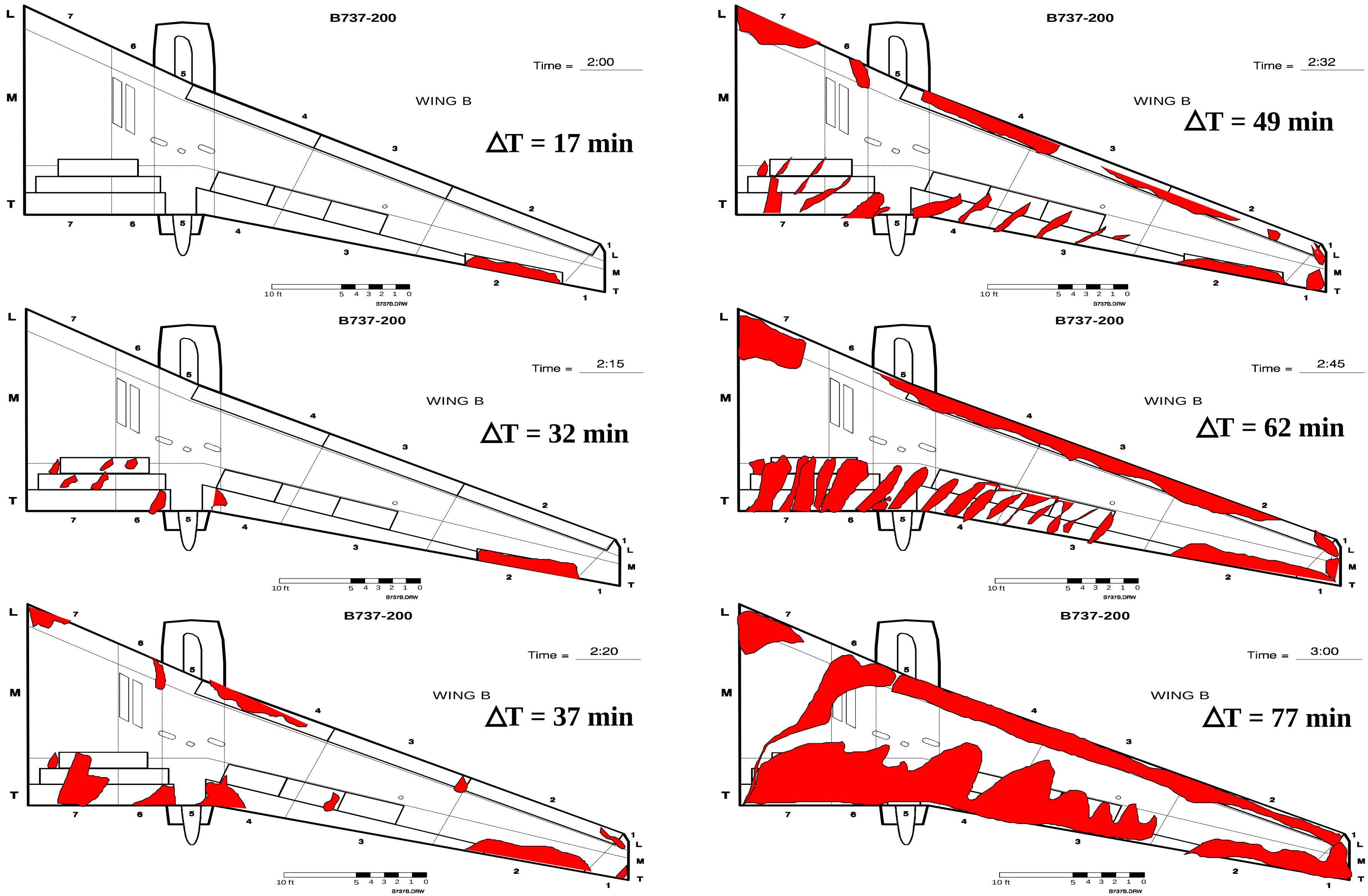
FIGURE 4.2

PROGRESSION OF FAILURES (WINTER 1996/97 TEST PROGRAM)

ID 24



File: cm1380\report\falc_20\Pro_id24.xls
Printed: 11/2/01

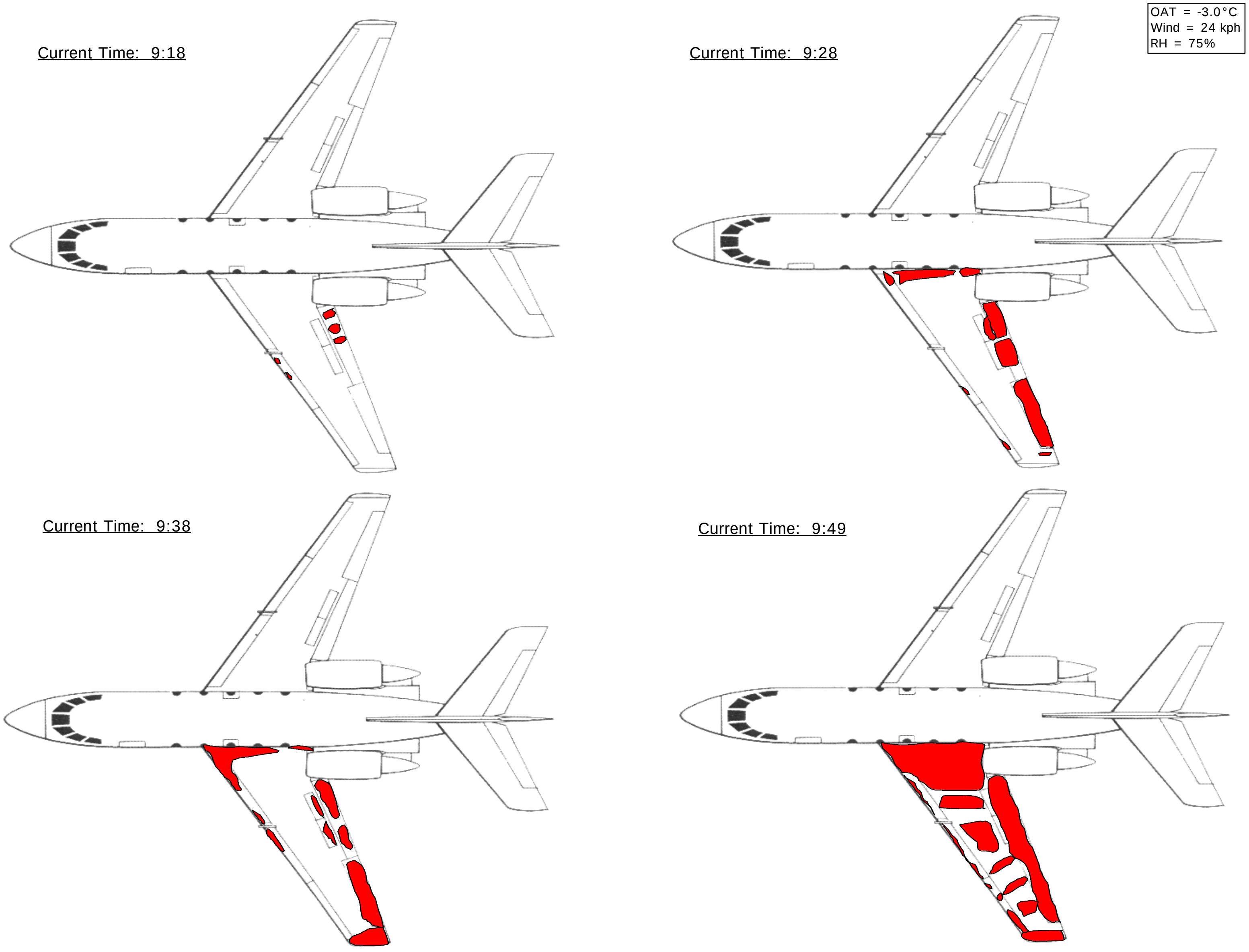
FIGURE 4.3

PROGRESSION OF FAILURE - STATIC TEST

Ucar XL54

Run 1 - March 14, 1998

Start Time: 9:03



OAT = -3.0°C
Wind = 24 kph
RH = 75%

4.2 Takeoff Run Tests

4.2.1 Run One: Starboard Wing Uncontaminated, Port Wing 1% Failed

The following are observations of wing conditions prior to and following the takeoff run, recorded by the outside observer, the experienced cabin observer, and the pilot.

Prior to Takeoff Run

- Outside observer: Figure 4.4 shows the port wing contaminated to initial (1%) failure according to the outside observer evaluation. The locations of failure on the outer chord are on the aileron and the leading edge, and on the inner chord, on the surface just forward of the flap and behind the spoiler panel (Figure 4.4a);

- Experienced cabin observer: Figure 4.4b shows the failed area on the aileron, while the failed areas on the leading edge and on the inner chord were not identified; and

- Pilot: Figure 4.4c shows failure on the leading edge just outboard of the fence, but none on the aileron and inner chord. The actual location of failure on the leading edge was further out on the wing.

Following Takeoff Run

- Outside observer: Figure 4.5a shows a small amount of the failed fluid is still remaining on the outer aileron, as corroborated by Photo 4.1. The failed fluid has been cleared from the leading edge, and from the inner chord; and

- Experienced cabin observer: Figure 4.5b accurately shows the remaining failed fluid on the outer end of the aileron. Fluid is still visible on the top of the wing.

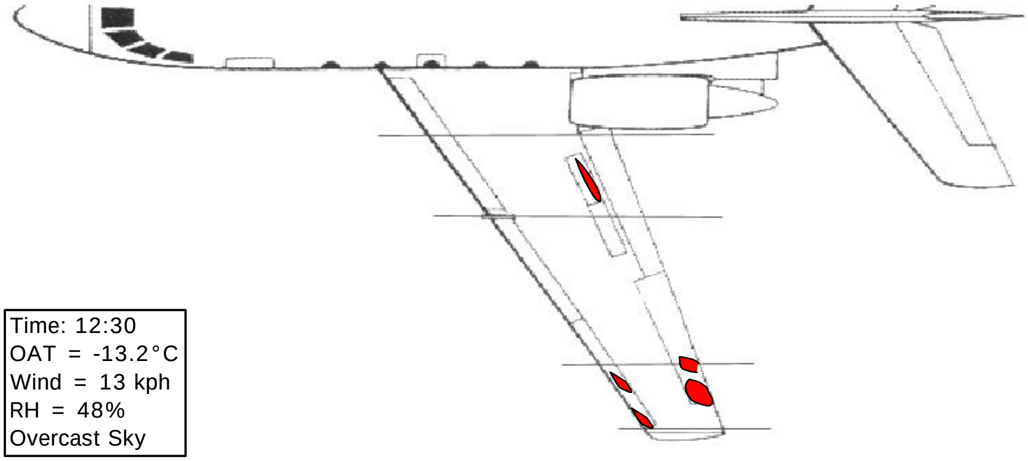
Figure 4.6 presents the fluid thickness data measured at indicated points on each test chord: after fluid application, after fluid failure, and after the takeoff run. A thin film of unfailed fluid up to 0.1 mm thick (5 mil) is still remaining on the wing surface. A thin film of fluid was also observed on the starboard wing after the takeoff run.

FIGURE 4.4

Failure Pattern Before Takeoff Run

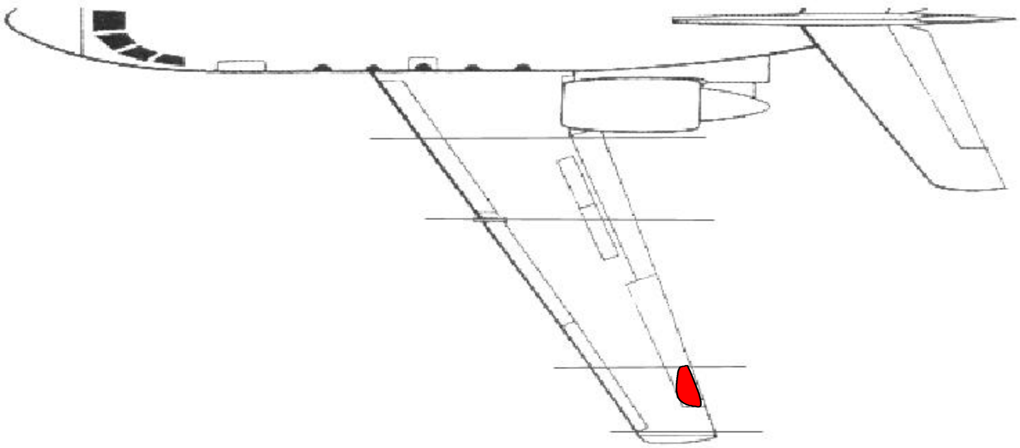
Run 1 - March 12, 1998

a) Failure Pattern Reported by Outside Observer



Time: 12:30
OAT = -13.2°C
Wind = 13 kph
RH = 48%
Overcast Sky

b) Failure Pattern Reported by Experienced Cabin Observer



c) Failure Pattern Reported by Pilot

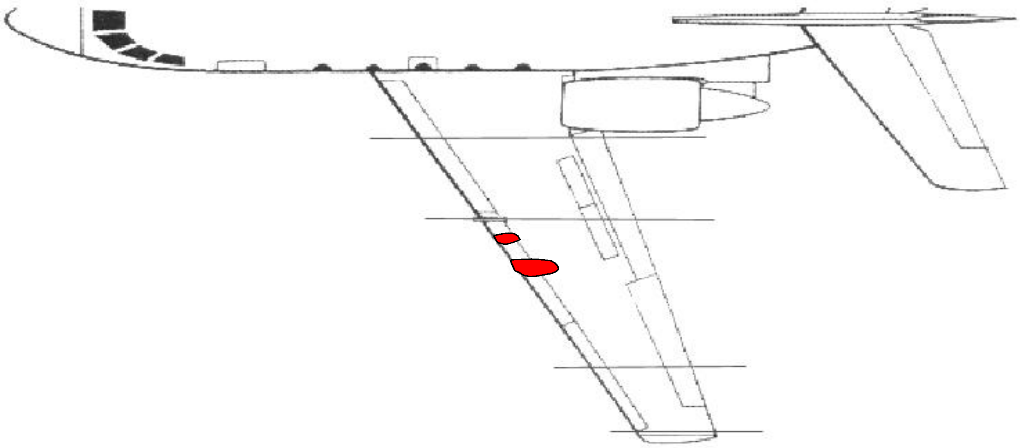
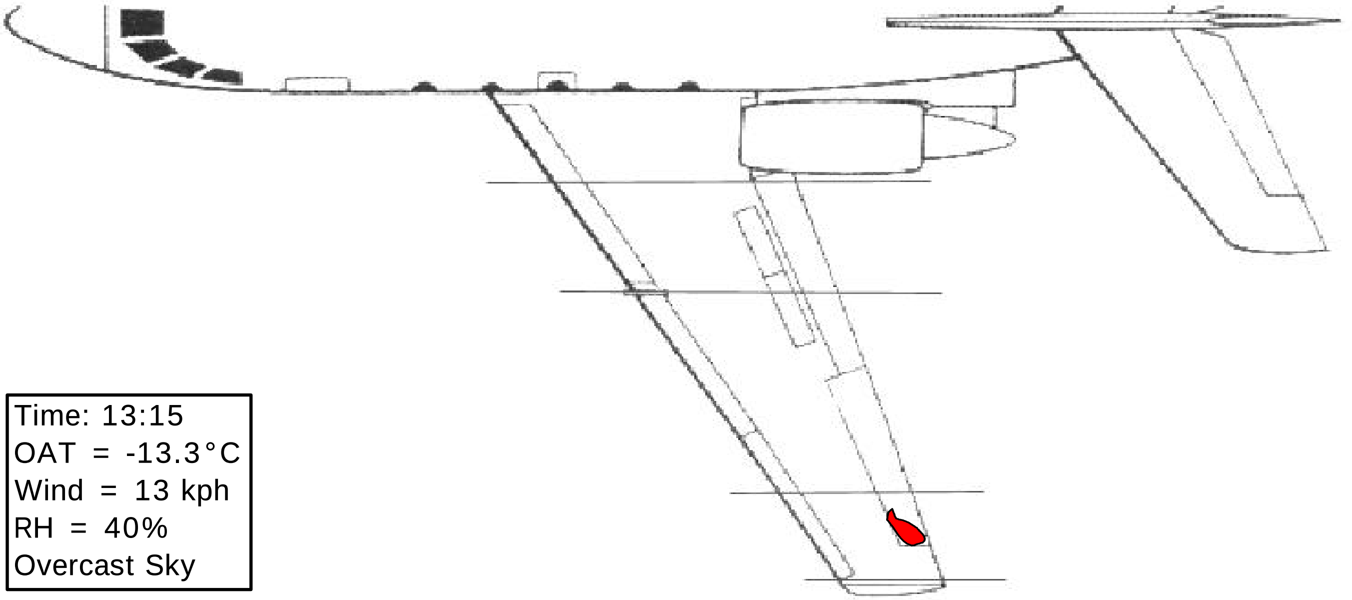


