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Survey of Nonglycol and Reduced Glycol Aircraft Deicing Methods

April 1999

Final Report

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16. Abstract

This survey of no glycol and low-glycol aircraft deicing practices, methods, and procedures used by the world's airlines, including cargo carriers, was conducted under contract to the Federal Aviation Administration (FAA) William J. Hughes Technical Center.

A representative sample of 80 of the world's airlines and airports with operations under winter ground icing conditions were surveyed by mail for their experience with no glycol or reduced-glycol deicing methods. Twenty-five responded. The written survey was supported by face-to-face interviews and telephone interviews.

The results are presented in descriptive format for each of the procedures identified along with sample illustrations where appropriate. A summary is given of the principle characteristics for each procedure.

Although the focus of the survey was the procedures in use, a number of technologies under development and which have been field tested have been included, such as truck-mounted blown air systems, mobile infrared heaters, and preheating of fuel prior to refueling.

Major reductions in glycol use can be achieved through the use of simple mechanical aids such as scrapers or brushes to remove snow accumulation prior to conventional deicing.

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LIST OF ABBREVIATIONS

AEA	Association of European Airlines
APU	Auxiliary power unit
ATC	Air traffic control
CAA	Civil Aviation Authority
DIN	Deutsches Institut fuer Normung
FP	Freezing point
FPD	Freezing point depressant
ISO	International Organization for Standardization
OAT	Outside air temperature
SAE	Society of Automotive Engineers
SAS	Scandinavian Airlines System

EXECUTIVE SUMMARY

This survey of no glycol and low-glycol aircraft deicing practices, methods, and procedures used by the world's airlines, including cargo carriers, was conducted under contract to the Federal Aviation Administration (FAA) William J. Hughes Technical Center.

A representative sample of 80 of the world's airlines and airports with operations under winter ground icing conditions were surveyed by mail for their experience with no glycol or reduced-glycol deicing methods. Twenty-five responded. The written survey was supported by face-to-face interviews and telephone interviews.

The results are presented in descriptive format for each of the procedures identified along with sample illustrations where appropriate. A summary is given of the principle characteristics for each procedure.

Although the focus of the survey was the procedures in use, a number of technologies under development and which have been field tested have been included, such as truck-mounted blown air systems, mobile infrared heaters, and preheating of fuel prior to refueling.

Major reductions in glycol use can be achieved through the use of simple mechanical aids such as scrapers or brushes to remove snow accumulation prior to conventional deicing.

1. INTRODUCTION.

1.1 PURPOSE.

The purpose of this report was to survey and document deicing methods and practices within the international airline industry, that are currently used or have been successfully used in the past, in which no glycol-based fluids or low-glycol methods are used. The use of new, experimental techniques or reduced temperature buffer fluids are not within the scope of this study.

1.2 BACKGROUND.

The Federal Aviation Administration (FAA) continues to support research and development of improvements in deicing methods and practices. This survey has compiled information on manpower, materials, and facilities and equipment as required to document and categorize nonglycol and low-glycol aircraft deicing practices, methods, and procedures used by the world's airlines, including cargo carriers.

The state of the art in deicing/anti-icing methods has been advanced by improvements to deicing fluids and their certification standards, application methods, training, techniques, and deicing equipment and the emerging technologies in ground and onboard ice detecting equipment. However, these advances in the deicing/anti-icing arena have not eliminated certain negative aspects of cost and environmental impact; the purchase cost of glycol-based deicing/anti-icing fluids is only a portion of the entire picture. The cost also must include the environmental issues since the proper disposal of spent fluid affects the overall cost of deicing and anti-icing aircraft. Proper disposal includes the reclamation and refining for future use and collection with the proper disposition or precise metering of the resultant deicing operation runoff into sewer systems in amounts deemed not ecologically detrimental. Allowing the uncontrolled runoff of glycol products has been shown to be damaging to the environment.

To eliminate the negative aspects of aircraft deicing is a formidable task. However, the negative aspects of the cost and environmental impact can be minimized. Obviously, by reducing the amounts of glycol used by the international aviation industry, both the cost of aircraft deicing and its environmental impact will be reduced. The use of glycol-based fluids comprises the major component for aircraft deicing with the remainder used for anti-icing operations.

The current work documents icing methods which use no glycol-based fluids or only very low levels of glycol. Such methods including hot water; high-pressure air streams (for blowing dry snow from aircraft surfaces); heated hangars; infrared heaters; and mechanical devices such as wing scrapers, brooms, and brushes are currently in use. Anti-icing in advance of a snow event to facilitate subsequent deicing is also a method of reducing glycol use.

The information collected in this project includes, but was not limited to, deicing medium used, type of equipment used and whether it was off the shelf or customized, application technique, number of persons required to use the method, training required, supervision required, type of frozen contaminant removed, and under what meteorological conditions such procedures were used or not used. Meteorological conditions recorded included all aspects under which the

nonglycol/low-glycol methods were used such as outside air temperature (OAT) and whether it is steady, rising, or falling; relative humidity; type of active precipitation (if any); wind velocity; and, if applicable, orientation of the aircraft relative to wind direction. The information also included reference to alternative nonglycol/low-glycol deicing methods that may be used by other airlines and whether aircraft wing type and skin temperature was a factor for consideration.

Practices that were successfully used in the past but have since been discontinued by a carrier and may be of use to others have been noted and reasons for their discontinuance documented. The promotion of nonglycol or low-glycol deicing methods that are or have been employed with success, but have little industrywide use, have the potential of greatly reducing the quantity of glycols used by the air transport industry.

1.3 NOTES ON TRAINING.

Training requirements for reduced glycol methods depend, to a large measure, on the skills, qualifications, knowledge, and capabilities of the personnel involved.

In general, it was assumed in the current study that, as appropriate, personnel were either members of a qualified deicing crew as would be the case for those using hot water or vehicle-mounted air blowers or relatively unskilled manual laborers available to assist with general ground handling work. In this latter case, significant training may be required depending on the nature of the work. For example, virtually no training is required for an operator to use a squeegee, scraper, or a broom; however, it is essential that the operator understands the need to avoid any damage to sensitive surface items, to ensure that the surfaces are clean, and to ensure that surplus snow is not swept into or onto standard deicing nonapplication areas.

The subject of training is addressed in individual sections of this report.

2. METHODOLOGY—SURVEY.

The form used to survey and document the nonglycol and reduced glycol aircraft deicing methods was developed from guidelines provided by the FAA and subsequent discussions with the FAA. The final survey is shown in appendix A.

The survey form was circulated to the appropriate organizations, associations, airlines, airports and handling agencies. A list of contacts is shown in appendix B.

3. DEICING METHODS IN USE OR SUCCESSFULLY USED IN THE PAST.

3.1 HOT WATER.

3.1.1 Background.

Significant use of hot-water deicing began in the late 70's. Air Canada reported widespread use by the winter of 1977/78. Initially standard single-tank deicing trucks designed for use with Type I fluids were used without modification. Onboard heating systems were adequate and standard

Type I nozzles were used. Two-tank trucks for use with Type I fluid and hot water then came into service, and most recently, three-tank trucks have been introduced with a capability for application of hot water, Type I deicing fluid, and Type II or IV anti-icing fluid. In all cases, the hot-water deicing personnel would be the same crew who conducted normal deicing. The practice has more recently fallen into disfavor and is in use only on a limited scale.

3.1.2 Procedure and Operational Experience.

The concept of hot-water deicing is similar to conventional deicing except that the first step is to use hot water, heated to a minimum temperature of 60°C (140°F) at the nozzle, to reduce the total glycol-based fluid requirement. A sample operation is shown in figure 1. Whether precipitation is ongoing or not, a limited quantity of glycol must be applied to prevent refreezing of the water after it cools. An exception to this practice occurs if ice, slush, snow, or frost is present on the aircraft at an ambient temperature of 0°C, and the temperature is rising. The use of the hot water is therefore, in general, the first step of a two-step procedure. The application procedure is covered by the Society of Automotive Engineer (SAE) Aerospace Recommended Practice (ARP) 4737, Aircraft Deicing/Anti-Icing Methods With Fluids, which provides pertinent guidelines applicable at outside air temperatures of -3°C (+27°F) and above. The second step should be performed in accordance with deicing/anti-icing guidelines.

FIGURE 1. HOT-WATER APPLICATION

The application of hot water at temperatures from ambient down to -7 to -8°C was originally undertaken by skilled crews with significant experience in deicing operations. Hot-water deicing would only be used when the temperature was steady or rising. Under conditions of falling temperature, even at 0°C, hot water would not be used. Wind is a significant factor and hot-water operations would not be conducted under windy conditions subject to the judgment of the deicing crew. Standard procedures by the operators call for deicing a wing such that the glycol-based fluid could be applied before the water refreezes. At lower temperatures or under restrictive combinations of temperature and wind, it might be necessary to hot-water deice only a section of a wing, apply (hot) glycol-based fluid, and then progress to the next section of the wing—again, at the judgment of the experienced deicing crew. Water sprayed onto the deicing pad surface either does not freeze or forms into nonslippery slush due to the presence of glycol from the second step.

