Transport Canada Transports Canada
**Safety and Security** **Sécurité et sûreté**
Civil Aviation Aviation civile

TP 10647E

# When in Doubt...

## Ground Crew

## Aircraft Critical Surface Contamination Training

Fourth Edition
January, 2001

Canada

## CONTENTS

**PAGE**



**CAUTION:**

This booklet contains information that may be at variance with, or deviate from, individual carrier or aircraft standards, policies, orders or recommendations. Canadian Aviation Regulations (CARs), your company operations and maintenance control manuals and the manufacturers' aircraft flight and maintenance manuals must be considered the final authorities.

Published by Transport Canada

## PREFACE

To assist air carriers in establishing Surface Contamination Training, Transport Canada has made available training programs concerning the adverse effect of critical surface contamination on aircraft performance. These programs consist of three videos with accompanying booklets: 1) Large Aircraft Program; 2) Small Aircraft Program; and 3) Ground Crew Program. It is intended that these programs reach all pilots and others who are involved in aircraft operations.

This is an updated version of the companion booklet for the Ground Crew video. As well, there is a combined booklet for the Small and Large Aircraft videos.

There is no such thing as a little ice. In airline operations where large numbers of aircraft are dispatched, the process of assuring that each flight will be safe must be a team effort. In smaller commercial and in private operations, the pilot may have to perform all the functions. In all cases, the pilot-in-command is ultimately responsible for ensuring that the aircraft is in a condition for safe flight. If the pilot cannot confirm that the aircraft critical surfaces are free of contamination, take-off must not be attempted.

A. Laflamme
Director General
Civil Aviation

# GENERAL INFORMATION

Where frost, ice or snow may reasonably be expected to adhere to the aircraft, the Canadian Aviation Regulations (CARs) require that an inspection or inspections be made before take-off or attempted take-off. The type and minimum number of inspections indicated by the regulations, and depends on whether or not the operator has an approved *Ground Icing Operations Program* using the *Ground Icing Operations Standards* as specified in CARs 622.11 *(Operating and Flight Rules Standards)*.

The reasons for the regulations are straightforward. The degradation in aircraft performance and changes in flight characteristics when frozen contaminants are present are wide ranging and unpredictable. Contamination makes no distinction between large aircraft, small aircraft or helicopters, the performance penalties and dangers are just as real.

The significance of these effects are such that take-off should not be attempted unless the pilot-in-command (PIC) has determined, as required by the CARs, that frost, ice or snow contamination is not adhering to any aircraft critical surfaces.

**Critical Surfaces** of an aircraft means the wings, control surfaces, rotors, propellers, horizontal stabilizers, vertical stabilizers or any other stabilizing surface on an aircraft and, in the case of an aircraft that has rear-mounted engines, includes the upper surface of its fuselage.

Flight safety during ground operations in conditions conducive to frost, ice or snow contamination requires a knowledge of the following:

– Adverse effects of frost, ice or snow on the aircraft performance and flight characteristics, which are generally reflected in the form of decreased thrust, decreased lift, increased drag, increased stall speed, trim changes, altered stall characteristics and handling qualities;

– Various procedures available for aircraft ground de-icing and anti-icing, and the capabilities and limitations of these procedures in various weather conditions, including the use and effectiveness of freezing point depressant (FPD) fluids;

– **Holdover Time (HOT)** is the estimated time that an application of an approved de-icing/ anti-icing fluid is effective in preventing frost, ice or snow from adhering to treated surfaces. Holdover time is calculated as beginning at the start of the final application of an approved de-icing/anti-icing fluid and as expiring when the fluid is no longer effective. The fluid is no longer effective when its ability to absorb more precipitation has been exceeded. This produces a visible surface build-up of contamination;

– Recognition that final assurance of a safe take-off rests in the pre-take-off inspection.

## THE CLEAN AIRCRAFT CONCEPT

CARs 602.11 (1) and (2) prohibit take-off when frost, ice or snow is adhering to any critical surface of the aircraft. This is referred to as *The Clean Aircraft Concept*. The Clean Aircraft Concept is essential to the maintenance of flight safety. In all aviation operations, the PIC has the ultimate responsibility to determine if the aircraft is in a condition for safe flight.

It is imperative that take-off not be attempted on any aircraft unless the PIC has determined that all critical surfaces of the aircraft are free of frost, ice or snow contamination. This requirement may be met if the PIC obtains verification from properly trained and qualified personnel that the aircraft is ready for flight.

However, a Notice of Proposed Amendment (NPA) to the pertinent sections of CAR 602.11 and CASS 622.11 has been submitted which, under specified conditions, would permit Canadian Air Operators and Foreign Air Operators in Canada operating aircraft with rear mounted engines to conduct a takeoff with hoar-frost on the fuselage. At the time of printing, this NPA had not been approved.

In the meantime, an exemption to CARs 602.11 (1) and (2) has been issued. The purpose of this exemption is to permit Canadian Air Operators and Foreign Air Operators in Canada utilizing aircraft with engines mounted on the rear of the fuselage to conduct a takeoff with hoar-frost on the fuselage after it has been determined that no other contamination is adhered to the fuselage. The exemption is subject to the following conditions:

1. For the purposes of this exemption hoar-frost shall be defined as:

   "a uniform, thin white deposit of fine crystalline texture that forms on exposed surfaces during calm, cloudless nights when the temperature falls below freezing and the humidity of the air at the surface is close to the saturation point. It is not associated with precipitation. The deposit is thin enough that the underlying surface features, such as paint lines, markings or lettering can be distinguished.";

2. Hoar-frost shall be the only acceptable contaminant on the fuselage of aircraft with engines mounted on the rear fuselage;

3. Prior to conducting a takeoff, the operator shall ensure that the hoar-frost is not mixed with other contaminants such as ice or snow. If any other contaminant or contaminants are on the fuselage, the operator shall de-ice the entire fuselage; and

4. A copy of this exemption shall be attached to the Aircraft De-icing/Anti-icing Procedures in the Operator's Manual.

## FROZEN CONTAMINANTS

Test data indicate that during takeoff, frost, ice or snow formations having a thickness and surface roughness similar to medium or coarse sandpaper, on the leading edge and upper surface of a wing, can reduce wing lift by as much as 30% and increase drag by 40%. Even small amounts of contamination such as this have caused and continue to cause aircraft accidents which result in substantial damage and loss of life. A significant part of the loss of lift can be attributed to leading edge contamination. The changes in lift and drag significantly increase stall speed, reduce controllability and alter aircraft flight characteristics. Thicker or rougher frozen contaminants can have increasing effects on lift, drag, stall speed, stability and control.