FIGURE 4.5

Failure Pattern After Takeoff Run

Run 1 - March 12, 1998

a) Failure Pattern Reported by Outside Observer



Time: 13:15
OAT = -13.3°C
Wind = 13 kph
RH = 40%
Overcast Sky

b) Failure Pattern Reported by Experienced Cabin Observer

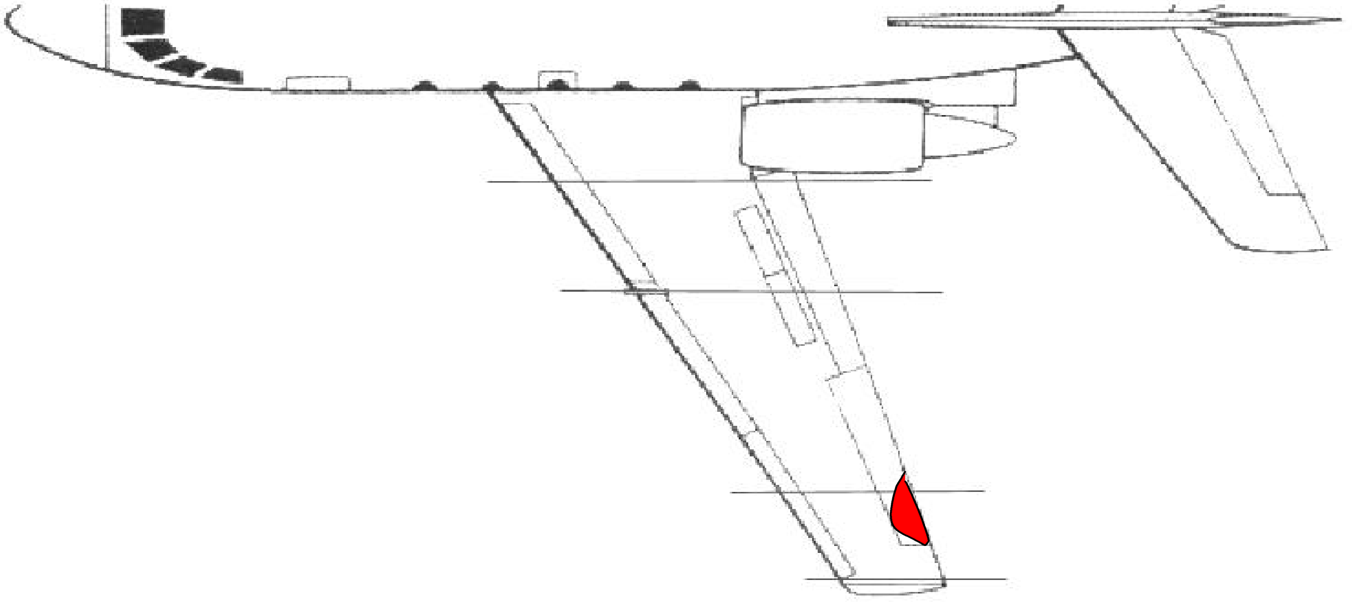


FIGURE 4.6

FLUID THICKNESS ON AIRCRAFT - RUN 1

DATE: 12-Mar-98

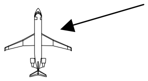
RUN #: 1

AIRCRAFT TYPE: Falcon 20

WING: [✓ PORT (A)] STARBOARD (B)

DIRECTION OF AIRCRAFT: ________ DEGREES

DRAW DIRECTION OF WIND WRT WING:



1st FLUID APPLICATION

Actual Start Time: 12:14:25

Actual End Time: 12:15:00

Amount of Fluid Sprayed: 55 Litres

Type of Fluid: XL54

Temperature of Fluid: 160°F

2nd FLUID APPLICATION

Actual Start Time: 12:15:35

Actual End Time: 12:16:40

Amount of Fluid Sprayed: 5 Litres

Type of Fluid: ULTRA +

	Chord 1 (Inner)						Chord 2 (Outer)					
	After Application		After Failure		After Take-off		After Application		After Failure		After Take-off	
Location	**Time**	**Gauge (mil)**	**Time**	**Gauge (mil)**	**Time**	**Gauge (mil)**	**Time**	**Gauge (mil)**	**Time**	**Gauge (mil)**	**Time**	**Gauge (mil)**
1	12:20:30	18.0	12:30:30	8.5	13:14	Film	12:16:56	37.5	12:35:58	5.5	13:12	Film
2	12:20:50	32.5	12:30:50	23.0	13:14	Film	12:17:00	43.0	12:36:10	6.4	13:12	Film
3	12:21:00	32.5	12:31:20	13.0	13:14	1.5	12:17:10	32.5	12:36:25	9.5	13:12	Film
4	12:21:15	32.5	12:31:30	18.0	13:14	2.5	12:17:30	32.5	12:36:31	11.0	13:12	1.5
5	12:21:30	43.0	12:31:46	32.5	13:14	4.5	12:17:53	32.5	12:36:40	9.5	13:12	2.5
6	12:20:05	18.0	12:32:50	15.0	13:14	4.5	12:18:30	32.5	12:35:42	5.5	13:13	4.5
7	12:19:55	23.0	12:32:40	13.0	13:14	2.5	12:18:35	19.0	12:35:20	6.4	13:13	5.5
8	12:19:45	18.0	12:32:30	11.0	13:14	3.5	12:18:40	23.0	12:35:05	12.0	13:13	2.5
9	12:19:30	19.0	12:32:16	11.0	13:14	2.5	12:18:54	19.0	12:34:50	11.0	13:13	3.5

<u>Location</u>

1 - LE Nose

2, 8- Half-way

3,4,6,7 - 1" from joint

5 - As far as can reach

9 - 6" from TE

COMMENTS:

MEASUREMENTS BY: John D'Avirro

HANDWRITTEN BY: Medhat Hanna

4.2.2 Run Two: Test of 10% Failed Fluid

Prior to Takeoff Run

- Outside observer: The port wing was contaminated to the 10% level according to the outside observer evaluation. Figure 4.7a shows failed areas on both leading and trailing edges for both test chords. The extent of failure on the rear of the wing is much greater than on the leading edge.

- Experienced cabin observer: Figure 4.7b shows failed fluid located on the flap and aileron. The small amount (identified by the exterior observer) located on the leading edge and on the spoiler panel is not identified.

- Pilot: Figure 4.7c inaccurately shows failure on the leading edge and on top of the wing just outboard of the fence. Actual failure on the outer test chord leading edge and aileron has been identified accurately. Failures on the flap and spoiler are missed.

Following Takeoff Run

- Outside observer: Figure 4.8a shows failed fluid still remaining at all areas except on the spoiler panel which seems to have cleared. The spoiler panel was raised to assist in deceleration during the takeoff run which may have cleaned it of ice; and

- Experienced cabin observer: Figure 4.8b shows the location of ice remaining. The extent of ice on the inner chord has diminished while the outer appears to be unchanged. Existence of fluid on the top surface of the wing is noted.

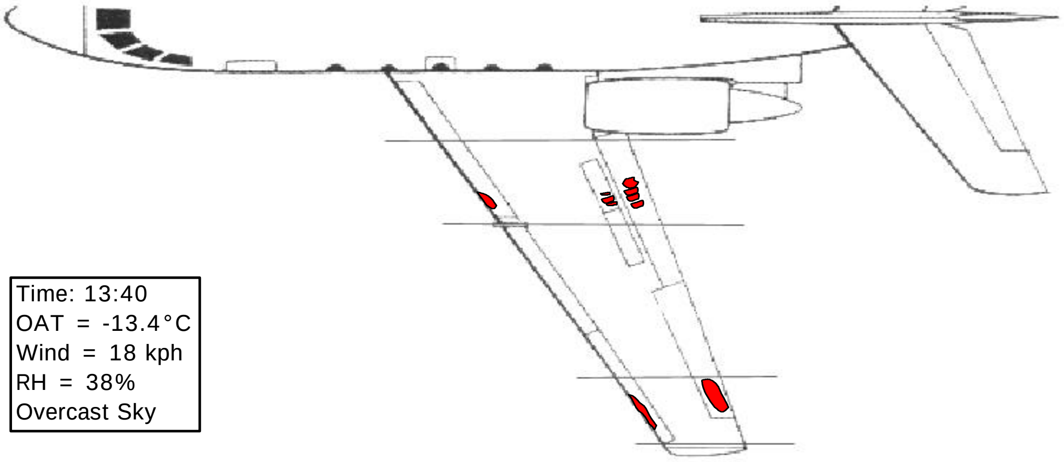
Figure 4.9 provides data on fluid thickness as well as ice formations prior to and following the takeoff run. Any fluid remaining on the wing following the takeoff run was reduced in thickness relative to measurements made on the previous run. This is probably a result of the greater fluid dilution with the longer exposure to precipitation. Ice formation on chord 1 appears to have been reduced in extent during the takeoff run, whereas the ice formation at chord 2 appears to have remained the same.

FIGURE 4.7

Failure Pattern Before Takeoff Run

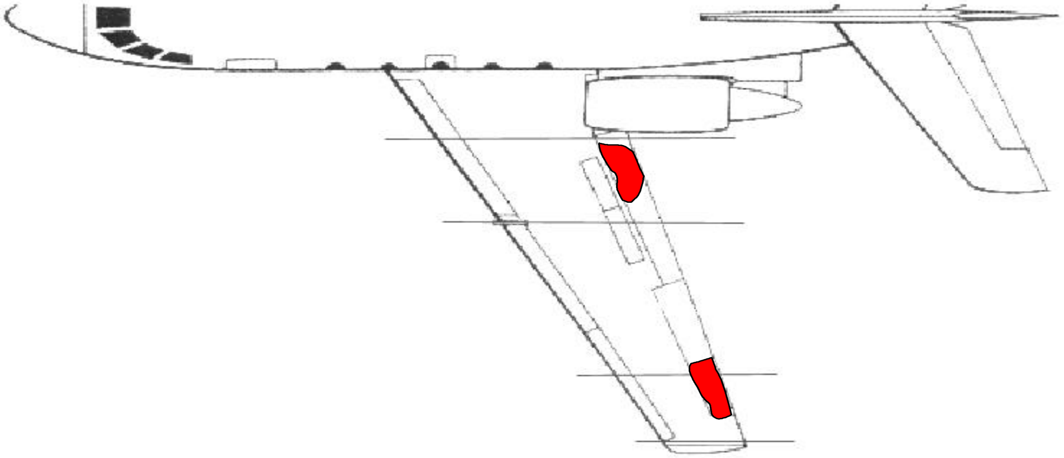
Run 2 - March 12, 1998

a) Failure Pattern Reported by Outside Observer



Time: 13:40
OAT = -13.4°C
Wind = 18 kph
RH = 38%
Overcast Sky

b) Failure Pattern Reported by Experienced Cabin Observer



c) Failure Pattern Reported by Pilot

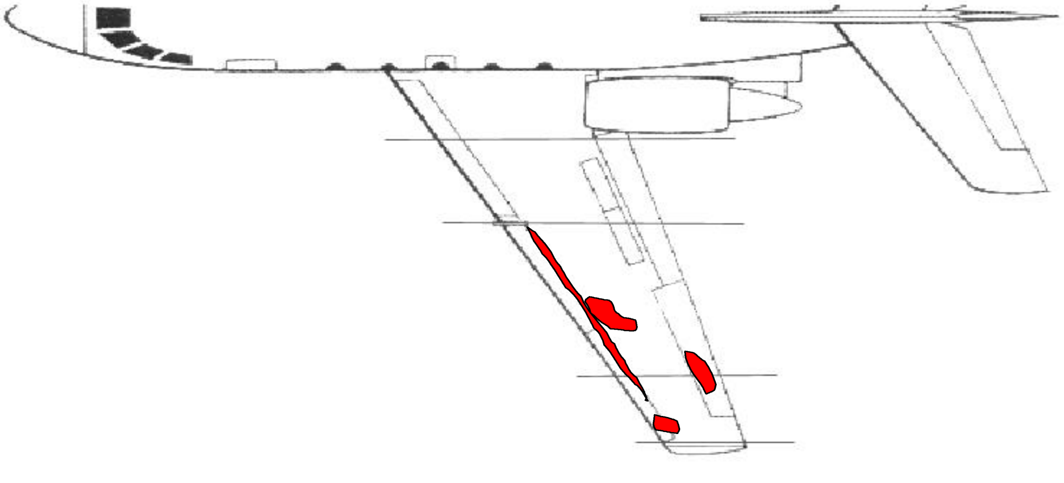
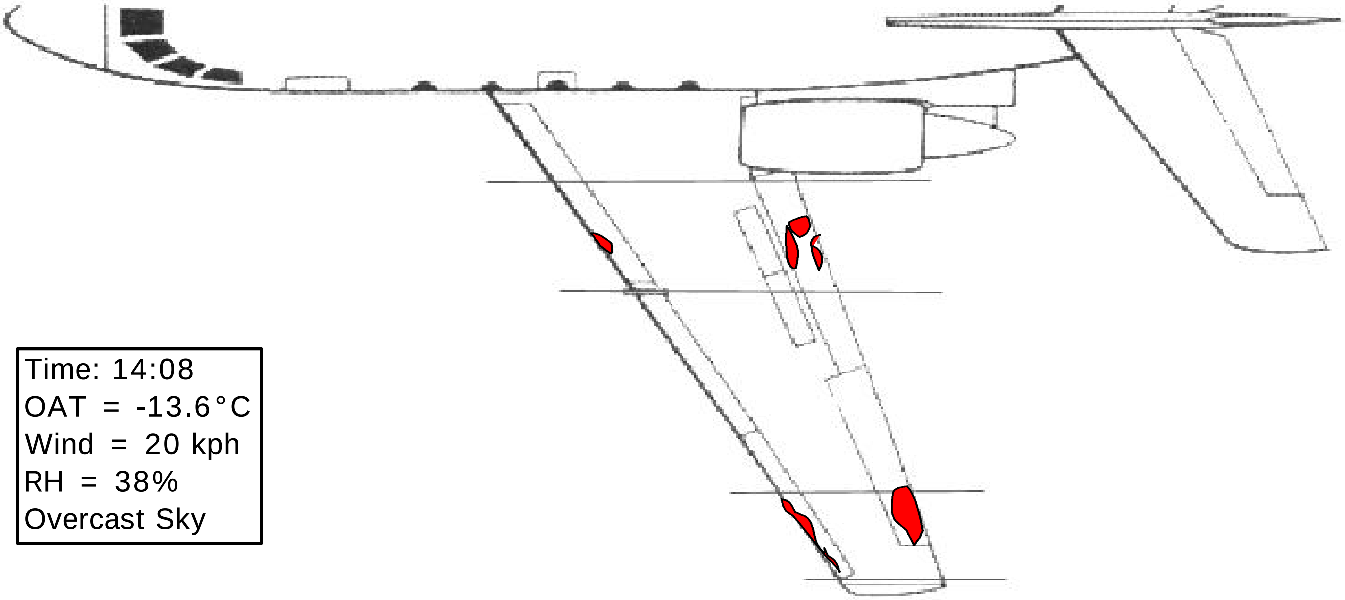