Immediately prior to the 1993/94 winter season, the SAE issued ARP 4737 which recommended that the permissible lower ambient temperature limit for the use of hot water be -3°C.

The reduction in the recommended temperature range for using hot water combined with other disadvantages has restricted the use of hot-water deicing in North America to the following conditions:

a. Special training is required. The skilled, experienced crews who do hot-water deicing must exercise judgment with respect to wind conditions and anticipated wing spray area and wing cool-down times.

b. In anticipation of refreezing problems, deicing crews have been observed to take a conservative approach with the result that as much glycol is frequently used to prevent refreezing as would have been used for a standard Type I deicing operation.

c. Once the truck tank has been filled with water, the heater must be run continuously to avoid freezing unless the truck can be parked indoors. Subject to the particular type of equipment used, care must be taken to ensure that hoses, valves, and the nozzle do not freeze.

A number of unofficial reports have been circulated in which deicing crews are alleged to have used hot water instead of deicing fluid or deicing crews have applied hot water without subsequent application of glycol-based fluid. In either case, the error was claimed to be easily made and resulted in reformation of ice on the aircraft surfaces. Such claims, taken together with disadvantages cited above, have given hot-water deicing an undeserved poor reputation in North America. Conversely, in Europe the use of hot water as the first step of a two-step process appears to be gaining in popularity.

3.1.3 Potential Future Use.

During the winter of 1994/95, Transport Canada, in cooperation with the FAA, Air Canada, and APS Aviation, undertook a series of tests to document the performance potential of hot water as

a deicing agent. A DC-9 was used for the tests that were conducted with the wing surface at ambient temperature. Time for the wing to refreeze was recorded as a function of ambient temperature and wind speed.

An outline table format for operator use was postulated based on limiting combinations of ambient temperature and wind. The results for hot water use were recorded in the coldest conditions encountered during the test period at -13°C (+9°F) with a 28-kph wind. On the basis of the SAE recommended practice, the minimum acceptable refreeze time of 3 minutes (i.e., 3 minutes available for application of a glycol-based fluid), hot water could be used at temperatures as low as -11°C on a calm day for the aircraft tested.

A full evaluation to quantify the suitability of hot water as a practical deicing agent for a wide temperature range would have to take into account such considerations as aircraft type, fuel load, and possibly initial wing surface temperature. However, it was noted in the tests that the first freezing occurred on spoilers, ailerons, and other low-thermal inertia surfaces which are common to all aircraft; therefore it was concluded that the test results might be valid for other aircraft. It should, however, be noted that composite material surfaces were not tested. The test program, as reported, was terminated before these factors could be addressed because of a combination of the disadvantages cited earlier. A follow-on program in cooperation with the FAA has recently been reactivated.

3.1.4 Summary Characteristics of Hot-Water Deicing.

Medium used:	Hot water.
Equipment used:	Standard deicing trucks with at least two tanks: one for hot water and one for deicing fluid.
Application technique:	Apply deicing fluid after hot-water deicing to prevent refreezing.
Personnel requirements:	Similar to standard deicing.
Training required:	Experience with standard glycol-based fluid deicing required. Crew must understand risk of refreezing of water on aircraft and of water freezing in application equipment. Need for effective, efficient post-application of deicing fluid.
Supervision required:	Close supervision.
Contaminants removed:	Ice, snow, frost, or slush.
Meteorological limitations:	Temperature must be steady or rising. Guidelines in SAE Recommended Practice ARP 4737C limit ambient temperature to ≥ -3°C (+27°F).

	Historically hot water has been used at -7°C (+19°F). Tests show this to be a safe condition in light winds. Investigations to develop and document procedures for hot-water deicing at temperatures below –3°C are ongoing. Light winds only.
Alternatives:	Conventional deicing.

3.2 LOW-GLYCOL FLUIDS.

Deicing and anti-icing fluids are normally delivered to most users as neat fluids.

The SAE/ISO Fluid Holdover Time Tables[1] present holdover times for Type I deicing fluid used for anti-icing purposes based on fluid dilution with water to maintain a freezing point buffer of at least 10°C (18°F) below the outside air temperature.

- For Type II and Type IV anti-icing fluids, holdover times are presented based on use of neat fluid, fluid diluted to 75/25 (neat fluid/water on a volumetric, percentage basis), and fluid diluted 50/50. No general buffer limitation is referred to in the tables though a 7°C (13°F) buffer must be respected at temperatures below -25°C (-13°F).

- For Type III fluids the tables make no reference to either dilution or to buffers in general: a 7°C (13°F) buffer must be respected at temperatures below -14°C (-7°F).

3.2.1 Application of Buffers for Type I Fluids.

The quantity of glycol used for deicing purposes can be minimized by making use of the buffer limitation rather than using the fluid at either 100% concentration (neat fluid as delivered, which may contain water) or premixed to 75% or 50% dilution. This was a frequent practice some years ago with the dilution level set to meet the buffer temperature by mixing water and fluid from separate tanks on the truck at the fluid application nozzle. Unfortunately, the nozzle settings and valving gained a reputation for being unreliable and many operators were reluctant to continue the practice. Recent equipment has, however, overcome earlier problems. Deicing trucks are now in use in Europe in which the required dilution/buffer can be set at the time of fluid application with an established record of reliability. This capability is also available in North America.

3.2.2 Reduced Glycol First-Step Deicing/Anti-Icing.

SAE Recommended Practice, ARP 4737, calls for the fluid applied in the first step of a two-step deicing/anti-icing procedure to have a freezing point of not more than 3°C (5°F) above ambient

[1] The SAE/ISO Fluid Holdover Time Tables are available from the SAE Aerospace Standards Division, 400 Commonwealth Drive, Warrendale, PA 15096, fax (412) 776-0243.

temperature. This is possible since the first-step Type I deicing fluid is applied hot and is followed by an anti-icing fluid application, typically within 3 minutes.

As in the case of Type I fluid buffers, significant savings can be effected by using appropriate equipment and adhering to this first-step fluid temperature limitation.

Recent tests conducted jointly by the FAA, Transport Canada, and US Airways suggest that the first-step negative buffer may be significantly increased; thus significantly increasing the level of fluid dilution and reducing the quantity of glycol used.

3.2.3 Deicing Only Fluid Applications.

The tests conducted jointly by the FAA, Transport Canada, and US Airways also indicate that the 10°C (18°F) buffer requirement for Type I deicing fluids may be unnecessarily severe. The tests showed that when fluid dilutions with a negative buffer were applied to aircraft, the water evaporated first so that the glycol concentration in the residual fluid/water mix increased as the fluid cooled. The net result was that the negative buffer/reduced glycol mix, as applied, resulted in effective deicing without subsequent refreezing. Also, investigations are ongoing to develop procedures for zero buffer mixes for deicing only applications.

3.2.4 Summary of Low-Glycol Fluid Applications.

Medium used:	Reduced glycol content fluids.
Equipment used:	(1) Standard deicing trucks equipped with either an onboard manual or programmable fluid/water mixing system or (2) Standard deicing trucks filled from a storage system able to deliver premixed fluid with an appropriate freezing temperature.
Application technique:	The same as conventional deicing.
Personnel requirements:	The same as conventional deicing.
Training requirements:	Education on buffers and fluid freezing characteristics.
Supervision required:	Experienced deicing operation supervision.
Contaminants removed:	Frost, ice, snow, or slush.
Meteorological limitations:	Ambient temperature (and buffer) implications for fluid dilution levels.
Alternatives:	No comparable alternatives.
Comments:	Reliable equipment required.

3.3 AIR BLOWERS.

3.3.1 Portable and Mobile Air Blowing Devices.

3.3.1.1 General Description.

A number of air blowing devices, as shown in figure 2, have been used by operators for removal of accumulations of excess snow from aircraft surfaces.

FIGURE 2. BLOWN AIR: PORTABLE BLOWER

Manually portable leaf blowers, either domestic or commercial types available from hardware stores, have been tried and in some cases are in use by operators. The advantage of blowers is their simplicity and ease of operation and reduced risk of damage compared to mechanical devices such as brooms, scrapers, and ropes which come in contact with wing surfaces.

Units which can be strapped onto the operators back have been reported as convenient to use. These units are typically powered by two-stroke gasoline engines of 35-45cc (2.4 cu. in.) capacity and deliver air at velocities of the order of 350 km/h (250 mph). Noise levels of 70 dba require use of ear protectors by the operators but are acceptable to other personnel in the area.

The hand-held delivery nozzle can be directed from the ground, a platform, or a truck basket as appropriate. Normal practice is to blow the snow from the leading edge towards the trailing edge. Relatively little training is required.

One of the disadvantages of portable blowers are their unsuitability for removal of heavy wet snow. The blown snow makes it difficult for other personnel to work on the aircraft at the same time and the blowers may be ineffective in windy conditions because the snow blows back onto previously cleaned surfaces.