More than 30 factors have been identified that can influence whether frost, ice or snow will accumulate, cause surface roughness on an aircraft and affect the anti-icing properties of FPD fluids. These factors include ambient temperature; aircraft surface temperature; the de-icing and anti-icing fluid type; temperature and concentration; relative humidity; and wind speed and direction. Because many factors affect the accumulation of frozen contaminants on the aircraft surface, holdover times for FPD fluids should be considered as guidelines only, unless the operator's *Ground Icing Operations Program* allows otherwise.

The type of frost, ice or snow that can accumulate on an aircraft while on the ground is a key factor in determining the type of de-icing/anti-icing procedures that should be used.

Where conditions are such that ice or snow may reasonably be expected to adhere to the aircraft, it must be removed before take-off. Dry, powdery snow can be removed by blowing cold air or compressed nitrogen gas across the aircraft surface. In some circumstances, a shop broom could be employed to clean certain areas accessible from the ground. Heavy, wet snow or ice can be removed by placing the aircraft in a heated hangar, by using solutions of heated FPD fluids and water, by mechanical means such as brooms or squeegees, or a combination of all three methods. Should the aircraft be placed in a heated hangar ensure it is completely dry when moved outside, otherwise, pooled water may refreeze in critical areas or on critical surfaces.

Conditions may be encountered whereby cold dry snow is falling onto the cold wing of an aircraft. The wind often causes the snow to swirl and move across the surface of the wing and it is evident that the snow is not adhering to the wing surface. Under these circumstances the application of de/anti-icing fluid to the wing of the aircraft would result in the snow sticking to the fluid. Under such operational conditions it may not be prudent to apply fluids to the wing. However, if snow has accumulated at any location on the wing surface it must be removed prior to take-off. It cannot be assumed that an accumulation of snow on a wing will "blow off" during the take-off.

A frost that forms overnight must be removed from the critical surfaces before take-off. Frost can be removed by placing the aircraft in a heated hangar or by other normal de-icing procedures.

**Ice Pellets**

Ice pellets are a type of precipitation consisting of transparent or translucent pellets of ice, 5 mm or less in diameter. They may be spherical, irregular, or (rarely) conical in shape. Ice pellets usually bounce when hitting hard ground, and make a sound on impact. There are basically two different types of ice pellets:

(1) *Grains of ice (Sleet in the U.S.A.)*; generally transparent, globular, solid grains of ice which have formed from the freezing of raindrops or the refreezing of the

largely melted snowflakes when falling through a below-freezing layer of air near the earth's surface;

(2) *Small hail;* generally translucent particles, consisting of snow pellets encased in a thin layer of ice. The ice layer may form either by the accretion of droplets upon the snow pellet, or by the melting and refreezing of the surface of the snow pellet.

It is believed that ice pellets are capable of penetrating the fluid and have enough momentum to contact the aircraft's surface beneath the fluid. Additionally, the ice pellets are of significant mass and therefore local dilution of the fluid by the ice pellets would result in very rapid failure of the fluid.

The holdover time (HOT) tables do not address ice pellet precipitation and the fluids have not been scientifically tested in such conditions. As a result, the HOT tables are not a reliable source of predicting fluid failure under ice pellets conditions. Thus, in conditions of ice pellet precipitation, extra caution should be taken and extra inspections conducted because there is believed to be a high risk of fluid failure and attendant wing contamination.

**The Cold-Soaking Phenomenon**

Where fuel tanks are located in the wings of aircraft, the temperature of the fuel greatly affects the temperature of the wing surface above and below these tanks. After a flight, the temperature of an aircraft and the fuel carried in the wing tanks may be considerably colder than the ambient temperature. An aircraft's cold-soaked wings conduct heat away from precipitation so that, depending on a number of factors, clear ice may form on some aircraft, particularly on wing areas above the fuel tanks. As well, cold-soaking can cause ice to form due to humidity in the air when there is no precipitation, even when the temperature is above freezing. Such ice is difficult to see and in many instances cannot be detected other than by touch with the bare hand or by means of a special purpose ice detector. A layer of slush on the wing can also hide a dangerous sheet of ice beneath.

Clear ice formations could break loose at rotation or during flight, causing engine damage on some aircraft types, primarily those with rear mounted engines.

The formation of ice on the wing is dependent on the type, depth and liquid content of precipitation, ambient air temperature and wing surface temperature. The following factors contribute to the formation intensity and the final thickness of the clear ice layer:

– low temperature of the fuel uplifted by the aircraft during a ground stop and/or the long airborne time of the previous flight resulting in a situation that the remaining fuel in the wing tanks is subzero. Fuel temperature drops of up to 18°C have been recorded after a flight of two hours;

– an abnormally large amount of cold fuel remaining in the wing tanks causing fuel to come in contact with the wing upper surface panels, especially in the wing root area;

– weather conditions at the ground stop, wet snow, drizzle or rain with the ambient temperature around 0°C is very critical. Heavy freezing has been reported during drizzle or rain even in a temperature range between +8°C to +14°C.