FIGURE 4.8

Failure Pattern After Takeoff Run
Run 2 - March 12, 1998

a) Failure Pattern Reported by Outside Observer



Time: 14:08
OAT = -13.6°C
Wind = 20 kph
RH = 38%
Overcast Sky

b) Failure Pattern Reported by Experienced Cabin Observer

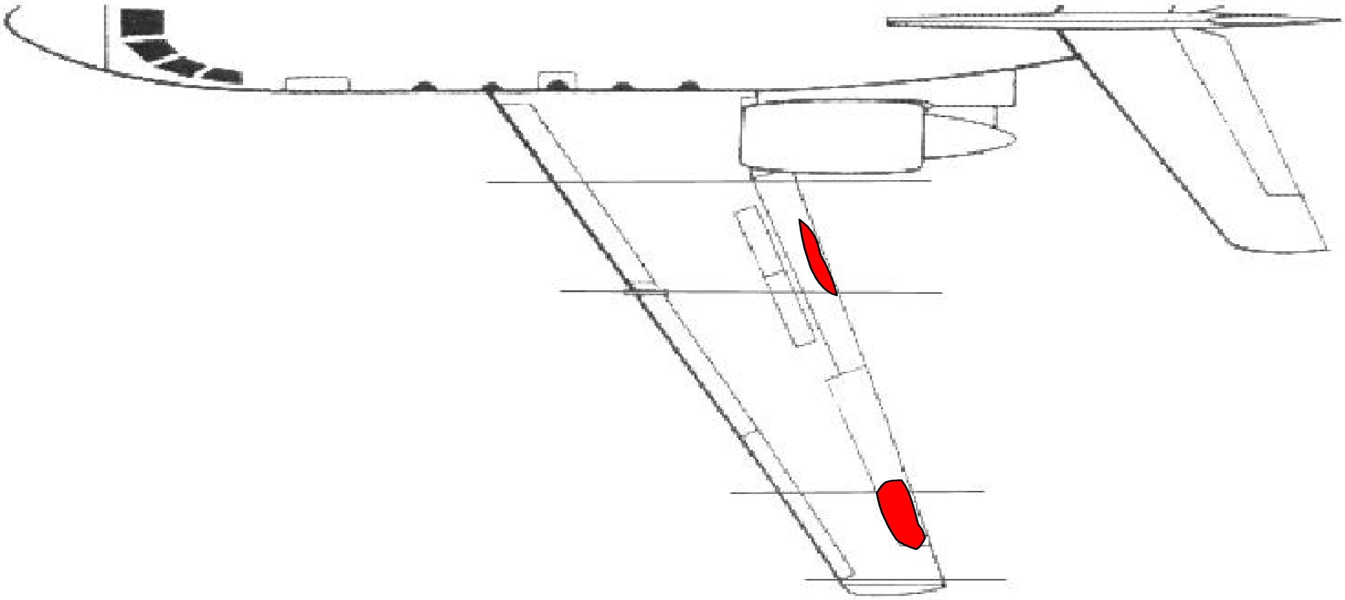


FIGURE 4

FLUID THICKNESS ON AIRCRAFT

DATE: 12-Mar-98

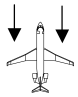
RUN #: 2

AIRCRAFT TYPE: Falcon 20

WING: [✓ PORT (A)] STARBOARD (B)

DIRECTION OF AIRCRAFT: ________ DEGREES

DRAW DIRECTION OF WIND WRT WING:



1st FLUID APPLICATION

Actual Start Time: 13:26:06

Actual End Time: 13:27:00

Amount of Fluid Sprayed: 32 Litres

Type of Fluid: XL54

Temperature of Fluid: 170°F

2nd FLUID APPLICATION

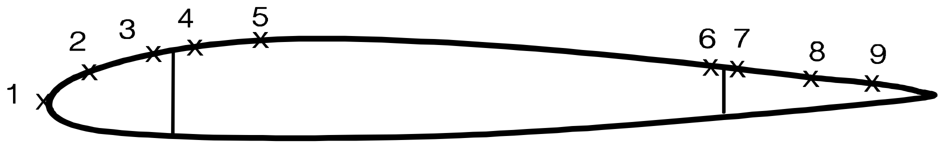
Actual Start Time: 13:27:00

Actual End Time: 13:27:30

Amount of Fluid Sprayed: 10 Litres

Type of Fluid: ULTRA +

	Chord 1 (inner)						Chord 2 (Outer)					
	After Application		After Freeze		After Take-off		After Application		After Freeze		After Take-off	
Location	**Time**	**Gauge**	**Time**	**Gauge**	**Time**	**Gauge**	**Time**	**Gauge**	**Time**	**Gauge**	**Time**	**Gauge**
1	13:28:20	18	13:40:00	6	14:08	Film	13:32:30	22	13:44:00	4	14:09	Film
2	13:28:30	20	13:40:00	11	14:08	Film	13:32:30	20	13:44:00	1	14:09	Film
3	13:28:40	18	13:40:00	12	14:08	Film	13:32:30	20	13:44:00	5	14:09	Film
4	13:28:50	20	13:40:00	22	14:08	1	13:32:30	20	13:44:00	7	14:09	Film
5	13:29:00	24	13:40:00	11	14:08	1	13:32:30	20	13:44:00	4	14:09	Film
6	13:29:45	10	13:39:00	Ice	14:11	Ice (<5)	13:31:50	16	13:45:00	3	14:11	Film
7	13:29:50	11	13:39:00	Ice	14:11	Film	13:31:00	9	13:45:00	Ice (7)	14:11	Ice
8	13:30:00	16	13:39:00	Ice	14:11	Film	13:30:55	10	13:45:00	Ice (7)	14:11	Ice (12)
9	13:30:10	14	13:39:00	Ice	14:11	Film	13:30:50	16	13:45:00	Ice (7)	14:11	Ice (12)



<u>Location</u>

1 - LE Nose

2, 8- Half-way

3,4,6,7 - 1" from joint

5 - As far as can reach

9 - 6" from TE

COMMENTS:

Inner Chord : Brix at # 9 = 12, Brix @ 2 = 43

Outer Chord, Brix at # 6 = 6

Brix of 47 on Mid-section of wing at 14:13

Brix of 11 on # 8 (Outer) at 14:15

MEASUREMENTS BY: John D'Avirro

HAND WRITTEN BY: Medhat Hanna

4.2.3 Run Three: Test of 33% Failed Fluid

Prior to Takeoff Run

- Outside observer: Precipitation was applied continuously until 33% of each test chord area had failed according to the outside observer evaluation. Figure 4.10a shows the location and the pattern of fluid failure reported. At this level of failure, the complete leading edge surface and all flight control surfaces within each chord area are covered with failed fluids. Photo 4.2 shows the thickness of ice formation on the leading edge. Photo 4.3 presents a view further back on the wing chord, showing fingers of ice formation extending onto the main wing, but with the major part of the main wing still covered with fluid. Photo 4.4 shows the pebbled ice formation on the aileron surface with a 25¢ coin placed for scale. Photo 4.5 gives a full perspective of the outer wing showing the extent of icing on the leading edge. Photo 4.6 shows slush formation in the thick layer of fluid on the top of the outer wing.

- Experienced cabin observer: Figure 4.10b reflects the actual pattern of failure. At this level of failure, the full extent of failure can be identified accurately from inside the cabin.

- Pilot: In Figure 4.10c, as with the experienced observer, the pilot has correctly identified the full extent of failure.

Following Takeoff Run

- Outside observer: Figure 4.11a reflects the extent of ice formation remaining in each test chord area following the takeoff run. At the outer test chord, the area covered by failed fluid appears to have diminished during the takeoff run (see Photos 4.5 and 4.8), while staying the same for the inner chord (Photo 4.7).

  Photo 4.9 shows that same outer chord area with the leading edge extended, demonstrating that the ice formation has adhered to the wing and does not slip off with the steep slope. The pattern of ice formation in this photo can be compared to Photo 4.6 (prior to takeoff run) for similarity.

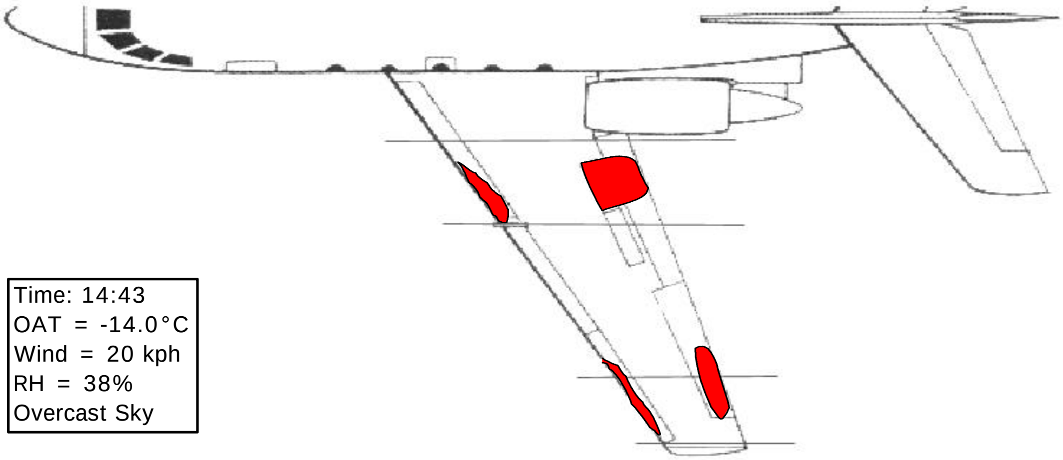
- Experienced cabin observer: Figure 4.11b indicates a larger area remaining covered with failed fluid than that noted by the outside observer.

FIGURE 4.10

Failure Pattern Before Takeoff Run

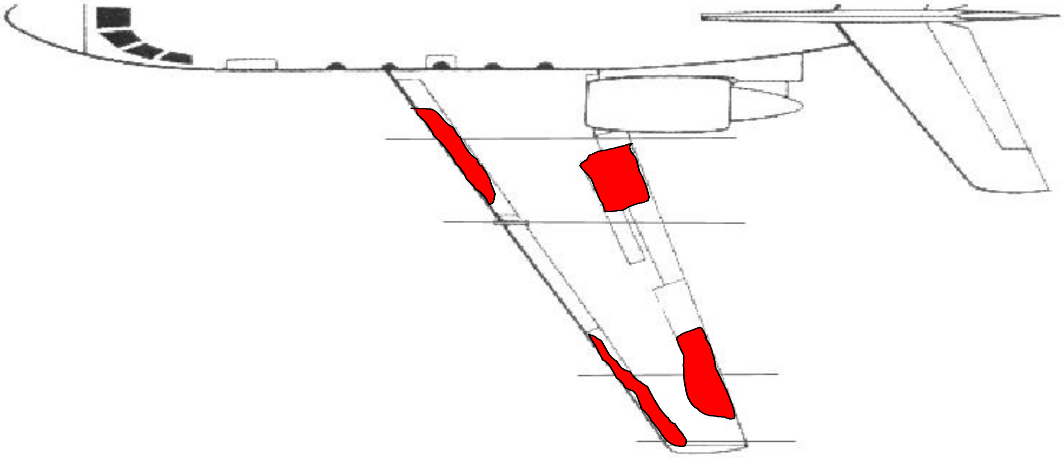
Run 3 - March 12, 1998

a) Failure Pattern Reported by Outside Observer



Time: 14:43
OAT = -14.0°C
Wind = 20 kph
RH = 38%
Overcast Sky

b) Failure Pattern Reported by Experienced Cabin Observer



c) Failure Pattern Reported by Pilot

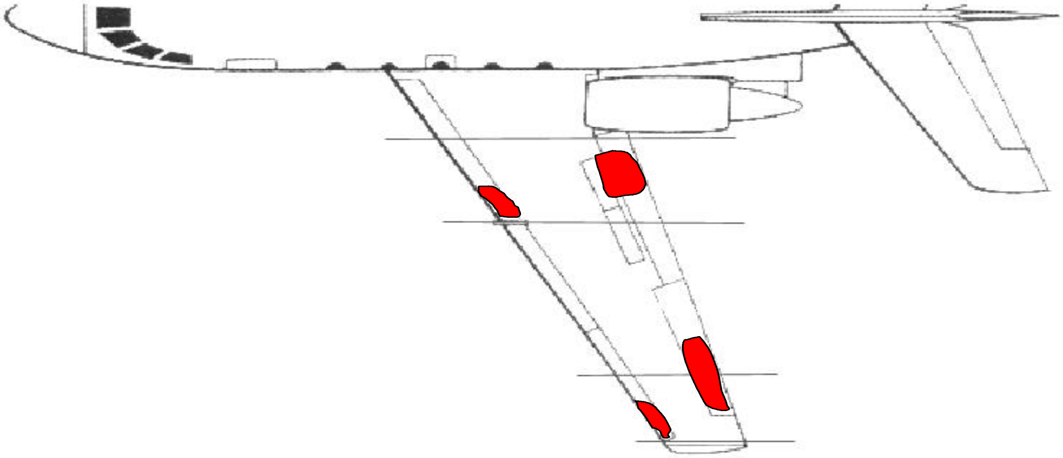
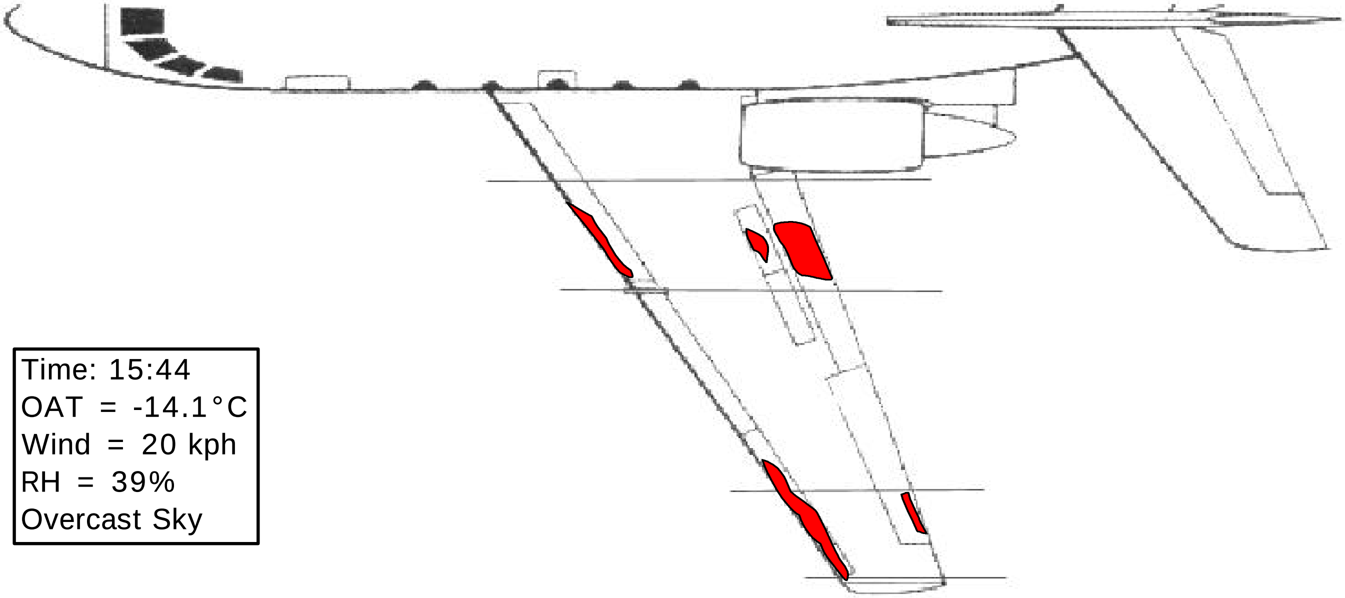