Hot-air blowers may be used effectively to remove contamination from engine intakes and landing gear/wheel wells. These blowers are also used in very cold climates either to preheat engines or to keep engines warm when the aircraft is not in use, and they have been adapted, on a trial basis, to blow hot air onto wings for frost removal at very low temperatures (-35°C and below). These hot-air blowers can be used by a single person and are potentially viable when it is too cold for glycol-based fluids to be used. However, the process is very slow and could take up to an hour to clean the wings of a twin engine commuter aircraft, and there have been no reports to date of this method being used on a regular basis.

The use of "Buddy Start" air hoses are also included in this section. The Scandinavian Airline System (SAS) and the United States Air Force (USAF) has used it on an experimental basis to deice landing gear and other surfaces in an emergency.

3.3.1.2 Summary Characteristics of Portable Blown-Air Devices.

Medium used:	Ambient air.
Equipment used:	Commercially available leaf blowers.
Application technique:	Use air jet to remove surplus, nonadhering precipitate prior to conventional deicing.
Personnel requirements:	One or more operators.
Training requirements:	Education on the need to blow contamination away from control surfaces, hinged or bay areas, and avoid blowing snow onto maintenance personnel.
Supervision required:	Light supervision.

Contaminants removed:	Surplus accumulation of light dry snow; removal of nonadhering ice, wet snow, or slush possible.
Meteorological limitations:	Above 0°C (32°F) ambient temperature, or in sunlight, snow may be wet and difficult to remove. Light wind conditions preferred. Use in strong winds restricted to headwinds.
Alternatives:	Truck-mounted blowers or other mechanical devices.
Comments:	Subsequent removal of residual/adhering ice, wet snow, frost, or slush by conventional deicing required.

3.3.2 Truck-Mounted Air Blowers.

3.3.2.1 General.

Blowers mounted on deicing trucks have been demonstrated by a number of companies. However, at the time of this survey no systems were identified in regular operational service. The technology does not, therefore, meet the stated criteria of reporting methods of glycol reduction that are in use or have been successfully used in the past. However, sufficient investment has been directed to the development of truck-mounted air blowers, and the development of equipment is sufficiently advanced that it has been included here for reference purposes.

3.3.2.2 Add-On Systems.

In one type of system the blower is installed as an add-on to an existing deicing truck.

A high-velocity hot-air jet system delivered by a Garrett T85 APU mounted on a standard Trump deicing truck was tested in service by United Airlines at Denver Stapleton Airport starting in the winter of 1992/93. The modified vehicle is shown in figure 3; the air delivery nozzle is shown in figure 4. A similar unit was also tested by Federal Express in Denver during the winter of 1993/94, and the United States Air Force was reported to have conducted parallel tests at Dayton Air Force Base with a modified nozzle. Another unit was delivered for testing to Canadian Airlines International Ltd., Toronto, during the winter of 1996/97. These units were all prototypes and reported to be particularly effective for fast removal of heavy overnight accumulated snowfall. However, significant detail engineering for improved control system response, fuel system improvements, and detail equipment integration remains to be done.

FIGURE 3. BLOWN AIR: TRUCK-MOUNTED SYSTEM

FIGURE 4. BLOWN AIR: TRUCK-MOUNTED SYSTEM NOZZLE

It was shown in these tests that major amounts of snow could be removed and followed by normal deicing would use much lower quantities of deicing fluid than normal. Later versions of the system used a very small quantity of deicing fluid injected into the airstream which proved very effective for frost removal or removal of lightly adhering precipitation with little or no glycol spillage onto the pad. The fluid injection also reduced the tendency for dry snow to recirculate.

The system has been reported to be easy to use. The nozzle is located beneath the basket and extends approximately 1.3 m (4 ft) forward. A joy stick control is conveniently located on the front of the basket at waist height to direct the air. A switch at the joy stick turns the air on and off and controls the glycol injection. The full wing chord from leading to trailing edge on a wide-body aircraft can be reached by a competent operator with practice.

Control of the nozzle is sensitive and requires some practice. However, United Airlines reported that a skilled deicing operator could develop adequate skills in 2-3 hours.

Disadvantages of the system are the high noise level from the auxiliary power unit (APU), which is nonetheless within limits for ramp operations; risk of aircraft strikes by the nozzle; and disruption of other activities if snow removal is done on the ramp. Compacted dry snow tends to fall in large clumps and loose snow is blown vigorously about making other ramp work impossible. The APU on the unit tested by United Airlines was removed during servicing for boom modifications; the level of equipment use at Denver did not warrant reassembly and return to service.

3.3.2.3 Original Equipment Blower Installations.

More recently, a truck-mounted system has been proposed by FMC Corporation to address limitations of the APU-based equipment. The AirFirst system integrates a blower with power takeoff from the vehicle engine into a conventional deicing truck design and delivers filtered, near ambient temperature air from a nozzle at high velocity. The blower necessitates a larger than standard power plant thus making retrofits impractical. The system can deliver air only or air with a light fluid injection for frost removal followed by heated Type I fluid then Type II or Type IV anti-icing fluid as required. Dry snow can be cleared to a distance of 3-5 m (10-15 ft) and wet snow 1.5-2 m (5-7 ft). Seventy to ninety percent fluid savings are claimed for deicing operations.

The nozzle has a rubber tip to minimize damage to aircraft surfaces should contact occur and has a laser sensor to warn when the nozzle is too close to any surface. There is no warm-up time, and the equipment can also be used to clean ground equipment.

A prototype unit has been delivered to Federal Express and production is planned. The high air velocity of 300 m/s (1000 ft/sec) provides effective ice removal but also gives rise to a high noise level—ear protectors are required. No objections to the use of the equipment have been raised by airframe manufacturers.

Significant training of regular deicing crews is required. However, the crew qualifications and the extent of skills needed require clarification. Operational equipment validation is also needed.

3.3.2.4 Summary Characteristics of Truck-Mounted Air Blowers.

Medium used:	Air at ambient temperature or heated. Possible low-level glycol injection.
Equipment used:	Standard deicing trucks with blower unit as an add-on or redesigned deicing trucks.
Application technique:	Use air jet to remove surplus of nonadhering precipitate prior to conventional deicing.
Personnel requirements:	Similar to standard deicing.
Training required:	Experience with standard glycol-based fluid deicing required. Additional training required for use of dedicated air blowers.
Supervision required:	Similar to conventional deicing.
Contaminants removed:	Surplus accumulation of light dry snow; removal of nonadhering ice, wet snow, or slush possible. Removal of light adhering ice/frost and snow possible with glycol injection.
Meteorological limitations:	Above 0°C (32°F) ambient surface temperature, or in sunlight, snow may be wet and difficult to remove. Light wind conditions preferred. Use in strong winds restricted.
Alternatives:	Portable blowers or other mechanical devices for nonadhering precipitation removal.
Comments:	Subsequent removal of residual/adhering ice, wet snow, frost, or slush by conventional deicing required.

3.4 HANGARS.

3.4.1 Hangar Applications.

Hangars, as shown in figure 5, have two self-evident applications:

a. protection of the aircraft from precipitation, in which case the hangars may be heated or unheated, and

b. parking of contaminated aircraft to melt frozen contamination, in which case the hangars need to be heated to a temperature above freezing.

In both cases, the aircraft's exposed surfaces may need to be cooled to a temperature below freezing if precipitation is present at the time of aircraft rollout. This can usually be done by simply opening the hangar doors; however, in the case of melting of accumulated frost or precipitation, it is necessary to ensure that all surfaces including quiet areas such as flap tracks, spoiler hinges, etc. are dry and will not refreeze. This latter requirement is usually time consuming at typical hangar temperatures. Note that care should be taken because freezing rain or wet snow could still adhere to a subzero surface.

FIGURE 5. PARKED AIRCRAFT IN A HANGAR

In the case where clean aircraft, not in use, are hangared to provide protection from precipitation, glycol use may be reduced even when precipitation continues at the time of scheduled takeoff. The aircraft can be protected with only anti-icing fluid (Type II or IV) applied with a small portable sprayer while in the hangar. Figure 6a illustrates a sample system; the sprayer is shown in figure 6b. This has the double advantage of eliminating the need for the application of a deicing fluid and indoor application facilitates careful application with minimum wastage and ease of cleanup from the hangar floor. Typical of operations where this can be done are on smaller overnight courier services.

FIGURE 6a. FLUID APPLICATION BY PORTABLE SPRAYER

FIGURE 6b. SAMPLE PORTABLE SPRAYER EQUIPMENT

3.4.2 Summary Characteristics of Hangar Applications.

Medium used:	Fixed protective cover, heated or unheated.
Equipment used:	Conventional aircraft hangars.
Application technique:	Indoor parking.
Personnel requirements:	No additional personnel required.
Training required:	Personnel should be made aware of the need to ensure that all surfaces are dry prior to rollout from hangar.
Supervision required:	No special supervision.
Contaminants removed:	Possible removal of ice, frost, snow, or slush.
Meteorological limitations:	None.
Alternatives:	No direct alternatives. Covers offer a partial alternative.
Comments:	Adequate hangar space frequently not available.