As well, cold-soaking can cause frost to form on the upper and lower wing under conditions of high relative humidity. This is one type of contamination that can occur in above freezing weather at airports where there is normally no need for de-icing equipment, or where the equipment is deactivated for the summer. This contamination typically occurs where the fuel in the wing tanks becomes cold-soaked to below freezing temperatures because of low temperature fuel uplifted during the previous stop or cruise at altitude where low temperatures are encountered, or both, and a normal descent is made into a region of high humidity. In such instances, frost will form on the under and upper sides of the fuel tank region during the ground turn-around time, and tends to reform quickly even when removed.

Frost initially forms as individual grains about 0.004 inches in diameter. Additional build-up comes through grain growth from 0.010 to 0.015 inches in diameter, grain layering, and the formation of frost needles. Available test data indicate that this roughness on the wing lower surface will have no significant effect on lift, but it may increase drag and thereby decrease climb gradient capability which results in a second segment limiting weight penalty.

Skin temperature should be increased to preclude formation of ice or frost prior to take-off. This is often possible by refueling with warm fuel or using hot FPD fluids, or both.

In any case, ice or frost formations on upper or lower wing surfaces must be removed prior to take-off. The exception is that take-off may be made with frost adhering to the underside of the wings provided it is conducted in accordance with the **aircraft manufacturer's instructions**.

### Heavy Snow

Operations during heavy snow conditions will require that an inspection be conducted immediately prior to take-off to ensure that contamination is not adhering to the critical surfaces. This inspection is required irrespective of the time that has elapsed since anti-icing occurred. Take-off needs to be initiated within 5 minutes of the inspection, otherwise the inspection must be repeated or the aircraft must be de/anti-iced again. Type I fluids should not be used as an anti-icing fluid during heavy snow conditions.

### Role of Ground Crew

Your role in "The Clean Aircraft Concept" starts before you get to the apron. If the conditions that promote icing are present, you have to be alert before you get out there. When in doubt, ask the weather office for the most up-to-date forecasts. Find out what kind of temperatures and precipitation aircraft will experience on the apron. if precipitation is forecast, find out what kind.

Check your manuals for the correct de-icing procedures for the various aircraft you'll be servicing. Some aircraft have specific control surface settings for de-icing. The pilot should know them and you should be familiar with these recommendations as well.

## DE-ICING AND ANTI-ICING FLUIDS

Frozen contaminants are most often removed in commercial operations by using FPD fluids. There are a number of FPD fluids available for use on commercial aircraft and, to a lesser extent, on general aviation aircraft. De-icing and anti-icing fluids should not be used unless approved by the aircraft manufacturer.

As shown in Table 1, the FPDs used to de-ice aircraft in North America are usually composed of ethylene glycol or propylene glycol combined with water and other ingredients. The exact formulation of commercial fluids are proprietary; some contain wetting agents or corrosion inhibitors for specialized applications. Users can purchase FPD fluid in a concentrated form or pre-mixed, depending on customer requests.

| Common Name | Colour | Primary Active Ingredients | Viscosity | Primary Use | Notes (see AC 20-117 for more complete information) |
|---|---|---|---|---|---|
| SAE Type I<br><br>ISO Type I | Orange | Propylene/ diethylene ethylene glycol | Low | De-icing | Propylene glycol based fluids not to be used undiluted at OAT < 14°F (-10°C). Aircraft performance changes may result. AMS** 1424 included. SAE, ISO specs similar. |
| SAE Types II & IV<br><br>ISO Types II & IV | Type II Clear and pale Straw<br><br>Type IV Emerald Green | Propylene/ diethylene glycol with polymer thickener | High to Low | De-icing and anti-icing | For use on aircraft with $V_r$ > 100 knots; lower viscosity than AEA*** Type II produced before 1988. AMS 1428 included. SAE, ISO specs similar. |
| Mil-A-8243D Type I | | Propylene glycol | Medium | De-icing | Less toxic to animals. **Not to be used undiluted or with HOT tables**. Not similar to Mil-A-8243C Type I or II. |
| Mil-A-8243D Type II | | 3 parts ethylene glycol, 1 part propylene glycol | Low | De-icing | Similar to Mil-A-8243C Type I and II. Not approved as SAE or ISO Type II. **Not to be used with HOT tables**. |
| Arktika (Russia) | | Ethylene glycol with thickener | High | De-icing and anti-icing | Not approved as SAE or ISO Type II. Considered thickened Type I. Effects on aerodynamics unknown to date. **Not to be used with HOT table**. |

**AMS – Aerospace Materials Specification
***AEA – Association of European Airlines

**Table 1. General Characteristics of Types I, II and IV FPDs**

The basic philosophy of using FPD fluids for aircraft de-icing is to decrease the freezing point of water in the liquid or crystal (ice) phase. The active ingredient in most FPD aviation fluids is glycol. Figure 1 shows the effect for various concentrations of glycol on the freezing point of water. The general characteristics of these fluids are outlined in Table 1.

Although FPD fluids are highly soluble in water, they absorb or melt slowly. If frost, ice or snow is adhering to an aircraft surface, the accumulation can be melted by repeated application of proper quantities of heated FPD fluid. As the ice melts, the FPD mixes with the water, thereby diluting the FPD. As dilution occurs, the resulting mixture may begin to run off the aircraft. If all the ice is not melted, additional application of FPD becomes necessary until the fluid penetrates to the aircraft surface. When all the ice has melted, the remaining liquid residue is a mixture of FPD and water at an unknown concentration. The resulting film could freeze (begin to crystallize) rapidly with only a slight temperature decrease. If the freezing point of the film is found to be insufficient, the de-icing procedure must be repeated until the freezing point of the remaining film is sufficient to ensure safe operation.

