TP 13481E

Feasibility of Use of Ice Detection Sensors for End-of-Runway Wing Checks

Prepared for

Transportation Development Centre
On behalf of
Civil Aviation

Transport Canada

APS AVIATION INC.

October 1999

Final Version 4.0

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by

Peter Dawson and
Antoni Peters

APS AVIATION INC. APS

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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 advance aircraft ground deicing/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time tables for new anti-icing fluids, and to validate fluid-specific and SAE holdover time tables;
- To gather enough supplemental experimental data to support the development of a deicing-only table as an industry guideline;
- To examine 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 and including rotation;
- To measure the jet-blast wind speeds developed by commercial airliners in order to generate air-velocity distribution profiles (to predict the forces that could be experienced by deicing vehicles), and to develop a method of evaluating the stability of deicing vehicles during live deicing operations;
- To determine the feasibility of examining the surface conditions on wings before takeoff through the use of ice-contamination sensor systems, and to evaluate the sensitivity of one ice-detection sensor system;
- To evaluate the use of warm fuel as an alternative approach to ground deicing of aircraft;
- To evaluate hot water deicing to determine safe and practicable limits for wind and outside ambient temperature;
- To document the appearance of fluid failure, to measure its characteristics at the point of failure, and to compare the failures of various fluids in freezing precipitation;
- To determine the influence of fluid type, precipitation (type and rate), and wind (speed and relative direction) on both the locations and times to fluid failure initiation, with special attention to failure progression on the Bombardier Canadair Regional Jet and on high-wing turboprop commuter aircraft;
- To evaluate snow weather data from previous winters to identify a range of snow-precipitation suitable for the evaluation of holdover time limits;
- To compare the holdover times from natural and artificial snow trials and to evaluate the functionality of the NCAR simulated snowmaking system; and
- To develop a plan for implementing a full-scale wing test facility that would enable the current testing of deicing and anti-icing fluids in natural and artificial freezing precipitation on a real aircraft wing.

The research activities of the program conducted on behalf of Transport Canada during the 1998-99 winter season are documented in twelve reports. The titles of these reports are as follows:

- TP 13477E Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1998-99 Winter;

- TP 13478E Aircraft Deicing Fluid Freeze Point Buffer Requirements for Deicing Only Conditions;
- TP 13479E Contaminated Aircraft Takeoff Test for the 1998-99 Winter;
- TP 13480E Air Velocity Distribution Behind Wing-Mounted Aircraft Engines;
- TP 13481E Feasibility of Use of Ice Detection Sensors for End-of-Runway Wing Checks;
- TP 13482E Evaluation of Warm Fuel as an Alternative Approach to Deicing;
- TP 13483E Hot Water Deicing of Aircraft;
- TP 13484E Characteristics of Failure of Aircraft Anti-Icing Fluids Subjected to Precipitation;
- TP 13485E Aircraft Full-Scale Test Program for the 1998-99 Winter;
- TP 13486E Evaluation of Snow Weather Data for Aircraft Anti-Icing Holdover Times;
- TP 13487E Development of a Plan to Implement a Full-Scale Test Site; and
- TP 13488E A Snow Generation System – Prototype Testing.

This report, TP 13481E, addresses the following objective:

- To determine the feasibility of examining the surface conditions on wings before takeoff through the use of ice-contamination sensor systems, and to evaluate the sensitivity of one ice-detection sensor system.

This objective was met by conducting a series of field trials wherein wings of departing aircraft were scanned with an ice contamination sensor camera located near the departing runway. Appropriate sites for scanner locations, and test procedures were developed with the cooperation of staff from airport and air traffic control organizations. Trials to evaluate the sensitivity of an ice detection sensor were postponed to the Winter 1999/2000 season.

ACKNOWLEDGEMENTS

This research has been funded by the Civil Aviation Group, Transport Canada, and with support from the Federal Aviation Administration. This program could not have been accomplished without the participation of many organizations. APS would like to thank, therefore, the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, the National Research Council Canada, Atmospheric Environment Services Canada, Transport Canada, and several fluid manufacturers. Special thanks are extended to US Airways Inc., Delta Air Lines, Royal Airlines, Air Canada, the National Research Council Canada, Canadian Airlines International, AéroMag 2000, Aéroport de Montreal, the Greater Toronto Airport Authority, Hudson General Aviation Services Inc., Union Carbide, RVSI, Cox and Company Inc., the Department of National Defence, and Shell Aviation, for provision of personnel and facilities and for their co-operation on the test program. APS would like also to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data.

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Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Twelve reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface. This project was co-sponsored by Cox and Company Inc.

16. Abstract

The objective of this study was to examine the feasibility of using remote ground ice detection sensors to provide information to pilots on the condition of aircraft wings following de/anti-icing and just prior to the take-off decision.

Feasibility was examined by determining test locations and developing tentative test procedures in cooperation with airport authorities; obtaining an appropriate vehicle for camera installation; and performing scanning trials on aircraft preparing for takeoff after deicing operations.

The suitability of selected scanning locations near departure runways, and the height requirements and limitations for remote ground detection sensor applications are discussed. Observations on the performance of an ice detection sensor system in this application are presented.

Results of field trials indicate that the most effective location for the sensor would be adjacent to the runway holding area.

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Les rapports de recherche produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs peuvent être obtenus auprès du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à douze rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports. Ce projet était coparrainé par Cox and Company Inc.

16. Résumé

Cette étude avait pour objectif d'évaluer la faisabilité de faire appel à des détecteurs de givrage en bout de piste pour informer les pilotes sur l'état de givrage des ailes juste avant le décollage.

Les chercheurs ont choisi les sites d'essais, élaboré de concert avec les autorités aéroportuaires un mode opératoire préliminaire pour les essais, obtenu un véhicule approprié pour le montage de la caméra de détection et fait un certain nombre d'essais de détection du givrage d'appareils en attente de décollage après avoir subi un traitement de dégivrage/antigivrage.

Le rapport aborde le bien-fondé des sites de contrôle choisis à proximité des pistes de décollage ainsi que les critères de hauteur d'installation à respecter. Il présente également des observations quant à la performance d'un système de détection du givrage fixe dans cette application.

D'après les résultats des essais réalisés, le meilleur endroit où installer ce système serait l'aire d'attente en tête de piste de décollage.

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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 application of a ground-based (or remote) ice detection sensor (GIDS) to provide information on the condition of aircraft wings just prior to departure.

This program comprised four principal activities:

1. Determining the feasibility of using a remote GIDS to assess the existence of frozen contamination on the wings of aircraft just prior to entering the departure runway. This was to include a series of field trials, during actual operations in weather conditions requiring active ground deicing, and use of an ice detection system installed on a mobile vehicle.

2. Evaluating the sensitivity of a remote GIDS and its ability to produce reliable results at such locations.

3. Determining the minimum ice thickness detectable in tactile tests. Results from these trials were intended for use in deciding the acceptability of replacing tactile tests with remote GIDS readings.

4. Proposing an approach to determining acceptable limits for levels of contamination on aircraft wings during actual operations.

The first objective was satisfied by:

- Selection and approval of test locations close to runways normally used for departures during storm conditions;
- Development of test procedures in collaboration with airport authorities;
- Selection of an appropriate vehicle for camera installation; and
- Execution of scanning trials on aircraft preparing for takeoff after deicing operations.

This report addresses the results and the observations made during the scanning trials using a remote GIDS located near departure runways.

Activities 2, 3, and 4 listed above were postponed to the 1999-2000 winter season. However, an experimental procedure was developed for examining the sensitivity of the sensor system.

Results and Conclusions

Scanning trials conducted at approved sites near the ends of departure runways demonstrated that selection of appropriate sites and operation of remote sensors are viable within existing airport regulations. While the sites approved for the tests were conservative, involving large separations between the detection equipment and aircraft traffic, reasonable results were obtained.

Scanning of stationary aircraft produced the best results. Selection of locations where the ice detection unit can take advantage of aircraft stops should be a primary siting consideration. Aiming the unit at aircraft awaiting takeoff clearance on the holding apron of the runway would be a good solution and would also minimize the elapsed time to takeoff following inspection.

The elevation of the sensor camera during the tests was suitable for scanning wings of aircraft up to narrow body in size. A camera height just below that of the B747 tail fin would enable satisfactory views of large wide body aircraft wings.

A number of issues were documented regarding the performance of the remote GIDS which, when addressed, will result in a system suitable for use at end of runway.

SOMMAIRE

À la demande du Centre de développement des transports (CDT) de Transports Canada, APS Aviation a entrepris un programme de recherche visant à déterminer l'efficacité d'un détecteur de givrage fixe (en bordure de piste) comme moyen d'informer les pilotes sur l'état de givrage des ailes de leur appareil juste avant le décollage.

Ce programme était articulé autour de quatre objectifs principaux :

1. Déterminer la faisabilité de faire appel à un détecteur de givrage fixe en bordure de piste pour vérifier l'état de givrage des ailes d'un avion juste avant qu'il amorce sa course au décollage. Ce volet devait comporter une série d'essais en piste dans des conditions météo opérationnelles exigeant un traitement de dégivrage au sol, le détecteur de givrage étant monté sur un véhicule.

2. Évaluer la sensibilité du détecteur de givrage fixe et la fiabilité des mesures produites aux endroits choisis.

3. Déterminer l'épaisseur minimale détectable par le toucher. Les résultats de ces essais devaient permettre de se prononcer sur l'acceptabilité de remplacer les contrôles tactiles par une détection instrumentale à distance.

4. Proposer une technique de détermination des limites acceptables de givrage en conditions réelles.

Pour les fins du premier objectif, les chercheurs ont :

- Choisi et fait approuver des sites de contrôle à proximité des pistes normalement utilisées en conditions de précipitations intenses;
- Développé, de concert avec les autorités aéroportuaires, le mode opératoire des essais;
- Choisi un véhicule approprié sur lequel monter la caméra de détection; et
- Réalisé des essais de détection du givrage d'appareils en attente de décollage après traitement de dégivrage/antigivrage.

Ce rapport présente les résultats des essais de détection au moyen d'un détecteur de givrage fixe à proximité de pistes de décollage.

Les objectifs 2, 3 et 4 ci-dessus ont été reportés à la saison hivernale 1999-2000. Par contre, les chercheurs ont mis au point le mode opératoire de l'essai visant à déterminer la sensibilité du détecteur de givrage.

Résultats et conclusions

Les essais de détection réalisés aux endroits approuvés à proximité des pistes de décollage ont montré qu'il était possible de trouver des sites de mesure appropriés et de mettre en oeuvre les détecteurs tout en respectant les règlements aéroportuaires en vigueur. Même si pour des raisons de sécurité les sites approuvés étaient considérablement éloignés des appareils à contrôler, les chercheurs ont obtenu des résultats raisonnables.

Les meilleurs résultats ayant été obtenus lorsque les appareils étaient immobiles, il y a lieu d'implanter les détecteurs de givrage fixes principalement à proximité des endroits où les appareils doivent normalement s'arrêter avant d'amorcer leur course au décollage. Un endroit de choix serait l'aire d'attente des appareils prêts à décoller, aire qui présente également l'avantage d'un délai réduit entre le contrôle de l'état de givrage et le décollage proprement dit.

La hauteur à laquelle se trouvait la caméra de détection durant les essais convient pour les avions de classe C et moins. Une caméra montée quasiment à la hauteur du sommet de l'empennage d'un B747 offrirait une vue satisfaisante des ailes des gros porteurs.

Les chercheurs ont énuméré un certain nombre de lacunes concernant la performance du détecteur de givrage fixe. Une fois ces points réglés, on disposera d'un système apte à servir en bout de piste.

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GLOSSARY

APS	APS Aviation Inc.
FAA	Federal Aviation Administration
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers
TDC	Transportation Development Centre
UCAR	Union Carbide Corporation
CDF	Central Deicing Facility

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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 application of ice contamination sensor cameras to provide additional information to pilots on the condition of aircraft wings just prior to departure.

This program was to encompass four principal activities:

1. Determining the feasibility of locating and using ground-based ground ice detection sensors (ground-based GIDS, from here forward referred to as remote GIDS) to assess the existence of ice contamination on the wings of departing aircraft just prior to entering the departure runway.

   This activity was to include a series of field trials during actual operations in weather conditions requiring active ground deicing, using a remote GIDS installed on a mobile vehicle.

2. Evaluation of the sensitivity of a remote GIDS, and its ability to produce reliable results at such locations.

   The SPAR/COX remote GIDS was selected for this examination. The principal factors to be determined in laboratory trials included:

   - Ice thickness threshold, based on FAA Ice Detection Thickness Plates;
   - Detection of ice under anti-icing fluid; and
   - Effect of contamination roughness.

   Additionally, the following parameters were to be examined in outdoor conditions:

   - Visibility in snow conditions; and
   - Accuracy in changing light conditions.

3. Determination of the minimum ice thickness detectable in tactile tests. Results from these trials were intended for use in deciding the acceptability of replacing tactile tests with remote GIDS readings.

4. Proposal of an approach for the determination of acceptable limits for levels of contamination on aircraft wings during actual operations.

   The development of a conceptual approach to the determination of operational limits was expected to draw from the experience and observations gained from the end-of-runway activity.

This report addresses the results associated with activity 1 and discusses scanning trials using the remote GIDS located near departure runways.

Activities 2, 3 and 4 listed above were postponed to the 1999/2000-winter season. The experimental procedure developed to examine the sensitivity of a sensor system is included as Appendix E in this report.

1.1 Background

Considerable R&D effort has led to the development of remote GIDS. These systems are operated remotely from the aircraft, and are able to scan a surface from some distance for evidence of frozen contamination. An important potential application for these cameras is to provide information on the condition of aircraft wings during periods of winter precipitation, just prior to departure. This information could be made available to the pilot as supplemental information to assist when performing visual pre-takeoff contamination checks, or it could potentially be used to make *GO/NO-GO* decisions.

During the winter season 1997/1998, a preliminary examination was conducted on the feasibility of locating and using a sensor camera near the entry point of a departure runway. Results of this activity were included in the report *Research on Aircraft Deicing Operations for the 1997/98 Winter TP13314E* (1). In that activity, a single field demonstration was conducted at Aéroports de Montreal (Dorval). A remote GIDS was mounted on a boom truck with a maximum elevation of 30 feet and positioned at the unused east deicing bay; a location where there were no conflicts with normal obstacle clearances for runways. This location allowed scanning of wings on aircraft enroute to the departure runway following deicing at the Central Deicing Facility.

The trial demonstrated the use of the sensor camera in this environment. The trial was observed by representatives from the Transport Canada Transportation Development Centre, NAVCAN and airport management (Aéroports de Montreal).

In addition, initial laboratory trials were conducted in the National Research Council Climatic Engineering Facility to explore the operating capabilities of a prototype Spar/Cox camera. The parameters investigated included distance from camera to subject, size of area contaminated, impact of different surfaces, and viewing angles.

Some preliminary, positive conclusions were drawn which indicated that the camera was capable of identifying contamination at distances in excess of

25 m, that the minimum angle of viewing may be suitable to end of runway application and that surface material or colour does not appear to interfere with the camera capabilities.

Based on the demonstrated capabilities of the remote GIDS, it was recommended that:

- Further field trials be conducted to fully assess the feasibility of examining aircraft wings prior to takeoff; and
- Further trials be conducted to fully assess sensor system limitations.

1.2 Work Statement

Appendix A presents the work statement for the APS Aviation Winter 1998/99 research program. Sections 5.8, 5.9 and 5.14.7 of Appendix A describe this project.

1.3 Objectives

The project objective addressed in this report was:

- To examine the feasibility of scanning aircraft wings with remote GIDS just prior to the aircraft's entry onto the departure runway (using Dorval airport as a trial installation).

This objective was satisfied by the selection and approval of test locations close to runways normally used for departures during storm conditions, the development of test procedures in collaboration with airport authorities, the selection of an appropriate vehicle for camera installation, and the execution of scanning trials on live aircraft departures during deicing operations.

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2 INSPECTION SITE SELECTION AND CRITERIA

Selection of the optimum site for positioning an inspection camera requires consideration of a number of factors. These include aerodrome standards designed to minimize the dangers presented by obstacles to an aircraft, local airport runway, taxiway and deicing facility layout, the nature of local airport operations during deicing conditions, and remote GIDS system limitations.

2.1 Aerodrome Standards

2.1.1 Obstacle Restrictions

The height limitation of the sensor camera installation is controlled by its location relative to the runway. All fixed and mobile objects that extend above a defined surface intended to protect aircraft in flight are described as obstacles. That defined surface is known as the Obstacle Limitation Surface (OLS). The element of the OLS that limits the height of a GIDS system is the transitional surface. Fixed objects are not permitted above the transitional surface except for frangibly mounted objects that are located on the strip because of their function. Mobile objects are not permitted above the transitional surface when the runway is used for landing.

The transitional surface has an inner lower edge running along the side of the runway with the plane of the surface sloping upwards and outwards. The surface also intersects with the take-off/approach surface that slopes upward and outward from the end of the runway.

Plan and profile views of the obstacle limitation surfaces are given in Appendix D (source *Aerodrome Standards and Recommended Practices, Transport Canada, 4th Edition, March 01, 1993),* Figure 4.1.

The slope of the transitional surface is defined in Appendix D, Table 4.1, as 14.3% or 1:7.

An example of the height limitation imposed by the transitional surface on the placement of a GIDS sensor follows. Consider a runway of width 60 m. If the sensor is located 100 m from the runway center line, or 70 m from the runway edge, the maximum height allowable would be 70 divided by 7, or 10 m.

2.1.2 Taxi-Holding Positions

The location of aircraft taxi-holding positions as well are controlled by the transitional surface. Both the tail height and nose height are considered in establishing minimum distances from the runway center line. Table 3.2 in Appendix D gives the minimum distances. In the case of a precision approach runway, the minimum distance from the runway center line to a holding bay is 90 m.

This is of interest to the decision for locating the GIDS camera because scanning of static aircraft, as opposed to taxiing aircraft, produces superior results. The height limitation imposed by the transitional surface using the previous example, would be 60 m divided by 7, or 8.6 m.

2.1.3 Taxiway Minimum Separation Distances

To permit the safe and expeditious movement of aircraft, certain separation distances between the taxiway center line and objects are defined. Table 3-1 in Appendix D gives the minimum separation distances. This table allows 26 m (87 ft) for B737 type aircraft and 47.5 m (158 ft) for B747 type aircraft.

2.2 Airport Layout

The layout or geography of each airport considered for installation of GIDS systems for end-of-runway scanning will influence the site decision.

Specific runways may be favored for departures during weather conditions requiring deicing and should be given prime consideration when designing GIDS installations. Whether these runways are dedicated to departures, or also used for landing, can affect the height of the sensor installation.

The taxiway routes from deicing facilities to the departure runway must be considered.

Similarly, an escape route is necessary to allow the aircraft to return to the deicing facility following scanning of the wing for frozen contamination. Should the aircraft require a respray, a return route to the deicing facility that does not tie up or interfere with other traffic is critical.

The design of holding bays where aircraft await departure clearance may influence the GIDS location decision. Bays having more than one center line to allow side-by-side aircraft positioning while awaiting departure clearance may prevent the scanning of both wings. Bays that require immediate turning of the aircraft when departing the holding bay may result in an unacceptably strong jet-blast in the area where a GIDS camera might be located.

2.3 GIDS System Limitations

The sensor operating characteristics and limitations must be considered. As with any optical instrument, the field of view is a function of the square of the distance between instrument and subject. Similarly, the level of detail within the scanned area is diminished with increased distance.

The angle of view on the scanned surface is important. Below certain viewing angles, the GIDS system can not identify contamination regardless of extent. In this application, the normal wing dihedral exaggerates the problem for a sensor located outboard from a wingtip. Scanning with more acute viewing angles reduces the ability to identify small areas of contamination.

Increased sensor height and minimum separation distances will produce enhanced results and better accuracy of contamination identification.

Placing the sensor installation where it can scan aircraft that come to a halt in their normal departure routine, such as when awaiting clearance for departure, will produce enhanced results as compared to the scanning of moving aircraft.

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3 METHODOLOGY FOR FEASIBILITY TRIALS

This section describes the test conditions and procedures, the test equipment, and the personnel required to carry out this investigation.