FIGURE 4.11

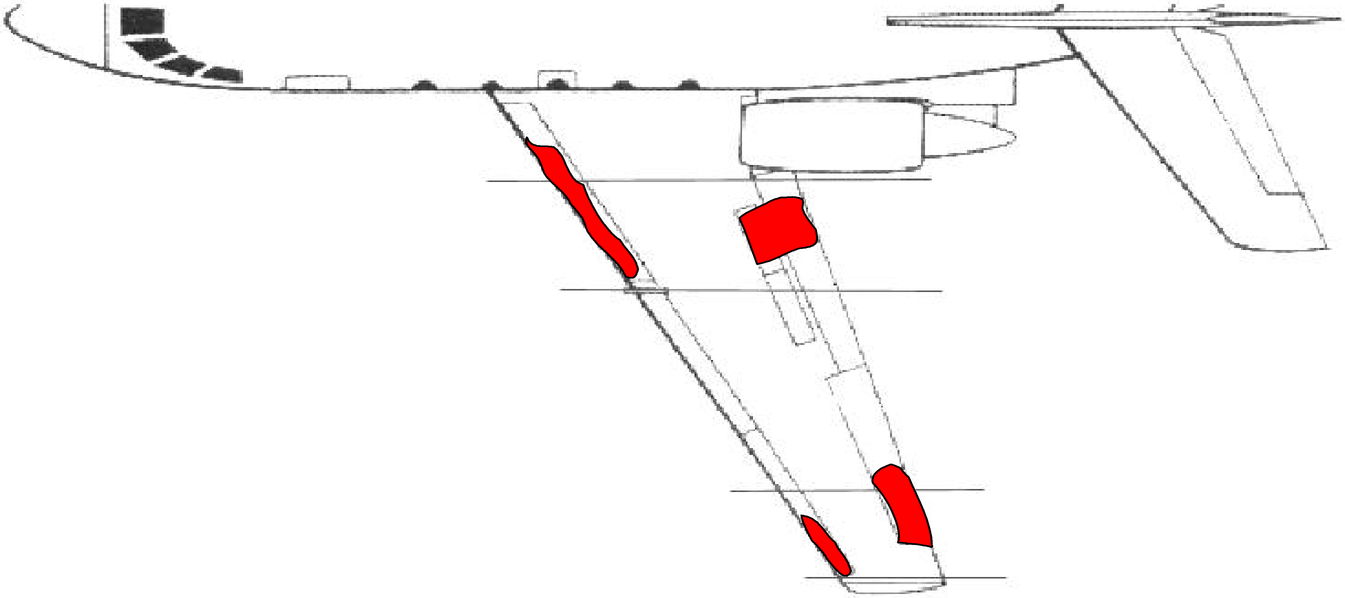
Failure Pattern After Takeoff Run

Run 3 - March 12, 1998

a) Failure Pattern Reported by Outside Observer



b) Failure Pattern Reported by Experienced Cabin Observer



File: \cm1380\report\falc_20\Run3_ymx.xls
At: F4.11
Printed: 29/10/01, 4:50 PM

FIGURE 4

FLUID THICKNESS ON AIRCRAFT

DATE: 12-Mar-98

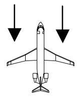
RUN #: 3

AIRCRAFT TYPE: Falcon 20

WING: [✓ PORT (A)] STARBOARD (B)

DIRECTION OF AIRCRAFT: ________ DEGREES

DRAW DIRECTION OF WIND WRT WING:



1st FLUID APPLICATION

Actual Start Time: 14:19:00

Actual End Time: 14:19:30

Amount of Fluid Sprayed: 32 Litres

Type of Fluid: XL54

Temperature of Fluid: 170°F

2nd FLUID APPLICATION

Actual Start Time: 14:19:35

Actual End Time: 14:20:50

Amount of Fluid Sprayed: 20 Litres

Type of Fluid: ULTRA +

	Chord 1 (inner)						Chord 2 (Outer)					
	After Application		After Freeze		After Take-off		After Application		After Freeze		After Take-off	
Location	**Time**	**Gauge (mm)**	**Time**	**Gauge (mm)**	**Time**	**Gauge (mm)**	**Time**	**Gauge (mm)**	**Time**	**Gauge (mm)**	**Time**	**Gauge (mm)**
1	14:21:00	26	14:43:00	thk ice	15:14:00	Ice	14:22:42	35	15:13:00	thk ice	15:15:00	Ice
2	12:21:20	35	14:43:00	Ice	15:14:00	Film	14:22:50	55	15:13:00	Ice	15:15:00	Ice
3	12:21:30	35	14:43:00	8	15:14:00	Film	14:22:55	55	15:13:00	12	15:15:00	Film
4	14:21:40	45	14:43:00	10	15:14:00	Film	14:23:00	60	15:13:00	24	15:15:00	Film
5	14:21:50	127	14:43:00	>80	15:14:00	1	14:23:20	96	15:13:00	>80	15:15:00	5
6	14:25:10	24	14:45:00	Ice	15:14:00	6	14:24:20	65	15:14:00	Ice >80	15:15:00	7
7	14:25:00	16	14:45:00	Ice	15:14:00	Film	14:24:00	30	15:14:00	Ice	15:15:00	8
8	14:24:50	18	14:45:00	Ice	15:14:00	1	14:23:49	40	15:14:00	Slush	15:15:00	8
9	14:24:35	44	14:45:00	Ice 10M	15:14:00	Film	14:23:45	30	15:14:00	Ice 40M	15:15:00	10

Location

1 - LE Nose
2, 8- Half-way
3,4,6,7 - 1" from joint
5 - As far as can reach
9 - 6" from TE

COMMENTS: Inner Adherence in most ice spots

Outer Chord, Brix at # 4 = 21, #2 = 9, #7 = 13 @15:15

MEASUREMENTS BY: John D'Avirro

HAND WRITTEN BY: Medhat Hanna

More Type IV fluid was applied for run 3 than the earlier runs with contamination: 20 litres compared to 5 litres and 10 litres in run 1 and run 2 respectively. The initial fluid thickness (after application) was greater as a result (see Figure 4.12). On the top of the wing, a very thick layer of fluid (>80 mil or 2 mm) still remained at the time that the desired extent of failure had been achieved as was seen in Photo 4.3.

Following the takeoff run, this fluid film had reduced to 1 to 5 mil (.03 to .13 mm). At other areas where a film of lesser thickness had been measured, the final thickness of fluid remaining was reported as a film, too low to be measured. After return from the takeoff run, it was noted that some of the remaining ice was adhered while some was not and was easily moved about on the wing skin with a pencil tip. At the time of this run, the sky had cleared and the sun was shining, which may have influenced adherence to the aircraft skin.

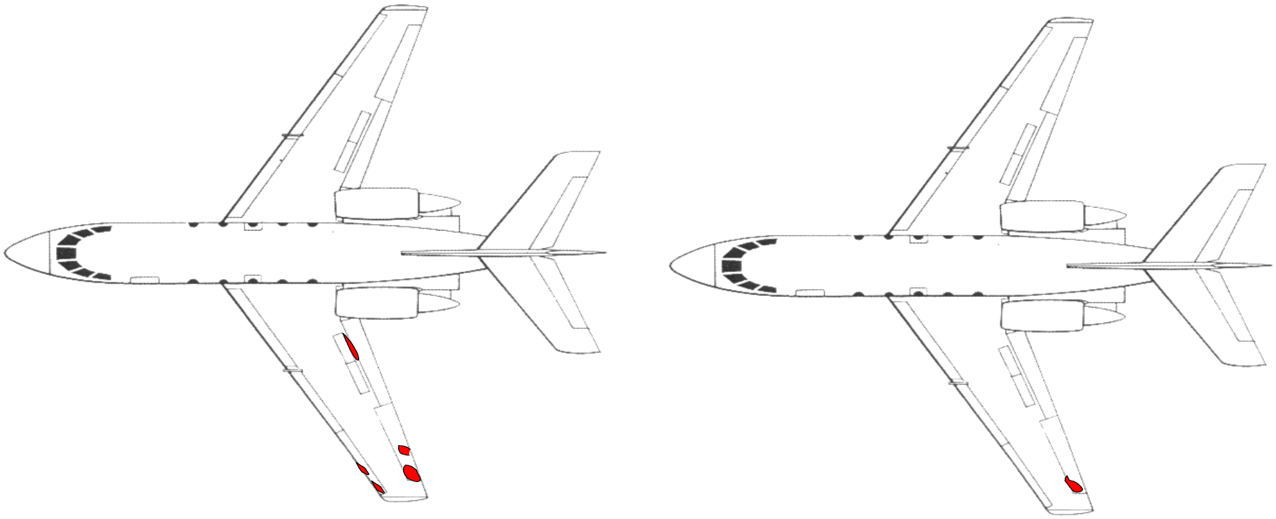
4.2.4 Summary of Results

Figure 4.13 presents a summary of the three trial runs, showing comparisons of "before and after" conditions for each run.

FIGURE 4.13

SUMMARY OF WING CONDITION FOR ALL TRIAL RUNS

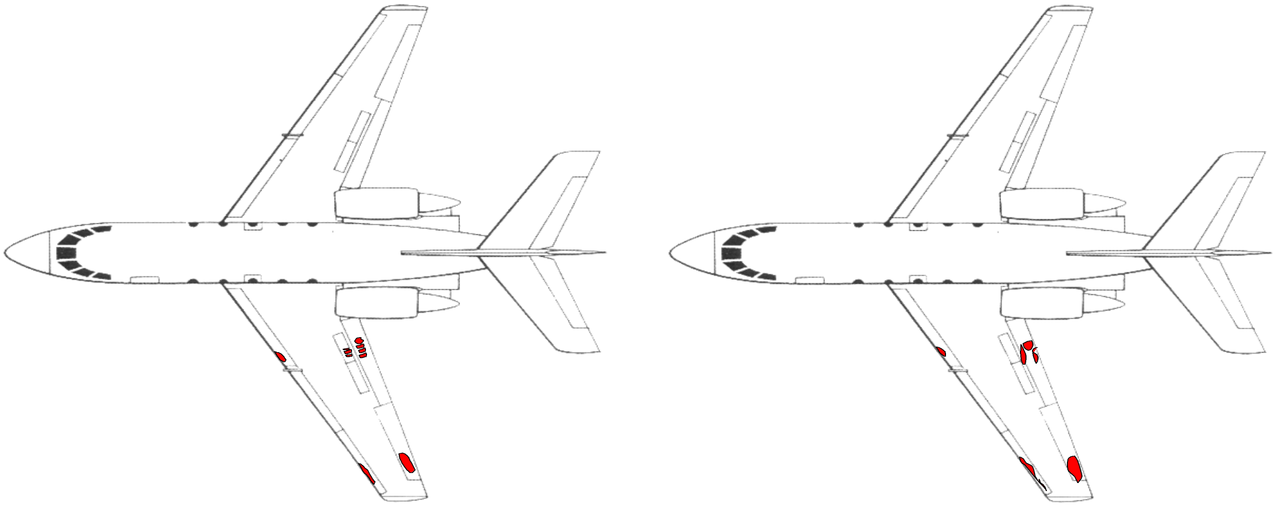
Run 1 (Initial Failure)



Before Simulated Takeoff

After Simulated Takeoff

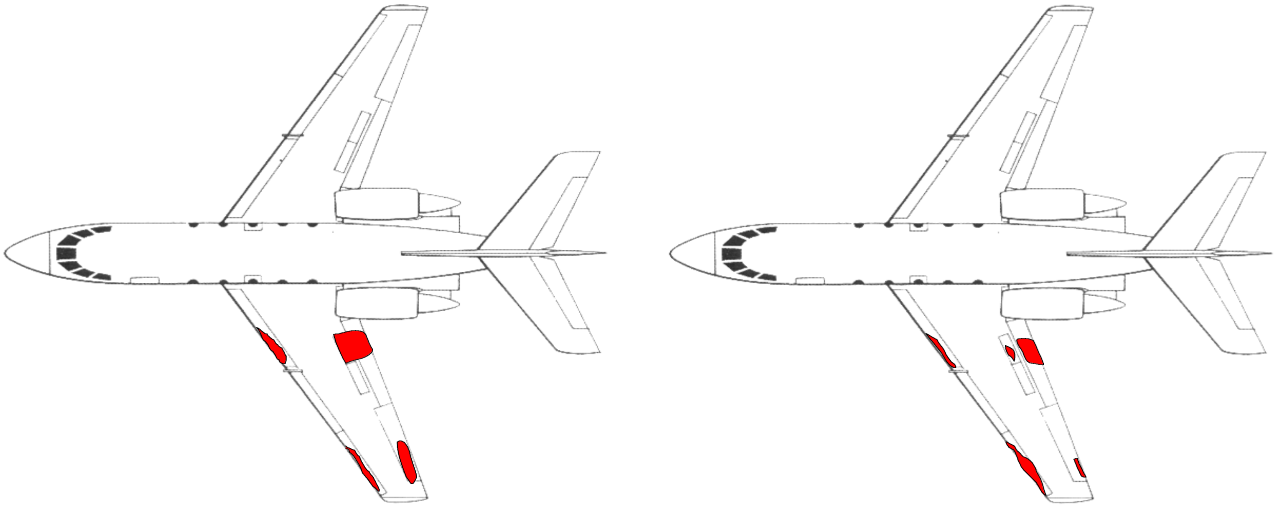
Run 2 (10% Failure)



Before Simulated Takeoff

After Simulated Takeoff

Run 3 (33% Failure)



Before Simulated Takeoff

After Simulated Takeoff

Photo 4.1

Run 1 (Initial Failure) Ice on Outboard Aileron - Following Takeoff Run

Photo 4.2

Run 3 (33% Failure) Ice on Leading Edge - Prior to Takeoff Run

Photo 4.3

Run 3 (33% Failure) Fluid on Top of Wing - Prior to Takeoff Run

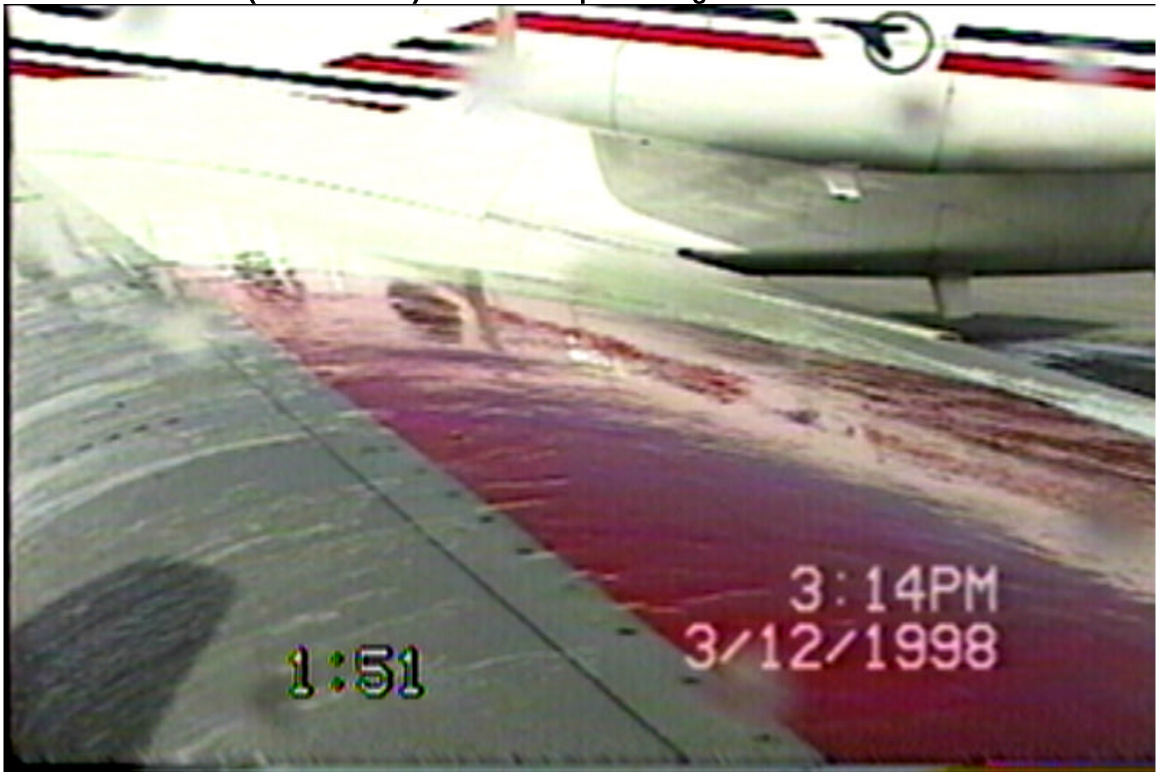


Photo 4.4

Run 3 (33% Failure) Failed Fluid on Aileron - Prior to Takeoff Run - 25¢ Coin for Scale

Photo 4.5

Run 3 (33% Failure) View of Icing on Outer Wing – Prior to Takeoff Run

Photo 4.6

Run 3 (33% Failure) Slush Over Top of Wing - Prior to Takeoff Run

Photo 4.7

Run 3 (33% Failure) Ice Remaining on Leading Edge Inner Chord - Following Takeoff Run

Photo 4.8

Run 3 (33% Failure) Remaining Ice on Leading Edge Outer Chord - Following Takeoff Run

Photo 4.9

Run 3 (33% Failure) Ice on Extended Leading Edge Slat – Following Takeoff Run

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5 CONCLUSIONS

5.1 Discussion of Test Results

5.1.1 Static Tests

The pattern of fluid failure on the wings of a Falcon 20D aircraft is consistent with that observed on other aircraft types during previous test programs, with failures generally initiating on flight control surfaces at the rear of the wing.