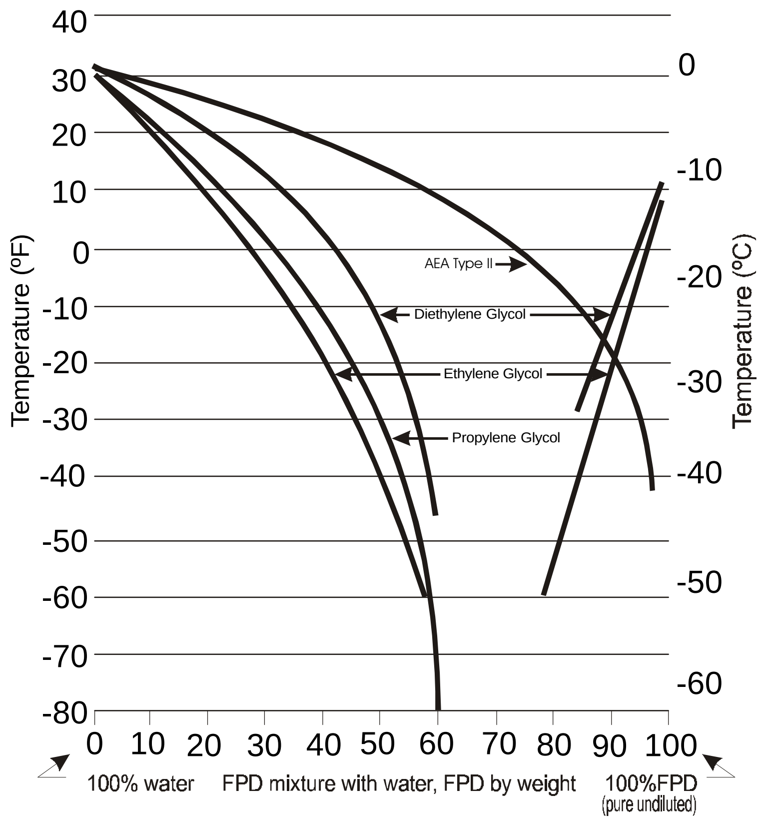


**Figure 1. Phase of aqueous glycol solutions**

**CAUTION :** THIS DIAGRAM IS NOT REPRESENTATIVE OF ANY COMMERCIALLY AVAILABLE AVIATION GROUND DE-ICING FLUID. IT IS FOR ILLUSTRATIVE PURPOSE ONLY.

The de-icing process can be speeded up considerably by using the physical energy of high-pressure spray equipment, as is the common practice.

**Note:** It is the heat contained by the Type I (de-ice) fluid that removes the frozen contaminants. The glycol provides some protection during precipitation conditions until Type II or IV fluid is applied.

### ISO Commercial Fluids

International Standards Organization (ISO) fluids were originally known as AEA Type I and Type II. Specifications for these two types of FPDs are provided in the ISO guidelines as ISO #11075. "Aircraft de-icing/anti-icing Newtonian fluids ISO Type I" and ISO #11078, "Aircraft de-icing/anti-icing non-Newtonian fluids ISO Type II".

### SAE Commercial Fluids

Society of Automotive Engineers (SAE) Type I and Type II fluids are very similar in all respects to ISO Type I and Type II fluids. These FPDs, specified by the SAE and ISO as Type I and Type II, are distinguished by material requirement, freezing point, rheological properties (viscosity and plasticity), and de-icing/anti-icing performance.

### SAE and ISO Type I Fluids (Orange)

These fluids in the concentrated form contain a minimum of 80% glycol and are considered "unthickened" because of their relatively low viscosity. These fluids are used for de-icing or anti-icing, but provide **very** limited anti-icing protection.

### SAE and ISO Type II Fluids (Clear or Pale Straw)

Fluids such as those identified as ISO Type II and SAE Type II will last longer in conditions of precipitation and afford greater margins of safety if they are used in accordance with aircraft manufactures' recommendations.

Flight tests performed by manufacturers of transport category aircraft have shown that SAE and ISO Type II fluids flow off lifting surfaces by rotation speeds ($V_r$), although some large aircraft do experience performance degradation and may require weight or other take-off compensation. Therefore, SAE and ISO Type II fluids should be used on aircraft with rotation speeds ($V_r$) above 100 knots. Degradation could be significant on aeroplanes with rotation speeds below this figure.

As with any de-icing or anti-icing fluid, SAE and ISO Type II fluids should not be applied unless the aircraft manufacturer has approved their use, regardless of rotation speed. Aircraft manufacturers' manual may give further guidance on the acceptability of ISO and SAE Type II fluids for specific aircraft.

Some fluid residue may remain throughout the flight. The aircraft manufacturer should have determined that this residue will have little or no effect on aircraft performance or handling qualities in aerodynamically quiet areas. However, this residue should be cleaned periodically.

SAE and ISO Type II fluids contain no less than 50% glycols and have a minimum freeze point of -32°C. They are considered "thickened" because of added thickening agents that enable the fluid to be deposited in a thicker film and to remain on the aircraft surfaces until the time of take-off. These fluids are used for de-icing when heated, and anti-icing. Type II fluids provide greater protection (holdover time) than do Type I fluids against frost, ice or snow formation in conditions conducive to aircraft icing on the ground.

These fluids are effective anti-icers because of their high viscosity and pseudo-plastic behavior. They are designed to remain on the wings of an aircraft during ground operations or short term storage, thereby providing anti-icing protection. However, when these fluids are subjected to shear stress, such as that experienced during a take-off run, their viscosity decreases drastically, allowing the fluids to flow off the wings and causing little adverse effect on the aircraft's aerodynamic performance.