3.1 End of Runway Trials

3.1.1 Test Site

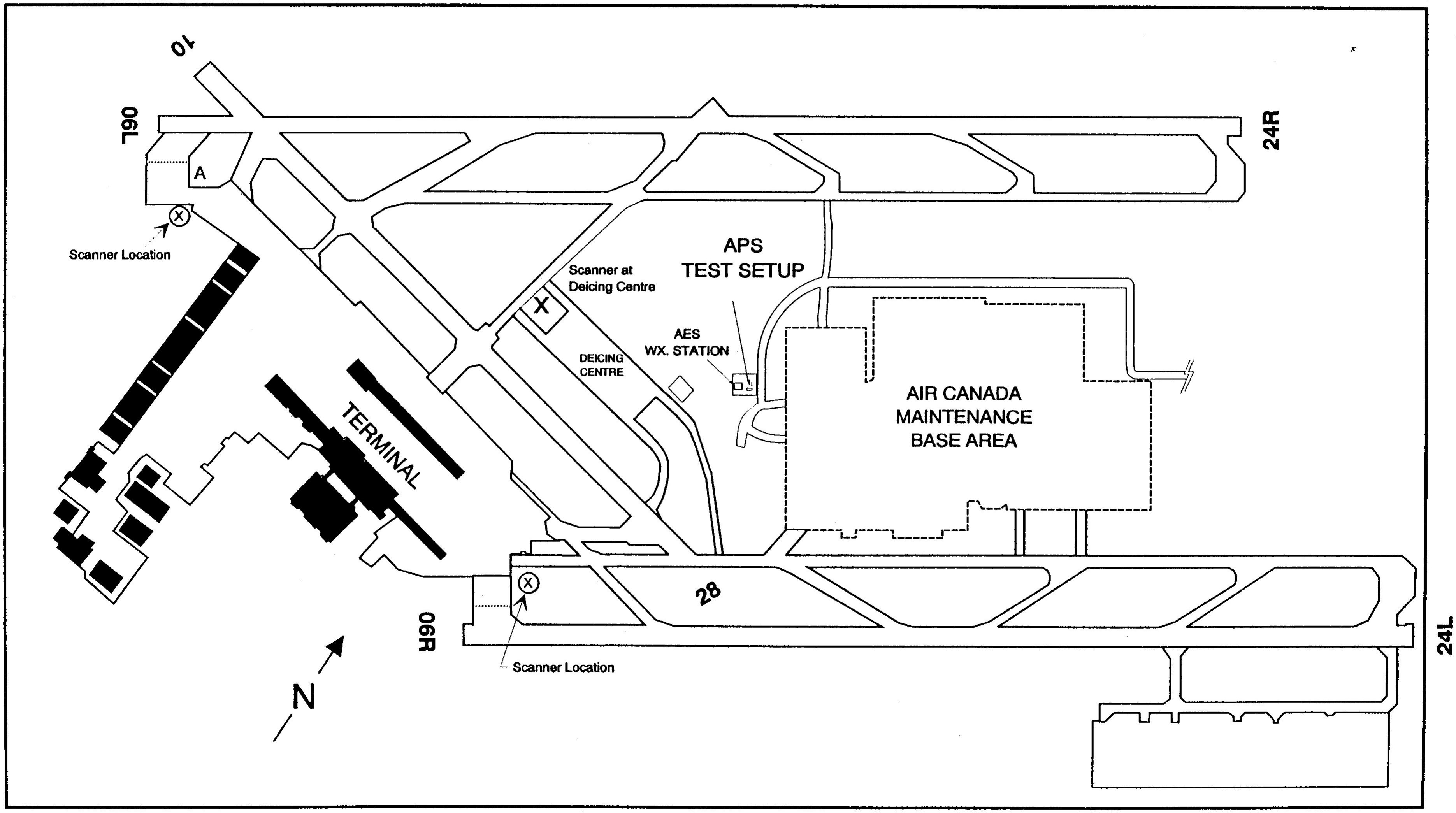
The end-of-runway trials were conducted at Montreal International Airport (Dorval). In collaboration with Aeroports de Montreal management, two locations suitable for scanning departing aircraft were identified and subsequently approved for the trials against the criteria that standard clearances should be respected (Appendix D, Table 5.1), that the maximum elevation of the boom should not exceed the height of the highest tail fin of an aircraft waiting to depart, and the truck should be no closer to the runway than a stationary aircraft waiting for clearance to take off. A vehicle with a 12.6 m (42 ft.) mast was used to mount the camera. The controls were operated from the interior of the vehicle. Details on approved locations are contained in Appendix C.

An overall view of Dorval Airport showing the general location of the two runway sites is given in Figure 3.1. During the field trials, only one of the locations was actually used: that near departure Runway 06R. This site was located about 30 m (100 ft.) back from the edge of the taxiway adjacent to the hold position for aircraft awaiting takeoff clearance.

Photo 3.1 shows the ice sensor-equipped vehicle in position at Runway 06R. In the photograph, a De Havilland Dash 8 aircraft is holding for departure at the prescribed hold position, and another aircraft is making a landing approach. The passenger terminal can be seen just beyond the vehicle.

Some scanning trials were also conducted near the west entrance to the Central Deicing Facility (CDF). The intent of testing at that location was to allow scanning of aircraft prior to deicing when contamination could be expected to exist on the wing surfaces, and sensor observations could be correlated with actual contamination.

FIGURE 3.1
SCANNING AIRCRAFT AT END OF RUNWAY DORVAL AIRPORT



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The site at Runway 06R was an appropriate location as 06R is the most commonly used departure runway during weather necessitating deicing operations. After having been deiced at the CDF, the aircraft proceeded to 06R along a taxiway that passed directly in front of the scanning site.

3.1.2 Description of Test Procedures

In preparation for these trials, a meeting was held with Aeroports de Montreal management (Dorval Airport), staff from the Transportation Development Centre (TDC) of Transport Canada, and APS, to discuss potential issues and solutions. The issues that required resolution in planning this project included:

- The question of equipment positioning in light of existing runway clearance limitations;
- Selection of mobile equipment capable of supporting realistic tests in the field, and representative of a permanent solution;
- Necessary airport support (snow clearance and escorts, etc.); and
- Communication protocols to support the trials.

APS staff monitored weather forecasts and initiated trials based on indications of a strong likelihood of freezing precipitation conditions requiring aircraft deicing. A contact was established with a member of the airport management, who was advised of intended trials, and who passed on the information to other departments as required. When necessary, this contact would also arrange for snow removal at the test site. As well, sensor technical support personnel were advised of expected trials, in time for a representative to travel to Montreal to participate in and support equipment operation.

The decision to initiate a trial required significant lead-time to allow for delivery of the mast-equipped vehicle on a lease basis. The vehicle was returned between operations. The sensor system was re-installed at the beginning of each trial. Following instrument installation and system check, the vehicle was moved to the approved test site for the departure runway in use. A security escort accompanied the test vehicle while on the airport.

Upon arrival at the test site, the truck mast, with ice detection camera installed, was raised to its full 12.6 m (42 ft.) height. This height was expected to enable scanning of wing surfaces of commuter and narrow body aircraft, as well as wing leading edges of large wide body aircraft. Horizontal tail surfaces were not examined in the trials.

Two standard aluminum test plates as used for SAE fluid holdover time testing were positioned on a portable test stand installed at a distance of 25 m from the sensor, clear of the taxiway, to serve as reference surfaces. These surfaces were allowed to accumulate contamination at an appropriate distance from the natural precipitation, and were periodically scanned to confirm that the sensor camera was able to identify contamination through the prevailing precipitation. One plate was treated with Type IV fluid while the second plate was exposed bare.

As aircraft taxied past the test location, a camera operator (located in the vehicle) turned the camera to scan the wing on the near side using the tilt and pan features integrated into the camera installation. A view of the scanned area was displayed on the TV monitor inside the vehicle. A key function performed by the operator was to trigger contamination detection when aircraft were in suitable locations. All camera views of the aircraft (normal video, and ice detection scans) were recorded on videotape. System data for all ice detection scans were saved on the system data base file.

One team member monitored and recorded radio transmissions of aircraft ground movements and details of aircraft deicing. This information was used during the trials to track aircraft approaching the test site. Aircraft records also allowed later retrieval of the complete deicing history from the CDF.

The test plan included provisions for a video operator to videotape aircraft as they taxied past the test position. The objective was to attempt to record visible evidence of any contamination on the aircraft. As this operator was situated at ground level, the resulting views of the aircraft were very limited and the activity was not continued beyond the first session.

Appendix B provides the detailed test plan for these trials, and sample data forms.

The data forms used during these trials were the following:

- Record of Scanned Aircraft
  This form was used to prepare a hand written record of the aircraft, the time, and the observed wing conditions.

- Deicing History for End-of-Runway Test
  This form was used to document the type(s) of fluid used to deice each aircraft, the prevailing weather conditions, the reason(s) for deicing, and the start of the holdover time.

3.1.3 Equipment

The main equipment required for these trials was the remote GIDS and the mast-equipped vehicle.

A Bell Canada microwave truck (a microwave diagnostic unit normally used for signal verification and transmission diagnostics) was selected to serve as the platform for mounting and controlling the sensor system. This vehicle was equipped with a 12.6 m (42 ft.) retractable mast, and had a cabin designed to facilitate electronics equipment installations. Photo 3.2 shows the vehicle with the mast at full vertical extension. The electronics cabin, situated behind the vehicle operator position, was sufficiently spacious to comfortably accommodate three observers. A power supply adequate to operate all electronics was integrated into the vehicle design. The portable test stand with flat plates is seen in the foreground. A white plate used to calibrate the system is mounted on a tripod in front of the vehicle.

Cox and Co provided the remote GIDS used for the trials. The Spar/Cox sensor system measures the intensity of infrared (IR) light in specific band widths. The contrast between the ambient IR intensity and the IR intensity from the surface image is used to detect contamination on the surface to be inspected.

The system (as provided) included a camera mount with remote tilt and pan controls. Photo 3.3 shows the camera control unit. This unit was designed to be the complete control for the remote GIDS in operational use. The camera controls can be seen on the unit face: Up/Down; Left/Right, On/Off switch, Inspect Aircraft switch, Inspect Engine switch, and a small monitor. Ice detection of the aircraft is initiated by pressing the *Inspect Aircraft* switch. The *Inspect Engine* mode causes a system auxiliary light to operate, allowing inspection inside the engine inlet. The monitor provides an image of the aircraft, and of areas of contamination (displayed as red areas) when the contamination detector is triggered. System data is automatically stored when either “inspect” switch is activated.

A TV monitor and VHS recorder were integrated into the system to support monitoring and recording of the camera view. Photo 3.4 shows this equipment installed in the vehicle. The monitor allowed viewing by several observers during the actual trials, and displayed the normal video view from the camera with the ice detection indications superimposed onto the video image momentarily after a scan was triggered.

The Spar/Cox remote GIDS was mounted on the vehicle mast, which gave a height sufficient to enable scanning of the tops of wings of small to medium-sized aircraft. Photo 3.5 shows the camera installation on the bucket of the mast. The systems own light source is seen beside the camera.

The camera pan/tilt controls, the monitor, the VCR (to videotape all video and sensor images), and the remote GIDS controls were installed in the vehicle cabin.

A VHS radio linked to an audiocassette recorder was used to monitor aircraft ground movements and deicing centre radio transmissions (Photo 3.6).

A portable flat plate test stand (Photo 3.7) with flat plates served as a reference surface during scanning operations.

The full list of equipment is included in Appendix B.

3.1.4 Fluids Used for Aircraft De/Anti-icing

Monitoring of radio transmissions from the deicing centre permitted recording of the fluid types used in the deicing operation. Fluids used at the Montreal (Dorval) CDF include UCAR Type I Aircraft Deicing Fluid and UCAR Ultra+ Aircraft Anti-icing Fluid.

Union Carbide Ultra+ Type IV fluid was used on one of the two reference plates, corresponding to the fluid used at the CDF.

3.1.5 Personnel

Representatives from Cox and Co. were present to support operation of the ice contamination sensor system.

Representatives from the Transport Canada Transportation Development Centre participated as observers.

A Bell Canada operator was provided for the microwave truck. In addition to driving, the operator's responsibilities included operation of the vehicle mast and the supplementary power supply.

The APS Aviation test team, composed of three people, initiated each trial session and collected test data.

Photo 3.1
Scanner Location at Runway 06R

Photo 3.2
Scanner Vehicle

Photo 3.3
Camera Control Unit

Photo 3.4
Camera Monitor and VCR in Truck Cabin

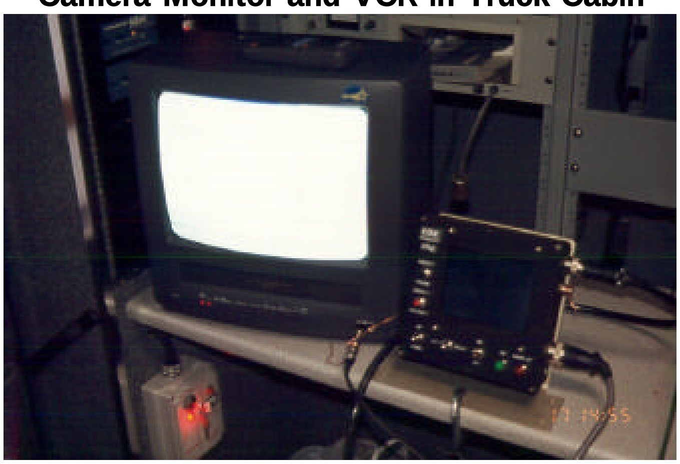

Photo 3.5
Camera Mounting on Mast

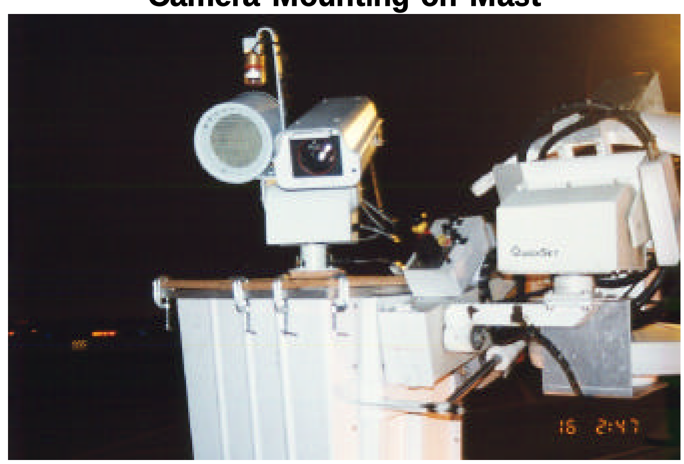

Photo 3.6
Monitoring Aircraft Movements

Photo 3.7
Reference Plates on Portable Stand

4 DESCRIPTION AND PROCESSING OF DATA

The objective of this study was to examine the feasibility of scanning wings of departing aircraft with a remote contamination sensor, just prior to the aircraft entering the departure runway. This was accomplished by positioning the remote contamination sensor at an appropriate location near the end-of-runway and then inspecting wings of departing aircraft. As well, aircraft scanning in a simulated end-of-runway set-up at the CDF was conducted to allow comparison of sensor indications of contamination to deicing crew visual observations.

During the scanning trials, a record of each scanned aircraft and its deicing history was maintained. Sensor system indications of any contaminant present on wings were recorded on videotape and were reviewed some time after the test session.

4.1 End of Runway Trials

Trial applications of the system were conducted on four occasions as shown in the following table. On two occasions scanning trials were conducted during winter precipitation at the approved location near the entrance to Runway 06R. As well, scanning trials were conducted on two occasions with the scanner located near the aircraft taxiway entry to the CDF.

DATE	TIME	LOCATION	WEATHER COMMENTS	RATE OF PRECIPITATION
Feb17, 1999	1500 1730	- 06R	Snowfall, -1 to –2°C	1 to 2 g/dm²/hr
Mar03, 1999	1430 1615	- 06R	Snowfall, -2°C	1 to 12 g/dm²/hr
Mar06, 1999	1200 1700	- Deicing Centre	Snowfall	4 to 10 g/dm²/hr
Mar07, 1999	0600 1000	- Deicing Centre	Accumulated overnight snow	Nil

During these trials, the fin numbers of the scanned aircraft were recorded. A videotape recording was maintained for all video and ice detection images. Data associated with the remote GIDS were recorded in the system database.

The ice detection TV monitor was observed for indications of contamination while the trials were in process, and the videotape record of contamination sensor images was subsequently reviewed for indications of contamination. During the two sessions at the test location near Runway 06, many of the scanned aircraft had just been deiced, including protection with anti-icing fluid, and review of sensor images showed no indication of contamination. In two instances of note contamination *was* indicated, however, and these cases, along with their contamination sensor images, are discussed in the following chapter.

At the position near Runway 06R with the mast fully extended, the camera offered reasonably good views of aircraft as they taxied past. A number of aircraft stopped immediately ahead of the scanner vehicle, where they held awaiting takeoff clearance. This significantly facilitated the scanning process.

The March 03, 1999 session at departure Runway 06R was typical. During that session, fifteen departures were observed. Usually each departing aircraft was scanned several times in an effort to examine the wing surfaces from various perspectives as the aircraft moved past the scanner position. This session took place during a snowfall that deposited a total of 7.4 cm (3 in.) during the day. An active snowfall was in progress during the period of scanning. Ongoing runway and ramp snow clearing was underway, resulting in eventual closing of Runway 06R and switching departing flights to Runway 06L. The ramp background was completely white (snow-covered) during the scanning session.

The February 17, 1999 session was very similar, but with lighter snowfall.

The March 06, 1999 session was conducted at the west entrance to the CDF (Figure 3.1) in an attempt to scan aircraft having snow on wing surfaces, prior to being deiced. Scanning aircraft at this location offers the opportunity to compare sensor indications of contamination with the actual level of contamination observed visually.

The March 07, 1999 session was also conducted at the west entrance to the CDF, with the intent to scan aircraft having snow accumulation on wing surfaces following the overnight snowfall. The sensor camera was operational for this session; however, very few aircraft proceeded to the centre for deicing. The sensor camera was located to allow scanning of taxiing aircraft as they entered the CDF. This proved to be a problem as the aircraft taxied past the position at a relatively high speed. It is evident that future site selections must take this limitation into account. For future scanning exercises at the CDF, scanning of static aircraft is recommended. Ideally, this would be conducted just after the aircraft has come to a halt in the deicing bay, and just before the start of deicing.

A wide range of aircraft types was scanned during the sessions: large wide-body aircraft (B747-400, A340); narrow body aircraft (MD-80, A320, F28); high-wing turboprops (de Havilland Dash 8, ATR-42); and commuter aircraft (Bombardier RJ; SAAB 340; Beechcraft 1900D; and others).

Because there was little sensor indication of contamination on the scanned aircraft, and such indication as provided was not clear, the data gathered relative to aircraft deicing history could not be utilised.

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5 ANALYSIS AND OBSERVATIONS

5.1 End of Runway Trials

5.1.1 Suitability of Location for Scanning

The ideal location for remote end-of-runway inspection would be at a point where the pilot makes the *GO/NO-GO* decision to take-off following anti-icing, where the aircraft is stationary before turning onto the runway and where a turn-back for re-deicing can be completed if necessary. Clearly, such a location is airport-specific.