Patterns of failure experienced as a result of application of simulated freezing rain during takeoff run trials conformed to the pattern experienced during the static test.

5.1.2 Elimination of Contaminated Fluid from Wings

During each test run all of the fluid was stripped from the leading edge, in some cases leaving areas of slush and ice. At the end of the runs much of the fluid still remained on the wing surface and it can be concluded that it would not be removed until after lift-off.

It was observed that some portion of failed fluid in the form of slush and ice remained on the wing during the acceleration to rotation. This was true even when fluid on the wing was at initial failure with only a very small area covered by the contaminant. For higher levels of contamination, a significantly larger area may remain covered with contamination.

It is concluded that tests need to include aircraft rotation in order to establish whether the changed aerodynamic flow patterns increase the shear and more effectively remove the contaminated fluid and the slush and ice.

5.1.3 Validity of Test Approach

This brief series of trials demonstrated the validity of the test approach for gaining an improved understanding of adherence. Direct observation of wing condition of a typical sample aircraft following a simulated takeoff run can provide reliable information regarding the question of whether or not failed fluid clears from the wing surface during the takeoff run.

Observations made from the cabin during the actual takeoff run gave only limited results. The duration of the run was extremely brief, limiting the area that a single observer could observe continuously and reliably. Aircraft movement and the nature of the window materials affected photographs and videos taken from the cabin. Contamination detection sensor cameras generally will not perform when viewing through window material, being limited by reflections from the window surface. Good documentation from the ground as to the condition of the wing prior to and following the takeoff run appears to be the simplest and most satisfactory approach to gathering reliable data. Special care needs to be taken to ensure the agreement of details in “before” and “after” sketches. Strong photographer procedures are necessary to ensure capture of corresponding "before and after" photos and videos. Real-time images of contamination as produced by an ice detection sensor camera would be valuable during the trial and for subsequent analysis.

The trial offered an opportunity to document reliability of identification of fluid failure as observed from inside the cabin. Very low contamination levels appear difficult to identify. As the extent of failure increased, the calls from inside the cabin improved in accuracy, although failures on the leading edge were more difficult to identify.

The adherence test device developed for these trials did not perform adequately. When the fluid contamination is actually adhering to the wing surface, the legs of the instrument tend to ride over the contamination, thereby elevating the bristles above the ice. A smaller, less invasive instrument would be preferable.

In these trials, the aircraft was operated to rotation speed without actually rotating. It has been suggested that a greater removal of fluid and ice formation may be experienced during actual rotation. This aspect should be considered for any future test programs.

5.2 Conclusions

The conclusions from these trials are:

1. These trials provide the first documented evidence with regard to the nature of the elimination of contaminated aircraft anti-icing fluid from aircraft wings during the takeoff run.

2. In some cases, the contaminated fluid did not adhere to the wing surface and did show freedom of movement, but stayed on the wing.

3. The contamination was not eliminated from the wing surface during acceleration of the aircraft during the takeoff run up to rotation speed.

4. There is a need to conduct a further series of tests at takeoff speeds up to and including rotation to verify results.

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6 RECOMMENDATIONS

Based on the results from this brief series of trials, it is recommended that further trials be conducted to provide full information on the nature of elimination of failed anti-icing fluid from aircraft wings during takeoff. Procedures should be refined for further tests.

Consideration should be given to whether the aircraft should be operated through actual rotation, and, if so, the safest approach should be determined.

An evaluation of different fluid brands should be undertaken to determine their influence on adherence.

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APPENDIX A

TERMS OF REFERENCE – WORK STATEMENT

APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 97/98

(Short Title: Winter Tests 97/98)

(Revised December 1997)

1 INTRODUCTION

Following the crash of a F-28 at Dryden in 1989 and the subsequent recommendations of the Commission of Inquiry, the Dryden Commission Implementation Project (DCIP) of Transport Canada was set up. Together with many other regulatory activities an intensive DCIP research program of field testing of deicing and anti-icing fluids was initiated with guidance from the international air transport sector through the SAE G-12 Committee on Aircraft Ground De/Anti-icing. As a result of the work performed to date Transport Canada and the US Federal Aviation Administration (the FAA) have been introducing holdover time regulations and the FAA has requested that the SAE, continue its work on substantiating the existing ISO/AEA/SAE Holdover Time (HOT) tables (DCIP research representing the bulk of the testing).

The times given in HOT Tables were originally established by European Airlines based on assumptions of fluid properties, and anecdotal data. The extensive testing conducted initially by the DCIP R&D Task Group and subsequently by Transport Canada, Transportation Development Centre (TDC), which has taken over the functions of the DCIP, has been to determine the performance of fluids on standard flat plates in order to substantiate the times, or if warranted, to recommend changes.

DCIP has undertaken most of the field research and much other allied research to improve understanding of the fluid HoldOver Times. Most of the HOT table cells been substantiated, however low temperatures have not been adequately explored and further tests are needed.

The development of ULTRA by Union Carbide stimulated all the fluid manufacturers to produce new long lasting anti-icing fluids defined as Type IV. All the Type IV fluids were upgraded in early 1996 and therefore all table conditions need to be re-evaluated and the table revised if necessary. Certain special conditions for which advance planning is particularly difficult such as low temperatures with precipitation, rain or other precipitation on cold soaked surfaces, and precipitation rates as high as 25 $gm/dm^2/hr$ need to be included in the data set. All lead to the need for further research.

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.

An important effort was made in the 94/95 and 95/96 seasons to verify that the flat plate data were representative of aircraft wings. Airlines cooperated with DCIP by making aircraft and ground support staff available at night to facilitate the correlation testing of flat plates with performance of fluids on aircraft. An extension of this testing was to observe patterns of fluid failure on aircraft in order to provide data to assist pilots with visual determination of fluid failure, and to provide a data to contamination sensor manufacturers. The few aircraft tests made to validate the flat plate tests were inconclusive and more such tests are needed. Additional tests testing with hot water and with hot air for special deicing conditions were not completed. All these areas are the subjects for the further research that is planned for the 96/97 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 Develop reliable holdover time (HOT) guideline material based on test information for a wide range of winter weather operating conditions.
3.2 Substantiate the guideline values in the existing holdover time (HOT) tables for fluids that have been qualified as acceptable on the basis of their impact on aircraft take-off performance.
3.3 Perform tests to establish relationships between laboratory testing and real world experience in protecting aircraft surfaces.
3.4 Support development of improved approaches to protecting aircraft surfaces from winter precipitation.

4 PROJECT OBJECTIVES

4.1 Develop new Holdover Time Tables
  (a) for Type IV and Type III fluids
  (b) for de-icing operations only, i.e. without precipitation;

. 4.2 Establish limits for the use of negative buffered deicing fluids for the first step of two step anti-icing procedures

4.3 Determine the influence of fluid type, precipitation and wind on location of fluid failure initiation, time to fluid failure initiation, pattern of fluid failure progression, and visibility of failed fluid on a sample high wing turbo-propeller and a low wing turbojet commuter aircraft.

4.4 Assess the practicality of using a vehicle mounted remote area contamination detection sensor for pre-flight (end of runway) checks.

4.5 Collect data on taxi times from start of de-icing or anti-icing, as applicable, to start of the take-off roll under winter precipitation conditions at sample airports.

5. DETAILED STATEMENT OF WORK

5.1 Planning and Preparation

5.1.1 Scope of Work

The work shall be executed as eleven separate sub-projects:

1) Planning and Preparation.
2) Holdover Time Testing and Evaluation of de/anti-icing fluids.
3) ‘Negative Buffer' De-icing Fluids
4) Development of a Low Glycol ‘De-icing only’ Fluid Table.
5) Aircraft Full Scale Tests.
6) Documentation of Pilot field of View, and Wing Visibility
7) Documentation of the Appearance of Failed Fluids.
8) Potential use of Remote Sensors for End-of-Runway inspection.
9) Taxi Times under conditions of Precipitation.
10) Support for Review of Alternative Technologies.
11) Provision of Support Services.

5.1.2 Program management

The work shall be broken down into the distinct areas of activity consistent with the project objectives.

A detailed work plan, activity schedule, cash flow projection, project management control and documentation procedure shall be developed for each of the seven sub-projects, and delivered to the TDC project officer for approval within one week of the pertinent start date.

5.1.3 Coordination

Prepare, plan, and coordinate with personnel from TDC, airlines, airport authorities, fluid manufacturers, Instrumentation suppliers, and the National Research Council of Canada (NRC) with respect to site requirements and test procedures; training of test personnel; conduct of dry-run(s) and tests.

5.1.4 Safety of Personnel and Aircraft

Planning shall include precautions to ensure safety of personnel, and safety (freedom from damage) of aircraft.

A safety officer shall be nominated to prepare an appropriate plan, and monitor its implementation.

Conduct of tests shall respect recognized safety standards and applicable sections of Federal and Provincial labour codes. Where exceptions are taken due to the nature of the work, e.g. emplacement of power and instrumentation cables in the work area, test personnel shall be made aware of potential hazards.

Within the work area, comprising the de-icing pad and access ways, test personnel shall co-ordinate their movements and be made aware of all other operations taking place. Movement of airline equipment - aircraft, tow trucks, de-icing trucks, shall have precedence over test personnel activities.

Care shall be taken to ensure that mobile equipment, such as inspection platforms, lighting stands etc. are not in contact with aircraft surfaces. Potential contact points for such equipment shall be padded.

Movements of visitors and personnel not directly involved in tests at any given time shall be tightly controlled, with safety as the governing criteria.

Obtain 'Airport owners and operators premises and products liability insurance' to indemnify and hold harmless the airport and the operators against any claim arising.

5.1.5 Tests at National Research Council, Climatic Engineering Facility

Arrangements will be made by Transport Canada for use of the National Research Council, Climatic Engineering Facility (NRC, CEF) for conduct of certain tests.

Coordinate with NRC for use of the Test facility, including setting of dates for tests, environmental conditions to be simulated, and equipment and test materials to be supplied by the respective agencies.

5.1.6 Supply and Condition of De/Anti-icing Fluids

Fluids will be made available by TDC at no cost to the contractor.

The contractor shall make arrangements for fluids delivery and on-site storage.

For dedicated flat plate tests, the contractor shall ensure that Type IV fluids are pre-sheared prior to delivery, and are representative of the manufacturer’s marketed product. Where the only samples available for the conduct of tests are those with the manufacturer’s lowest level of viscosity, this shall be duly recorded.

Where exceptions are taken to this requirement these shall be noted, and every effort shall be made to obtain samples which comply with the requirements.

Where flat plate testing necessitates application of fluids sheared consistent with normal truck application, and such fluids are not available, the contractor shall bring the problem to the attention of the scientific authority for appropriate action. This may require subjecting the fluids to shearing by other means.

5.2 Holdover Time Testing and Evaluation of de/anti-icing fluids

5.2.1 Site preparation.

Set up experimental sites and install sensors as inspection aids to provide consistent plate failure conditions under field and laboratory conditions.

5.2.2 Flat Plate Tests for New Type IV fluids

Conduct flat plate tests under conditions of natural snow and freezing drizzle precipitation to record the holdover times, and to develop individual Holdover Time Tables based on samples of new and previously qualified Type IV fluids supplied by Fluid Manufacturers under as wide a range of temperature, precipitation rate, precipitation type, and wind conditions as can be experienced. Tests shall be anticipated for at least four different manufacturer's fluids and shall be conducted in the field and the laboratory.

5.2.3 Validation of "Fluid-Specific" and SAE Tables

Conduct flat plate tests to validate "fluid-specific" and SAE tables that currently lack sufficient supporting data. For the "freezing fog" condition the current upper holdover time shall be revised as necessary.

5.2.4 Evaluation of Snow Weather Data

Evaluate snow weather data (precipitation rate/temperature data) from previous winters to ascertain the suitability of the data ranges used to date for evaluation of HOT limits.

Obtain data from Environment Canada for four sites in Quebec: Rouyn, Mingan (Sept Isles), Pointe-au-père (Mont Joli), and Ancienne Lorette (Québec City), in addition to Dorval (Montreal).

5.2.5 Analysis of Current Type I and Type II Holdover Time Tables

Conduct an analysis of current Type I and II fluid holdover time data to determine their concurrence with values determined from the data ranges established in task 5.2.4 above. This evaluation will be conducted for all fluid dilutions and precipitation conditions. Develop appropriate regression equations.

5.2.6 Evaluation of the SPAR Aerospace Ice Detection Camera

TDC will arrange for provision of a SPAR Aerospace (Also referred to as a "SPAR/Cox") camera, with software modifications appropriate for data collection and evaluation.

Install the Camera at the Dorval "Field" test site for use in standard flat plate tests.

Calibrate camera output to characterize fluid 'failure' consistent with visual and other instrumented failure 'calls'. Compare camera observations during conduct of flat plate tests with visual observations of fluid behaviour under conditions of precipitation, and similar observations by other sensing devices.

5.2.7 Supplementary Tests

Conduct supplementary tests in the NRC Climatic Engineering Facility to:

- Measure film thickness of ‘new’ fluids (fluids made available by TDC, but not previously tested) on flat plates.
- Observe the effects of fluids on ice-phobic materials on standard (aluminum) plates.
- Determine the effect on holdover time of spraying versus pouring of Type IV fluids.
- Determine the effect on holdover time of applying heated versus cold Type IV fluids for standard flat plate tests.

5.2.8 Compatibility with De-icing Fluids

Holdover time tests shall in general be conducted with fluid applied directly to clean plates. Additional tests shall be conducted to determine compatibility of the Type IV fluid samples with a proposed new category, "Type 0" fluid, derived from reclaimed spent fluid.

5.2.9 Measurements and instrumentation

In addition to measurements and records of environmental conditions pertinent to the tests, measurements may be made during the conduct of the tests to obtain histories at selected locations on the plates of fluid thickness, refractive index, and viscosity through to the end of the tests.