**The pseudo-plastic behavior of SAE and ISO Type II fluids can be altered by improper de-icing/anti-icing equipment or handling.** Therefore, some North American airlines have updated de-icing and anti-icing equipment, fluid storage facilities, de-icing and anti-icing procedures, quality control procedures, and training programs to accommodate these distinct characteristics. Testing indicates that SAE and ISO Type II fluids, if applied with improper equipment, may lose 20 to 60% of their anti-icing performance.

All Type II fluids are not necessarily compatible with all Type I fluids. Therefore, you should refer to the fluid manufacturer or supplier for further information. As well, the use of Type II fluid over badly contaminated Type I fluid will reduce the effectiveness of Type II fluid.

SAE and ISO Type II fluids were introduced in North America in 1985 with widespread use beginning to occur in 1990. Similar fluids, but with slight differences in characteristics, have been developed, introduced, and used in Canada.

**Type III Fluids**

Type III is a thickened FPD fluid which has properties that lie between Types I and II. Therefore, it provides a longer holdover time than Type I but less than Type II. Its shearing and flow off characteristics are designed for aircraft that have a shorter time to rotation and this should make it acceptable for some aircraft that have a $V_r$ of less than 100 knots.

The SAE has approved a specification in AMS 1428A for Type III anti-icing fluids that can be used on those aircraft with rotation speed significantly lower than the large jet rotation speeds, which are 100 knots or greater. Although the Type III HOT table has been published, at the time of printing this document there were no qualified Type III fluids available. Type III may be used for anti-icing purposes on low rotation speed aircraft, but only in accordance with aircraft and fluid manufacturer's instructions.

**SAE and ISO Type IV Fluids (Emerald Green)**

A significant advance is Type IV anti-icing fluid. These fluids meet the same fluid specifications as the Type II fluids and in addition have a significantly longer HOT. In recognition of the above, holdover timetables are available for Type IV.

The product is dyed emerald green as it is believed that the green product will provide for application of a more consistent layer of fluid to the aircraft and will reduce the likelihood that fluid will be mistaken for ice. **However, as these fluids do not flow as readily as**

**conventional Type II fluid, caution should be exercised to ensure that enough fluid is used to give uniform coverage.**

Research indicates that the effectiveness of a Type IV fluid can be seriously diminished if proper procedures are not followed when applying it over Type I fluid. The SAE G-12 Committee has directed the major fluid manufacturers to evaluate Type IV and Type I pairings to determine if fluid incompatibilities exist amongst the various "pair" combinations. The results of this evaluation will be passed on to the operators directly from the fluid manufacturer.

Research has indicated that if the fluid is not applied correctly, the HOT table values are not achievable.

Proper fluid coverage is absolutely essential for proper fluid performance. It is imperative that the personnel applying the fluid be properly trained and that a consistent fluid application technique be utilized.

## Qualified Fluids

A list of *Qualified* de-icing and anti-icing fluids is included in the current Commercial and Business Aviation Advisory Circular (CBAAC) Ground Icing Update. If reliable holdover times are to be achieved, only qualified fluids, stored, dispensed and applied in accordance with the manufacturers' instructions are acceptable. The qualified fluids have undergone laboratory testing to quantify their protection endurance and to confirm aerodynamic acceptability during simulated take-off conditions. The fluids listed may be used with the HOT tables shown in the CBAAC.

There is no regulatory requirement for providers of de-icing or anti-icing services to use products which have passed a certification process. However, the operator of the aircraft is ultimately responsible for ensuring that only qualified fluids are used if predicating holdover time upon their use.

It is expected that additional fluids will be qualified from time to time. Operators are encouraged to contact suppliers or manufacturers to determine the qualification status of any de-icing or anti-icing fluid which does not appear in the CBAAC. However, the operator will be required to prove that fluids not on the approved list have been properly tested.

## Freezing Characteristics of FPD Fluids

Before a fluid is used on an aircraft, it is crucial that the user knows and understands its freezing characteristics. These characteristics can be determined through understanding of the fluid procurement specifications and tolerances and through quality control inspections. FPD fluids are either pre-mixed (diluted with water) by the manufacturer or mixed by the user from bulk supplies. To ensure known freezing characteristics, samples of the final mixture should be analyzed before use. FPD fluid manufacturers can supply methodology and suggest equipment needed for quality control examinations. Refer to your procedures manual for more details.

**FPD Fluid Strength When Applied**

The ratio of FPD ingredients to water, or fluid strength, is a significant factor in the de-icing fluid properties. HOT tables present guidelines for holdover times achieved by SAE and ISO Type I, SAE and ISO Type II, Type III and Type IV fluids as a function of fluid strength, weather conditions and outside air temperature (OAT).

**Do not use pure (100%) ethylene glycol or pure propylene glycol fluids in non-precipitation conditions.** The reasons for this caution are explained below:

– Pure ethylene glycol has a much higher freezing point than ethylene glycol diluted with water. Slight temperature decreases can be induced by factors such as cold-soaked fuel in wing tanks, reduction of solar radiation by clouds obscuring the sun, wind effects, and lowered temperature during development of wing lift;

– Undiluted propylene glycol, having a strength of about 88% glycol at temperatures less than -10°C (+14°F), is quite viscous. In this form, propylene glycol based fluids have been found to cause lift reductions of about 20%.

Propylene glycol FPD fluids are not intended to be used in the undiluted state unless specifically recommended by the aircraft manufacturer.

Check the concentrations of the fluids you have available and know how they react under various conditions. If you do a quality insurance test as part of your procedure, don't skimp. If the test results are borderline, get help from your supervisor. Check with your supervisor, operations or maintenance to get the most up-to-date information available.

**FPD Temperature Buffer**

Temperature buffer is the temperature difference between the freezing point of the fluid as applied, and the ambient temperature.

Generally, the holdover time is increased with an expansion of the temperature buffer. Therefore, if the choice is available, use the maximum buffer. However, greater buffers require the use of more glycol, which is more costly and which increases the burden for collection and processing of FPD spillage and runoff. FPD fluid mixtures and their attendant buffers should be determined after consideration of the following factors in the listed order of priority:

– Safety;
– Environmental impact;
– Cost.