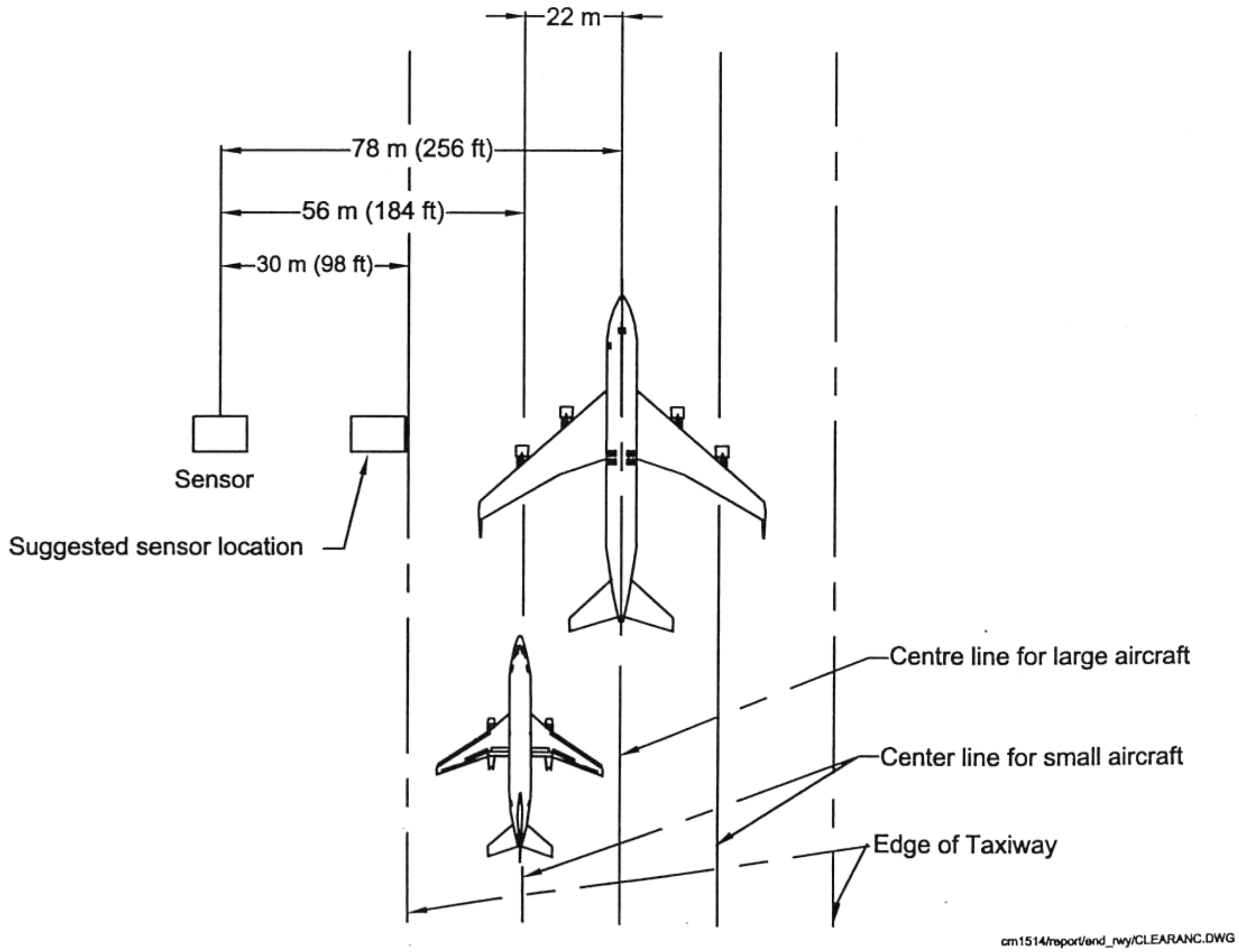
The approved location for the mobile scanning vehicle at Runway 06R at Montreal Dorval had advantages as well as shortfalls:

- It was near the normal hold position for aircraft awaiting clearance for the departure runway. This proved to be useful for trial purposes, since some aircraft stopped directly in front of the scanner site. This allowed for scans of stationary aircraft and repeated scans of the same aircraft in the same position so that any contamination detection reproducibility could be verified.

- The taxiway from the deicing centre passed nearby one side of the scanner position and afforded a frontal view of aircraft as they approached, providing a view of the wing leading edges. Photo 5.1 shows a B-747 approaching the scanning site en route to Runway 06R.

- The approved position was set back 30 m (100 ft) from the edge of the taxiway. The distance to the closest aircraft taxiway centre line was about 56 m (190 ft) (Figure 5.1). Even at that distance a reasonable view was offered. Clearance from scanner mast to wingtip for those aircraft on the closest track was 38 m (130 ft) for narrow-body type aircraft. Clearance to the wingtip of a B747 on the centre track was also about 45 m (150 ft.). The distance to the furthest taxi guideline was over 100 m (333 ft.). Planning for future trials should consider site locations with smaller clearances. Table 3-1 in Appendix D, entitled Taxiway Minimum Separation Distances specifies minimum separation distances from object to taxiway centre line. That standard allows 26 m (87 ft.) for B737 type aircraft and 47.5 m (158 ft.) for B747 type aircraft, which would place the object at the edge of the taxiway. The suggested positioning of the sensor shown

FIGURE 5.1
CLEARANCES AT APPROVED SITE AT RUNWAY 06R



in Figure 5.1 reflects this minimum distance which provides a separation of 12 m (40 ft.) between scanner equipment and wingtip, for both the B737 and B747 aircraft.

- The distance from the scanner vehicle to aircraft was too great. The wide departure taxiway at 06R was marked with two parallel guidelines for use by aircraft up to medium size (E.g. A320). Wide-body aircraft (B767 and larger) followed a taxi guideline located between the two narrow body taxi guidelines. A reasonable view of wing surfaces was offered for aircraft that followed the guideline closest to the scanner, but not for those that followed the furthest track. The wing leading edge of wide-body aircraft on the centre track could be scanned. Photo 5.2 shows an A-340 aircraft on the centre line, behind a smaller propeller aircraft on the near taxiway guideline.

- The approved test position for Runway 06L involved a distance from vehicle to taxi-line similar to that for the most distant taxi-line at 06R. Although no trials were conducted at Runway 06L, less satisfactory results would be attained with the distance involved. Location of the test site closer to the taxi-line was limited by a vehicle roadway running parallel to the taxiway that had to be kept clear. Another problem with the approved site is its location well before the normal hold area for aircraft awaiting takeoff clearance; scanning of moving aircraft would be necessary in all cases. A location in the area indicated by ‘A’ in Figure 3.1, close to the normal *hold* point, would be a much more suitable vantage point.

In summary, from the perspective of delay (which should be minimal) between inspection and take-off, the approved locations were good. From the point of view of clearances, either these should be reduced consistent with capabilities of presently available sensors or improved sensor performance, consistent with approved clearances, is required.

5.1.2 Scanner Height

The scanner height (12.5 m or 42 ft.) was marginally adequate for viewing wings of narrow-body aircraft taxiing on the nearest guideline. An additional 5.5 m (18 ft.) in height would be necessary to provide the same angle of viewing on the wing surface for aircraft on the far guideline.

As long as the clearance requirements from scanner to wingtip are reasonably small, the tested height appears to be the minimum height acceptable for aircraft up to B737 in size. For the B737, this test provided an angle of view on the inner wing surface of about 10 degrees (Figure 5.2). System Image 5.1 gives a view of a de Havilland Dash 8 wing as seen from the remote GIDS at full mast height, demonstrating system capability.

To achieve the same angle on the inner wing of a B747, a scanner height of 18 m (60 ft.) would be required. This height is just below the height of the vertical fin (19 m or 63.5 ft.).

As height limitations are established with reference to the runway, not the taxiway, the height of the scanning equipment could be considered relative to the height of an aircraft tail. Resultant encroachment on runway zoning (obstacle limitation surfaces) is a consideration that must be resolved.

5.1.3 Suggested Scanner Location and Height

Locating scanning equipment with a mast height equivalent to that of a B747 tail fin, at a location relative to the runway similar to the approved aircraft holding location, could be considered. Table 3-2 in Appendix D provides the current standards for minimum distance from the runway centre line to a holding position. Figure 5.3 shows the separation distances that would be respected between aircraft and scanner location. The sensor scanning angles are much improved in this set-up, giving a viewing angle of 16 degrees (versus the trial value of 6 degrees) for the B747 wing surface, and 32 degrees (versus the trial value of 10 degrees) for the B737 wing surface. The importance of larger viewing angles and reduced distances is discussed further in Section 5.1.5.3. While not a problem for most tests, any *significant* swaying motion tended to interfere with ice detection performance.

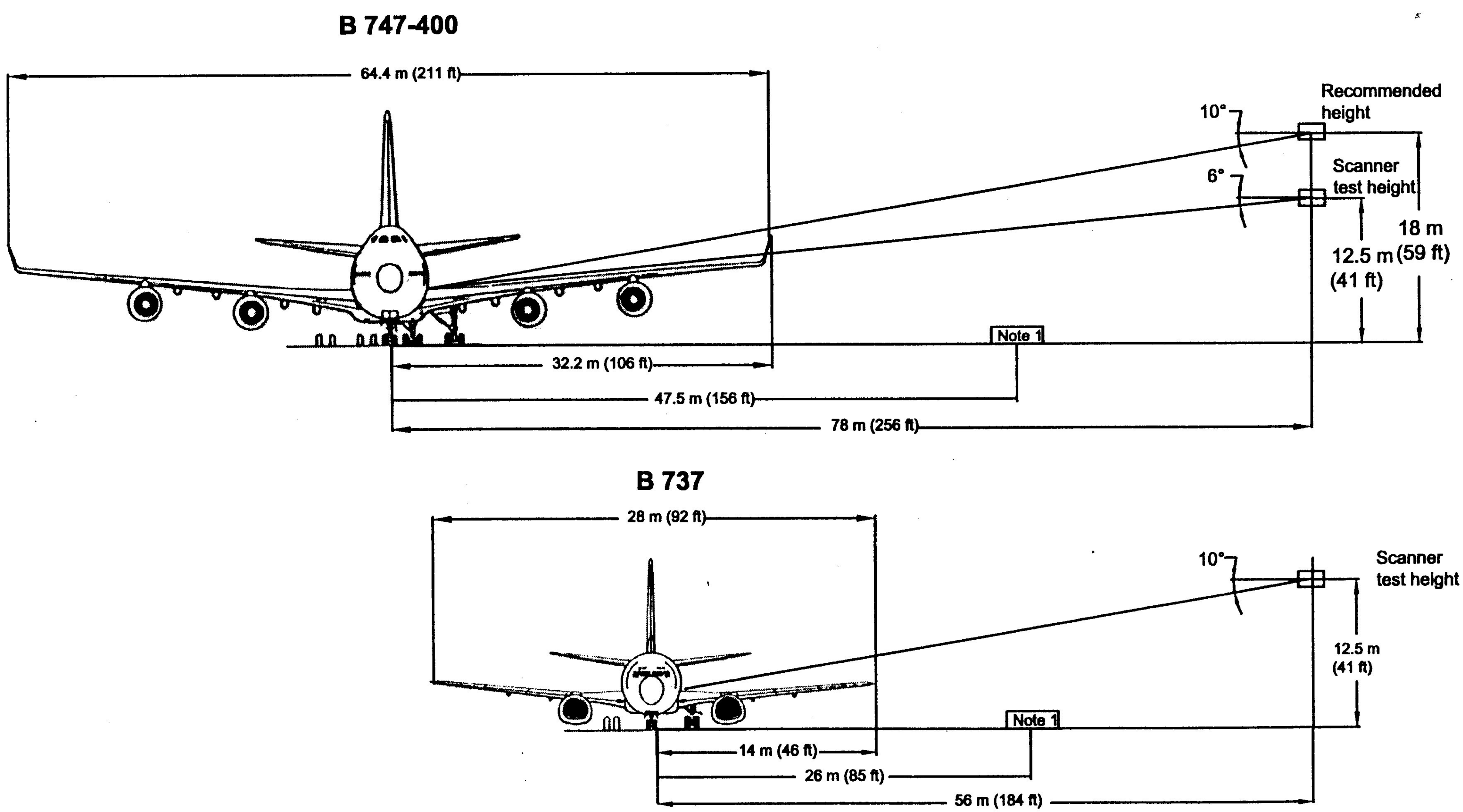
5.1.4 Mobile Equipment versus Fixed Installation

A final solution for locating a remote GIDS near a departure runway would involve use of either mobile equipment or fixed installations. Some of the operating considerations that would be examined in designing a final solution can be addressed from the experience of this trial:

- Electrical power supply: Adequate power supplies for the scanning system can be provided by a vehicle, such as the one used in this study.

FIGURE 5.2

SENSOR SCANNING ANGLES

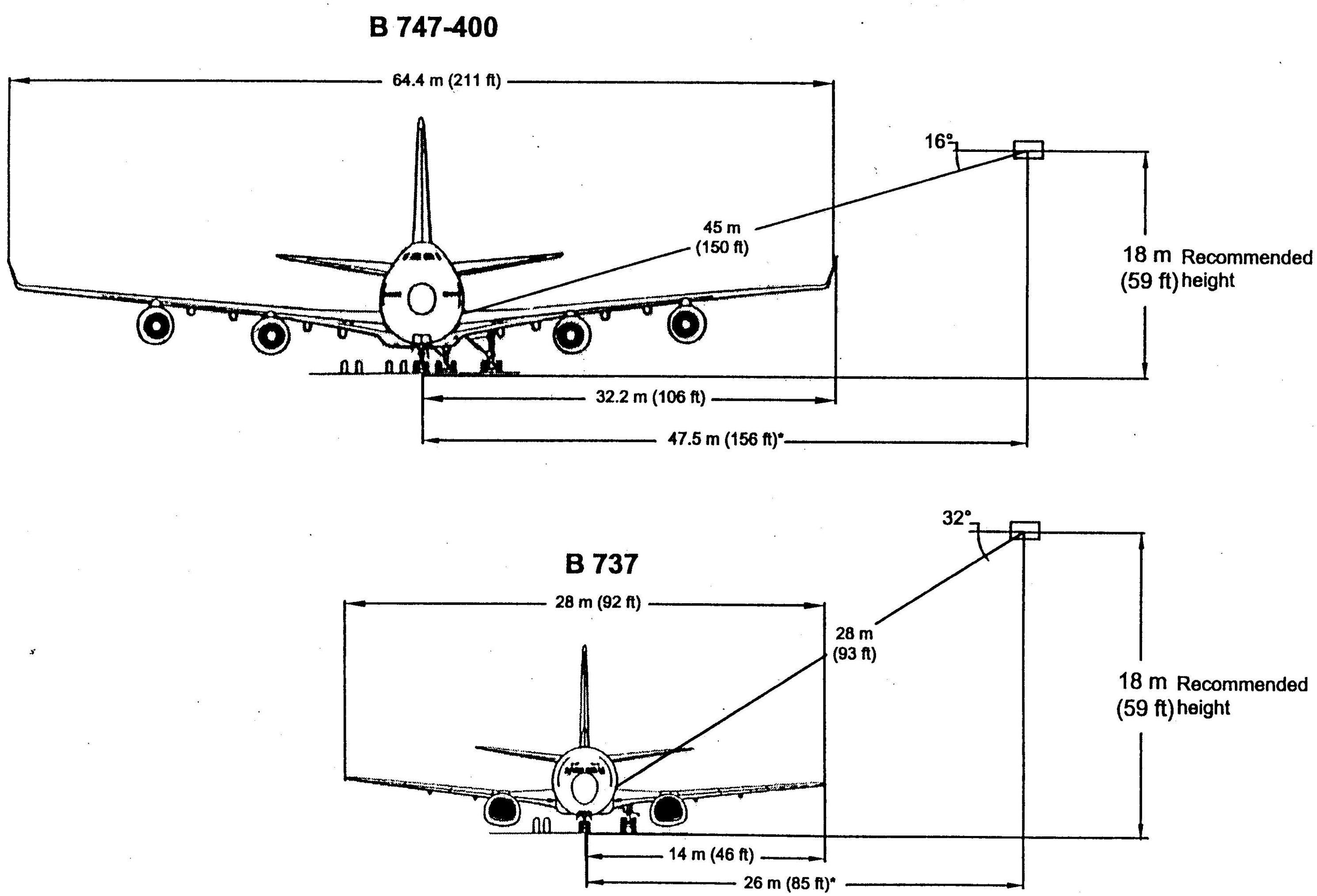


(1) Aerodrome Standards and Recommended Practices - Minimum Separation Distances

(Aircraft not drawn to scale.)

cm1514/report/end_rwy/SCAN_ANG.DWG

FIGURE 5.3
SENSOR SCANNING ANGLES AT SUGGESTED POSITION AND RECOMMENDED HEIGHT



* Aerodrome Standards and Recommended Practices - Minimum Separation Distances.
(Aircraft not drawn to scale.)

cm1514/report/end_rwy/Scan Angles 2.DWG

- Manned versus remotely operated: Use of mobile equipment infers manning of each vehicle involved. Fixed installations could be operated remotely by one person from a central facility.

- Conflicts with runway clearances: Mobile equipment may be more difficult to reconcile with obstacle clearances for this type of operation than would a specially designed fixed facility. A fixed facility could be remotely operated, based on a "pop-up" concept with a mast periscoping into a well below ground level when not in use. Alternately, a light and frangible fixed mast with a remotely operated sensor could be used.

- Mast height and stability: Either mobile equipment or fixed facility should be able to satisfy the mast requirement of sufficient height and stability.

- The ability to quickly relocate scanning operations when departure runways are switched: Time to relocate mobile equipment to a different departure runway may be excessive. With the vehicle used in the trials, at least one-half hour would be required to relocate and re-setup.

- Need for rapid extension and retraction of sensor boom. This would be desirable in a concept based on mobile equipment that needed to be moved quickly to respond to runway switches, which is not necessary in a fixed facility concept.

Cost considerations for the alternative approaches would need to examine staffing implications, in addition to fixed costs.

5.1.5 Remote GIDS Application Feasibility

5.1.5.1 Moving versus stationary aircraft

Scanning moving aircraft for ice detection was attempted by two approaches:

1. The first involved fixing the camera field of view and waiting for the aircraft image to appear on the monitor, then triggering the system to initiate a scan.

2. The second approach tracked the aircraft using the pan feature on the remote GIDS mount, and scanned for ice detection while the camera was in motion.

Neither method was completely successful. Success with the first approach depended on the speed of the aircraft, producing successful scans if the aircraft taxi speed was not too fast.

Generally, aircraft speed on the taxiway at the test location 06R, estimated at 10 knots was satisfactory for scanning. However, during periods of very light traffic when higher speeds were common, a single scan was the most that could be obtained. During trials when the camera was located at the entrance to the deicing centre, it was impossible to scan some aircraft because of their high taxi speed. The general result of scanning higher speed aircraft was a false positive indication of contamination; that is, contamination was detected with none present. Turning propeller blades on stationary aircraft also produced a false indication of contamination.

The second method required a high degree of operator dexterity in attempting to hold the aircraft image stationary in the camera field of view.

Best results were gained from scans of stationary aircraft holding for takeoff clearance on the holding apron directly ahead of the scanner site. If scans of moving aircraft were a necessary element of a final solution, then a system that locks onto and tracks the image of the target aircraft would be useful.

Scan sites positioned opposite the holding apron where aircraft normally stop and hold awaiting take-off clearance is recommended. In operations during freezing precipitation conditions, it may be necessary to stop each aircraft momentarily to allow the scanning activity to take place, and to allow time to communicate the results. Locating the scanner to take advantage of aircraft holds already in effect would minimize the impact on takeoff operations. This location would have the added advantage of minimizing time elapsed between wing inspection and start of takeoff.

5.1.5.2 Size of ice detection images

With large distances from camera to aircraft, system images of specific wing areas were quite small. If these large distances, greater than 50 m, are to be experienced, the use of a zoom feature on the scanning camera to provide a magnified view of those areas of the wing that are of interest would be helpful.

The issue of contamination patch size viewable by the sensor is an important one. The sensor system manufacturer provided a grid of values for ice length viewable at different combinations of distances and viewing angles for the particular equipment used in the trials. Values provided in that grid varied directly with distance and sine function of the viewing angle, and values were extrapolated to represent the distances and viewing angles. Table 5.1 outlines values for detectable ice length resulting from that exercise.

Table 5.1
Length of Ice Patch Viewable

Distance to target (m)	Ice length (cm) viewable at viewing angle					
	90 degrees	30 degrees	20 degrees	15 degrees	10 degrees	6 degrees
15	6	11	16	22	32	53
22	8	17	25	32	48	80
30	11	22	33	43	64	107
38	14	28	41	54	80	134
46	17	34	49	65	97	160
53	20	39	57	76	113	187
68	25	50	74	97	145	241

Distance to target (ft.)	Ice length (inches) viewable at viewing angle					
	90 degrees	30 degrees	20 degrees	15 degrees	10 degrees	6 degrees
50	2	4	6	9	13	21
75	3	7	10	13	19	32
100	4	9	13	17	25	42
125	6	11	16	21	32	53
150	7	13	19	26	38	63
175	8	15	23	30	44	74
225	10	20	29	38	57	95

The beneficial impact of reduced distances and increased viewing angles is illustrated in Table 5.2, which compares the ice length viewable based on the trial set-up with that of the suggested set-up.