3.5 INFRARED HEATERS.

3.5.1 Fixed Installations.

Direct melting of frozen contamination can be done with infrared heaters. Hot-water application and hot-air blowers are technologies which use heat as a deicing medium.

Process Technologies has built a fixed-base operations in Buffalo, New York, and Rochester, New York, which are in use on a regular basis, see figure 7. A third installation is planned in Minnesota.

The system is comprised of a drive-through shell building with direct combustion propane infrared heaters in the roof directed towards the aircraft upper surfaces. Sensors monitor the temperature distribution of the aircraft surfaces and are combined with a computerized template for each aircraft type. The thermal radiation is then adjusted to give a near uniform melting/drying rate for aircraft tail surfaces, fuselage top, and wing surfaces without any excessive local temperature rises. The system can also be adjusted to accommodate snow or ice. It has been reported that 10-12 minutes is required to dry the surface of a Boeing 727. If precipitation continues, anti-icing fluid is applied as soon as the aircraft leaves the building with its surfaces still warm.

FIGURE 7. INFRARED HEATER FIXED INSTALLATION

The system has a relatively high initial cost when compared to other nonglycol methods since, in addition to the heaters, a building structure must be provided that can accommodate wind and snow loads. Furthermore the system does not eliminate the need for conventional anti-icing equipment after infrared deicing. Conversely, the direct operating cost is reported to be much lower than the cost of glycol spray deicing.

Questions have also been raised with respect to passenger reaction to confinement within a building for deicing and the implications of combustion heaters from an insurance standpoint. These factors do not appear to have compromised the existing installations.

3.5.2 Mobile Installations.

A mobile propane fueled catalytic infrared heater unit mounted on a boom truck, named the Ice Cat, is being developed by Infrared Technologies Inc. Figure 8 illustrates the heater element assembly on the boom. Figure 9 shows the unit in operation (at the gate) above the wing of a Fokker F100. This system, which is in the late stages of development, has the potential for deicing at the gate where environmental restrictions may preclude the use of glycol and deicing on the deicing pad as an alternative to hot-fluid deicing.

The equipment incorporates a wing surface temperature sensor intended to limit the thermal radiation and avoid localized overheating of wing surfaces. The system is purported to be easy to operate by a single experienced deicing operator with minimal additional training. The cost of propane consumption at 6.8 kg/h (15 lb./h) is small compared to the cost of deicing fluid required to do the same task. In its present form, the operation is deemed to be time consuming, particularly under conditions where dry surfaces are required to prevent refreezing.

FIGURE 8. INFRARED HEATER MOBILE UNIT: THE HEATER ELEMENT ASSEMBLY

FIGURE 9. INFRARED HEATER MOBILE UNIT: APPLICATION

It has been reported that in cases where slush is present, for instance on undercarriages of certain airplanes after landing or taxiing, that infrared heaters are not appropriate.

3.5.3 Summary Characteristics of Infrared Heaters.

Medium used:	Heat radiation.
Equipment used:	Direct combustion or catalytic infrared heaters.
Application technique:	Fixed heater units mounted inside a drive-through shelter or heater units mounted on the boom of a boom truck.
Personnel requirements:	Additional operating personnel required for fixed installation. Single operator for mobile units.
Training required:	Training required for start-up of heaters, equipment operation, and maintenance, risks associated with surfaces overheating.
Supervision required:	Knowledgeable supervision required.
Contaminants removed:	Ice, frost, snow, or slush from surfaces exposed to radiant heat.
Meteorological limitations:	None.
Alternatives:	Conventional deicing or possible use of hot water.
Comments:	Limited deicing fluid application required if surfaces are not dry. Anti-icing fluid required during on-going precipitation.

3.6 MECHANICAL DEVICES.

3.6.1 General.

Mechanical devices, in the present context, refers to apparatus used by operators to assist with manual removal of snow, slush, ice, and/or frost. Although power assisted and automated devices have been proposed, none have been identified that have been in service or are in current use. Devices which have been used or are in use have been categorized as scrapers, brooms (brushes), and ropes.

3.6.2 Wing Scrapers.

A variety of scrapers are used for manual removal of frozen precipitate. The most commonly used are standard commercial tools as shown in figures 10-12.

Tools for removing excessive snow from domestic house roofs, shown in figure 10, comprise a flat, semirigid plastic blade typically 6" to 9" high by 2' to 2'-6" wide (150 to 225 mm by 300 mm to 450 mm) mounted perpendicularly to a long handle. The blade is placed on the wing and the handle pulled towards the operator to drag off the snow (or slush). Such inexpensive scrapers

FIGURE 10. SAMPLE USE OF A SCRAPER

FIGURE 11. SAMPLE USE OF A BROOM

FIGURE 12. SAMPLE USE OF ROPES

are available from hardware stores—the only modification required is the addition of some form of protection to the handle such as commercial foam insulation to prevent damage by the scraper handle to the aircraft wing.

A second type of roof scraper used is one that has a soft rubber blade used for clearing water from smooth concrete floors (e.g., in garages), also readily available from hardware stores.

Verbal reports have been received of wooden aircraft wing scrapers being used in Russia. These have been described as similar in geometry to the two types described above though heavier and slower.

Scrapers are particularly effective for removal of wet snow where the snow tends to bind together. In dry snow there is a tendency for significant quantities of snow to scatter with the motion of the scraper and to remain on the wing. Multiple passes are required, and even so, some light snow tends to remain.

A low-cost alternative to the roof scraper is the squeegee. These devices are similar in principle to those used for cleaning car windshields but of a size appropriate to store windows. One side of the squeegee has a foam pad with nylon (or other plastic) mesh cover, the other side has a soft rubber blade. As in the case of scrapers, the handle is normally covered with foam to prevent damage to the wing.

3.6.3 Brooms and Brushes.

All types of common brooms and brushes used for sweeping floors can be used to remove wet and dry snow. In most instances, the operators either sweep from a step ladder or platform, or for smaller aircraft this can be done from the ground (figure 11), to remove as much snow or slush as possible.

A particular case for use of clean brushes is the application for “sweep to shine” removal of adhering snow, frost, or ice at temperatures of typically -37°C (-35°F) and below. At such temperatures glycol-based deicing fluids cannot be used. Under these conditions conventional, clean, soft bristle floor brushes are used for the removal of the bulk of the ice or frost. At -37°C and lower, the ice is brittle and most of it is relatively easy to remove. With multiple passes, the residual ice can easily be polished to a thin, smooth layer typically of the order of 0.05 mm to 0.10 mm (0.002" to 0.004") thick, which has little or no influence on wing aerodynamic performance.

It has been observed that a single, competent operator can sweep the critical surfaces of a typical commuter aircraft such as a SAAB 348 in 15-20 minutes.

Minimal training and practice is required to achieve the necessary competence provided that the operator understands the necessity of achieving a smooth surface with no roughness on the remaining ice.

3.6.4 Ropes.

Ropes can be effectively used to remove light dry snow on aircraft wings with smooth upper surfaces or where the wings upper surface can be seen (figure 12). The practice was frequently employed on old aircraft such as the DC3 but with the introduction of vortex generators, boundary layer fences, and a range of nonsurface flush sensing devices, the risk of damage now requires either significant training or employment of qualified personnel.

The usual practice is to have one person at the leading edge and one person at the trailing edge dragging the rope along the span from root to tip while holding the rope tight to the wing's upper surface.

Austrian Airlines has a significant reduction in glycol usage by removing excess snow from fuselages using ropes. Nylon ropes, such as those used for climbing or mountaineering, are used; cotton ropes have been found to get wet and subsequently freeze stiff. A back-and-forth motion by two people, one on each side of the fuselage, removes the excess snow. Care has to be exercised to ensure that the ropes are clean and free from ice build-up because painted surfaces can be easily scratched. In some instances, as on an Airbus A320, the number of protuberances, such as antennae, makes using ropes too difficult. Scandinavian Airlines' experience has been similar to Austrian Airlines, although they have noted that ropes also tend to stain the white painted finish on their aircraft.

3.6.5 Summary Characteristics of Mechanical Devices.

Medium used:	Mechanical devices for direct operator removal of contamination.
Equipment used:	Scrapers, brooms, brushes, and ropes.
Application technique:	Physical displacement of snow, ice, or slush.
Personnel requirements:	One or more, as required. Two personnel for ropes.
Training required:	Care to avoid damage to aircraft; and accumulation of ice or snow at flight controls, hinge points, and bay area locations.
Supervision required:	No special supervision.
Contaminants removed:	Accumulated snow or slush, loose ice.
Meteorological limitations:	None.
Alternatives:	Air blowers.
Comments:	Subsequent (reduced quantity) deicing may be required. Mechanical devices are the least expensive and the most effective way to remove accumulated precipitation, especially dry snow, and reduce glycol requirements.

3.7 COVERS.

Covers are used for wings, fuselages, and engines. In general it has been found by experience that covers made of plastics, which do not absorb moisture, are preferred to canvas type covers that will frequently adhere to aircraft surfaces under freezing conditions. If covers should adhere, they can be most effectively removed by pulling back the cover at 90° to the surface.