SPAR/Cox and RVSI remote sensors should also be used to record the initiation and progression of fluid failure.

5.2.10 Location of Tests

Planning shall be based on conduct of outdoor (field) tests at Dorval Airport, Montreal, and indoor laboratory tests in the NRC Climatic Engineering Facility, Ottawa. Anticipate 20 days occupancy in the laboratory.

Consideration shall be given to conduct field tests at alternate sites where desirable test conditions may occur more frequently.

5.3 ‘Negative Buffer' De-icing Fluids

(Note: The guidelines for holdover times given in the SAE Tables call for the freezing points of fluid mixtures to be at least 10^0C (18^0F) for Type I, and 7^0C (13^0F) for Type II below the ambient air temperature).

Conduct tests to determine the limits of the use of hot water, and reduced glycol content de-icing fluids under conditions of precipitation.

Focus of activity shall be conduct of tests in the laboratory (NRC Environmental Test Facility) under controlled conditions. Availability of aircraft and procurement of laboratory services will be by TDC.

All other services and facilities shall be provided by the contractor.

5.3.1 Aircraft Tests

C Conduct two test sessions with a selected aircraft at Dorval Airport, Montreal to establish a ‘reference’ case for comparison with laboratory results. Choice of aircraft shall be determined in cooperation with US Airways and TDC. Test records shall include relative humidity at the time of test, and the fuel load of the aircraft to be tested.

C Test shall be conducted under conditions without precipitation, at zero or low wind velocity, and with low level of insolation - i.e. overcast or night-time. Plan for conduct of tests at two temperature ranges.

C Tests shall be conducted with hot water heated and applied in accordance with the first step of SAE ARP4737, latest edition, Two-Step de-icing/anti-icing procedure.

C Tests shall be conducted for two dilutions of an ethylene-glycol based Type I fluid, to be selected in coordination with TDC.

C Condition of fluid as applied, duration of application, and quantity of fluid applied shall be recorded.

Temperature histories on the wing surfaces at selected locations shall be recorded starting prior to fluid application and terminating after fluid freezing. Locations shall include ‘over fuel tank’ and low thermal inertia surfaces such as control surfaces.

C Simultaneous tests shall be conducted adjacent to the aircraft using standard 1/8" (1.2mm) thick ‘SAE’ flat plates, increased thermal capacity 1/4" (6mm) plates, and ‘Cold-Soak’ boxes developed for laboratory simulation of cold-soaked wing. Boxes of appropriate depth shall be provided, as necessary, to ensure that the observed range of fluid behaviour on the wing can be adequately simulated in the laboratory.

5.3.2 Laboratory Tests

C Schedule a test session of one-week nominal duration in the NRC Environmental Test Facility in coordination with TDC. Notify TDC of the anticipated start date with minimum of two weeks notice.

C Anticipate tests using Type I ethylene glycol, and Type I propylene glycol de-icing fluids, and at least one Type IV fluid, heated and applied in accordance with the first step of SAE ARP4737, latest edition, Two-Step de-icing/anti-icing procedure.

C Conduct a matrix of tests using standard 1/8" (1.2mm) thick ‘SAE’ flat plates, increased thermal capacity 1/4" (6mm) plates, and ‘Cold-Soak’ boxes developed for laboratory simulation of cold-soaked wing, based on:

A range of selected temperatures (e.g. -3^{0}C, -7^{0}C, -14C, -25^{0}C,).

A range of appropriate precipitation rates, based on simulated Freezing Rain.

A range of selected buffers, i.e. fluid dilutions.

Relative humidity at time of test shall be recorded.
Effects of wind are not to be considered.

- Record all test conditions, and time to fluid failure.
- Prepare recommendations for use of ‘Negative Buffer’ fluids based on ambient temperature, an appropriate, conservative delay (e.g. 3 minutes) before application of Anti-icing fluid, and limitations which might be imposed by wind conditions.

5.4 Development of a Low Glycol ‘De-icing only’ Fluid Table

Conduct tests to develop a ‘De-icing Only’ table for removal of ice, slush, snow or frost, in the absence of precipitation when the fluid is applied in accordance with SAE ARP 4737, latest revision. It is anticipated that the table would give values of minimum acceptable de-icing fluid glycol content, with appropriate buffer, as a function of a set of ambient temperature ranges.

Focus of activity shall be conduct of tests in the laboratory (NRC Environmental Test Facility) under controlled conditions. Procurement of laboratory services will be by TDC.

5.4.1 Laboratory Tests

- Schedule a test session of one-week nominal duration in the NRC Environmental Test Facility in coordination with TDC. Notify TDC of the anticipated start date with minimum of two weeks notice.
- Anticipate tests using water; a proposed new category "Type '0'" fluid based on recycled spent fluid; and Type I ethylene glycol, and Type I propylene glycol diluted to provide a range of ’low-glycol’ heated de-icing fluids.
- Conduct a matrix of tests using standard 1/8" (1.2mm) thick ‘SAE’ flat plates, increased thermal capacity 1/4" (6mm) plates, and ‘Cold-Soak’ boxes developed for laboratory simulation of cold-soaked wing, based on:
    A range of five or more selected temperatures.
    A range of simulated wind velocities, representative of those encountered in operational service.
    A range of selected buffers, i.e. fluid dilutions.
- Record the relative humidity.
- Record all test conditions including history of test surface temperature, and time to fluid failure.
- Develop a draft ‘De-Icing, only,Table’
- Prepare a presentation to the SAE G-12 HoldOver Time Subcommittee.

5.5 Aircraft Full Scale Tests

5.5.1 Purpose of tests

Conduct full scale aircraft tests:

- to generate data which can be used to assist pilots with visual identification of fluid failure;
- to assess a pilot's field of view during adverse conditions of winter precipitation for selected aircraft;
- to assess whether Representative Surfaces can be used to provide a reliable first indication of anti-icing fluid failure;
- to explore the potential application of point detection sensors to warn the Pilot in Command (P.I.C.) of an 'unsafe to take-off condition';
- to obtain failed fluid contamination distributions and profiles which can serve as inputs to a theoretical program designed to assess the effects of such contamination on possible aircraft take-off performance; and
- to compare the performance of de/anti-icing fluids on aircraft surfaces with the performance of de/anti-icing fluids on flat plates.

5.5.2 Test Locations

Conduct tests at the Central De-icing Facility, Dorval International Airport, Montreal using aircraft made available by airlines.

Contingency plans shall be made to conduct tests at alternative sites: Ottawa, Uplands Airport; Quebec City, Ancienne Lorette Airport.

Tests shall be performed at the new central de-icing facility. Coordinate with the facility operator for application and clean-up of fluids.

5.5.3 Facilities to be Provided

Provide all necessary equipment and facilities for conduct of the tests. Negotiate provision of ancillary equipment and services where possible with the pertinent airlines. Notify TDC of such arrangements. Equipment shall include lighting fixtures as necessary, observation platforms, vehicles, storage facilities, office facilities and personnel rest accommodation. Additional facilities and test equipment, if required, may be requested subject to agreement by all parties involved.

5.5.4 Test Plans

Prepare Test Plans for full-scale aircraft tests to include the following:

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:

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

c) A list of test 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) Data to be acquired from the tests including:

- ! Identification of fluid failure criteria;
- ! Location and time of first point of fluid failure on the wing, and of 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.

Plans shall include concurrent comparison tests of fluids on flat plates with the aircraft tests.

Present plans for review and approval by the TDC project officer.

Present the approved program to the airline and de-icing facility operator involved prior to the start of field tests.

5.5.5 Test Scheduling

Schedule tests on the basis of forecast freezing precipitation.

Notify the airline and de-icing facility operator in advance 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.

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

5.5.6 Personnel and facility preparation

Recruit and train local personnel who will conduct test work.

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

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

Arrange (with the cooperation of TDC) for deicing equipment and aircraft to be made available for the tests .

Arrange for the provision of fluids for spraying an aircraft.

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

5.5.7 Aircraft, De-Icing Pads and Crews

Planning shall be based on the following aircraft and facilities:

Aircraft	Airline	Test Locn.	De-Icing Pad	De-Icing Crew
Canadair RJ	Air Canada	Dorval	Central	Aeromag 2000
DHC-8	Air alliance	Dorval	Central	Aeromag 2000

5.5.8 Dry Runs

Conduct a 'dry run' for test team personnel to ensure familiarity with their requested roles. Dry runs shall be scheduled as early in the winter season as can reasonably be achieved and shall be scheduled at the participating airline's convenience. Operations shall include Type I and Type IV fluid applications and re-orientation of the aircraft.

5.5.9 Full-Scale Tests

Conduct up to 8 full all-night test sessions.

Note: In general, aircraft will be made available for testing outside regular service hours, i.e. available between 23:00 hrs. and 06:00 hrs. Subject to weather conditions additional test sessions may be requested.

Tests shall be conducted under a selection of the following conditions:

Aircraft orientations:	Headwind, Crosswind, Tailwind
Precipitation:	Snow, Freezing drizzle (If possible)
Fluids:	Type I, Type IV ‘Ultra’ and Octagon.
Engine Operations:	Anticipate dry run & full scale tests with engines running for Turbo-prop aircraft.

The following matrix of tests is anticipated:

Aircraft	No. of Tests	A/C Orient's*	Comments
Canadair RJ	4	T, C, H	Dry Run required
DHC-8	3	T, C, H	Engines running
Total Tests	7 + 1 dry run		

T = Tail Wind, C = Cross- Wind, H = Head Wind

5.5.10 Priority of Tests

Initial planning for tests shall be based on the matrix of tests covered by items 5.5.7 and 5.5.9, above.

Plans shall be made such that the number of tests with each aircraft and sequence of tests can be easily revised.

5.5.11 Aircraft Orientation and Fluid Application:

Tests shall be conducted in the following sequence: Tail to wind, Cross wind, Head wind.

Type IV tests shall be conducted with UCAR ULTRA, except as otherwise indicated.

For tests with Tail to wind and Nose to wind, Type I fluid shall be applied to the port wing, and Type I fluid followed by Type IV fluid shall be applied to the starboard wing in a standard 2-step application procedure. Tests with Type I fluid, only, shall be repeated without change in aircraft orientation until failure of the Type IV fluid.

For cross-wind tests both wings shall be treated with Type I only and observations of fluid behaviour shall be to failure of the fluid on both wings.

Under conditions of light precipitation when the expected time to failure of the Type IV fluid is judged to be be 'excessive' the Type IV test shall be aborted, and the aircraft re-orientaion shall proceed for further Type I tests.

Under conditions of heavy precipitation when the expected time to failure of the Type IV fluid is judged to be be 'short', Type IV test(s) shall also be conducted in a cross-wind, with the same fluid application to both wings.

A maximum of three (3) Type I tests and one Type (IV) test are contemplated for each orientation, on a given test night.

5.5.12 Tests with a Canadair RJ

Tests with a Canadair RJ shall include sessions with a local area of the wing having fluid thinly applied. Thickness distribution and history shall be monitored, and observations made to determine whether local fluid failure occurs, and in such an event whether the failure propagates prematurely.

Tests shall also be conducted during a single test session with UCAR ULTRA and with OCTAGON fluids to compare their behaviours.

5.5.13 Tests with Turbo-prop aircraft

True functional tests with Turbo-prop aircraft require that the engines should be running.

Gather available information applicable to the ground operations of these aircraft in regular service. Based on observation and the observations of others, assess the influence of propeller 'wash' on fluid flow-back patterns, and on precipitation behaviour, particularly under cross wind conditions.

Particular consideration shall be given to safety. In the event of conflict between access for data gathering to obtain required test results and safety considerations, safety shall govern.

5.5.14 Test Measurements

Make the following measurements during conduct of each test:

Contaminated thickness histories at points on wings, selected in cooperation with TDC.

Contamination histories at points on wings to be selected in cooperation with TDC.

Location and time of first failure of fluids on wings -
Concurrent measurement of time to failure of fluids on flat plates; plates to be mounted on standard frames and on aircraft wings at agreed locations.
Pattern and history of fluid failure Progression.
Wing temperature distributions.
Amount of fluid applied in each test run, and fluid temperature
Meteorological conditions.

5.5.15 'Clean' Fluid Thickness Measurements

In the event that there is no precipitation at the time of the dry run, or during full scale tests, advantage shall be taken to make measurements of fluid thickness distributions on the wings. These measurements shall be repeated for a number of fluid applications to assess uniformity of fluid application.

5.5.16 Pilot Observations

Contact airlines and arrange for pilots to be present during tests to observe fluid failure and failure progression. Record pilot observations for later correlation with aircraft external observervations.

5.5.17 Remote sensor records

Record the progression of fluid failure on the wing using RVSI and/or SPAR remote contamination detection sensors.

5.5.18 Videotape Records

Make videotape records of tests. Advise with respect to professional video tape coverage for at least two overnight test sessions.

5.5.19 Return of equipment

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

5.5.20 Assembly and analysis of results

Assemble and analyze all results.

5.5.21 Flat plate tests

Conduct standard flat plate tests concurrently with the aircraft tests.

5.6 Documentation of Pilot field of View, and Wing Visibility

5.6.1 Aircraft Types

Document the area of the wing that is visible to the PIC from inside the cockpit and from inside the cabin for as many aircraft types in service in Canada as can reasonably be checked. Aircraft types shall include at least DC-9, B-767, Canadair RJ, DHC-8 and Bae-146.

5.6.2 Lighting Conditions

Area of visibility shall be recorded under conditions of 'normal' daylight, and at night under conditions of precipitation with on-board lighting, only.

5.6.3 Documentation

Provide sketches, illustrations and photographic records of the visible area(s) of the wing.

5.7 Documentation of the Appearance of Failed Fluids

5.7.1 Tests

Conduct flat plate tests in the NRC CEF laboratory, and in the field designed to address the following issues:

What is the appearance of a failed fluid.

How does the appearance of a Type I fluid failure differ from a Type IV fluid failure.

How does the appearance of failure under conditions of freezing drizzle differ from failure in freezing rain, and in snow.

Under what conditions do de/anti-icing fluids "Flash freeze".

Are there differences in failure appearance between ethylene-, and propylene-glycol fluids when exposed to freezing drizzle.

Do strong winds significantly affect failure appearance.

5.7.2 Records

For each test record the following information with appropriate instrumentation:

- Fluid thickness history at selected locations.
- Viscosity at selected locations.
- Refractive Index history at selected locations.
- Video camera appearance of flat plate at time of fluid failure.
- Video camera appearance of 'cross-hair' detail at time of fluid failure.
- RVSI and/or SPAR/COX remote sensor record of fluid failure.
- C/FIMS point sensor record of fluid failure.

and record the description of the visual appearance of fluid failure

5.7.3 Documentation

For each test provide the following documentation:

- Record of purpose of test, and test conditions.
- Photographic record of initiation and progression of failure.
- Output 'traces' for each of the three sensors as a function of time.
- Fluid freeze point temperature history and Fluid viscosity history.
- Fluid thickness history.
- A subjective determination of failed fluid adherence, together with

criteria used.

5.8 Potential use of Remote Sensors for End-of-Runway inspection

5.8.1 Preparation

Purpose of the task is to determine the problems and possible solutions with respect to operation of remote sensors for to supplement the PIC's visual pre-takeoff contamination inspection.

Arrange for installation of a SPAR/COX remote sensor to be installed on a mobile vehicle.

Arrange with pertinent agencies having jurisdiction for the sensor and vehicle to be operated on a trial basis suitable for conduct of pre-takoff inspection of aircraft at, or close to, the end of runway immediately prior to start of the take-off roll.

Anticipated duration of the test period will be approximately two weeks and shall encompass at least two periods of freezing precipitation.

5.8.2 implementation

Anticipated problems include:

accessibility of the vehicle to the end of runway,
liasion with the tower
communication between vehicle, tower, and aircraft,
responsibility for communication of sensor observations to the PIC,
qualifications required for the vehicle/sensor operator.