Table 5.2
Enhanced Viewing of Ice Patches with Shorter Viewing Distances

Aircraft type	Trial set-up			Suggested set-up		
	Distance from camera to wing (m)	Viewing angle (degrees)	Ice length viewable (cm)	Distance from camera to wing (m)	Viewing angle (degrees)	Ice length viewable (cm)
B737	54	10	112	28	32	20
B747	68	6	240	45	16	60

Aircraft Type	Trial Set-up			Suggested Set-up		
	Distance from camera to wing (ft.)	Viewing Angle (degrees)	Ice Length Viewable (in.)	Distance from camera to wing (ft.)	Viewing Angle (degrees)	Ice Length Viewable (in.)
B737	178	10	45	93	32	8
B747	225	6	96	150	16	24

The improvements in visibility of ice contamination with the suggested set-up are very significant, and bring the size of contamination patches visible to the sensor (particularly for narrow body aircraft) into an acceptable range.

5.1.5.3 Resolution of ice detection images

During the two sessions at the test location near Runway 06, many of the scanned aircraft had just been deiced and showed no indication of contamination. Contamination *was* indicated in two instances, however.

During the first session on February 17, 1999, a B747 was deiced. Following deicing and before leaving the deicing pad, the aircraft was configured with leading edge slats extended. The aircraft then taxied through falling snow with leading edge slats extended. The aircraft was scanned, when stationary, on the holding apron, 12 minutes following the start of the holdover time. Contamination was indicated on the extended leading edge surface as well as on top of the engine cowling (system image 5.2). The large dark area (shown as red on the actual sensor image) above the aircraft is a contamination indication of the snow-covered ramp area beyond the aircraft.

This case is of interest as it demonstrates the problem inherent in configuring the aircraft for takeoff just after being deiced and before taxiing to the departure point. The resulting exposure of unprotected areas of flight control and wing surfaces to precipitation may lead to contaminated surfaces well before the expected holdover times expire.

During the same session, after the rate of snowfall had diminished, a de Havilland Dash 8 departed directly from the passenger terminal without proceeding through the deicing centre. The aircraft was scanned when stationary while it was holding for clearance to proceed onto the departure runway. System image 5.3 indicates ice contamination on the Dash-8 wing. System Image 5.4 is a repeat scan of the same wing, showing a quite different pattern of contamination. Both images have unclear boundaries defining the area affected.

The boundary of the area affected was of poor resolution and not sharply defined in these images. It was not possible to accurately estimate the size of the area contaminated, nor to determine its precise location or boundary. Repeated scans of the same subject produced images of contamination quite different in pattern and size.

5.1.5.4 Adapting to ambient light

The remote GIDS experienced difficulty in responding to changes in levels of ambient light. At dusk, there was a period when the camera could not be used because of changing light levels.

During one session in heavy snowfall, the system appeared to be searching for the correct light setting, in which the screen repeatedly stepped through several shades of grey in an attempt to lock into an optimum integration time.

The same remote GIDS was used in a separate study reported in Transport Canada Report, TP 13479E, *Contaminated Aircraft Takeoff Tests for the 1998/99 Winter*[2], to identify the existence and extent of contamination on wings of the test aircraft. During that trial, conditions of bright sunlight overwhelmed the detector, resulting in most pixels being rendered invalid.

5.1.5.5 Viewing Through Precipitation

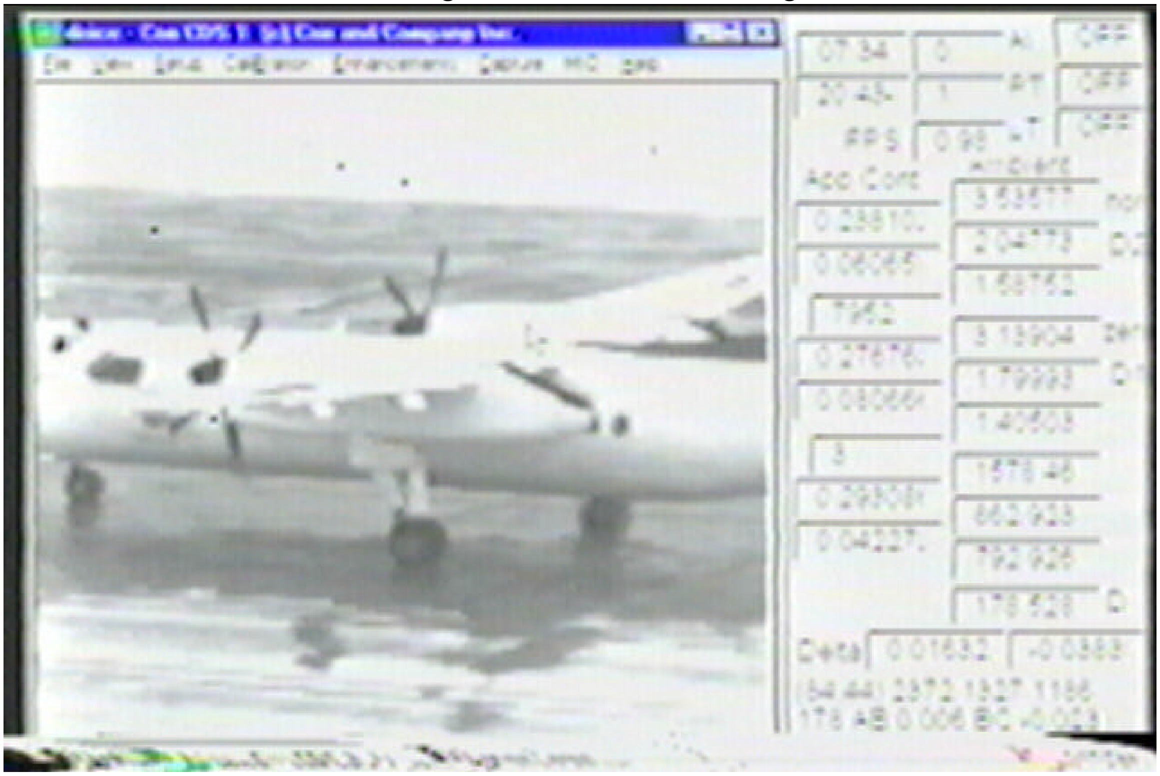
The two test sessions at end-of-runway were conducted with snow falling at rates from 1 to 12 g/dm^2/hr. The sensor did not demonstrate any difficulty in being able to view through this rate of snowfall.

Photo 5.1
B747 Approaching Scanning Site from Deicing Centre

Photo 5.2
Aircraft Holding in Front of Scanner Location

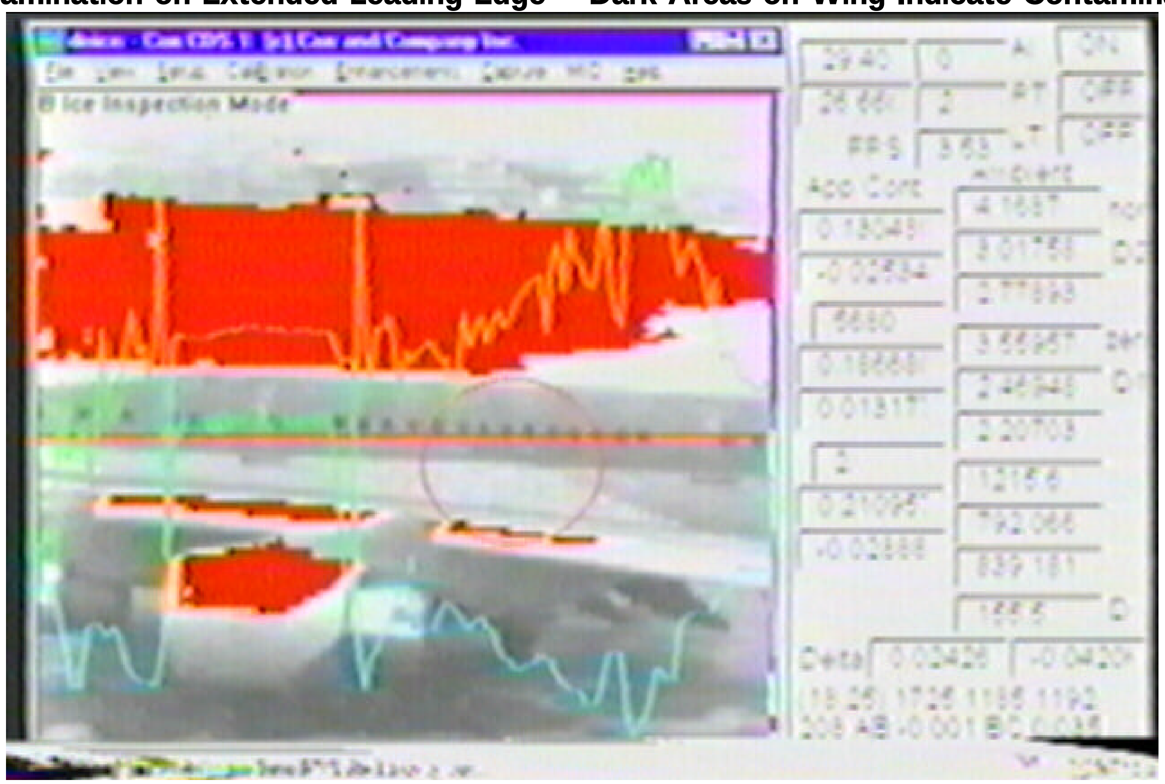
System Image 5.1

Camera View of Aircraft Wing – Dark Areas on Wing Indicate Contamination

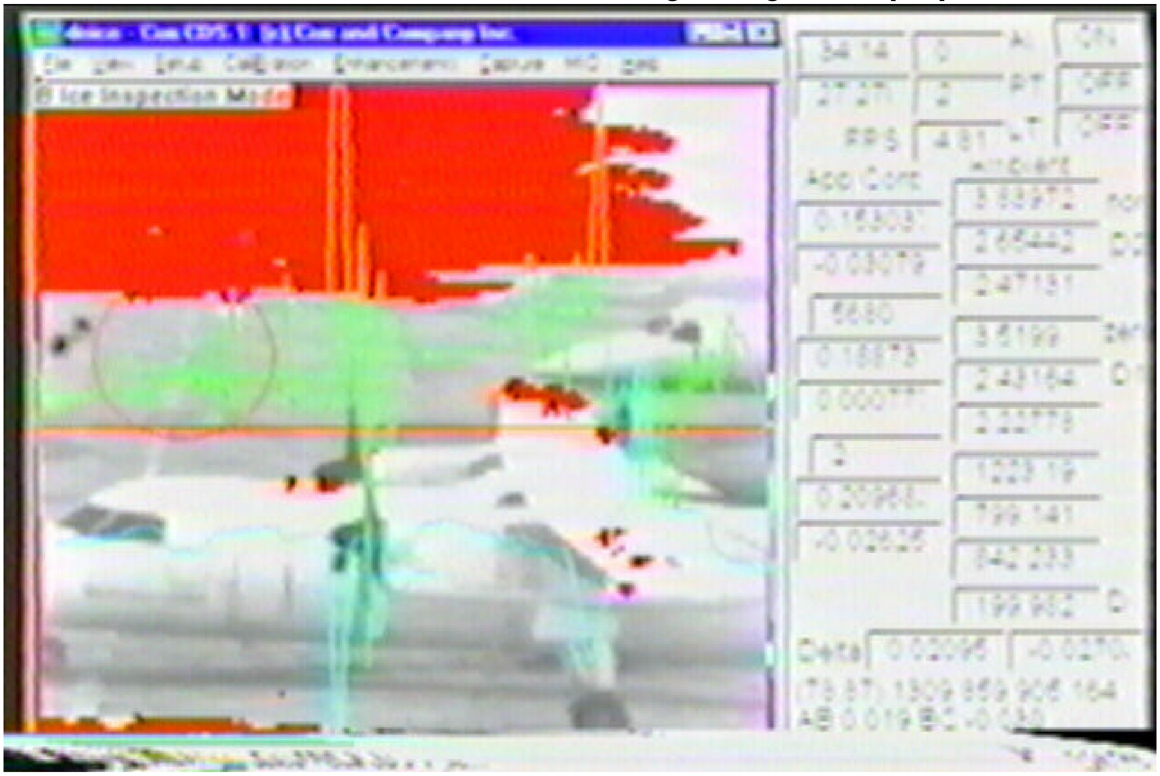


System Image 5.2

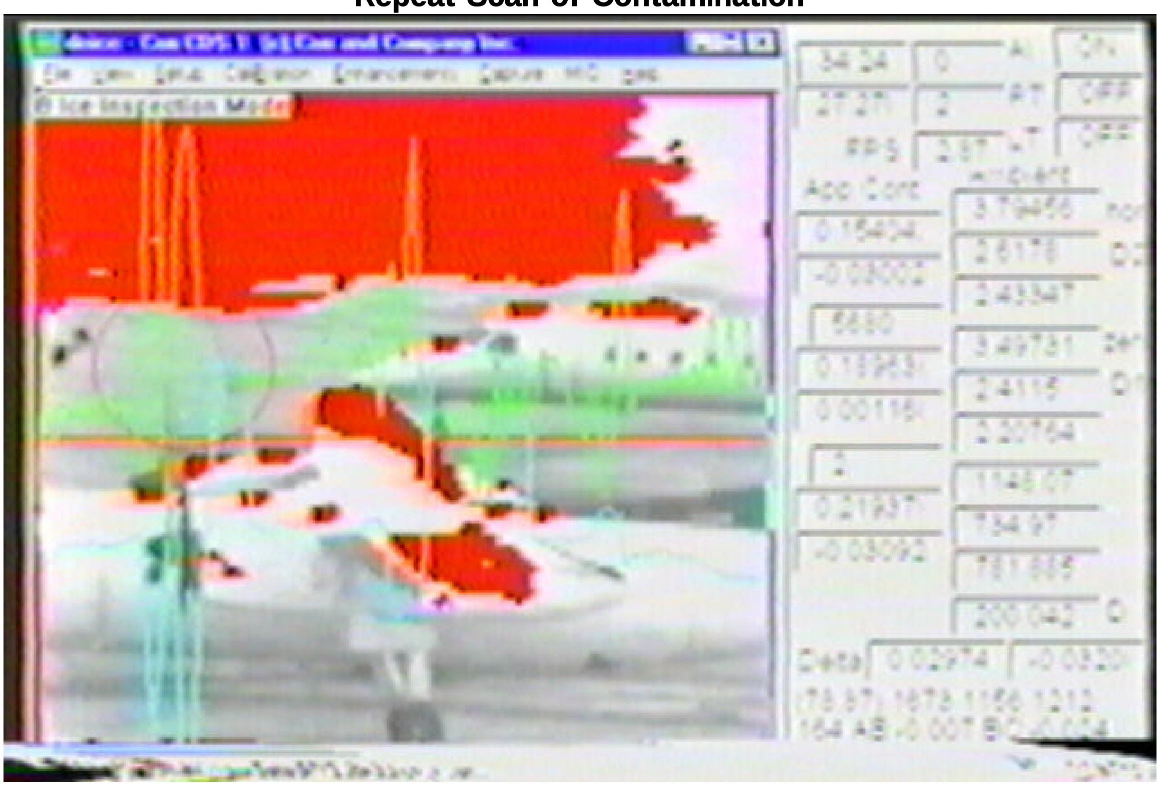
Contamination on Extended Leading Edge – Dark Areas on Wing Indicate Contamination



System Image 5.3
Contamination Indication on High-wing Turbo-prop



System Image 5.4
Repeat Scan of Contamination



6 CONCLUSIONS

6.1 End of Runway Trials

This short series of trials addressed the issues that exist in selecting locations suitable for positioning scanning equipment so that operating aircraft can be scanned just prior to departure. Based on the experience of this first attempt to locate remote GIDS near a departure runway, it is believed that optimal scanning locations can be found and approval gained, without interfering with normal departure operations.

6.1.1 Location Relative to Taxiway

The Runway 06R location was advantageously placed near the normal holding point for aircraft awaiting takeoff clearance. Vehicle setback from the taxiway was conservative, with fairly large distances between the camera vehicle and taxiing aircraft on the nearest guideline. Even at these distances, the present technology of the system used was able to scan the aircraft for contamination. In a final solution for this specific runway, the scanning equipment could be safely located closer to the edge of the taxiway adjacent to the aircraft hold position while awaiting takeoff clearance. This would support improved performance from the scanning system.

The use of the multiple taxiway guidelines at Runway 06R suggested a possible further enhancement that could optimize scanning of narrow-body and smaller regional aircraft. Aircraft of that size could be brought closer to the scanning equipment (i.e., not limiting scanning of these aircraft by forcing them to adhere to centre line separation distances required for large wide-body aircraft). This approach has an inherent disadvantage in that only one wing would be scanned. This typifies the type of problem which must be addressed for remote sensors to be adopted for general use.

Finding a suitable location at Runway 06L was a greater challenge because of the interference of a vehicle roadway running parallel to the taxiway. A site situated near point A (Figure 3.1) close to the normal aircraft holding position might be more suitable for scanning, if mast height could be approved for that location.

Positioning the ice detection equipment at a location opposite to the normal hold position for aircraft awaiting take-off clearance generally offers the best vantage point for scanning, and minimizes the elapsed time between inspection and start of takeoff.

6.1.2 Scanner Height (Location Relative to Runway)

The camera height was 12.6 m (42 ft.), which proved to be marginally adequate for scanning aircraft up to B737 size, with a very shallow viewing angle resulting at the separation distances tested.

The use of a mast with a height near that of the vertical fin of B747 aircraft (19.4m; 63 ft) would enable scanning of wings of the B747 and other large wide-body aircraft.

As height limitations are established with reference to the runway, not the taxiway, the height of the scanning equipment could be considered in the same view as the height of an aircraft tailfin assembly. There is an evident justification in considering placement of scanning equipment having a mast height equal to or less than that of a B747 tail fin, at a location relative to the runway similar to the approved aircraft holding location. Encroachment on runway zoning (obstacle limitation surfaces) must be considered.

6.1.3 Stationary versus Moving Aircraft

Scanning of stationary aircraft produced the best results. Operational procedures may need to be modified whereby each departing aircraft would be stopped momentarily at the normal hold position to allow for scanning to take place and to communicate the results. Many aircraft, particularly in periods of heavy traffic, already hold to await takeoff clearance.

6.1.4 Fixed Facility versus Mobile Equipment

From an operational perspective, a concept for scanner installations based on either mobile equipment or fixed facilities should be satisfactory. The financial implications of each alternative would be the main factors in determining the more feasible scheme.

7 RECOMMENDATIONS

It is recommended that:

- Approvals for enhanced locations for scanner sites, and greater height for the scanner camera, be sought from regulatory authorities.
- The remote GIDS equipment be upgraded to resolve shortcomings noted during this study.
- Upgraded remote GIDS equipment be evaluated through a series of trials on aircraft wings where the actual area and location of contamination can be determined and reconciled versus the remote GIDS indication. Conduct of trials at the central deicing facility is recommended for this approach, as well as conducting trials using the static test wing.
- Following the previous steps, further scanning trials be conducted at the newly approved sites during live operations in winter storm conditions.
- Data from future scanning trials be used as a basis for developing an approach to determining acceptable limits for contamination levels on aircraft wings.

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APPENDIX A
WORK STATEMENT

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TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 98/99

(December 1998)

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 (TC) was set up. Together with many other regulatory activities an intensive research program of field testing of deicing and anti-icing fluids was initiated with guidance from the international air transport sector through the Society of Automotive Engineering (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 (TC research representing the bulk of the testing).

The times given in HOT Tables were originally established by the Association of 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 its successor Transport Canada, Transportation Development Centre (TDC) Aviation Winter Operations R&D (AWORD) Group has been to determine the performance of fluids on standard flat plates in order to substantiate the times or, if warranted, to recommend changes.