For SAE and ISO Type I fluids, the freeze point buffer of the anti-icing should be as great as possible but not less than 10°C (18°F).

For SAE and ISO Type II and IV, the freeze point buffer should not be less than 7°C (13°F).

Contact the fluid manufacturer for information on the Type III temperature buffer.

| Fluid Type | OAT Range | Buffer |
|---|---|---|
| SAE and ISO Type I | All | 10°C |
| SAE and ISO Type II | All | 7°C |
| SAE and ISO Type IV | All | 7°C |

**Table 2. FPD Temperature Buffers**

It is recommended that the remaining film of FPD fluid have a freezing point of at least 12 degrees Celsius below the colder of ambient air temperature or aircraft surface temperature. The common practice has been to obtain the lowest possible freezing point for the FPD to provide an increased margin of safety. The reason for this is to delay refreezing of the FPD fluid based on the most probable fluid temperature as opposed to ambient temperature and to take into consideration such factors as:

– Temperature reduction during climb or in the production of aerodynamic forces (lift in particular) and the possibility that residual fluids will freeze at altitude;

– Freeze point change as freezing precipitation or moisture from any source contacts and is absorbed by the residual anti-icing fluid; and

– Quality control margin for error.

A greater temperature buffer will minimize the affects of these changes, resulting in a longer holdover time.

## DE-ICING AND ANTI-ICING PROCEDURES

Most aircraft ground icing related accidents have occurred when the aircraft was not de-iced prior to take-off. The de-icing process is intended to restore the aircraft to a clean configuration so neither degradation of aerodynamic characteristics nor mechanical interference from contaminants will occur.

Common practice over many years of experience is to de-ice and, if necessary, anti-ice an aircraft as close to the time of take-off as possible. Various techniques of aircraft ground de-icing and anti-icing have been developed. The most common technique is to use FPD fluids in the ground de-icing process and to anti-ice with a protective film of FPD fluid to delay formations of frost, ice or snow.

### De-icing and Anti-Icing the Airframe

Operational procedures employed in aircraft ground de-icing and anti-icing vary, depending on the type of accumulation on the surface of the aircraft and the type of aircraft. The general procedures used by aircraft operators are similar and are based on the procedures recommended by the aircraft manufacturer, which, in turn, may be based upon procedures recommended by the fluid manufacturer, engine manufacturer, and the SAE and ISO. HOT tables provide guidance suggested by SAE based upon SAE and ISO recommendations for the application of SAE and ISO Types I, II, III and IV fluids as a function of OAT.

An aircraft may be de-iced by any suitable manual method. Parking the aircraft in a heated hangar for an appropriate amount of time to melt all contamination is a common de-icing procedure for a smaller aircraft. Using wing covers or other temporary shelters will often reduce the amount of contamination and the time required for de-icing and anti-icing aircraft, especially when the aircraft must be stored outside. Some types of contamination such as light, dry snow can be removed with a shop broom, or very light frost can be rubbed off using a rope sawed across the contaminated area.

De-icing is normally accomplished using heated water or solutions of heated water and FPD fluids, often followed by anti-icing using cold, rich solutions that may have a lower freezing point. Each fluid has very unique characteristics and handling requirements.

One of the more common de-icing procedures in commercial operations involves using water, FPD fluids, or solutions of FPD fluids and water. Heating these fluids increases their de-icing effectiveness; however, in the anti-icing process unheated fluids are more effective because the thickness of the fluids is greater. High pressure spraying equipment is often used in large operations to add physical energy to the thermal energy of FPD fluids.

De-icing and anti-icing with FPD fluids may be performed as a one-step or two-step process, depending on predetermined practices, prevailing weather conditions, concentration of the FPD used and available de-icing and anti-icing equipment and facilities.

The **one-step method** is accomplished using a heated FPD mixture. In this process, the residual FPD fluid film provides a very limited anti-icing protection which can be enhanced by the use of cold fluids or by the use of techniques to cool heated fluid during the de-icing process.

The **two-step procedure** involves both de-icing and anti-icing. De-icing is accomplished with hot water or a hot mixture of FPD and water. The ambient weather conditions and the type of accumulation to be removed from the aircraft must be considered when determining which de-icing fluid to use. The second (anti-icing) step involves applying a mixture of SAE or ISO Type II or IV and water to the critical surfaces of the aircraft.

**CAUTION:**

– The effectiveness of Types II and IV fluids can be seriously diminished if proper procedures are not followed when applying it over Type I fluid. Consult the fluid manufacturer for further information.

– Ensure Type IV fluids are applied evenly and thoroughly and that an adequate thickness has been applied in accordance with the fluid manufacturer's recommendations.

**Under no circumstances** should SAE and ISO Type II or IV fluids, in the concentrated (neat) form, be applied to the following areas of an aircraft:

– Pitot heads, static ports and angle-of-attack sensors;
– Control surface cavities;
– Cockpit windows and the nose of fuselage;
– Lower side of the radome underneath the nose;
– Air inlets and intakes; and

– Engines.

The freezing point of residual fluids on aircraft surfaces resulting from FPD fluids mixing with precipitation or melted ice can be found in the current CBAAC “Ground Training Update”. FPD freezing point can be determined by using a refractometer or other similar techniques.

An aircraft must be systematically de-iced and anti-iced in weather conditions conducive to icing. Each aircraft surface requires a specific cleaning technique.

The wings are the main lifting surfaces of the aircraft and must be free of contamination to operate efficiently. An accumulation of frost, ice or snow on the wing changes the airflow characteristics, reducing its lifting capabilities, increasing drag, increasing stall speed and changing pitching moments. The weight increase is slight and its effects are secondary to those caused by surface roughness.