3.7.1 Wing Covers.

Covers used 20 years ago were generally heavy, as much as 100 to 150 kg (200-300 lbs) for an aircraft such as a Boeing 707, and required considerable manpower to handle. They absorbed moisture and therefore could freeze to the wing surface. Recent enhancements in cover materials have addressed these problems. Covers for Boeing 737s have been supplied by Air Cover Corporation of Calgary, Alberta, Canada, as light as 9 kg (20 lbs). In Idaho Falls, American Airlines uses even lighter covers that were made from parachute fabric, though the use of these covers were also labor intensive.

Single-piece wing covers are commonly used on smaller aircraft in general aviation (figure 13), and have been used on aircraft such as a Boeing 737 and even larger. The covers under-hang the leading edges and trailing edges by typically 30 cm (12") with or without cutouts to fit around such projections as boundary layer fences. For aircraft with vortex generators, locally reinforced double-thick fiber-reinforced polyethylene covers have been used with the slippery surface in contact with the projections. For larger aircraft, two-piece covers have been used.

FIGURE 13. SMALL WING COVERS

The recommended sequence for installing wing covers, shown in figure 14, starts by placing the rolled-up covers across the wing roots and tying the covers tightly to each other under the fuselage. The covers are then unrolled outwards to the wing tip, attaching ropes or straps from

front to rear below the wing. In some cases covers have been designed with pockets to fit, for instance, over the corners of retracted flaps to hold the covers in place during installation. There would be typically 7-8 front-to-rear attachment straps of 5-cm (2-in)-wide webbing. Each cover detail design is aircraft specific.

FIGURE 14. WING COVER INSTALLATION SEQUENCE

Covers should be installed any time frost or precipitation is anticipated. It is essential that the covers be pressed tight against the wing surfaces to avoid condensation and ice formation under the covers.

Removal of the covers calls for a reversal of the installation sequence followed by a careful fold-up as shown in figure 15. In cases where there is a snow accumulation on the cover, the cover can usually be removed by pulling it rearwards from the trailing edge with the snow on it.

FIGURE 15. WING COVER REMOVAL SEQUENCE

Korean Airlines has been successfully using wing covers of thin cotton cloth with a vinyl backing for the past two years for the prevention of accumulation of light frost and snow on their MD80 and F100 aircraft. The wing covers are in two separate pieces, left hand and right hand. The dimensions of the wing covers for both the MD80 and the F100 are shown in figures 16 and 17.

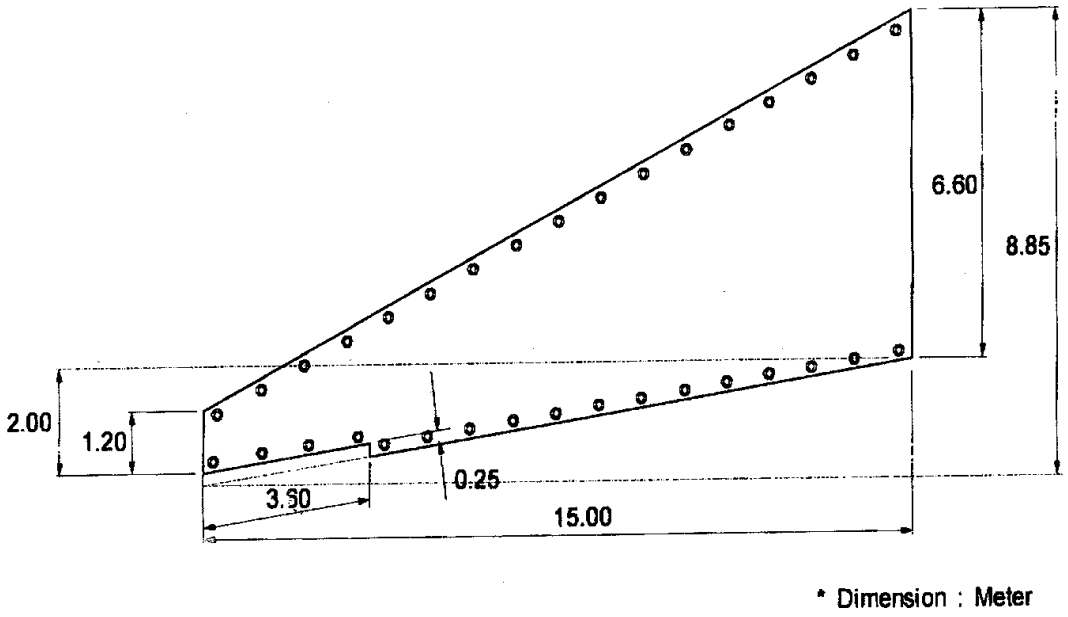

FIGURE 16. SAMPLE MD80 WING COVER DIMENSIONS

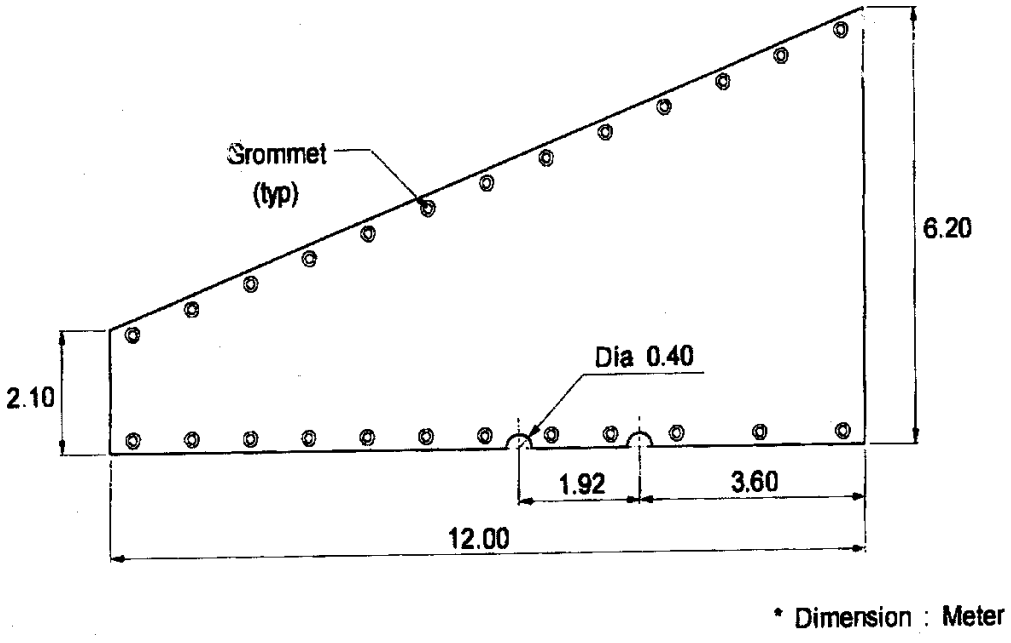

FIGURE 17. SAMPLE FOKKER F100 WING COVER DIMENSIONS

To cover the wing, the cover is put on the upper wing surface and unfolded and stretched out flat against the wing surface. The cover is then tied in place using woven cord attached under the lower wing surface from each grommet. The operation requires three to five personnel.

Operators with considerable field experience have reported problems with the use of wing covers under certain conditions:

- In winds above 7-10 m/s (15-20 kts) installing covers is difficult. In the case of high wings or horizontal stabilizers, which necessitate use of ladders or boom-truck baskets, installation has been described as dangerous.

- Despite care to ensure proper installation of covers several operators have complained of condensation under the covers making it difficult to remove and requiring conventional glycol deicing afterwards.

- Wet or damp covers have been another concern since the area required for dry out can be significant.

- Abrasion is also a problem. Operators have reported abrasion of wing surfaces due to grit on covers which necessitates labor-intensive cleaning.

- Finally, when there has been a significant accumulation of snow on the covers, removal of the snow prior to removing the covers is awkward. Overnight accumulation is particularly problematic since the entire operation of excess snow removal, cover removal and fold-up, and cover cleaning and drying is labor intensive at a time of high traffic volume.

Although there are serious disadvantages in the use of wing covers and conventional deicing touch-ups are frequently required, the reported savings in glycol usage, a 50 percent typical reduction in glycol use is claimed by the wing cover manufacturers.

3.7.2 Engine Covers.

Engine covers, shown in figure 18, are used primarily in cold regions either as insulated covers or in conjunction with heaters to maintain engine temperature rather than for protection against icing or glycol reduction.

3.7.3 Cockpit/Fuselage Covers.

Cockpit covers are commonly used in general aviation, but there have been few reported instances of their use by airline operators and, as with engine covers, are not primarily used for glycol reduction.

FIGURE 18. ENGINE COVER: GENERAL AVIATION

3.7.4 Summary Characteristics of Covers.

Medium used:	Protection against direct accumulation of precipitation or frost formation on critical surfaces.
Equipment used:	Covers, custom designed for specific applications.
Application technique:	Installation of covers on dry surfaces to be protected prior to onset of icing conditions
Personnel requirements:	Two or more, as required; subject to cover size and wind conditions.
Training required:	For larger covers; method of installation and removal. Care to avoid damage to aircraft. Care to keep covers clean and dry.
Supervision required:	Experienced supervision, particularly under limiting wind conditions.
Contaminants removed:	Accumulation of precipitation avoided.