TDC 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 for special deicing conditions were not completed. All these areas are the subjects for the further research that is planned for the 98/99 winter.

The primary objective of 97/98 testing was the performance evaluation of new and previously qualified Type IV fluids over the entire range of conditions encompassed by the holdover time tables. The effect of different variables on the fluid holdover time, in particular the effect of fluid viscosity, was examined and deemed to be significant. As a result, any future Type IV fluid holdover time testing will be conducted using samples representative of the manufacturers lowest recommended on-wing viscosity. Current methods for establishing holdover times in snow involve outdoor testing, which has been the source of industry concern for some time. It is recommended that a snowmaking device in development need to be evaluated for the future conduct of snow holdover time tests in controlled conditions. The study of fluid buffers was also continued in 97/98 and identified several industry concerns which will be addressed in further research. The adherence of contaminated fluid to aircraft wings was also evaluated in a series of simulated takeoff runs without aircraft rotation. Further research in these areas is needed.

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 holdover 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 holdover time data for all newly qualified de/anti-icing fluids.
4.2. Develop holdover time data for Type IV fluids using lowest qualifying viscosity samples.
4.3. Develop supplementary data for a reduced buffer 'de-icing only' Table.
4.4. Determine whether recycled, recovered fluid can be used as a 'De-icing only' fluid.
4.5. Determine whether the extreme precipitation rates used for laboratory testing of de/anti-icing fluids are in fact encountered in practice.
4.6. Obtain equipment for laboratory production of artificial snow which most closely reproduces natural snow.
4.7. Assess the limiting conditions of wind, precipitation and temperature under which water can be used as the first step of a two-step de-icing procedure.
4.8. Determine the patterns of frost formation and of fluid failure initiation and progression on the wings of high-wing turbo-prop and jet commuter aircraft.
4.9. Assess the practicality of using vehicle-mounted remote contamination detection sensors for pre-flight (end-of-runway) inspection.
4.10. Provide base data on the capabilities of remote sensors.
4.11. Provide pilots with reference data for the identification of fluid failure. Quantify pilot capabilities to identify fluid failure
4.12. Provide support services for the conduct of tests to determine under what conditions contaminated fluid adheres to aircraft lifting surfaces.
4.13. Assess whether pre-warming fuel at time of re-fuelling will help to eliminate the 'cold soaked' wing problem.
4.14. Develop a low-cost test wing which can be used in the laboratory in lieu of field testing full scale aircraft.
4.15. Establish the safe limits for de-icing truck operation when de-icing aircraft with the engines running.
4.16. Provide general support services.
4.17. Disseminate test findings

5. DETAILED STATEMENT OF WORK

5.1. General

5.1.1. Planning and Control

Develop a detailed work plan, activity schedule, cash flow projection, project management control and documentation procedures (as specified in Section 9,"Project Control") within three weeks of effective commencement date, confirming task priorities, suggesting hardware and software suppliers, broadly identifying data needs and defining the roles of subcontractors, and submit to TDC for review and approval.

5.1.2. Safety and Security

Particular consideration will be given to safety in and around aircraft on the airport and deicing sites In the event of conflict between access for data gathering to obtain required test results and safety considerations, safety shall always govern.

5.2. Holdover Time Testing and Evaluation of De/Anti-icing Fluids

5.2.1. Newly Certified Fluids

Conduct flat plate tests under conditions of natural snow and artificial precipitation to record the holdover times, and to develop individual Holdover Time Tables based on samples of newly certified or re-certified fluids supplied by Fluid Manufacturers under as wide a range of temperature, precipitation rate, precipitation type, and wind conditions as can be experienced. Anticipate tests for one new fluid. Snow tests shall be conducted outdoors, and ZD, ZR-, Zfog, and CSW tests will be performed in the laboratory. All testing shall be performed using the methodology developed in the conduct of similar tests for Transport Canada in past years.

5.2.2. Low Viscosity Type IV Anti-icing Fluids

Fluid holdover time testing of Type IV fluids will be conducted using procedures established during past test seasons but using fluid with the lowest operational use viscosity.

5.2.2.1. Flat Plate Tests for New Type IV Fluids

Conduct flat plate tests under conditions of natural snow and artificial precipitation to record the holdover times, and develop individual Holdover Time Tables based on samples of new 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. Anticipate for four new fluids using samples with one viscosity. Snow tests shall be conducted outdoors, and ZD, ZR-, Zfog, and CSW tests shall be performed in the laboratory using methodology applied in past years.

5.2.2.2. Effect on Holdover Time of Viscosity

Conduct tests aimed at determining the effect of fluid viscosity on holdover time. Tests shall be conducted in light freezing rain and freezing drizzle conditions at various temperatures in the National Research council (NRC) Climatic Environment facility (CEF) using low and high viscosity samples representing production limits of three anti-icing fluids: a propylene, an ethylene and the Fluid X (which will become the benchmark for laboratory based HOT testing).

Anticipate a total of approximately 100 tests to be conducted under ZR- and ZD at -3 and -10 Celsius at low and high rates.

5.2.3. Recycled Fluids as Type I Fluids

5.2.3.1. Holdover Times

A complete set of holdover time tests shall be conducted using two fluid test samples of recovered glycol based freezing point depressant fluid which have been recycled and exhibit nominal conformance to Type I de-icing fluid performance characteristics. The objective of this series of tests is to establish a sound base of data sufficient to establish valid holdover time tables for these fluids.

5.2.3.2. Compatibility with Type IV Fluids

Fluid compatibilty trials shall be conducted using various combinations of the recycled fluids and commercial Type IV fluids. Determine how the Inland fluids perform when used in conjunction with a Type IV fluid overspray.

5.3. Supplementary Data for Deicing Only Table

Evaluate the test conditions used in establishing the deicing only table by undertaking the following test series at sub zero temperatures but with no precipitation.

5.3.1. Establish Quantity of Fluid for Field Tests.

Conduct a series of comparative laboratory tests with 0.5, 0.25 and 0.1 litre per plate. Consider the case of spraying for frost with a fan shape to cover a wide area with a small amount of fluid compared with a stream as used to remove snow or ice. Examine typical fluid quantities representing frost removal spray. Conduct some tests on aircraft piggybacking on other testing if feasible.

5.3.2. Establish Temperature of Fluid for Field Tests

Laboratory tests will be performed with fluids initial temperatures at the spray nozzle of 60ºC, 50ºC, and 40ºC initial temperature.

Field tests on aircraft will be designed to measure the loss of fluid temperature and to measure fluid evaporation and enrichment during the air transport phase between spray nozzle and wing surfaces, for various distances and shapes of spray pattern (3 distances; 2 spray patterns).

5.3.2.1.

Examine the effect on the final freeze point of sprayed fluids on the wing, resulting from variations in the temperature of the fluid (60ºC, 50ºC, and 40ºC).

5.3.2.2.

Examine the effect on wing heat and fluid evaporation of removing contaminant from the wing surface. Various degrees of ice depth shall be deposited using a hand-held rainmaker, including a very light coating to simulate frost. The amount of fluid sprayed shall be controlled by the operator, spraying until a clean surface results.

5.3.3. Perform tests at current buffer limit as baseline.

Perform a series of comparative tests using buffers at 3ºC and 10ºC to compare to the new data and the data collected last season with buffers at 0ºC .

5.3.4. Simulate High Wind Conditions

Tests shall be performed using NRC fans producing winds up to 30 kph for comparison with the earlier series of tests with speeds up to 20 kph

5.3.5. High Relative Humidity

Perform a series of plate tests at 90% RH to compare results to those already gathered. Review the condition with weather services to determine typical RH values during deicing only conditions.

5.3.6. Cold Soaked Wings

Perform a series of tests on cold soak boxes to establish whether the natural buffer provided by evaporation would be sufficient to provide protection if the wing were in a cold-soaked condition, with wing temperature several degrees below OAT. These tests can be run in conjunction with high humidity tests when deposition of frost on cold soaked surfaces would normally be expected.

5.3.7. Effect of Snow Removal on Fluid Heat Input

Perform tests to establish whether removal of snow results in extesive amounts of heat being carried away and insufficient heat being transferred to the wing during deicing.

Expose flat plates to snowfall (either natural or as simulated by approved equipment) and protect snow catches of various thicknesses. Tests shall be run in an area protected from further snowfall. Fluid shall be applied with a hand sprayer, until the plate is cleaned, measuring the amount of fluid applied. The final fluid concentration on the plate shall be measured. The heat lost in fluid run off shall be measured. Parallel tests will be conducted on bare surfaces.

A carefully calculated heat balance shall be determined for each experiment based on the temperatures of the applied fluid, the plate and the collected run-off material.

5.3.8. Effect of Composite Surfaces on Evaporation

Evaluate the effects of the use of composite materials in wings on the heat transfer from deicing fluid to the wing. Conduct a series of laboratory comparative tests on a several samples of composite surfaces.

Identify an appropriate aircraft having a wing surface composed of new technology composite material as well as aluminium, determining the thermal pathways connecting the composite surfaces to the main wing structure.

Conduct field tests on a sample aircraft.

5.3.9. Unpowered Flight Control Surfaces

Field trials will be conducted on DC9 aircraft to assess the impact of fluids of various buffers on the freedom of operation of the unpowered elevator control tabs to establish whether the natural buffer provided by evaporation would be sufficient to provide protection if the wing were in a cold-soaked condition, with wing temperature several degrees below OAT

5.3.10. Field Tests on Aircraft

Three overnight test sessions shall be planned for these tests. Tests shall be conducted on aircraft types including the McDonnell Douglas DC-9 and Canadair RJ, with a minimum of one night for each type. Testing on a third aircraft type would be useful to improve confidence and to confirm the universality of the results. Use an ice detector sensor system to provide a separate source of data.

5.3.11. Laboratory Tests

The number of proposed tests shall be controlled by limiting tests to the minimum number of ambient conditions that will support conclusions on the significance of the issues raised while maintaining a good level of confidence. As a minimum, this encompasses about 230 plate tests and would require about 8 days at the NRC CEF Facility or other suitable facility.

5.4. Flow of Contaminated Fluids from Wings during Takeoff

5.4.1. Requirement

Evaluate anti-icing fluids for their influence on adherence, in particular, propylene based Type IV fluids which were observed during fluid failure

A test plan shall be developed jointly with NRC.

Two days of testing at Mirabel Airport shall be planned.

Use an ice contamination sensor to assist in documenting contamination levels to provide valuable assistance in data gathering. A contingency allowance to fund sensor company participation shall be included.

Data collected during these trials shall include:

- type of fluid applied;
- record of contamination level prior to take off runs,;record of level of contamination following takeoff runs;
- observations, photography and video taping, and ice sensor records; and
- specifics on aircraft takeoff runs obtained from NRC personnel.

5.4.2. Conduct of Trials and Assembly of Results

Coordinate all test activities, initiating tests in conjunction with NRC test pilots based on forecast weather. Analyse results and document all findings in a final technical report and in presentation format.

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 generate data to be used to assess a pilot's field of view during adverse conditions of winter precipitation for selected aircraft; (See item 5.11)
- To compare the performance of de/anti-icing fluids on aircraft surfaces with the performance of de/anti-icing fluids on flat plates;
- To examine the pattern of failure using Type IV fluid brands not tested in the past; and
- To further investigate progression of failure on the two wings in crosswind conditions.

5.5.2. Planning and Coordination

Planning and preparation for tests including provision of facilities, personnel selection and training, and test scheduling shall be the same as provided to TDC in previous years

5.5.3. Testing

All tests and dry runs shall be performed using the methodology developed in the conduct of similar tests for Transport Canada in past years.
Test planning will be based on the following aircraft and facilities:

Aircraft	Airline	Test Locn.	Deicing Pad	Deicing Crew
Canadair RJ	Air Canada	Dorval	Central	Aéromag 2000
ATR42	Inter Canadian	Dorval	Central	Aéromag 2000

5.5.4. Test Measurements

Make the following measurements during the conduct of each test:

- Contaminated thickness histories at selected points on the wings. The selection of test points shall be made in cooperation with the Transportation Development Centre,
- Contamination histories at selected points on wings (selected in cooperation with the Transportation Development Centre),
- Location and time of first failure of fluids on the wings,
- Pattern and history of fluid failure progression,
- Time to failure of one third of the wing surface
- Concurrent measurement of time to failure of fluids on flat plates. The plates will be mounted on standard frames and on aircraft wings at agreed locations,
- Wing temperature distributions,
- Amount of fluid applied in each test run and fluid temperature,
- Meteorological conditions, and
- For crosswind tasks, effects of rate of accumulation on each wing.

In the event that there is no precipitation during full-scale tests, the opportunity 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 the uniformity of fluid application.

5.5.5. Pilot Observations

Contact airlines and arrange for pilots to be present during the tests to observe fluid failure and failure progression, and to record pilot observations from the cockpit and the cabin for later correlation with aircraft external observations.

5.5.6. Remote Sensor Records

Record the progression of fluid failure on the wing using RVSI and/or Cox remote contamination detection sensors if these sensors are made available.

5.6. Snowmaking Methods and Laboratory Testing for Holdover Times

5.6.1. Evaluation of Winter Weather Data

5.6.1.1. Snow Rates

Collect and evaluate snow weather data (precipitation rate/temperature data) during the winter to ascertain the suitability of the data ranges used to date for evaluation of holdover time limits.

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

5.6.1.2. Fog Deposition Rates

Devise a procedure and conduct fog deposition measurements outdoors on at least two occasions to determine the range of fog deposition rates which occur in natural conditions.

5.6.1.3. Frost Deposition Rates

Frost deposition rates shall be collected at various temperatures in natural conditions in order to determine a deposition range for this condition. Consideration shall be given to collecting deposition rates in cold temperatures (for example in Thompson, Manitoba). A total of five sessions shall be planned.

5.6.2. Snowmaking Methods

Acquire a version of the new snow generation system recently developed by the National Centre for Atmospheric Research (NCAR).

Evaluate the NCAR system for the future conduct of holdover time testing in simulated snow conditions. Tests shall be conducted in a small climatic chamber at Concordia University, PMG Technologies, or at NRC. Tests shall also be conducted with one Type IV fluid over a range of temperature and snowfall rates to compare the SAE holdover times for this fluid in natural and simulated conditions.

A further series of tests shall be performed with the system in order to assess the holdover time performance of the reference fluid (as described in the proposed SAE test procedures).

A total of 8 days of climatic chamber rental shall be planned for the conduct of the proposed tests.

5.7. Documentation of Appearance of Fluid Failure for Pilots

Current failure documentation deals largely with freezing drizzle and freezing rain conditions

5.7.1. Documentation of Failures

Finalise documentation of failure through limited further research as follows:

5.7.1.1.

provide similar documentation for fluids exposed to snow conditions, taking advantage of the availability of a snow making device for laboratory use;

5.7.1.2.

provide documentation for a propylene based Type IV fluid at typical delivered viscosity, for precipitation conditions tested previously, to determine characteristics at its operational limits and the nature and mechanisms of failure. Conduct selected comparison tests with a second fluid to test commonality of responses. Data from this activity will be cross-analysed with data from proposed research to examine the flow of similar fluids at different levels of contamination from aircraft wings during a simulated takeoff; and

5.7.1.3.

examine and document the appearance and nature of failure of propylene base fluids at cold temperatures (-10 C).

5.7.1.4.

Conduct tests at the National Research Council Climatic Environmental Facility based on last years' procedures, with enhancements as necessary and available. Snow documentation may be conducted in a different laboratory facility. Documentation under outdoor snow conditions will be conducted for comparison purposes to laboratory conditions.

5.7.2. Conduct of trials/assembly of results

Coordinate all test activities, scheduling tests with NRC CEF in conjunction with other test activities. Analyse results and document all findings, recommendations and conclusions in a final technical report and in presentation format. Provide timely updates of schedule revisions to TDC.

5.7.3. 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 observations.

5.8. Feasibility of Performing Wing Inspections at End-of-runway

5.8.1. Requirement

Examine the feasibility of scanning aircraft wings with ice contamination sensors just prior to aircraft entering the departure runway using Dorval airport as an example scenario.

Explore ways of positioning sensors at agreed locations on an airport.

Composition and conduct of tests shall be adapted as information is gained on the practicality of this activity.

5.8.2. Planning

A Project Plan shall be prepared which will include:

a) activities to determine the parameters, operational issues and constraints related to the proposed process, and

b) a test plan for operational trials to examine the capabilities of the contamination sensors to determine the feasibility of their operational use.

The test plan for operational trials (three sessions) shall include:

- establishing test locations with airport authorities,
- establishing operational procedures with airport authorities,
- arranging equipment for scanning; vehicle, sensor installation and radios,
- collecting and coordinating information from the deicing activity at the deicing centre,
- test procedures with detailed responsibilities for all participants,
- control of the confidential data gathered on wing condition, and

- notification to all concerned in the project, including aircraft operators, that scanning activities will take place.

5.8.3. Coordination

Coordination all activites with authorities from Aéroports de Montréal and arrange support from Cox and/or RVSI

5.8.4. Field Trials

Conduct trials to further evaluate the feasibility of integrating such a process within current airport operations management, as well as to gather information on wing condition, just prior to takeoff, during deicing operations. These trials shall be based on the use of mobile equipment currently available. A “truthing” test pannel shall be present at each trial to demonstrate the validity of the wing readings on an ongoing basis

The trials shall be designed to address issues such as:

- equipment positioning versus current runway clearance limitations,
- time delay between inspection and start of take-off
- system capabilityto meet its design objectives in severe weather
- suitability of mobile equipment or fixed facility.
- need for rapid extension and retraction of sensor booms,
- airport support needed, e.g. snow clearance, provision of operating locations,
- accommodating scanner limitations for distance, light, angle of incidence.
- communications needed to support scanning operation,
- recording data from the sensors, and
- communicating results of the scanning to pilots and regulatory authorities.

5.8.5. Test Personnel and Participation

Initiate all tests based on suitable weather conditions. The individual test occasions shall be coordinated with Aéroports de Montréal and Aéromag 2000.

Coordinate the provision of a suitable vehicle and the installation of an ice detection sensor. Monitor the test activity, ensuring the collection and protection of all scanning data, as well as the collection of data related to weather conditions and previous aircraft deicing activities. Ensure that the instrument providers deliver data and an objective measure of wing contamination based on scanner information in a timely and reproducible manner.

5.8.6. Study Results

Results from the feasibility study shall be presented in technical report format which shall include comments pertinent to long term implementation.

Results from the scanner tests shall be provided in technical report format and shall include analysis of wing contamination data cross-referred to the deicing history of individual aircraft scanned.

5.9. Ice Detection Sensor Certification Testing

5.9.1. Minimum Ice Thickness Detectable in Tactile Tests

Prepare procedures and conduct tests to establish human limits in identifying ice through tactile senses. These tests shall use the NRC or equivalent test facilities acceptable to TDC and a test setup equivalent to that planned for sensor certification. Several ice thicknesses and textures shall be tested to establish tactile sensing limiting thickness for smooth ice and for roughened ice.

The experiment shall involve sufficient participants and test conditions such as to provide reliable results usable in approving sensors to replace human tactile testing.

TDC shall assist in the experimental design

Tests shall be conducted with both contractor personnel and a selection of pilots as subjects.

A professional human factors scientist shall be used to establish testing parameters such as:

- what proportion of plates should be bare
- whether subjects should be blindfolded to eliminate visual cues.
- whether the same plate should be judged more than once
- how to ensure that subjects do not compare plates
- what should be the minimum time between plate touching

Results of the tests shall be analysed statistically to establish confidence limits for the findings

5.9.2. Field Tests for Sensor Distance and View Angle Limits

Develop a detailed test plan with a matrix of all test parameters, required coordination of equipment detailing the responsibilities of all participants.

Collect test data, including photo and video records of all tests.

The areas of ice contamination used for sensor evaluation shall be quantified by size, location and thickness. Angles of incidence, sensor heights and distances shall be verified independently. In concert with the sesor manufacturer, data from sensor readings and observer data shall be collated and analysed to reach conclusions on sensor limitations for distance and angle of incidence in various weather conditions.

5.10. Planning a Wing Deicing Test Site

Develop a plan for implementing a deicing test site, centred on an aircraft wing and supported by current fluid and rainmaking sprayers.