On many aircraft, de-icing of the wing begins at the leading edge wing tip, sweeping in the aft and inboard direction. This procedure avoids increasing the snow load on outboard wing sections, which under some very heavy snow conditions could produce excessive wing stresses. This method also reduces the possibility of flushing ice or snow deposits into the balance bays and cavities.

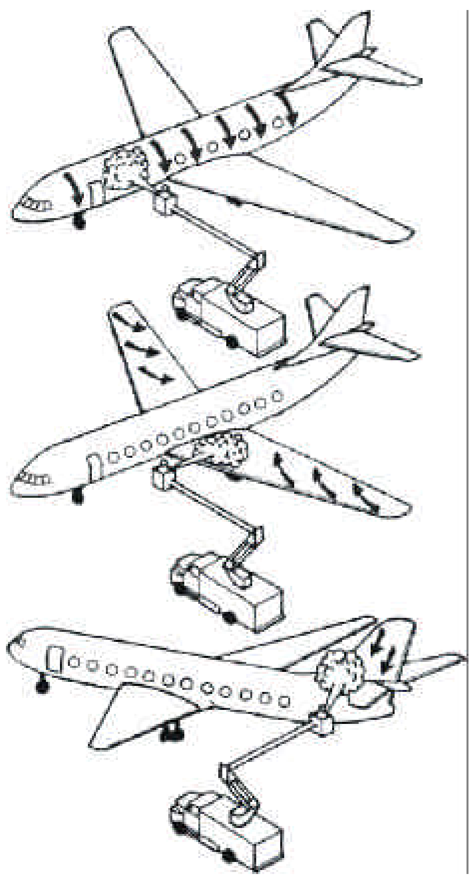

**Figure 2. Systematic de-icing of aircraft in conditions conducive to icing.**

If ice accumulation is present in areas such as flap tracks and control cavities, it may be necessary to spray from the trailing edge forward  Also, under some weather or ramp conditions, it is necessary to spray from trailing edge.  Consult the aircraft manufacturer for specific details.

It is important for operators to consider the configuration of their aircraft during de-icing. Manufacturers may indicate that their aircraft need to be in a specific configuration during the de-icing and anti-icing process. However, if an aircraft is in a clean configuration, that is with all high lift devices retracted, during de-icing the operator needs to consider what untreated areas of the wing are subsequently exposed to freezing precipitation once the devices are extended/deployed. The areas under a leading edge flap or slat, if not protected by anti-icing fluids, have the potential of becoming a contaminated critical surface prior to take-off. Air operators need to consider this scenario and may need to develop additional procedures to ensure that the aircraft is taking off in an uncontaminated condition.

Two possible options include: delaying slat/flap deployment until just prior to take-off; and deploying the devices prior to de/anti-icing so that the surfaces under these devices are treated.

Training and checklist changes may be required.

The tail surfaces require the same caution afforded the wing during the de-icing procedure.  It is important that both sides of the vertical stabilizer and rudder be de-iced because it is possible for directional control problems to develop on certain aeroplanes if the contamination is removed from one side only.  The balance bay area between moveable and stationary tail surfaces should be closely inspected.  For some aircraft, positioning the horizontal stabilizer in leading-edge-down position allows the FPD fluid and contaminants to run off rather than accumulate in balance bays.  For some aircraft, the horizontal stabilizer must be in the leading-edge-up position .  Consult  your manuals for complete information.

Balance bays, control cavities and gap seals should be inspected to ensure cleanliness and proper drainage.  When contaminants do collect in the surface juncture, they must be removed to prevent the seals from freezing and impending the movement of the control surface.

Generally, the fuselage should be de-iced and anti-iced from the top down.  Clearing the top of the fuselage manually instead of by spraying requires that personnel use caution not to damage protruding equipment (e.g., antennae) while de-icing.  Spraying the upper section with heated FPD fluid first allows the fluid to flow down, warming the sides of fuselage and removing accumulations.  This is also effective when de-icing the windows and cockpit windshield of the aircraft.  Direct spraying of these surfaces can cause thermal shock, resulting in cracking or crazing of the windows.  De-icing the top of the fuselage is especially important on aircraft with an aft-mounted centreline engine.  The ingestion of ice or snow can result in compressor stalls or damage to the engine.

The radome or nose of the aircraft should be de-iced to eliminate snow or ice accumulations from being projected into the crew's field of vision during take-off.  The nose also contains navigation and guidance equipment; therefore, it must be cleared of accumulations to ensure proper operation of the sensors.

The cargo and passenger doors must also be de-iced and anti-iced to ensure proper operation.  All hinges and tracks should be inspected to ensure that they are free of accumulation. Although accumulation may not impair operation on the ground, it may freeze at flight altitude and prevent normal operation at the aircraft's destination. Frozen accumulation may also cause damage and leakage on cargo and passenger door latches and seals.

Sensor orifices and probes along the fuselage (e.g., static ports, pitot tubes, air intakes or temperature sensors) require caution during the application of FPD fluid. Direct spraying into these openings can damage the equipment, or residues could result in faulty readings.

**De-icing The Engine Area**

Minimal amounts of FPD fluid should be used to de-ice the engine area and auxiliary power unit (APU). FPD fluids ingested in the APU can cause smoke and vapours to enter the cabin. Engine intake areas should be inspected for the presence of ice immediately after shutdown. Accumulations should be removed while the engine is cooling and before installation of plugs and covers. Any accumulation of water must be removed to prevent the compressor from freezing.

For turbo-jet engines, FPD fluids should not be used for de-icing internal components. Fluid residue on the engine fan or compressor blades can reduce engine performance or cause stall or surge. In addition, this could increase the possibility of glycol vapours entering the aircraft through the engine bleed air system.