Meteorological limitations: Winds above 7-10 m/s (15-20 kts).

Alternatives: Hangars.

Comments: Subsequent (reduced quantity) deicing may be required.

3.8 ANTI-ICING IN ADVANCE.

3.8.1 General.

Typically anti-icing fluid (Type II or Type IV) is applied directly onto the aircraft surfaces under dry, nonicing conditions without a preliminary application of deicing (Type I) fluid. Subject to the amount of precipitation or frost formation at the time of dispatch, the aircraft may still be clean. Alternatively, if the contamination check reveals failed fluid or fluid close to failure then regular deicing and possible anti-icing will be required. However, even in the case of major precipitation, the quantity of deicing fluid required to clean the aircraft surface will be considerably less than for an unprepared aircraft surface.

In a number of operations, such as small courier services, aircraft can be parked in a hangar prior to departure. In such cases, during periods of precipitation, the aircraft can be anti-iced in the hangar, typically using a small backpack sprayer prior to rollout. Besides eliminating the need for using deicing fluid, the anti-icing application can be performed at the convenience of the operator under controlled conditions resulting in a more uniform application of the fluid, reduced wastage, and easier clean up (from the hangar floor) of any spillage.

In the case of anticipated ice formation on cold-soaked wings, anti-icing fluid can be applied immediately upon arrival of the pertinent aircraft to prevent the formation of ice. SAS has used this technique at Copenhagen Airport.

3.8.2 Summary Characteristics of Advance Anti-Icing.

Medium used: Anti-icing fluid.

Equipment used: Conventional anti-icing trucks, possibly backpack sprayers.

Application technique: Conventional application of anti-icing fluid, no deicing required.

Personnel requirements: The same as conventional anti-icing. One operator only for backpack.

Training required: The same as conventional anti-icing, no additional special training.

Supervision required: The same as conventional anti-icing.

Contaminants removed: Preventative fluid application, no contaminants present.

Meteorological limitations:	No precipitation.
Alternatives:	Hangars.
Comments:	Subsequent (reduced quantity) deicing/anti-icing may be required.

4. OTHER GLYCOL REDUCTION METHODS IN USE OR UNDER DEVELOPMENT.

4.1 HOT-AIR DEICING—GAS TURBINES.

4.1.1 General.

Reports have been published where truck-mounted refurbished gas turbine engines were used in Russia for clearing snow and ice from airfield runways, aprons, aircraft stands, and to deice surfaces of commercial airliners. The exhaust ducts were modified to a flat letterbox configuration and engine rpm and nozzle area were selected to reduce engine thrust.

For deicing, the exhaust is directed onto the aircraft wings. While this method will undoubtedly work effectively and probably offer significant anti-icing protection due to the rise in wing temperature, the danger of overheating is obvious. Although some airlines considered the use of this Russian equipment, it was felt that there was a potential for aircraft damage by the direct jet blast. The apparent risks outweighed the benefits and further consideration was discontinued.

4.1.2 Summary Characteristics of Gas Turbine Exhaust Deicing.

Medium used:	High-temperature, high-velocity engine exhaust.
Equipment used:	Refurbished, derated gas turbine engine with modified exhaust profile.
Application technique:	Direct hot-gas jet exhaust onto contaminated surfaces.
Personnel requirements:	Truck driver and engine controller.
Training required:	Knowledge of risks associated with hot-gas impingement on aircraft surfaces. Gas jet application, Truck/Gas Turbine coordination. Actual operator training received—not reported.
Supervision required:	Knowledgeable supervision required.
Contaminants removed:	All.
Meteorological limitations:	None.

Alternatives:	Conventional deicing.
Comments:	Possible risk of excess critical surface heating.

4.2 FUEL HEATING.

4.2.1 General.

A system has been developed and tested by Polaris Thermal Energy Systems Inc. in which the fuel is preheated prior to refueling. Although the system is not in general use, prototype systems have been tested and reported. The Polaris system is comprised of a heating processor at the fuel storage site, transfer of the warm fuel to the refueling truck, and conventional refueling of the aircraft with the fuel temperature similar to that of summer conditions.

Tests in Cleveland at an ambient temperature of -8°C (18°F) gave positive results in that the average wing temperature on a refueled MD80 rose to +4°C (39°F) within 15 minutes of the start of the recording and remained above freezing for 1 hour, at which time the average wing temperature was +14°C (56°F) and recording was stopped. For this particular case it was estimated that protection would be afforded for some 6 hours. While surfaces far from the fuel tanks may not be fully protected for the full duration, the reduced glycol requirements would, almost certainly, more than offset the fuel heating cost.

The system will require further evaluation before it can be adapted for general use.

4.2.2 Summary Characteristics of Fuel Preheating.

Medium used:	Heat.
Equipment used:	Fuel, preheated before loading tanker trucks.
Application technique:	Conventional refueling.
Personnel requirements:	One operator, only during evaluation phase.
Training required:	Precautions and safety for fuel heating system.
Supervision required:	Regular tanker truck refilling operations.
Contaminants removed:	Ice, frost, snow, and on-going precipitation.
Meteorological limitations:	Not yet defined.
Alternatives:	Conventional deicing/anti-icing.
Comments:	Deicing/anti-icing of aircraft cold areas (tailplane, engine nacelles, and fuselage) required.

4.3 ICE-PHOBIC COATINGS.

Many proposals have been put forward for ice-phobic coatings or ice-phobic materials for applications to electrical power transmission lines, offshore oil rigs, bridges, and aircraft surfaces. A number of recent studies have concluded that while the adhesive strength of ice to aircraft surfaces can be radically reduced, at the present time no surface finishes exist where the aerodynamic forces on a wing at takeoff can be relied upon to remove any ice or slush present.

Ice-phobic coatings are available on the market which claim to reduce the adhesion of ice to wings and thereby facilitate the shedding of in-flight ice buildup when the in-flight deicing system is turned on. Great care is needed with these coatings since not only do they reduce the adhesion of ice, they also cause deicing and anti-icing fluids to bead (visibly similar to rain water on a newly polished car) and not to cover the surfaces uniformly.

4.4 LASER DEICING.

Laser heating devices have been proposed for deicing operations. At the present time, no full-scale field demonstrations are known to have been made.

5. DISCUSSION—SPECIFIC PROCEDURES AND COST SAVINGS.

Regulations require airline operators to have an approved deicing/anti-icing program in order to operate under icing conditions. This program has to include the elements of management, procedures, inspection, and training and testing. The procedures described in this report are therefore, in general, already contained in approved plans, and it would be expected that sample written procedures would be readily available. Furthermore, the methods of glycol reduction described are in use because they are economically advantageous.

Notwithstanding the foregoing, very little data have been made available for publication as sample procedures or of specific cost savings.

The most direct savings in reduced glycol use are achieved through investment in specially trained personnel. SAS reports that such a program is in place at main stations: "To Do It Right."

The largest reported savings in the cost reduction of glycol use based on equipment use are achieved with the small air blowers and brooms, brushes, scrapers and to a lesser extent, ropes. These mechanical devices are easy to use, quick, and do not need extensive training of personnel. The procedures can usually be executed concurrently with other operations so as to have little or no impact on scheduling. Subsequent deicing is frequently required, if only as a touch-up, but significant quantities of glycol required for the removal of accumulated precipitation are easily saved.

Typical written procedures simply call for mechanical removal of excess snow and any nonadhering ice prior to standard deicing procedures followed by a short list of precautions addressing

- personnel safety,
- avoidance of damage to the aircraft,
- avoidance of contamination being pushed into flight controls, hinge points, etc., and
- communication to the flight crew and/or maintenance crew that contamination removal has been started or is underway or has been completed.

6. CONCLUSIONS.

The promotion of nonglycol or low-glycol methods that are or have been employed with success, but have little industrywide use, has the potential of greatly reducing the quantity of glycol used by the air transport industry.

7. SOURCE INFORMATION DOCUMENTS.

AEA Recommendations for Deicing/Anti-Icing of Aircraft on the Ground, Eleventh Edition, October 1997.

ICAO Manual of Aircraft Ground Deicing/Anti-Icing Operations, First Edition, 1995. (Doc. 9640-AN/940).

SAE document ARP 4737(c), "Aircraft Deicing/Anti-Icing Methods With Fluids."

8. GLOSSARY.

This text is adapted from the ICAO definitions.

Anti-icing. Anti-icing is a precautionary procedure by which clean aircraft surfaces are protected against the formation of ice and frost and the accumulation of snow and slush for a limited period of time.

Clear ice. A coating of ice, generally clear and smooth, but with some air pockets. It is formed on exposed objects at temperatures below or slightly above the freezing temperature by the freezing of supercooled drizzle, droplets, or raindrops. Clear ice is very difficult to detect visually and may break loose during or after takeoff.