The plan shall include the acquisition of a surplus complete wing, from either a scrapped or an accidented moderate sized aircraft or an outboard section of a larger aircraft. The wing section should if possible include ailerons and leading edge slats
The design of the test site shall include a test area that could contain and recover sprayed fluids. Installation of the wing should entail a mounting designed to allow the wing to be rotated relative to current winds. The site must be secure yet allow ease of access and ability to install inexpensive solutions to control sprayed fluid.
Costs shall be estimated for the main elements of the development of a wing test bed site including:
wing purchase and delivery,
site lease and development, and
wing mount design and fabrication.

5.11. Evaluation of Hot (and Cold) Water Deicing

Investigate unheated and hot water deicing/defrosting, to determine under what meteorological conditions and temperatures these procedures are safe and practicable.
Unheated water deicing shall be evaluated at air temperatures above 1 degree C(34 degrees F).
Hot water deicing shall be evaluated at air temperatures below 1 degree C and include temperatures below –3 degrees C (27 degrees F).
These experiments shall establish how long it takes for the water to freeze on the surface under these conditions.
This is to be the first step of a two step procedure. From these data, a safe and practical lower limit shall be established considering the three-minute window required for second step anti-icing in the two-step deicing procedure.
Precipitation rates, as utilised in the generation of holdover time tables, shall be considered. Environmental chamber tests shall be correlated with outdoor aircraft tests. All laboratory test procedures and representative test results shall be recorded on videotape, including failure modes where applicable. The video shall depict a recommended full-scale aircraft hot water deicing procedure. A written report shall include the laboratory test results and a recommended aircraft unheated/hot water deicing procedure, including the limitations of precipitation, OAT and wind.

5.12. Evaluation of Warm Refuelling

Conduct a feasibility study of the suitability of refuelling with warm fuel to reduce susceptibility to "cold-soaked wing" icing, and to improve holdover times.
Coordinate activities to support testing the "warm fuel" concept using operational aircraft, including arranging;

- Participation of interested airlines, along with provision of aircraft for test purposes;
- Participation of local refueller;
- Arrangements with the equipment supplier (Polaris) to deliver the equipment to the selected airport along with the required technical support.

Testing will be conducted at Dorval on three occasions, one of which will include snow or freezing precipitation. Test aircraft selected should include a representation of both "wet" and "dry" wings if possible.

Wing surface temperatures of test wings will be monitored at several points over a period of time, to assess the influence thereon of warmed fuel. A reference case based on fuel boarded at the normal local temperature will be conducted.

5.13. Engine Air Velocity Distributions near Deicing Vehicles

Measure air velocity distributions in the vicinity of a de-icing truck when de-icing a large aircraft whose engines are running.

Tests shall be conducted during a period of no precipitation, either frost deicing or following snowfall, on two separate occasions at the Dorval International Airport deicing facility. Aircraft with engines mounted on the wing (e.g. B737) as well as rear engines mounted aircraft (e.g. DC-9 and RJ) will be sampled during live deicing operations, the precise type to be agreed by TDC. The tests shall be coordinated with Aéroport de Montréal and Aéromag 2000.

Wind velocity shall be measured from an Elephant-mu de-icing truck at locations recommended by TDC around the tail of the aircraft at different elevations and distances from the engines depending on the aircraft type, and the de-icing procedure followed by Aéromag 2000.

Photograph and video record the conduct of all tests.

5.14. Provision of Support Services

Provide support services to assist TDC with testing, the reduction of data and presentation of findings in the activites identified below which relate to the content of this work statement, but are not specifically included.

5.14.1. Re-Hydration

Conduct a series of exploratory trials on flat plates at the Dorval site or NRC to observe the behaviour of re-hydrated Type IV fluids and to help determine how re-hydration affects the flow- off characteristics of a Type IV fluid exposed to frost conditions.

5.14.2. Frost Tests on a Regional Jet

Conduct a series of tests to determine the roughness of frost deposition on the wings of a Regional Jet aircraft. Conduct tests on three overnight occasions.

5.14.3. Ice-Phobic Materials Evaluation

Conduct a series of tests on flat plates to determine the effects of ice-phobic materials on the film thickness and on holdover time of de/anti-icing fluids.

5.14.4. Evaluation of Infra-Red Thermometers

Evaluate use of infra-red technology as a method of determining accurate skin and fluid temperatures during operational conditions. Conduct tests in conjunction with full-scale and holdover time testing.

5.14.5. Frost Self-Elimination

Examine the self-elimination of frost on several test surfaces under variable weather conditions. Conduct test in conjunction with frost deposition trials on flat plates.

5.14.6. Environmental Impact Assessment

Assess the environmental issues related to the use of glycol-based products for aircraft de-icing purposes. Examine the waste fluid collection and disposal procedures for several deicing facilities in relation to current and future environmental legislation.

5.14.7. An Approach to Establish Wing Contamination

Document an approach to determining operational limits for levels of contamination on aircraft wings. This approach will include consideration of the location of contamination on the wings and the area contaminated. The levels of contamination on aircraft wings prior to takeoff as determined during the scanning trials prior to takeoff will be factored in.

The approach will discuss how the limits (when defined) could be used in software routines to enable sensor systems to provide Go/No-Go indications to the aircraft pilot and regulatory authorities.

5.14.8. Accident/incident Database Analysis

Provision of database manipulation and support aimed at establishing problem areas and their significance.

5.14.9. Other activities

Other activities, such as the evaluation of forced air technology, the evaluation of alternate (zero glycol) deicing methods, and the evaluation of frost removal equipment at gates, or others may emerge as issues during the course of the winter season.

5.15.2 Reporting

Present results to TDC in accordance with Section 7.2 “Reporting and other Illustrative Deliverables” and Section 10 “Reporting Requirements”, below. Separate final reports shall be issued for each area of activity consistent with the project objectives.

Final Reports, Presentations and Other Deliverables.

APPENDIX B
EXPERIMENTAL PROGRAM
EVALUATION OF THE USE OF REMOTE SENSORS FOR END-OF-RUNWAY INSPECTION

CM1514.001

EXPERIMENTAL PROGRAM
EVALUATION OF THE USE OF REMOTE SENSORS FOR END-OF-RUNWAY INSPECTION

Winter 1998/99

APS AVIATION INC.

February 4, 1999
Version 2.0

EXPERIMENTAL PROGRAM
EVALUATION OF THE USE OF REMOTE SENSORS FOR END-OF-RUNWAY INSPECTION

Winter 1998/99

APS will examine implications and conduct trials to evaluate the use of a remote ice contamination sensor to assess ice contamination on wings of operating aircraft prior to the aircraft entering the departure runway.

1. OBJECTIVES

The purpose of this project is to determine the feasibility of installing Ice Contamination Sensors at critical locations near departure runways to enable the sensors to adequately scan aircraft wings while not interfering with operations and safety limits. The ultimate objective is to provide information on wing condition to assist the Pilot-in-Command in the performance of the pretakeoff contamination inspection.

Determination of feasibility will identify and examine issues associated with implementation of such a system in an actual operation, using Dorval Airport as a model. As well, a series of trials will be conducted during an actual operation using a sensor system temporarily installed in a mobile vehicle.

The issues that potentially require investigation include;

- equipment positioning versus current runway clearance limitations,
- recommended type of mobile equipment or fixed facility. The need for an eventual installation to have rapid extension and retraction functionality of sensor booms needs to be understood.
- airport support needed, e.g. snow clearance, provision of operating locations,
- accommodating scanner limitations for distance, light, angle of incidence. Further information on limitations that may become available as a result of certification testing on the Spar/Cox sensor will need to be considered,
- communications needed to support scanning operation,
- the procedure for recording data from the sensors, and
- in an eventual installation, the communication of results from a scanning system to pilots and regulatory authorities.

These issues will be examined with the participation of appropriate staff at Dorval Airport and other regulatory authorities.

The test plan for operational trials (three sessions) will include:

- establishing test locations with airport authorities,

- establishing operational procedures to support the trials with airport authorities,
- arranging equipment for scanning; vehicle, sensor installation and radios,
- collecting and coordinating information from the deicing activity at the deicing centre,
- test procedures with detailed responsibilities for all participants,
- control of the confidential data gathered on wing condition, and
- notification to all concerned in the project, including aircraft operators, that trial scanning activities will be taking place.

2. TEST REQUIREMENTS

2.1 Preparation

Sensor trials will be conducted at Dorval Airport during actual operations in periods of snow or freezing precipitation. A Spar/Cox sensor mounted in a high-lift vehicle will be used to scan wings of departing aircraft, after having been deiced and just prior to entering the departure runway. The vehicle will be positioned in a fixed location in compliance with normal wing tip clearance regulations.

The ice sensor camera must be located near the entrance to active departure runways. The ice sensor camera must be sufficiently high above ground to provide an acceptable angle of incidence between wing surfaces and the scanner line of sight. Preliminary laboratory trials conducted during the 1997/98 season indicated that the minimum angle of incidence that is viewable by the sensor is 23 degrees. Tail surfaces will not be examined during these trials in view of the additional sensor height required. Reconciliation of sensor heights above ground, with airport runway clearance regulations will be necessary.

For the trials, a reference surface with a predetermined area of contamination will be located nearby, and will be periodically scanned.

Data on any icing contamination on the wings will not be distributed but will be collected for subsequent analysis.

APS will coordinate the installation of a Spar/Cox contamination sensor in a mobile vehicle, which will be made available for a two week period. The type of vehicle selected will be based on capability to raise the camera to sufficient height for scanning, and ease of operation. Preference will be given to the type of vehicle used by mobile TV crews, in which the camera is supported by a vertical telescoping mast. It is proposed to install the camera for remote operation with pan and tilt controls in the truck.

APS will coordinate planning and conduct of operational trials with Transportation Development Centre, Aéroports de Montreal, and NavCan. Test procedures will be developed and approved by all parties prior to trials, to ensure that required runway clearances and communications during operations are respected. The precise location and method of operation of the sensor vehicle for these trials will be agreed with these agencies. Advice will be provided to aircraft operators by a distributed notice (to be prepared by the Transportation Development Centre) as well as a briefing by Aéroports de Montréal and the Transportation Development Centre to the Airport Operating Committee.

2.2 Conduct of Trials

APS personnel will monitor forecasted weather and initiate operational trials based on suitable conditions. Contacts at the Transportation Development Centre, Aéroports de Montréal and NavCan will be advised when tests are planned.

Trials during actual operations will involve situating the sensor vehicle at a location beside the taxiway, as near to the point of entry to the departure runway as possible.

As aircraft taxi past the parked sensor vehicle, the sensor will scan the wing on the near side and record any evidence of contamination. Aircraft identification will be recorded. A reference surface having a predetermined area of contamination and at a defined distance and angle of incidence, will then be scanned after each aircraft scan to confirm that the sensor camera is actually seeing contamination through current precipitation.

At the end of the test session, deicing history of each aircraft will be retrieved from the deicing operator, to be incorporated into the data analysis. There will be no communication of results of sensor readings during the course of the trials. Weather conditions will be recorded on an ongoing basis. Simultaneous testing on flat plates will be conducted (at the nearby APS test site) to assist in documenting actual operating conditions and related fluid holdover times.

At least three trial sessions during periods of snow or freezing precipitation will be attempted.

Complete photo and video records of test setup will be maintained.

3. EQUIPMENT

Test equipment is included in Attachment I.

4. PERSONNEL

It is anticipated that a team of two people will be required to conduct the sensor trials. Descriptions of responsibilities and duties of each team member are given in Attachment II. One team member will be an experienced airport driver, with a background in airport operations.

A third person will monitor and record deicing details for aircraft deiced during these trials. A VHF radio tuned to the deicing facility radio frequency will be used. The purpose of this is to provide back-up to deicing history data provided by the deicing facility.

In addition, staff will be involved in the conduct of simultaneous fluid failure trials on flat plates. It is expected that this staff will be in place to conduct normal scheduled tests on fluid failure, and that no additional staff will be required for this activity.

Support from Spar/Cox will be coordinated for installation of the sensor on the vehicle, and, as required, for actual tests.

5. DATA FORMS

The following data form will be used:

C Figure 1 Record of Scanned Aircraft.

C Figure 2 Deicing History.

FIGURE 1
RECORD OF SCANNED AIRCRAFT

Montreal International Airport
Date: _________ Runway Location: _______________

Aircraft Type	Fin #	Carrier	Time	Wing Condition

Recorded by:_____________________________

ATTACHMENT I
TEST EQUIPMENT CHECKLIST

TEST EQUIPMENT	RESP.	STATUS
Security escort		
COX Sensor System, installed in vehicle		
Generator		
Personnel van		
Still camera		
Video camera		
Binoculars		
Security passes		
Reference contaminated surface for scanning (portable plate stand with plate)		
Plate failure data forms		
VHS radio with audio cassette recorder		
Deicing fluids - XL54 - Ultra +		
Scrapers		

ATTACHMENT II
RESPONSIBILITIES/DUTIES OF TEST PERSONNEL

Team Leader
CSafe operation of truck and bucket;
CEstablish and maintain radio contact with NavCan; and
CMaintain record of aircraft scanned, noting condition observed visually.

Sensor Operator
COngoing operation of sensor; and
CDirecting sensor camera toward aircraft surfaces, to obtain various views of the wing while the aircraft is approaching and taxiing past.
C Periodic scanning of reference surface to confirm sensor operation.

APS Test Site Staff
CPerform fluid holdover trials using same fluids as used for operational deicing, during course of scanning trials.

Coordinator
COutlook weather forecasts and initiate scanning trials;
CAdvise NavCan, Aéroports de Montréal of intention to conduct trials; and
C Ensure deicing records for trial period retrieved from AéroMag.

Radio Monitor
C Monitor deicing facility frequency, record data on deicing history form.

FIGURE 2

DEICING HISTORY FOR END-OF-RUNWAY TEST

Date	Flight ID	Aircraft Type or Code/ Fin #	Fluid Type	Start of HOT	Reason for Deicing	Amount of Precip. On ground

cm1514/procedur/end_rwy/DE_HIST

APPENDIX C
APPROVALS FOR SCANNING LOCATIONS

Aube, Charles

De :	Aube, Charles
Date:	mardi 16 février 1999 08:18
A :	*DDYUL
Cc :	Champagne, André; Perrier, Hélène
Objet :	test de dégivrage

la firme APS Aviation inc. en collaboration avec Transports Canada va procéder a des vérifications des ailes des avions sortant du dégivrage.

Pour ce faire ils vont filmer à l'aide d'une caméra spéciale installée dans un boom truck. Ce véhicule sera positionné près des baies d'attente 06R et 06L, voir les plans en annexe. J'ai obtenu la dérogation nécessaire pour ces "grues", no 99-06. Je procéderai à l'émission du NOTAM approprié. 990129

Ces tests auront lieu du mardi 16 février au dimanche 28 février 99, lors de conditions favorables, c-à-d lorsqu'il neige.

je vous trouverai un numéro de téléphone pour joindre les responsables qui seront escortés de toute façon.

si vous avez des questions supplémentaires, n'hésitez pas à communiquer avec moi.

Charles Aubé
Directeur adjoint, Centre de dégivrage
Services à l'Aviation
Aéroports de Montréal
633-3485

Transports Canada
Région du Québec

Transport Canada
Quebec region

Aviation civile

Civil aviation

APPROBATION Nº : 99-06

APPROBATION DE GRUES
CRANES APPROVAL

Propriétaire/ Owner	APS Aviation
Téléphone/ Telephone	(514) 633-3095 ADM - André Champagne
Emplacement/ Location	138FT nord-est seuil 06L 860FT à droite de l'axe 06L 413FT nord-est seuil 06R 492FT à gauche de l'axe 06R
Hauteur/ Height	42FT AGL 138FT ASL pour la grue 06L 42FT AGL 140FT ASL pour la grue 06R
NOTAM Nº :	À être émis par ADM
Dates :	99 02 15 au 99 02 28
Coordination :	
Restrictions :	
Remarques/ Remarks	La grue doit être de couleur orange ou d'une couleur contrastante avec une lumière rouge double au sommet si utilisée de nuit

Approuvé par/
Approved by

Sécurité des aérodromes/
Aerodrome Safety

Date : 99 02 12

Canada

Transports Canada
Région du Québec

Aviation civile

Transport Canada
Quebec Region

Civil Aviation

700, Leigh Capréol
Dorval (Québec)
H4Y 1G7

Bordereau de Transmission pour Télécopieur - Facsimile Transmittal Form

Date	N° de Dossier - File No.	Page
99 02 12		1 of/de 2

Classe de sécurité Security Classification	Non classifié Unclassified	Confidentiel Confidential	Protégé Protected
	☐	☐	☐

À - To	De - From
André Champagne ADM Dorval	Rita Blanchet Inspecteur Sécurité des aérodromes
Téléphone - Telephone (514) 633-3096	Téléphone - Telephone (514) 633-2807
N° de Télécopieur - Facsimile Telephone (514)633-3368	N° de Télécopieur - Facsimile Telephone (514) 633-3052

Instructions Spéciales - Special Instructions

NAV Canada Tour de contrôle Fax 633-3309

<u>Approbation de grue 99-06</u>

Pour votre information

Salutations !

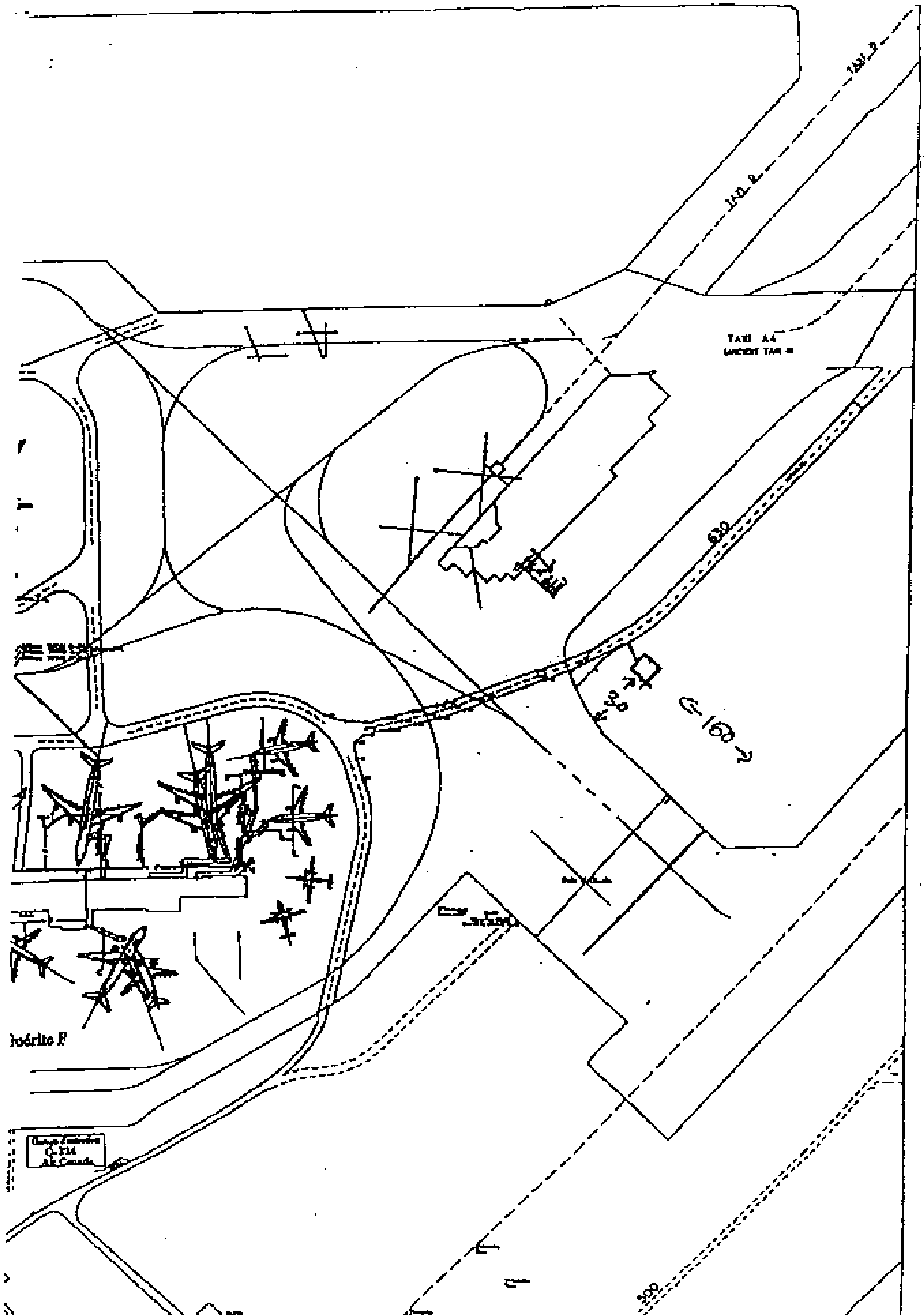
Position des camions grues .

piste 06R un carré de 30pi X 30pi sera déneigé à partir du chemin 630,
le coin sud-ouest de ce carré sera à 150mètres à gauche de l'axe de la 06R et à 30 mètres au nord-est de la baie d'attente.
Le boom de la grue sera pointé vers la baie d'attente pour filmer le dessus des ailes.