Problems encountered should be reported and recommendations for solutions made.

5.8.3 Sensor Outputs

Sensor electronic outputs shall be recorded for analysis at the end of the winter season. During conduct of the task the sensor operator shall NOT report the sensor observations of the condition of the aircraft critical surfaces.

5.9 Taxi Times under conditions of Precipitation

Record and report taxi times from start of hold-over time to start of take-off roll (Nominal time of conduct of the pre-takeoff inspection) under conditions of winter precipitation to assess actual taxi times experienced and the impact of conditions of precipitation on ground operations.

Record and report taxi times under daylight conditions in the absence of precipitation, for aircraft requiring de-icing only, in order to provide reference times for sample runway use.

5.9.1 Locations

Collect data for operations at Montreal, Dorval Airport, and at Toronto, Lester B. Pearson Airport, and supply any additional relevant data as may be readily available.

5.10 Support for Review of Alternative Technologies

Provide support services for the evaluation of an infra-red heating device to be demonstrated by Infra-Red Technologies Inc. as a low cost and zero environmental impact alternative technology for aircraft de-icing.

5.11 Provision of Support Services

Provide support services to assist with conduct of tests, collection/reduction of data and presentation of findings, all in areas associated with other tasks of this work statement. These services shall include assistance with TDC project “Contaminated Aircraft Take-off Tests”.

5.12 Presentations of test program results

5.12.1 Preliminary Findings

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 May 30 1997.

5.12.2 Presentation of findings to the SAE

Participate at the SAE meeting to be held in Vienna in May1998, and present the results of the work conducted during the winter season 1997/98.

5.13 Reporting

Reporting shall be in accordance with section 10 "Reporting", below. Separate final reports shall be issued for each area of activity consistent with the project objectives.

APPENDIX B

DETAILED WORK STATEMENT

CONTAMINATED AIRCRAFT TAKEOFF TEST

APPENDIX B

TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT

CONTAMINATED AIRCRAFT DYNAMIC TESTS

(January 1997)

1 INTRODUCTION

Regulations require that no-one attempt a takeoff if ice, frost, snow, or slush is adhering to the critical surfaces of an aircraft. Currently failure of the protection provided by anti-icing fluid is identified by visible frozen contamination on the fluid surface usually discernable only when almost a third of the area has such surface contamination. However it is not known whether such visible frozen contamination is in fact adhering or at what level of coverage the contamination becomes excessive.
Literature surveys and discussions with researchers have failed to identify any useable quantitative data to assist with resolution of the problem as to whether failed anti-icing fluid remains adhering to a wing at lift-off.

Observations in the NRC open circuit wind tunnel have proven inconclusive and simulations of takeoff runs with an LS(1) wing section show that the contamination frequently, though not always, remains in place through to lower turbo-prop commuter rotation speeds; but only one wing section has been tested and the tunnel is limited to a maximum velocity of 45m/sec, well below the 65m/sec typical of flow over a jet aircraft wing at rotation speed.

Direct observation for a typical sample aircraft is needed to evaluate the adhesion of contaminated fluid to the wing surfaces. In such tests care must be taken that the aircraft not attempt a takeoff with excessive wing contamination, and that other concerns associated with accelerate-stop manoeuvres are respected.

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

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

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

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

4 PROJECT OBJECTIVE

Establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation adheres to the wing of a jet transport aircraft up to rotation speed.

5. DETAILED STATEMENT OF WORK

5.1 Coordination

Support services for conduct of tests will be provided by TDC acting through a contractor. The contractor will nominate a contact person, and will provide services as identified below.

5.2 Planning and Preparation

In cooperation with NRC the contractor will prepare a detailed workplan and activity schedule for review with the TDC project officer.

5.3 Aircraft and Services to be Provided

NRC shall provide the Falcon 20 Research Aircraft to be piloted by the NRC Falcon Facilities Manager, or his delegate, for conduct of static tests under conditions of freezing precipitation; and for dynamic tests, in the absence of precipitation. comprising a 'dry-run' at reduced maximum velocity, and other tests at speeds up to rotation speed, the number to be determined by NRC and the contractor

5.4 Schedule

The contractor and NRC shall develop a proposed schedule.

The project would involve tests on two to three days. The static test could be performed at night and does not require the presence of aircrew. Subject to the judgement of the NRC Falcon Facilities Manager the dynamic tests may be conducted in a single day test session.

Test work should be completed prior to March 31, 1998; the estimated overall project duration is five months, effective from February 1, 1998 to June 30, 1998.

5.5 Airport Selection

The contractor and NRC shall select the airfield for conduct of the tests

Mirabel is the preferred airport; North Bay is a suitable alternative.

5.6 Instrumentation and Measurements

NRC shall coordinate with the contractor for use of the instrumention and provide advice and data necessary.

For conduct of dynamic tests remote SPAR and/or RVSI contamination detection sensor camera(s), and video recording cameras will be located in the aircraft cabin. Installation of test equipment will not necessitate any changes to the aircraft.

A video camera or other means will record airspeed and time and shall be synchronised to the fluid recording devices

Before and after ground roll the contractor will measure the depth and dilution of the fluid at a limited number of chordwise locations, at one spanwise station; NRC will arrange how this might best be accomplished safely,

5.7 Simulated freezing precipitation

Tests under these conditions shall be performed under overcast skies, but with no natural precipitation, at sub-freezing temperatures and at a relative humidity in excess of 75%. The contractor will provide the equipment to produce simulated precipitation.

5.8 Static Test

The static tests shall be performed under conditions of natural freezing precipitation or failing that, simulated freezing precipitation.

The aircraft shall be parked tail to the wind at a location appropriate for conduct of tests involving use of de/anti-icing fluids.

The contractor will deice and anti-ice one wing, and allow the aircraft to stand in freezing precipitation , natural or simulated, until the fluid has failed over more than 25% of the wing area.

Observations of first failure and failure progression will be made from inside

the aircraft for reference purposes.
The test shall be repeated with the aircraft oriented in a cross-wind and in a head wind subject to the judgement of the contractor.

5.9 Dynamic Tests

5.9.1 Dry Run

Conduct a 'dry run' on a clean runway with clean wings and with all instrumentation installed, observers, cameras and instruments in place to ensure correct functionning of equipment and recording devices.

5.9.2 Contamination Runs

Dynamic tests will be conducted to determine the behaviour of anti-icing fluid with various levels of freezing precipitate contamination on a wing.
All dynamic tests will be performed under conditions of simulated freezing precipitation. Tests will comprise deicing and anti-icing of both wings followed by exposure of selected areas of the wings to simulated precipitation. Contamination levels equivalent to 1%, 10%, 25% and 33% area coverage of the wing are anticipated. Final decision will be taken at time of test. TDC in conjunction with the contractor will determine when the contamination has reached the required level for test.
When ready, the aircraft will accelerate to rotation speed, brake to stop, return for deicing and then take-off and fly for brake cooling.

5.10 Presentations of test program results

5.10.1 Preliminary Findings

Prepare and present preliminary findings to the Transport Canada Standing Committee on Operations in Icing Conditions at end of the test season, but no later than May 30 1998.

5.10.2 SAE G-12 Committee

Prepare and present, in conjunction with Transport Canada personnel, winter test program results at the SAE G-12 Committee meeting in Vienna in May 1998.

APPENDIX C

EXPERIMENTAL PROGRAM

FIELD TRIALS TO EXAMINE REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING THE TAKEOFF RUN

CM1380.001

EXPERIMENTAL PROGRAM
FIELD TRIALS TO EXAMINE REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING THE TAKE-OFF RUN

Winter 1997/98

APS AVIATION INC.

October 30, 2001
Version 2.0

EXPERIMENTAL PROGRAM
FIELD TRIALS TO EXAMINE REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING THE TAKEOFF RUN

Winter 1997/98

APS will support a series of trials conducted by the National Research Council examining the elimination of failed fluid from aircraft wings during takeoff.

These trials will be conducted on a Falcon 20 aircraft owned and piloted by the National Research Council. Tests will be conducted at Montreal International Airport (Mirabel) (YMX) and at Ottawa International Airport (McDonald Cartier) (YOW).

This document provides the detailed procedures and equipment required by APS to support these trials.

1. OBJECTIVES

This project addresses the objective:

i) To establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft up to rotation speed.

2. TEST REQUIREMENTS

APS will coordinate and plan test activities and prepare a final report as well as present results at industry deicing meetings.

APS will provide support to this series of tests in the areas of instrumentation, fluids application, and artificial precipitation application.

Desired weather conditions are dry, with subfreezing outside air temperature, overcast skies and a relative humidity in excess of 75%. Runway conditions are to be clear and dry.

Attachment I provides a description of test procedures. Figure 1 provides a plan overview of the different tests.

3. EQUIPMENT AND FLUIDS

3.1 Equipment

Equipment to be employed is shown in Attachment II.

3.2 Fluids

SAE Type I and Type IV fluids will be used.

4. PERSONNEL

Six APS staff are required for tests on aircraft at Mirabel airport.

Three APS staff are required for static tests on aircraft at Ottawa airport.

Aircraft spraying will be provided by Aéromag 2000.

The National Research Council aircraft will be operated by a National Research Council pilot.

Attachment III provides task assignments.

5. DATA FORMS

Figure 1	Test Plan
Figure 2	General Form (Every Test)
Figure 2a	General Form (Once per Session)
Figure 3	De/Anti-icing Form for Aircraft Wing
Figure 4	Fluid Thickness on Aircraft

FIGURE 1
TEST PLAN - REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING TAKEOFF RUN

RUN	Trial Type	Location of Tests	Area on Wing	Degree of Contamination
1	Failure Pattern	YOW (or YUL)	Full Wing	Failed Wing
2	Dry Run	YMX	Inboard Area 1 Outboard Area 2	None
3	Takeoff Run 1	YMX	Inboard Area 1 Outboard Area 2	1%
4	Takeoff Run 2	YMX	Inboard Area 1 Outboard Area 2	10%
5	Takeoff Run 3	YMX	Inboard Area 1 Outboard Area 2	25%
6	Takeoff Run 4	YMX	Inboard Area 1 Outboard Area 2	33%

FIGURE 2

GENERAL FORM (EVERY TEST)

(TO BE FILLED IN BY PLATE/WING COORDINATOR)

DATE: ______________________

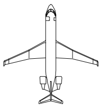
RUN #: ______________________

AIRCRAFT TYPE: ATR-42 F-100 B-737 RJ DHC-8

WING: PORT (A) STARBOARD (B)

DIRECTION OF AIRCRAFT: ________ DEGREES

DRAW DIRECTION OF WIND WRT WING:



1st FLUID APPLICATION

Actual Start Time: ______________ **am / pm** **Actual End Time:** ______________ **am / pm**

Amount of Fluid Sprayed: ______________ **L / gal** **Type of Fluid:** ______________

2nd FLUID APPLICATION

Actual Start Time: ______________ **am / pm** **Actual End Time:** ______________ **am / pm**

Amount of Fluid Sprayed: ______________ **L / gal** **Type of Fluid:** ______________

End of Test Time: ______________ (hr:min:ss) am/pm

COMMENTS:

MEASUREMENTS BY: ______________

HAND WRITTEN BY: ______________

File: h:\cm1380\procedur\to_run\Gform4.xls
30/10/01, 11:47 AM

FIGURE 2a

GENERAL FORM (ONCE PER SESSION)

(TO BE FILLED IN BY OVERALL COORDINATOR)

AIRPORT: YUL YYZ YOW

AIRCRAFT TYPE: ATR-42 F-100 B-737 RJ DHC-8

EXACT PAD LOCATION OF TEST: ______________________

AIRLINE: ______________________

DATE: ______________________

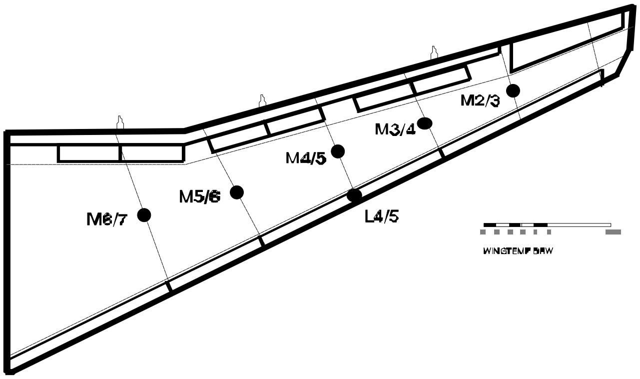
FIN #: ______________________

APPROX. AIR TEMPERATURE: ________ °C

FUEL LOAD: ______________________ **LB / KG**

TYPE I FLUID APPLICATION	***TYPE IV FLUID APPLICATION***
TYPE I FLUID TEMP: ________ °C	**TYPE IV FLUID TEMP:** ________ °C
Type I Truck #: ________	**Type IV Truck #:** ________
Type I Fluid Nozzle Type: ________	**Type IV Fluid Nozzle Type:** ________
Sample collected: Y / N	**Sample collected: Y / N**

TEMPERATURE MEASUREMENTS



ENTER FLUID TYPE:						
TIME	**TEMPERATURE AT LOCATION (°C)**					
(min)	**M6/7**	**M5/6**	**L4/5**	**M4/5**	**M3/4**	**M2/3**
Before[1] ( )						

(1) Actual Time Before Fluid Application

COMMENTS: ______________________

____

____

____

____

____

____

____

MEASUREMENTS BY: ______________________

HAND WRITTEN BY: ______________________

FIGURE 3

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Winter 97/98

DATE:	**RUN NUMBER:**

FAILURES CALLED BY:

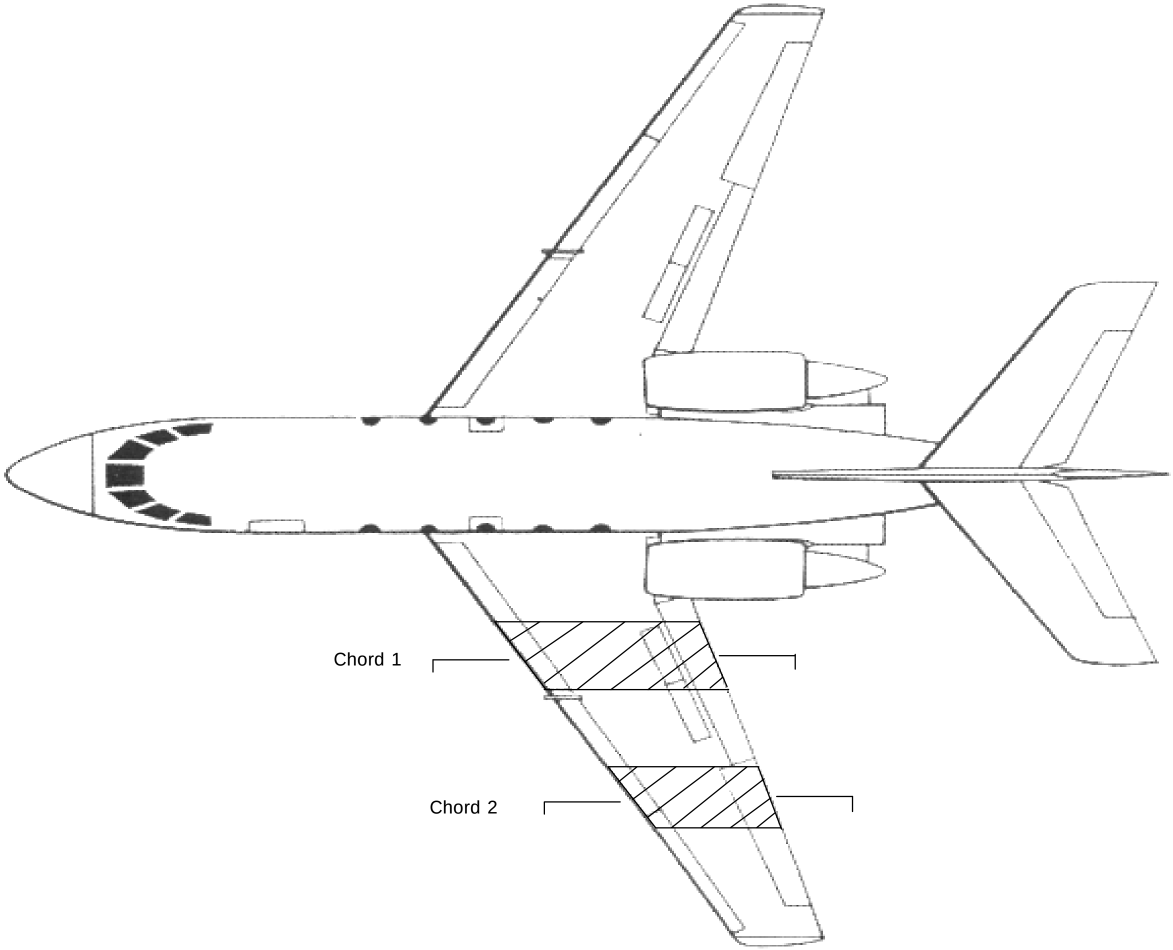
HANDWRITTEN BY:

ASSISTED BY:

COMMENTS:

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

FALCON 20



Cross-hatched area = Area of wing to be tested

File: \cm1380\procedur\t_orunFalc_20.xls
Printed: 30/10/01, 11:48 AM

FIGURE 4

FLUID THICKNESS ON AIRCRAFT

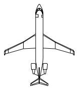
AIRPORT: YUL YYZ YOW

AIRCRAFT TYPE: ATR 42 F100 B-737 RJ DHC-8

DATE: ______________________

WING: PORT (A) STARBOARD (B)

DRAW DIRECTION OF WIND WRT WING:



RUN #: ______________________

DIRECTION OF AIRCRAFT: ____________ DEGREES

1st FLUID APPLICATION

Actual Start Time: ____________________ **am / pm** **Actual End Time:** ____________________ **am / pm**

Amount of Fluid Sprayed: ____________________ **L / gal** **Type of Fluid:** ____________________

2nd FLUID APPLICATION

Actual Start Time: ____________________ **am / pm** **Actual End Time:** ____________________ **am / pm**

Amount of Fluid Sprayed: ____________________ **L / gal** **Type of Fluid:** ____________________

Location	Time	Gauge	Time	Gauge	Time	Gauge	Time	Gauge	Time	Gauge
1										
2										
3										
4										
5										
6										
7										
8										
9										

Location

1 - LE Nose

2, 8- Half-way

3,4,6,7 - 1" from joint

5 - As far as can reach

9 - 6" from TE

COMMENTS: ______________________________

____

____

____

____

____

MEASUREMENTS BY: ____________________

HAND WRITTEN BY: ____________________

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ATTACHMENT I
TEST PROCEDURES

1. PRE TEST SETUP

- Coordinate with Aéromag for deicing spraying, and access to deicing pad;
- Coordinate with Aéroports de Montréal (Mirabel) and NavCan;
- Coordinate with RVSI or Spar/Cox for ice detection sensors;
- Identify wing areas to be tested (wing only, Figure 3);
- Arrange with the National Research Council to use video camera to record readings from air speed indicator on flight deck;
- Prepare freezing rain sprayer;
- Transport equipment to Mirabel;
- Brief team including Aéromag 2000;
- Synchronize times on all test instruments and watches; and
- Mark wing for thickness tests.

2. CONDUCT FLUID FAILURE TEST ON WING

- Plan to conduct this test at Ottawa airport under natural precipitation;
- Monitor weather for Ottawa outlooking a period of snow or freezing precipitation;
- Coordinate initiation of test with Knighthawk (Falcon 20 operator) and local deicing operator. Ensure aircraft is at outside air temperature;
- APS staff travels to Ottawa airport in time for test during precipitation;
- If acceptable, apply fluid with aircraft on the ramp. Alternatively, taxi the aircraft to the deicing area, receive a spray including anti-icing fluid, and return to the ramp and shut down. The aircraft is to be parked in a *tail to the wind* orientation;

- APS staff monitor the wing to identify and record initiation and progress of fluid failure on the wing following standard test procedures until more than 25% of the wing has failed;
- Repeat the trial for crosswind and *nose to the wind* orientations, if possible; and
- Observe initiation and progress of failures from inside the aircraft cabin, if possible.

3. CONDUCT DRY RUN

Note: Tests at YMX will be conducted with engines running, necessitating adequate hearing protection for all ground personnel.

- Setup equipment on board the aircraft and board operating team;
- Spray the entire wing following standard procedures for two step fluid application;
- Perform a taxi-only test. This involves:
- Thickness measure of fluid after 10 minutes setting period;
- Taxi the aircraft for typical duration and return to centre; and
- Re-measure thickness of fluid on wing.
- Operate the aircraft through normal taxi and take-off phases, rejecting take-off when rotation speed is reached;
- Conduct required documentation of fluid condition during the entire test, checking out the operation of the ice detection sensor and all cameras;
- When the aircraft has returned and parked at the test location, examine the wing to document any remnants of fluid on the wing. Measure thickness of any fluid remaining;
- Ensure that the flight deck camera has filmed the air speed indicator, and that all other cameras and the ice detection sensor operated as planned; and
- The aircraft will be flown on a short flight (about five minutes) to cool brakes between tests. Any contamination must be deiced prior to each flight.

4. CONDUCT CONTAMINATION TESTS

- Mount the test plate on the wing at the edge of the selected test area. The further use of the plate will be decided following the first trial;

- Take sample of fluids from the deicing vehicle, measure and record temperature and Brix;
- Spray the entire wing including the mounted test plate, following standard procedures for two step fluid application. Measure fluid thickness at several points;
- Using the freezing rain sprayer, apply precipitation over the test areas including the flat plate;
- Conduct pilot visibility of failure observations from the aircraft cabin;
- When the wing has reached the desired level of contamination, cease water application. Identify and record the wing and plate areas contaminated and degree of contamination on the data sheet, and by ice detection sensor. Measure thickness, adherence and dilution of fluid at points of contamination and at several locations along the chord. Remove the plate from the wing;
- With test crew onboard, perform the take-off run to rotation speed. With the video camera, film the nature of the fluid on the wing during the take-off run, capturing any movement, rippling or flowing action. Concentrate on the fluid area that is known to be failed;
- With the ice sensor, record images on a continuous basis to provide a record of any change in the indication of contaminated area;
- With the fixed video camera, record readings from the air speed indicator;
- When the aircraft has returned and parked at the test location, examine the wing to document any remnants of fluid on the wing. Measure thickness, adherence and Brix of any fluid remaining. Photograph any remnants of fluid still on the wing and scan the area with the ice detection sensor; and
- Deice the aircraft, and repeat the test for different levels of contamination.

Note: Perform the taxi test (described in Dry Run) at the 33% contamination condition.

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ATTACHMENT II
ADHERENCE OF CONTAMINATED FLUID
TEST EQUIPMENT CHECKLIST

TASK
Logistics for Every Test
Rent Van / Rent cube / Rent lighting
Call Personnel
Advise Airlines (Personnel, A/C Orientation, Equip)
Monitor Forecast
Call potential participants
Test Equipment
Freezing Rain Sprayer
Generator
Deicing Truck with Types I and IV
Flat Plate with Surrounding Skirt to Mount on Wing
Thickness Gauges
Brixometer
Thermometer
Thermometer Probe
Spar/Cox Sensor
RVSI Sensor
Video Camera X 3 plus tripod
Support Equipment for Video Camera
Cube Van to Transport Equipment
Personnel Van
Hearing Protectors
Step Ladders - Short + Tall
Thickness Measuring Kit
Contamination Adherence Instrument
Rolling Stair - Medium X 2
Heat Guns
Inclinometer

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ATTACHMENT III
APS STAFF TASK DESCRIPTION
AIRCRAFT TRIALS AT YMX

Coordinator
- Initiate test with all parties;
- Ensure that all required equipment is available and functional;
- Provide direction as required during the tests; and
- Ensure all data is collected and recorded, and that all test records submitted.

Photographer
- Video and photograph all test setup, outside and onboard the aircraft; and
- Operate video camera on board the aircraft during take-off run tests.

Ice Detection Sensor Operator
- Responsible to operate the ice detection sensor during the spray and contamination phase, during the take-off run phase, and following return to ramp.

Wing Observer
- Measure wing temperature at beginning of session and record word on General Form;
- Monitor and record condition of fluid on the wing and flat plate during the application of water. Alert the water spray operator when desired level of contamination has been reached; and
- Examine the wing for fluid or contamination remaining after aircraft return to the test site.

Water Spray Operator
- Responsible to ensure proper functioning of this equipment, giving attention to preventing lines from freezing between tests; and
- Responsible for spraying freezing rain over the protected area of the wing and the flat plate until advised that contamination has occurred.

Wing Observer Assistant
- Measure thickness, adherence and dilution of fluid on wing at points of contamination and other selected chordwise locations. Record on aircraft form (Figure 3) and on fluid thickness form (for taxi-only tests).

Cabin Observer
- Make observations of failures on wing from inside the cabin. Enlist and instruct Falcon 20 pilot to record pilot observations; and
- Occupy jump seat during aircraft runs to videotape air speed instrument.

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APPENDIX D

EXPERIMENTAL PROGRAM

FULL-SCALE FLUID FAILURE STATIC TESTS ON FALCON 20D

CM1380.001

EXPERIMENTAL PROGRAM
FULL-SCALE FLUID FAILURE STATIC TESTS ON FALCON 20

Winter 1997/98

APS AVIATION INC.

October 30, 2001
Version 1.0

EXPERIMENTAL PROGRAM
FULL-SCALE FLUID FAILURE STATIC TESTS ON FALCON 20
Winter 1997/98

This document supplements the standard tests on a Canadian Regional Jet and ATR 42. This document highlights any changes or differences that need addressing.

1. OBJECTIVE

The objective of the Falcon 20 static tests are to supplement the Falcon 20 dynamic tests at Mirabel (see separate procedure), and to determine the patterns of failure and roughness.

2. LOCATION; TEST LOCALE; SETUP

Aircraft:	Falcon 20
Operator:	KnightHawk
Deicer:	Shell or Hudson General
Location:	Shell pad or central pad, Ottawa International

3. TEST PROGRAM

- Three tests planned during the daytime in one session.
  - 2 X Leading edge into wind
  - 1 X Trailing edge into wind
- Snow or freezing rain/drizzle.
- Type IV (Ultra+) over Type I (XL54).

4. EQUIPMENT

- Portable test stand;
- Balance for rates;
- Plates and plate pans;
- Thickness gauges (feet, oct.);
- Ladders X 2;
- V1 kit;
- P1 kit;
- Marking kit;
- Squeegees;
- XL54 fluid;
- Ultra+ fluid;
- Compass;
- Passes for personnel;
- Data forms for plates, rates, wing and general;
- Temperature probe on an extension pole;
- Clipboards;
- Watches;
- VHF radios;
- Test procedures X 6; and
- Anemometer.

5. PERSONNEL

i) Wing observer (T2)	(MC) from YUL
ii) Video (V1)	(DR) from YUL
iii) Photographer (P1)	(JM) from YUL
iv) Meteo (T1)	(CB) from YOW
v) End condition (T3)	(MA) from YOW

6. PROCEDURES AND MEASUREMENTS

Refer to the standard procedure. Any changes or differences to the standard procedure are given below.

- Falcon 20 must be cold-soaked prior to start of testing;

- Tow Falcon 20 to Shell deicing pad, than apply Type I followed by Type IV. It the equipment used to apply the fluids are not suitable to APS, then consider towing the aircraft to the central deicing facility for fluid application. Then tow the aircraft back to the Shell pad; and

- Measure film thickness after application of Type IV fluid at three wing span locations on the leading edge surface, halfway between the nose and the leading edge joint. Note the time.

7. DATA FORMS (Refer to Standard Procedure)

- Figure 3 by MC;
- Figure 3a by MC;
- Figure 4 by MC (Falcon 20 attached to this document);
- Figure 5 by MC;
- Table 1 by MA; and
- Table 2 by CB.

FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 4.0 Winter 97/98

DATE: **RUN NUMBER:**

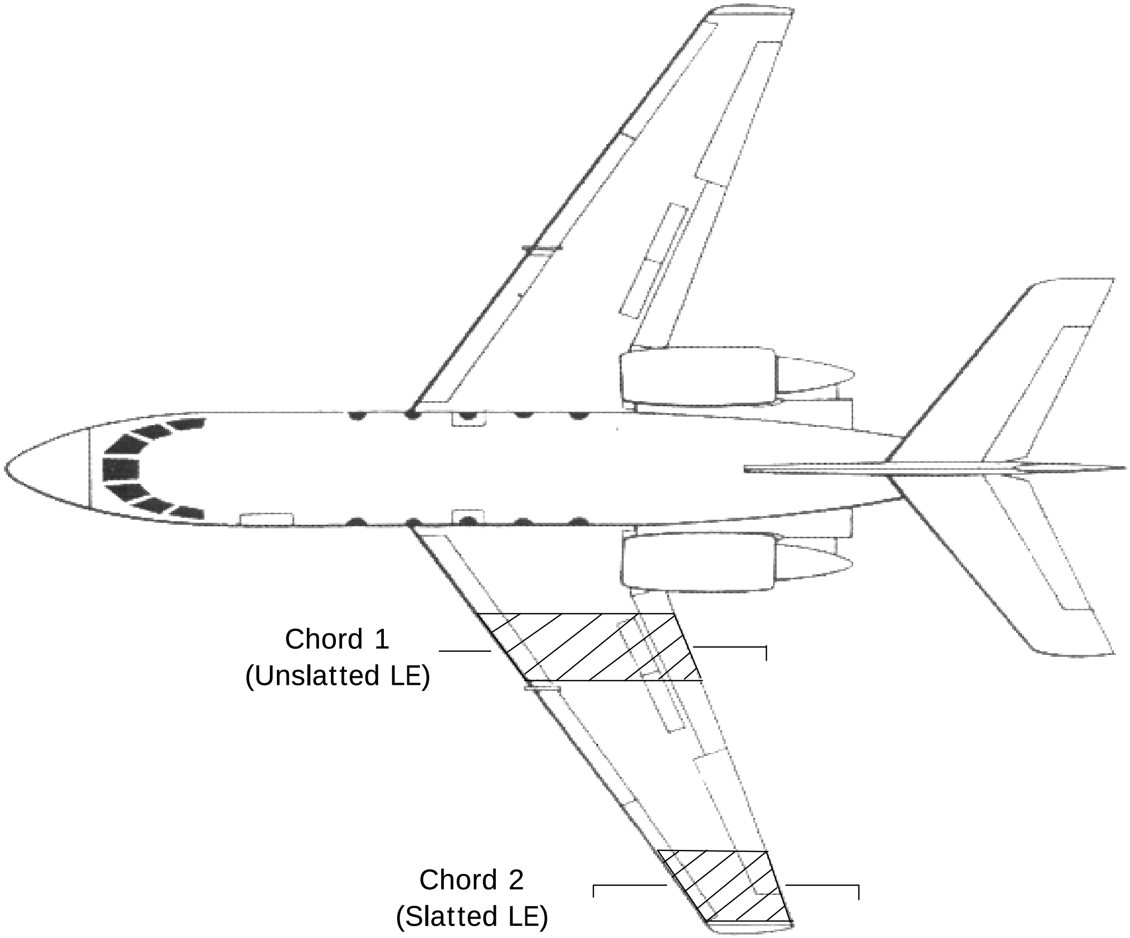
FAILURES CALLED BY: ____________________ **COMMENTS:** ____

HANDWRITTEN BY: ____________________ ____

ASSISTED BY: ____________________ ____

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

FALCON 20



Cross-hatched area = Area of wing to be tested

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