Cold-soak effect. The wings of aircraft are said to be "cold soaked" when they contain very cold fuel after landing after a flight at high altitude or after refueling with very cold fuel. Whenever precipitation falls on a cold-soaked aircraft while on the ground, clear icing may occur. Even in ambient temperatures between -2°C and 15°C, ice or frost can form in the presence of visible moisture or high humidity if the aircraft structure remains at 0°C or below. The following factors contribute to cold soaking: temperature and quantity of fuel in fuel cells, type and location of fuel cells, length of time at high altitude, temperature of refueled fuel, and time since refueling.

Critical surfaces. A surface of an aircraft which shall be completely free of ice, snow, slush, or frost before takeoff. The critical surfaces shall be determined by the aircraft manufacturer.

Deicing. The process that removes ice, snow, slush, or frost from aircraft surfaces. Mechanical methods, pneumatic methods, or heated fluids may be used. Mechanical methods may be preferred under extremely cold conditions or when it has been determined that the frozen contaminant is not adhering to the aircraft surfaces. When using heated fluids and optimum heat transfer is desired, fluids should be applied at a distance from the aircraft surfaces in accordance with the approved operator procedure and fluid manufacturer specifications.

Deicing/anti-icing. A procedure combining both the deicing process and the anti-icing process and which can be performed in one or two steps:

- *One-step deicing/anti-icing.* This procedure is carried out with an anti-icing fluid that is typically heated. The fluid is used to deice the aircraft and remains on the aircraft surface to provide anti-icing capability. Type I or Type II fluids can be used, but the protection provided by Type I fluid is less than that provided by Type II fluid.

- *Two-step deicing/anti-icing.* This procedure contains two distinct steps. The first step, deicing, is followed by the second step, anti-icing, as a separate fluid application. After deicing, a separate overspray of anti-icing fluid is applied to protect the aircraft's critical surfaces, thus providing maximum anti-icing protection.

Drizzle. Fairly uniform precipitation composed exclusively of fine water drops very close together. Drizzle appears to float while following air currents although, unlike fog droplets, it falls to the ground.

Fog and ground fog. A visible aggregate of minute water particles (droplets) in the air reducing the horizontal visibility at the earth's surface too less than 1 kilometer.

Freezing fog. A fog formed of supercooled water droplets that freeze on contact with exposed objects and form a coating of rime/glaze.

Freezing rain and freezing drizzle. Rain or drizzle in the form of supercooled water drops that freeze upon impact with any surface.

Frost. Referred to as hoarfrost. A deposit of ice having a crystalline appearance, generally assuming the form of scales, needles, or fans. Frost is formed by sublimation, i.e., when water vapor is deposited on surfaces whose temperatures are at or below freezing.

High humidity. An atmospheric condition where the relative humidity is close to saturation.

Holdover time. Holdover time (HOT) is the *estimated* time the application of anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow or slush on the protected surfaces of an aircraft.

Holdover time begins when the final application of deicing/anti-icing fluid commences, and it expires when the deicing/anti-icing fluid applied to the aircraft loses its effectiveness. For departure planning purposes, the Society of Automotive Engineers (SAE) and the International Organization for Standardization (ISO) publish Type I, Type II, and Type IV fluid holdover time charts in SAE Aerospace Recommended Practice (ARP) 4737, *Aircraft Deicing/Anti-Icing Methods With Fluids for Large Transport Aircraft* and ISO 11076, *Aerospace—Aircraft Deicing/Anti-Icing Methods With Fluids.* The Association of European Airlines (AEA) notes "Due to the many variables that can influence holdover times, these times should not be considered minimum or maximum as the actual time of protection may be reduced or extended, depending upon particular conditions existing at the time."

Precipitation intensity. Intensity of precipitation is an indication of the amount of precipitation collected per unit time interval. It is expressed as light, moderate, or heavy. Each intensity is defined with respect to the type of precipitation occurring, based either on rate of fall for rain and ice pellets or visibility for snow and drizzle. The rate of fall criteria are based on time and do not accurately describe the intensity at a particular time of observation.

Rain. Precipitation of liquid water particles, either in the form of drops of more than 0.5 mm in diameter or smaller drops which, in contrast to drizzle, are widely separated.

Rime. A deposit of ice, produced by freezing supercooled fog or cloud droplets on objects at temperatures below or slightly above freezing. It is composed of grains separated by air, sometimes adorned with crystalline branches.

Shear force. Shear force is a force applied laterally on an anti-icing fluid. When applied to a Type II fluid, the shear force will reduce the viscosity of the fluid; when the shear force is no longer applied, the anti-icing fluid should recover its viscosity. For instance, shear forces are applied whenever the fluid is pumped, forced through an orifice, or when subjected to an airflow. If excessive shear force is applied, the thickener system could be permanently degraded and the anti-icing fluid viscosity may not recover and may be at an unacceptable level.

Slush. Water-saturated snow which, with a heel-and-toe slap-down motion against the ground, will be displaced with a splatter.

Snow. Precipitation of ice crystals, mostly branched in 6-pointed stars. The crystals are isolated or agglomerated to form snowflakes.

- *Dry snow.* When the ambient temperature is below or well below freezing.
- *Wet snow.* When the ambient temperature is near or above freezing.

Type I and Type II deicing and anti-icing fluids. Type I fluids are Newtonian (unthickened) fluids and Type II fluids are non-Newtonian (thickened) fluids used in the removal or prevention of frozen deposits of frost, ice, and snow on exterior surfaces of parked aircraft. Fluids are glycol-based fluids with additives, such as wetting agents, inhibitors, etc., meeting specific fluid specifications established by such organizations as SAE, ISO, and AEA. Since different Type I

and Type II fluids are in use today, the appropriate fluid specification identifier should precede the word "Type," e.g., SAE Type I, ISO Type II, AEA Type II. One use of fluid prefixes promoted by SAE, ISO, and AEA is the standardized use of 4-element deicing/anti-icing codes to give flight crews the minimum details to assess holdover times.

Visible moisture. Fog, rain, snow, sleet, high humidity (condensation on surfaces), ice crystals, or when taxiways and/or runways are contaminated by water, slush, or snow.

ICAE - International Centre for Aviation and the Environment
CIAE - Centre international pour l'aviation et l'environnement

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QUESTIONNAIRE ON SURVEY AND DOCUMENTATION OF NONGLYCOL AND REDUCED GLYCOL AIRCRAFT DEICING METHODS

JANUARY 1998

NOTES FOR THE COMPLETION OF THE ICAE QUESTIONNAIRE ON SURVEY AND DOCUMENTATION OF NONGLYCOL AND REDUCED GLYCOL AIRCRAFT DEICING METHODS

The International Centre for Aviation and the Environment (ICAE), on behalf of the United States Federal Aviation Administration (FAA), is conducting a survey and documentation of nonglycol/low-glycol aircraft deicing practices, methods and procedures used by the world's major airlines.

OBJECTIVE

The objective is to investigate and document deicing methods and practices within the airline industry, on a worldwide basis, that are currently used or have been successfully used in the past, in which no glycol-based fluids or low-glycol methods are used. Experimental techniques are not considered to be within the scope of this study.

If you are unable to understand a particular question, please do not hesitate to contact:

Name: Jeremy L. Cornish - Executive Director.

Tel: (514) 283-0064

Fax: (514) 283-7158

E-mail: cornisj@tc.gc.ca

Note: Survey is available by e-mail on request.

If you are unable to complete a particular question because you do not have the relevant information, or the information is sensitive; indicate not available (N/A) next to the question. Please feel free to write your own comments or observations on the back of the form or include applicable supporting technical information.

To facilitate completion of this questionnaire a special effort was made to limit the number of questions to an absolute minimum.

Thank you for taking the time to complete the questionnaire and for participating in the survey. Please note that the final report is due for submission to the FAA by mid March, 1998.

1. BASELINE ON CURRENT GLYCOL USAGE

1.1 Indicate the number of deicing events and quantity:

(a) Estimate the present number of deicing events per winter.

(b) Estimate of number of departures per winter.

(c) Indicate the quantity of glycol used per winter.

1.2 Indicate if you use glycol reduction system/technology(ies).

(a) Describe the system/technology(ies) adopted

(b) How long has the system/technology(ies) been in use?

2. DEICING METHODS IN USE OR SUCCESSFULLY USED IN THE PAST

2.1 Advise the use and experience with the technologies which involve reduced glycol application.

2.1.1. **Hot water.**

What method do you use?

Equipment used, (off the shelf or customized)

Number of personnel typically involved

Brief description of training required

Supervision required

Under what MET conditions are current methods used:-

(a) Outside Air Temperature (OAT)

(b) Temperature rising/falling

(c) Relative Humidity (RH)

(d) Type of Precipitation

(e) Wind velocity

(f) Aircraft orientation to wind (if Applicable)

Title, Number and date of latest issue of pertinent procedure.

To your knowledge are there alternate (no/low-glycol) technology used by others under similar circumstances.

Reason for use, cost reduction, scheduling or other.

Is the method efficient?/Are there significant cost savings?

What methods have you used in the past, and have discontinued?

Why were they discontinued?

2.1.2. **Air blowers, including air/low-glycol methods.**

What method do you use?