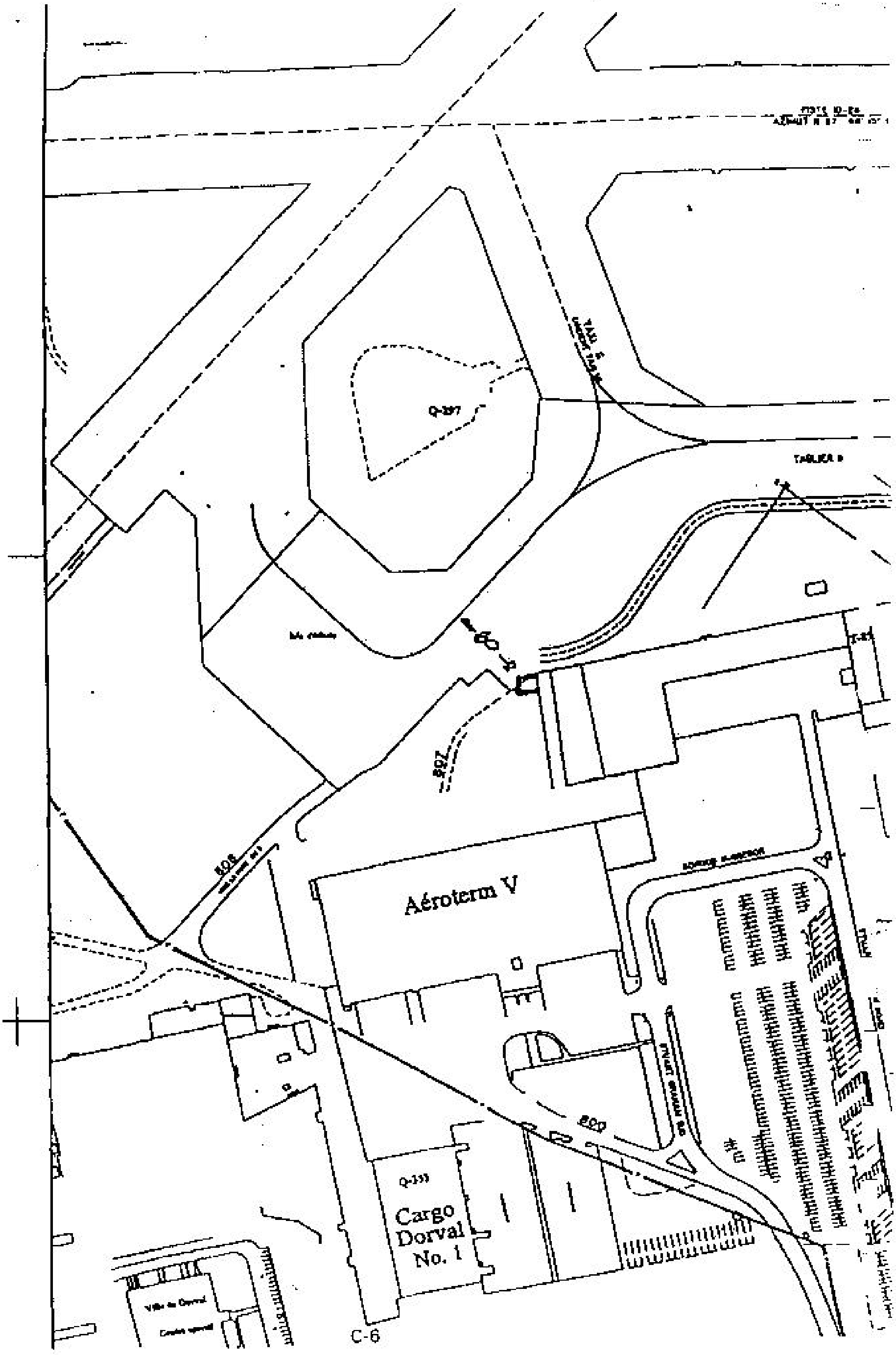
Piste 06L le camion grue sera stationné le long de la clôture sur le petit chemin menant vers Aéroterm, à la fin du corridor des véhicules.
Le véhicule sera 260 mètres à droite de l'axe de la 06L et 280 mètres à l'est du seuil 06L. Ce sera aussi 60 mètres au sud-est de la ligne de guidage menant vers la baie d'attente
Le boom de la grue sera pointé vers le nord.

633-3465

R. BLANCHET



R. BLANCHET



AÉROPORTS DE MONTRÉAL

RECEIVED
FEB 09 1998

Le 3 février 1999

Référence : 5851-3

Mme Rita Blanchet
Inspecteur, Sécurité des aérodromes
Transports Canada
700, Leigh Capréol
Dorval (Québec) H4Y 1G7

OBJET : Demande de dérogation pour grues

Madame,

Dans le cadre du programme de recherche sur le dégivrage de Transports Canada, la firme APS Aviation Inc. voudra installer des camions grues à proximité des seuils des pistes 06R et 06L (voir plans en annexe). Ces camions, dont la flèche atteindra une hauteur de 42 pieds, veulent filmer le dessus des ailes des avions, après avoir dégivré, juste avant qu'ils ne circulent en position pour décoller.

Ces opérations auraient lieux lors de la 3ième et 4ième semaine de février, soit du 15 au 28 février. Il y aura d'abord des tests de positionnement, puis en fonction de la météo, ils filmeront officiellement les avions à l'aide d'une caméra spéciale.

Si vous avez besoin d'informations supplémentaires, n'hésitez pas à communiquer avec le soussigné. Nous vous remercions de l'attention portée à cette requête.

Le directeur des Services à l'aviation,
Aéroport international de Montréal - Dorval

André Champagne

AC/CA/dc

p.j. (1)

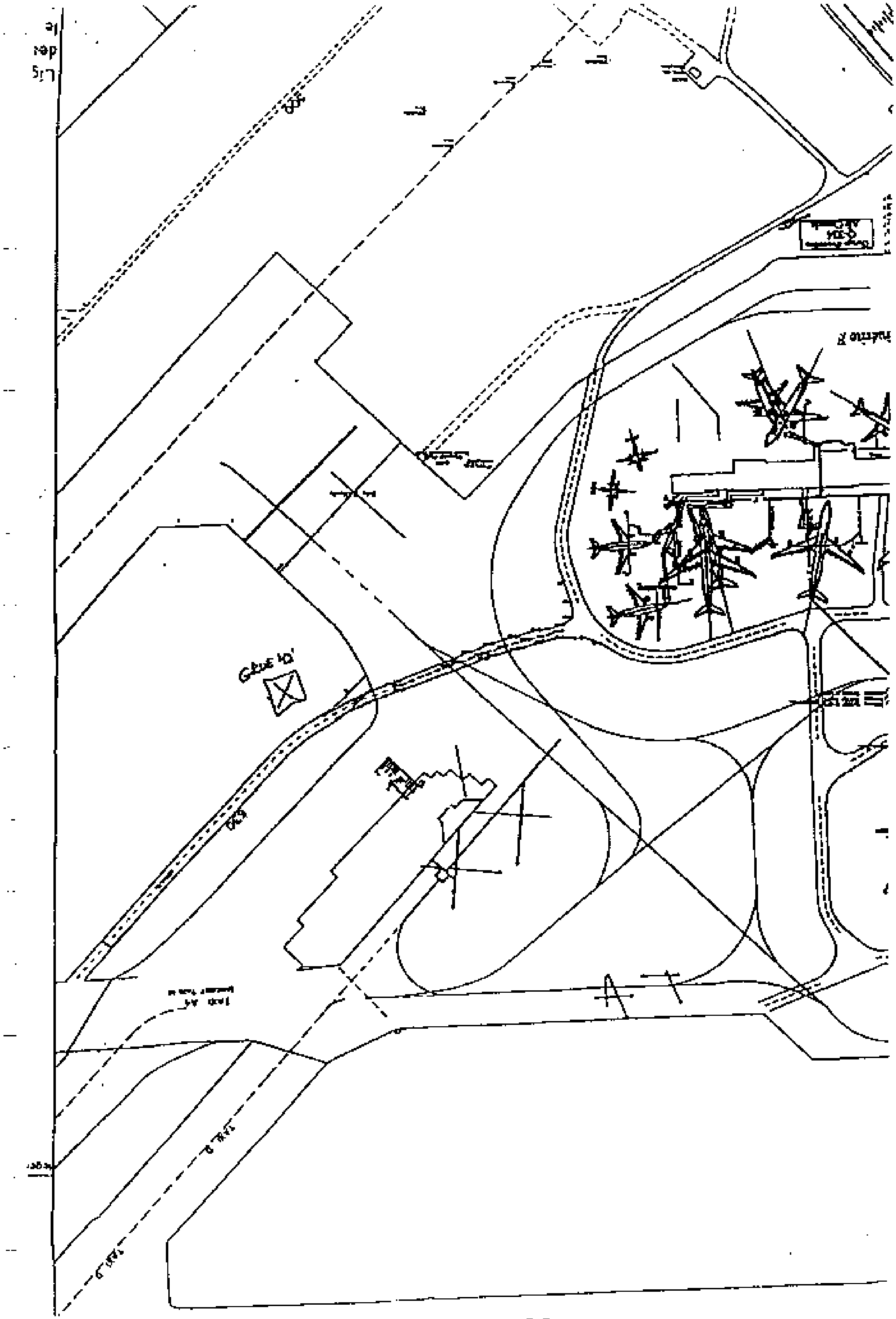
c.c. Peter G. Dawson, APS Aviation Inc.
Barry B. Myers, Transports Canada

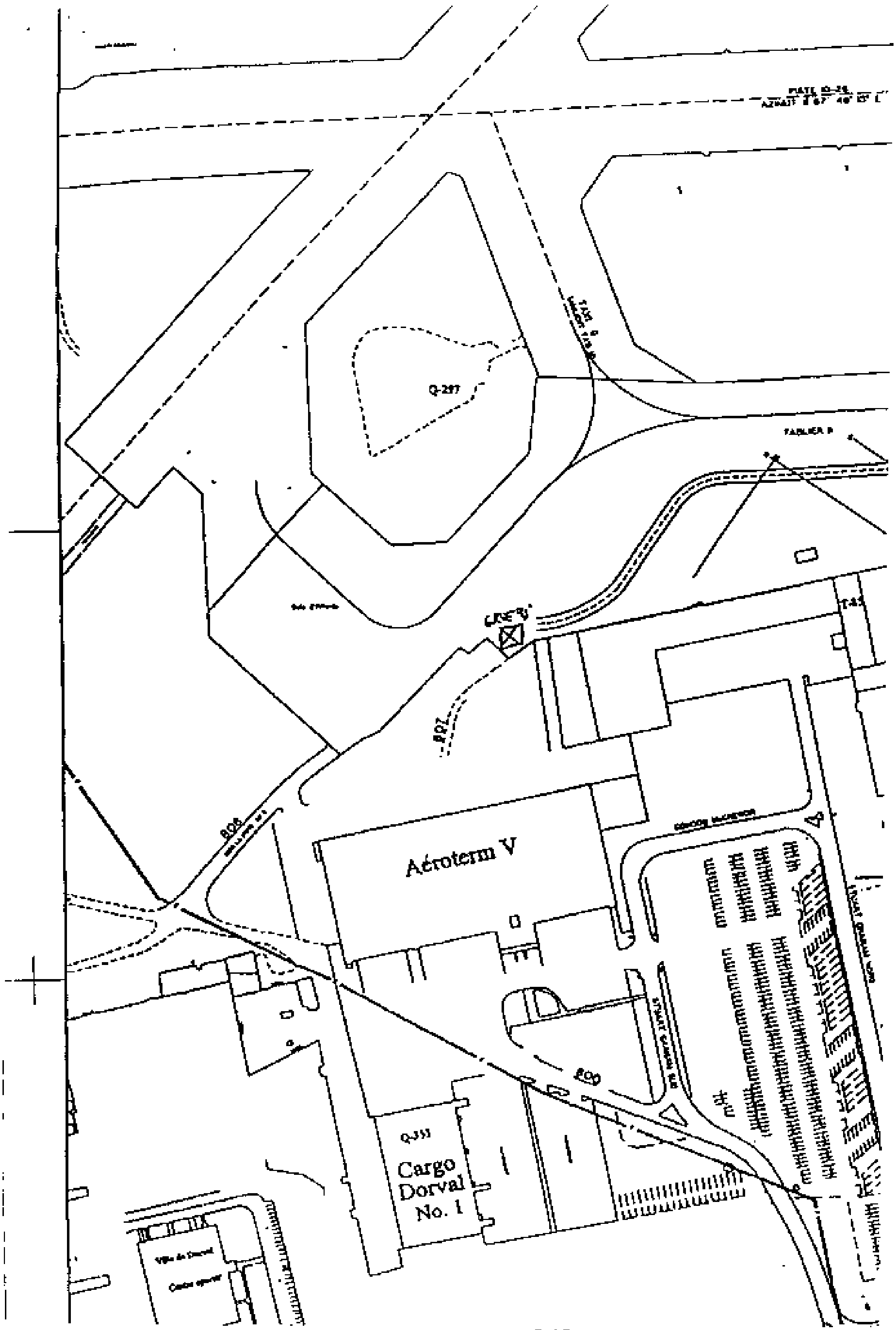
H:\documents\...\C.-Blanchet, Grues APS

Annexe

- Position de la grue près de la 06R : 150 mètres à gauche de l'axe
  187,5 mètres au nord-ouest du seuil

- Position de la grue près de la 06L : 262,5 mètres à droite de l'axe
  112,5 mètres à l'est du seuil





Q-297
TABLIER R
808
807
Aéroterm V
800
Q-353
Cargo
Dorval
No. 1

APPENDIX D
SEPARATION DISTANCES

Transport Canada / Transports Canada

Aviation / Aviation

TP 312E

AERODROME STANDARDS AND RECOMMENDED PRACTICES

4th Edition

March 1993

Air Navigation System Requirements Branch

1.2.3 Standard.— Wherever a colour is referred to in this Document, the specifications for that colour given in Appendix 1 shall apply.

1.3 REFERENCE CODE

Introductory Note.— The intent of the reference code is to provide a simple method for interrelating the numerous specifications concerning the characteristics of aerodromes so as to provide a series of aerodrome facilities that are suitable for the aeroplanes that are intended to operate at the aerodrome. The code is not intended to be used for determining runway length or pavement strength requirements. The code is composed of two elements which are related to the aeroplane performance characteristics and dimensions. Element 1 is a number based on the aeroplane reference field length and element 2 is a letter based on the aeroplane wing span and outer main gear wheel span. A particular specification is related to the more appropriate of the two elements of the code or to an appropriate combination of the two code elements. The code letter or number within an element selected for design proposes is related to the critical aeroplane characteristics for which the facility is provided. When applying TP 312, the aeroplanes which the aerodrome is intended to serve are first identified and then the two elements of the code.

1.3.1 Standard.— An aerodrome reference code (code number and letter) which is selected for aerodrome planning purposes shall be determined in accordance with the characteristics of the aeroplane for which an aerodrome facility is intended.

1.3.2 Standard.— The aerodrome reference code numbers and letters shall have the meanings assigned to them in Table 1-1.

1.3.3 Standard.— The code number for element 1 shall be determined from Table 1-1, column 1, selecting the code number corresponding to the highest value of the aeroplane reference field lengths of the aeroplanes for which the runway is intended.

Note.— The determination of the aeroplane reference field length is solely for the selection of a code number and is not intended to influence the actual runway length provided.

Table 1-1. Aerodrome reference code (see 1.3.2 to 1.3.4)

Code element 1		Code element 2		
Code number	Aeroplane reference field length	Code letter	Wing span	Outer main gear wheel span [a]
	(1)		(2)	(3)
1	Less than 800 m	A	Up to but not including 15 m	up to but not including 4.5 m
2	800 m up to but not including 1200 m	B	15 m up to but not including 24 m	4.5 m up to but not including 6 m
3	1200 m up to but not including 1800 m	C	24 m up to but not including 36 m	6 m up to but not including 9 m
4	1800 m and over	D	36 m up to but not including 52 m	9 m up to but not including 14 m
		E	52 m up to but not including 65 m	9 m up to but not including 14 m

a. Distance between the outside edges of the main gear wheels.

Taxiway minimum separation distances

3.4.1.8 Recommendation.— The separation distance between the centre line of a taxiway and the centre line of a runway, the centre line of a parallel taxiway or an object should not be less than the appropriate dimension specified in Table 3–1, except that it may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.

Note 1.— Guidance on factors which may be considered in the aeronautical study is given in TP 7775, Procedures for the Certification of Aerodrome as Airports, Chapter 5.

Note 2.— ILS installations may also influence the location of taxiways due to interferences to ILS signals by a taxiing or stopped aircraft. Information on critical and sensitive areas surrounding ILS installation is contained in TP 1247, Land Use in the Vicinity of Airports, Part 2

Note 3.— The separation distances of Table 3-1, column 4 do not necessarily provide the capability of making a normal turn from one taxiway to another parallel taxiway. Guidance for this condition is given in the ICAO Aerodrome Design Manual, Part 2.

3.4.2 SLOPES ON TAXIWAYS

Longitudinal slopes

3.4.2.1 Recommendation.— The longitudinal slope of a taxiway should not exceed:

- 1.5 per cent where the code letter is C, D or E; and
- 3 per cent where the code letter is A or B.

Longitudinal slope changes

3.4.2.2 Recommendation.— Where slope changes on a taxiway cannot be avoided, the transition from one slope to another slope should be accomplished by a curved surface with a rate of change not exceeding:

- 1 per cent per 30 m (minimum radius of curvature of 3000 m) where the code letter is C, D or E; and
- 1 per cent per 25 m (minimum radius of curvature of 2500 m) where the code letter is A or B.

Sight distance

3.4.2.3 Recommendation.— Where a change in slope on a taxiway cannot be avoided,

Table 3-1. Taxiway Minimum Separation Distances

Code Letter	Distance between taxiway centre line and runway centre line (metres)												Taxiway centre line to taxiway centre line (metres)	Taxiway centre line to object (metres)
	Precision approach runway				Non-precision approach runway				Non-instrument runway					
	(1)				(2)				(3)				(4)	(5)
	Code number				Code number				Code number					
	1	2	3	4	1	2	3	4	1	2	3	4		
A	82.5	82.5	----	----	53.0	53.0	----	----	37.5	37.5	----	----	23.75	16.25
B	87.0	87.0	162.0	----	57.8	57.8	87.0	----	42.0	42.0	57.0	----	33.5	21.5
C	----	----	168.0	----	----	----	92.0	----	----	48.0	63.0	----	44.0	26.0
D	----	----	176.0	176.0	----	----	101.0	176.0	----	----	71.0	101.0	66.5	40.5
E	----	----	----	182.5	----	----	----	182.5	----	----	----	107.5	80.0	47.5

3.5.2 TAXI–HOLDING POSITIONS

Application

3.5.2.1 Standard.— A taxi–holding position or positions shall be established:

a) at an intersection of a taxiway with a runway;

b) at an intersection of a runway with another runway when the former runway is part of a standard taxi–route; and

c) at an intersection of a runway with a runway where the runway is used for simultaneous intersecting runway operations.