Equipment used, (off the shelf or customized)

Number of personnel typically involved

Brief description of training required

Supervision required

Under what MET conditions are current methods used:-

(a) Outside Air Temperature (OAT)

(b) Temperature rising/falling

(c) Relative Humidity (RH)

(d) Type of Precipitation

(e) Wind velocity

(f) Aircraft orientation to wind (if Applicable)

Title, Number and date of latest issue of pertinent procedure.

To your knowledge are there alternate (no/low-glycol) technology used by others under similar circumstances.

Reason for use, cost reduction, scheduling or other.

Is the method efficient?/Are there significant cost savings?

What methods have you used in the past, and have discontinued?

Why were they discontinued?

2.1.3. **Heated hangars; and unheated hangars for overnight protection.**
What method do you use?

Equipment used, (off the shelf or customized)

Number of personnel typically involved

Brief description of training required

Supervision required

Under what MET conditions are current methods used:-

(a) Outside Air Temperature (OAT)

(b) Temperature rising/falling

(c) Relative Humidity (RH)

(d) Type of Precipitation

(e) Wind velocity

(f) Aircraft orientation to wind (if applicable)

Title, number, and date of latest issue of pertinent procedure.

To your knowledge are there alternate (no/low-glycol) technology used by others under similar circumstances.

Reason for use, cost reduction, scheduling or other.

Is the method efficient?/Are there significant cost savings?

What methods have you used in the past, and have discontinued?

Why were they discontinued?

2.1.4. **Infrared heaters.**

What method do you use?

Equipment used, (off the shelf or customized)

Number of personnel typically involved

Brief description of training required

Supervision required

Under what MET conditions are current methods used:-

(a) Outside Air Temperature (OAT)

(b) Temperature rising/falling

(c) Relative Humidity (RH)

(d) Type of Precipitation

(e) Wind velocity

(f) Aircraft orientation to wind (if applicable)

Title, number, and date of latest issue of pertinent procedure.

To your knowledge are there alternate (no/low-glycol) technology used by others under similar circumstances.

Reason for use, cost reduction, scheduling or other.

Is the method efficient?/ Are there significant cost savings?

What methods have you used in the past, and have discontinued?

Why were they discontinued?

2.1.5. **Mechanical devices;**

wing scrapers
brooms, brushes
ropes
wing covers advance anti-icing.

What method do you use?

Equipment used, (off the shelf or customized)

Number of personnel typically involved

Brief description of training required

Supervision required

Under what MET conditions are current methods used:-

(a) Outside Air Temperature (OAT)

(b) Temperature rising/falling

(c) Relative Humidity (RH)

(d) Type of Precipitation

(e) Wind velocity

(f) Aircraft orientation to wind (if applicable)

Title, number, and date of latest issue of pertinent procedure.

To your knowledge are there alternate (no/low-glycol) technology used by others under similar circumstances.

Reason for use, cost reduction, scheduling or other.

Is the method efficient?/ Are there significant cost savings?

What methods have you used in the past, and have discontinued?

Why were they discontinued?

(f) other technologies encountered (please specify).

3. WHAT OTHER GLYCOL REDUCTION METHODS DO YOU USE?

Do you recycle fluids?

4. SUPPLEMENTARY INFORMATION

Airline/Airport;.....

Name (optional).....

Position:.....

Address:.....

.....

.....

Telephone:

Fax:

E-Mail:

5. DETAILED QUESTIONNAIRE

Would you be prepared to complete a more detailed water pollution questionnaire ? ☐ Yes ☐ No

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Members		*Adria Airways*	*Aer Lingoes*	*Air France*	*Air Malta*	
		Austrian Airlines	*Balkan*	*British Airways*	*British Midland*	
		CSA	*Cyprus Airways*	*Finnair*	*Iberia*	
		JAT	*KLM*	*Lufthansa*	*Luxair*	
		Olympic Airways	*Sabena*	*SAS*	*Swissair*	
		Turkish Airlines	*Alitalia*	*Cargolux*	*Icelandair*	
		Malev	*TAP Air Portugal*			
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Mr. Hi Young Choi		011-82-2-656-6400	SEOUL	KOREA	KOREAN	
Ueda Hirohisa		011-03-5756-3529.	TOKYO	JAPAN	JAL	

APPENDIX C—SURVEY RESPONDENTS

SURVEY RESPONDENTS	USE MECHANICAL MEANS
1. Lu Yong Manager/Mechanical System Department Engineering and Maintenance Division **AIR CHINA** Capital Airport Beijing, P. R., 100621 China Tel: 86-10-64597340 Fax: 86-10-64594445	
2. Hirohisa Ueda Manager of Flight Operation Engineering **JAPAN AIRLINES** Narita Airport Japan Tel: Fax: 03-5756-3529	Air Blowers Heated Hangars if Available Brooms and Ropes
3. Carlos Sailcedo Williams Operations Engineering Manager **AEROPERU** Lima Peru Tel/Fax: 51-1-575-0873 Voice: 51-1-575-1341	
4. Hans-Joachim Pueschner Managing Director EFM-Aircraft Deicing and Towing Services GMBH **MUNICH AIRPORT AUTHORITY** P.O. Box 23 16 25 D-85325, Munich Airport Germany Tel: 49 89 977 5001 Fax: 49 89 977 5330 E-mail: HANS-JOACHIM.PUESCHNER@DLH.DE	Heated Maintenance Hangars

SURVEY RESPONDENTS	USE MECHANICAL MEANS
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8. Pertti Pitkanen Environmental Engineer **FINNAIR** EVM/28 01053 Finnair Finland Tel: 358-9-818-6748 Fax: 358-9-818-6043	Brushes Hangars
9. Jimmie Wyche **FRONTIER AIRLINES** Denver International Airport Denver, Colorado 80249-6361 USA Tel: Fax: 303-371-7007	Brooms and Ropes

SURVEY RESPONDENTS	USE MECHANICAL MEANS
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15. Mr. R. MacCullam **AIR CANADA** Dorval, Quebec Canada Tel: 514-422-6649 Fax: 514-422-5473	
16. Captain Steve Burton Manager, Flight Training and Standards **AIR ONTARIO INC** Lester B. Pearson International Airport P.O. Box 6002 Toronto AMF Ontario, L5P T84 Canada Tel: Fax:	Wing/Tail Covers (discontinued) Propeller Protective Covers Hangars
17. Dr. Hugh Sommerville **BRITISH AIRWAYS Plc** Speedbird House Heathrow Airport Hounslow TW6 2JA England	
18. Keith Hellyer **BRITISH AIRWAYS LHR** Compass Centre (S743) P.O. Box 10 Heathrow Airport Hounslow, MIDDX, TW6 2JA England Tel: 011-44-181-513-1177 Fax: 011-44-181-513-0444 E-mail: keith.m.hellyer@british-airways.com	

SURVEY RESPONDENTS	USE MECHANICAL MEANS
19. Kevin Black **UNITED AIRLINES INC** Senior Staff Representative P.O. Box 66100-WHQSY Chicago, Illinois 60666 USA Tel: 847-700-7603 Fax: 847 700-7269 E-mail: kevin.black@ual.com	Brushes and Ropes
20. Bruce Saunders Manager Environment-Safety and Environment Department **QANTAS AIRWAYS LIMITED** Qantas Jet Base MA9 203 Coward Street Mascot 2020 Australia Tel: 61-2-9691-9274 Fax: 61-2-9691-8833	
21. Mr. Adriaan Gerritsen **KLM ROYAL DUTCH AIRLINES** Schiphol Airport The Netherlands Tel: 31-20-649-0559 Fax: 31-20-648-8039 E-mail: klm89324@td.klm.nl	
22. Darcy Zarubiak Senior Environmental Planner **DALLAS FORT WORTH** P.O. Drawer 619428 Dallas Fort Worth Airport TX 75261 Tel: 972-574-8940 Fax: 972-574-8709 E-mail: dzarubiak@DFWAirport.com	
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SURVEY RESPONDENTS	USE MECHANICAL MEANS
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25. Don Muirhead **CALM AIR INTERNATIONAL LTD** Thompson, Manitoba R8N 1Y8 Canada Tel: 204-778-6471 Fax: 204-677-2867	Heated Hangar/Main Base Brooms
26. Allison Bird Project Engineer Environmental Programs **FEDERAL EXPRESS** P.O. Box 727 Memphis, TN 38194-8415 USA Tel: 901-922-4746 Fax: 901-922-2042	
27. Tim Moffatt Manager Ramp Procedures & Operations **FIRST AIR** 100 Thad Johnson Road Gloucester, Ontario K1V 0R1 Canada Tel: 613-521-5435 Fax: 613-521-1962	Air Blowers and Heaters Heated Hangars Infrared Heaters in Hangar Ropes and Wing Covers
28. Sylvain Desmarteaux Chief Flight Engineer **Air Transat** 11600, rue Cargo A-1 Aeroport International de Montreal Mirabel, Quebec J7N 1G9 Canada Tel: 514-476-1011, Ext 3068 Fax: 514-476-6710	

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