Location

3.5.2.2 Standard.— Except as specified in para 3.5.2.3, the distance between a taxi-holding position established at a taxiway/runway intersection and the centre line of a runway shall be not less than the appropriate dimension specified in Table 3–2, and in the case of a precision approach runway, such that a holding aircraft or vehicle will not interfere with the operation of radio navigation aids.

3.5.2.3 Recommendation.— Where a taxiway/runway intersection occurs at other than the runway threshold and aircraft hold for the purpose of crossing the runway on a frequent or recurring basis, the distance between the taxi-holding position and the centre line of the runway should be increased to be not less than the appropriate dimensions specified in Table 3–3.

3.5.2.4 Standard.— A taxi–holding position at a runway/runway intersection shall be located at a distance not less than 60 m from the nearest edge of the intersecting runway.

3.5.3 ROAD–HOLDING POSITIONS

Application

3.5.3.1 Standard.— A road–holding position shall be established at an intersection of a road with a runway.

Location

3.5.3.2 Standard.— The distance between a road–holding position and the centre line of a runway shall be not less than the

Table 3-2 Minimum distance from the runway centre line to a holding bay, taxi-holding position, or road-holding position

Type of Runway	CODE NUMBER			
	1	2	3	4
Non-instrument approach	30 m	40 m	75 m	75 m
Non precision approach	40 m	40 m	75 m	75 m
Precision approach Cat I	60 m (1)	60 m (1)	90 m (1)	90 m (1)
Precision approach Cat II and III	-----	-----	90 m (1)	90 m (1)
Take-off Runway	30 m	40 m	75 m	75 m

Note 1.—This distance shall not be closer than the ILS/MLS critical/sensitive area.

Note 2.— The distance of 90m where the code number is 4, is based on an aeroplane with a tail height of 20m, a distance from the nose to the highest part of the tail of 52.7m and a nose height of 10m holding at an angle of 45 degrees or more with respect to the runway centre line, being clear of the obstacle free zone and not accountable for the calculation of obstacle clearance for instrument approach procedures.

Note 3.— The distance of 60m where the code number 2 is based on an aeroplane with a tail height of 8m, a distance from the nose to the highest part of the tail of 24.6 and a nose height of 5.2m holding at an angle of 45 degrees or more with respect to the runway centre line, being clear of the obstacle free zone.

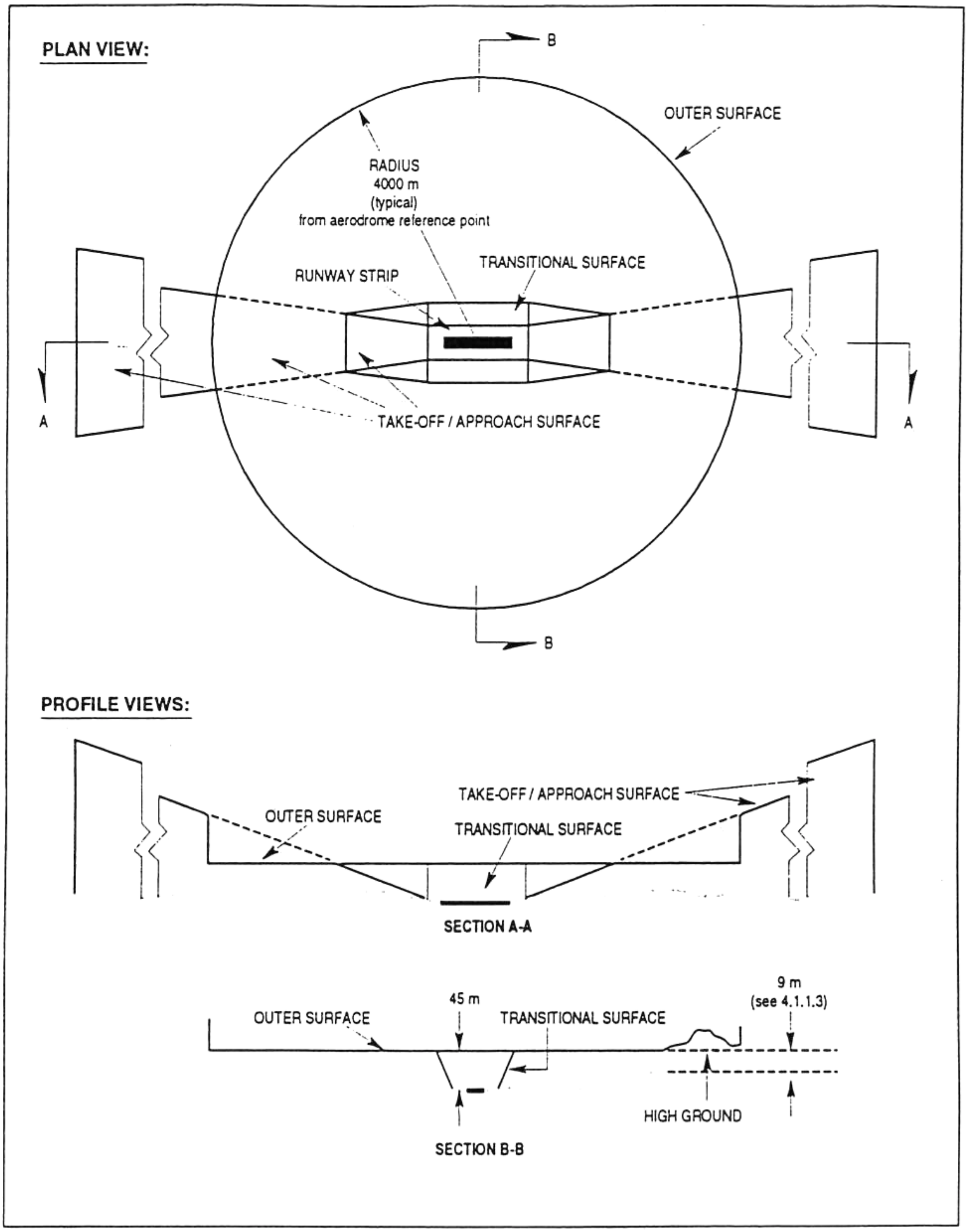


Figure 4-1. Obstacle Limitation Surfaces

Note.— Circumstances in which the shielding principle may reasonably be applied are described in the ICAO Airport Services Manual, Part 6.

4.2.2.7 Recommendation.— New objects or extensions of existing objects should not be permitted above the outer surface except when, in the opinion of the certifying authority, the object would be shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aircraft.

4.2.2.8 Recommendation.— In considering proposed construction, account should be taken of the possible future development of an instrument runway and consequent requirement for more stringent obstacle limitation surfaces.

4.2.3 NON-PRECISION APPROACH RUNWAYS

Note.— See 8.6 for information regarding siting and construction of equipment and installations on operational areas.

4.2.3.1 Standard.— The following obstacle limitation surfaces shall be established for a non-precision approach runway:

- outer surface;
- take-off/approach surface; and
- transitional surfaces.

4.2.3.2 Standard.— The heights and slopes of the surfaces shall not be greater than, and their other dimensions not less than, those specified in Table 4-1.

Table 4-1. Dimensions and Slopes of Obstacle Limitation Surfaces

SURFACE and DIMENSIONS	RUNWAY TYPE / CODE NUMBER								
	Non-instrument				Non-precision approach			Precision approach Cat I	
	(1)				(2)			(3)	
	Code number				Code number			Code number	
	1	2	3	4	1&2	3	4	1&2	3&4
OUTER SURFACE									
- Height	45m	45m	45m	45m	45m	45m	45m	45m	45m
- Radius	4000 m	4000 m	4000 m	4000 m	4000 m	4000 m	4000 m	4000 m	4000 m
TAKE-OFF/APPROACH SURFACE									
- Length of Inner Edge	30 m	30 m	45 m	75 m	45 m	75 m	150 m	75 m	150 m
- Distance from threshold	30 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m
- Divergence (minimum each side)	10%	10%	10%	10%	10%	15%	15%	15%	15%
- Length (minimum)	2500 m	2500m	2500m	2500m	2500 m	3000 m	3000 m	15000m	15000m
- Slope (maximum)	5% (1:20)	4% (1:25)	2.5% (1:40)	2.5% (1:40)	3.33% (1:30)	2.5% (1:40)	2.5% (1:40)	2.5% (1:40)	2.0% (1:50)
TRANSITION SURFACE									
- Slope (maximum)	20.0% (1:5)	20.0% (1:5)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)	14.3% (1:7)

APPENDIX E
EXPERIMENTAL PROGRAM
TRIALS TO ESTABLISH SENSITIVITY LIMITS FOR AN ICE DETECTION CAMERA
WINTER 1998/99

CM1514.001

EXPERIMENTAL PROGRAM
TRIALS TO ESTABLISH SENSITIVITY LIMITS
FOR AN ICE DETECTION CAMERA

Winter 1998/99

APS AVIATION INC.

July 12, 1999
Version 2.1

EXPERIMENTAL PROGRAM
TRIALS TO ESTABLISH SENSITIVITY LIMITS FOR AN ICE DETECTION CAMERA

Winter 1998/99

APS will conduct a series of tests on specially designed ice contamination discs and and other test surfaces, both in a controlled environment offered by a laboratory facility and in the open under natural environmental conditions. This document provides the detailed procedures and equipment required for the conduct of these tests.

1. OBJECTIVE

The objective of this series of tests is to determine operational limits for an ice detection camera system. The SPAR/COX ice detection camera system will be the subject of this examination.

The principal parameters to be examined will include:

- Ice thickness threshold; determining the smooth ice thickness threshold as a function of camera distance and viewing angle, using FAA Ice Detection Thickness Plates;

- Detection of ice under anti-icing fluid; determining the effect on ice detection of an overlying layer of Type IV fluid of varying thicknesses and manufacture;

- Effect of contamination roughness; generate rough ice surfaces to assess the affects of surface roughness on camera image and identification of contamination;

- Determine typical roughness profiles of slush; during standard fluid holdover trials, record the resultant roughness profile as a function of time at selected intervals until test end.

Additionally, the following parameters will be examined in outdoor conditions:

- Visibility in snow conditions; these trials will use both the ice detection thickness plates and standard plates;

- Accuracy in changing light conditions; a contamination target will be examined progressively during the 2-hour period encompassing sunrise or sunset.

2. TEST REQUIREMENTS

Procedures addressing each of the camera parameters under scrutiny follow.

A Ice thickness threshold. The objective is to determine the smooth ice thickness threshold as a function of camera distance and viewing angle, using FAA Ice Detection Thickness Plates.

The ice detection plates are to be filled with water and then frozen to form ice discs in plate recesses of various depths. It may be necessary to add a wetting agent such as a small amount of household detergent to the water to avoid cavities at edges of the disc recess and to ensure a flat surface.

Ability of the system to detect ice of the various depths will be determined for the matrix of test conditions as provided in Figure 1.

B Detection of ice under anti-icing fluid. The objective is to determine the effect on ice detection of an overlying layer of Type IV fluid of varying thicknesses and manufacture.

SAE Type IV anti-icing fluid, both ethylene glycol and propylene glycol-based will be applied over ice samples on the ice detection plates described in Test 1. If none of the COX plates are viewable at a designated test cell, such as the cell 50 ft / 30 degrees, then a standard plate with contamination will be employed as the test subject.

Effect of overlying fluid on the system ability to detect ice contamination will be measured for the matrix of test conditions as provided in Figure 1.

C Effect of contamination roughness. The objective is to assess the affects of surface roughness on camera image and the system ability to identify contamination.

An attempt will be made to generate rough ice surfaces to serve as subjects for this test. Generation of frost with the use of cold soaked boxes will be examined, with and without the use of ice detection plates on top of the box surface. Roughness profiles must be in excess of 0.5mm.

Another possibility for producing rough surfaces includes the failing of fluid on a cold soaked box by the sprinkling of snow.

Some of these trials will be conducted outdoors to satisfy distance parameters.

D Determine typical roughness profiles of slush. The objective is to record the roughness profiles as a function of time at selected intervals until test end during standard fluid holdover trials.

During a standard tests of anti-icing fluid holdover time, record the roughness Profile of the resultant slush as accurately as possible, as a function of time at selected intervals until test end.

Simultaneously observe the test plate with the sensor camera, and coerelate level of roughness with camer observation. Monitor and record the slush appearance at the time of profile measurement with a video camera.

E **Visibility in snow conditions.** The objective is to determine the ability of the sensor camera to see ice through falling snow.

These trials will use ice detection thickness plates for shorter distances up to 50 feet. If none of the COX plates are viewable at a designated test cell, such as the cell 50 ft / 30 degrees and cells beyond, then a standard plate with a level of contamination known to be discernible at that distance in non-precipitation conditions, will be employed as the test subject. This level of contamination will need to be determined.

These trials will be conducted outdoors during natural snow fall.

F **Adaptability to changing light conditions.** The objective is to determine how susceptible the system is to changing natural light conditions.

These trials will use ice detection thickness plates for shorter distances up to 50 feet. If none of the COX plates are viewable at a designated test cell, such as the cell 50 ft / 30 degrees and cells beyond, then a standard plate with a level of contamination known to be discernible at that distance in non-precipitation conditions, will be employed as the test subject.

These trials will be conducted outdoors. The test subject will be examined at predetermined intervals during the 2-hour period encompassing sunrise or sunset.

3. EQUIPMENT AND FLUIDS

Equipment to be employed is listed in detail in Attachment II.

Type IV fluids involved will be Ultra+ and Kilfrost ABC/S .

4. PERSONNEL

A test team of two personnel and a coordinator will conduct these trials.

Representatives from the equipment manufacturer (Cox and Co) will be invited to be present for these trials.

5. TEST PLAN

A test matrix is shown in Figure 1.

A detailed test plan is provided in Attachment III.

6. DATA FORMS

The following data forms are required:

- Ice Thickness Threshold and Ice Under Fluid Test Form (Figure2)
- Ice Detection Sensitivity Trials Contamination Roughness (Figure3)

ATTACHMENT I

Equipment
VHS tapes
Cox System
Fluids
Detergent (for water)
Thickness gauges
Inclinometer
Cameras - still & video
Steel rule for scale in photos
Stand, modified to allow variable slope
Backing for Cox plates
Hi-lift
Cold-Soak boxes, filled
Data sheets
Snow shaker
Rent
Chamber (large)
Mobile cooler for cold-soak boxes and fluid

FIGURE I

TEST PLAN FOR ESTABLISHING SENSITIVITY LIMITS FOR AN ICE DETECTION CAMERA

Distance (Horizontal)		**Viewing Angle**				
m	**ft**	**10º**	**20º**	**30º**	**45º**	**60º**
	15	**A**	**A (1.9)**	**A (1.3)**	**A (0.9)**	**A (0.8)**
	25	**A**	**A,B,C,E,F (3.2)**	**A,B,C,E,F (2.2)**	**A,C (1.6)**	**A (1.3)**
	50		**A (6.5)**	**A,B,C,E,F (4.4)**	**A (3.1)**	**A (2.5)**
	100			**C,E,F**	**(6.2)**	**(5.1)**
	150			**C,E,F**		

TEST TYPE

A Ice thickness threshold tests
B Ice under Type IV fluid tests; T4E & T4P
C Contamination roughness; 3 levels will be attempted
E Visibility in Snow Conditions
F Adaptability to Changing Light Conditions

NOTE

Within the cells, values in brackets indicate the minimum length (inches) of ice viewable by the sensor (Source: Cox & Co). The diameter of the ice disc in the ice thickness threshold plates is 3 inches.

FIGURE 2

ICE THICKNESS THRESHOLD AND ICE UNDER FLUID TEST FORM

Location: ______________

Date: ______________

Time: ______________

Distance Camera to Surface:_____________

FAA Plate #	Other Surface	Fluid Applied	Identification of Ice at Angle of Incidence				
			10°	20°	30°	45°	60°

cm1514/procedure/sensor/Ct_rough.xls
At:Treshold
Printed: 5/21/02, 11:31 AM

FIGURE 3

ICE DETECTION SENSITIVITY TRIALS

CONTAMINATION ROUGHNESS

Location: __________

Date: __________

Time: __________

Test Run	Distance	View Angle	Roughness Condition	Description of Sensor Image

cm1514/procedure/sensor/Ct_rough.xls
At: Sensitivity
Printed: 5/21/02, 11:31 AM

ATTACHMENT II
PERSONNEL ASSIGNMENT

Overall Coordinator

- Assists team leaders as required; and
- Discusses and approves any changes to test procedures as determined necessary from test results or circumstances.

Test Team

- Prior to test, mount FAA ice thickness plates on plywood backing.
- Predetermine area of contamination that is visible on standard plates to serve as a baseline for tests using those surfaces.
- Prepare stand to enable test subject to be mounted at varying slopes
- Prepare ice on thickness plates
- Prepare cold soak boxes to generate frost
- Operate ice detection camera and record pertinent images
- Position test plates and camera to match test requirements
- Conduct tests and record observations

ATTACHMENT III

ICE DETECTION SENSOR SENSITIVITY TRIALS

TEST TYPE	A	Ice Thickness Threshold
	B	Ice under Type IV Fluid
	C	Contamination Roughness
	D	Determine Typical Roughness Profiles during HOT Trials
	E	Visibility in Falling Snow Condiitions
	F	Adaptability to Changing Light Conditions

DISTANCE M	FT	VIEW ANGLE (Deg)	TEST TYPE	FLUID TYPE	LEVEL OF ROUGHNESS	TRIAL LOCATION	TEST SURFACE
4.5	15	10	A			PMG	FAA Plates
4.5	15	20	A			PMG	FAA Plates
4.5	15	30	A			PMG	FAA Plates
4.5	15	45	A			PMG	FAA Plates
4.5	15	60	A			PMG	FAA Plates
7.5	25	10	A			PMG	FAA Plates
7.5	25	20	A			PMG	FAA Plates
7.5	25	20	B	T4E		PMG	FAA Plates
7.5	25	20	B	T4P		PMG	FAA Plates
7.5	25	20	C		a	PMG	ColdSoak BOX
7.5	25	20	C		b	PMG	ColdSoak BOX
7.5	25	20	C		c	PMG	ColdSoak BOX
7.5	25	20	E			SITE	FAA Plates
7.5	25	20	F			SITE	FAA Plates
7.5	25	30	A			PMG	FAA Plates
7.5	25	30	B	T4E		PMG	FAA Plates
7.5	25	30	B	T4P		PMG	FAA Plates
7.5	25	30	C		a	PMG	ColdSoak BOX
7.5	25	30	C		b	PMG	ColdSoak BOX
7.5	25	30	C		c	PMG	ColdSoak BOX
7.5	25	30	E			SITE	FAA Plates
7.5	25	30	F			SITE	FAA Plates
7.5	25	45	A			PMG	FAA Plates
7.5	25	45	C		a	PMG	ColdSoak BOX
7.5	25	45	C		b	PMG	ColdSoak BOX
7.5	25	45	C		c	PMG	ColdSoak BOX
7.5	25	60	A			PMG	FAA Plates
15	50	20	A			PMG	Std PLATE
15	50	30	A			PMG	FAA orPLATE
15	50	30	B	T4E		PMG	FAA orPLATE
15	50	30	B	T4P		PMG	FAA orPLATE
15	50	30	C		a	PMG	ColdSoak BOX
15	50	30	C		b	PMG	ColdSoak BOX
15	50	30	C		c	PMG	ColdSoak BOX
15	50	30	E			SITE	FAA orPLATE
15	50	30	F			SITE	FAA orPLATE
15	50	45	A			PMG	FAA Plates
15	50	60	A			PMG	FAA Plates
30	100	30	C		a	SITE	ColdSoak BOX
30	100	30	C		b	SITE	ColdSoak BOX
30	100	30	C		c	SITE	ColdSoak BOX
30	100	30	E			SITE	Std PLATE
30	100	30	F			SITE	Std PLATE
45	150	30	C		a	SITE	ColdSoak BOX
45	150	30	C		b	SITE	ColdSoak BOX
45	150	30	C		c	SITE	ColdSoak BOX
45	150	30	E			SITE	Std PLATE
45	150	30	F			SITE	Std PLATE