Most turbo-jet and turbo-prop engine manufacturers recommend that thrust levers be advanced periodically to an N1 rpm of 70 to 80% while the aircraft is in ground operations to prevent ice accumulation that can result in reduced thrust, dynamic imbalance of the fan or compressor or excessive induction of shed ice. Pilots must be aware of these operating procedures and should comply with the procedures established for their aircraft.

**Ground De-Icing/Anti-Icing With Main Engines Running**

A number of aircraft and engine manufacturers have published information on the advisability of de-icing/anti-icing with the main engines running, and when permitted, the procedures to be followed in order to protect the engines.

Experience shows that problems can be minimized if precautions are taken to limit the ingestion of de-icing/anti-icing fluid by the engines. The following procedures, which must be adapted to the specific aircraft type, were developed to protect the aircraft during de-icing/anti-icing with the main engines running:

- Operate as few engines as possible during the de-icing process;
- Operate at the lowest practicable power setting;
- If possible select air conditioning 'OFF';
- Avoid spraying fluid directly into the engine, APU, and air conditioning system intakes;
- Avoid a large run-off of fluid from adjacent surfaces into the intakes, e.g., from a vertical stabilizer into a tail-mounted engine or APU;
- Minimize the generation of spray in the vicinity of the intakes.

Particular care should be exercised for the APU inlet because fluid ingestion could cause an APU runaway condition or, in an extreme case, an APU rotor burst.

More information can be found in the current CBAAC: “Ground De-Icing/Anti-Icing Of Aircraft With The Main Engines Running”

**Central and Remote De-Icing**

De-icing and anti-icing near the departure end of the runway has obvious advantages. This practice:

- Reduces the time between de-icing/anti-icing and take-off;
- Facilitates the recycling of FPD in the de-icing mixture;
- Reduces the potential environmental impact; and
- Facilitates the application of correct ratio FPD/water for existing environmental conditions at departure.

This practice is encouraged when adequate facilities exist and if performed by **qualified personnel**.

**Your role**

Ground Crew are an important part of the flight team. The aircraft crew usually meet before a flight and good pilots involve everyone in the watch for contamination. But cabin and cockpit crew can't see all the aircraft surfaces from inside the aircraft. **You have to be their eyes and hands.**

**Inspection for contaminants**

As part of the walk-around, the crew is going to be looking very closely at the aircraft. If it's snowing or raining, an icy wing looks just like a wet wing. You must check your own area closely. **The best testing tools are your eyes and your hands.** If a surface looks suspect and conditions are ripe for freezing contamination, run your hand across the surface. If it is wet, you'll slosh water around. But if you feel thick water or a mild, gritty feeling, you are feeling snow and water or ice crystals and water. Light sheet ice is sometimes found over a coating of water. It will break or shift around when you feel it. Heavy ice, sticking to the aircraft, will feel pebbly, or feel too smooth. Heavy ice also looks slightly cloudy. Some ice is rough and hard to see through to the aircraft skin, while other ice is smooth and as clear as water. Snow accumulation is obvious : it looks like snow. But some areas of certain aircraft can fool you. For example, most jet engine intakes have a built-in heater to keep the intake clear of ice in flight and on the ground. If melted ice in the intake is allowed to refreeze (while overnight, for example) and snow falls on that refreezing water, you'll find what looks like some snow in the intake. Run your hand through it and you'll find a hard lump of ice with a fine cover of snow sitting in the intake.

## TECHNIQUES FOR IMPLEMENTING THE CLEAN AIRCRAFT CONCEPT

- Establish training programs to update crew members on the hazards of winter operations, adverse effects of ice formations on aircraft performance and de-icing and pre-take-off procedures during ground icing operations.

- Establish training programs for maintenance or other personnel who perform aircraft de-icing to ensure thorough knowledge of the adverse effects of ice formations on aircraft performance and flight characteristics, critical components, specific ground de-icing and anti-icing procedures for each aircraft type, and the use of ground de-icing and anti-icing equipment including detection of abnormal operational conditions.

- Establish quality assurance programs to ensure that FPD fluids being purchased and used are of the proper characteristics, that proper ground de-icing and anti-icing procedures are utilized, that all critical areas are inspected, and that all critical components of the aircraft are clean prior to departure.

- Perform thorough planning of ground de-icing activities to ensure that proper supplies and equipment are available for forecast weather conditions and that responsibilities are specifically assigned and understood. This is to include service contracts.

- Monitor weather conditions very closely to ensure that planning information remains valid during the ground de-icing or anti-icing process and subsequent aircraft operations. Type or concentration of FPD fluids, de-icing or anti-icing procedures, and departure plans should be altered accordingly.

- De-ice or anti-ice areas that are visible from the cockpit first, starting at the wing tip where practicable, so that during the pre-take-off check the pilot may be assured that other areas of the aircraft are clean. Areas de-iced or anti-iced first will generally freeze first.

- When applicable, use two stage de-icing process where ice deposits are first removed, and secondly all critical components of the aircraft are coated with an appropriate mixture of FPD fluid to prolong the effectiveness of the anti-icing.

- Ensure thorough co-ordination of the ground de-icing and anti-icing process so that the final treatments are provided just prior to take-off.

- Ensure communication with the de-icing/anti-icing crew is maintained at all times. It is essential that the PIC know exactly what surfaces are being treated and when de-icing/anti-icing operations are complete and crews are clear.

- When feasible, provide and use remote sites near the take-off position for de-icing, anti-icing and final inspection, to reduce the time between de-icing and take-off.

- Use multiple aircraft de-icing or anti-icing units for faster and more uniform treatment during precipitation.

- Use FPD fluids that are approved for use by the aircraft manufacturer. Some fluids may not be compatible with aircraft materials and finishes, and some may have characteristics that impair aircraft performance and flight characteristics or cause control surface instabilities.

- Do not use substances that are approved for use on pneumatic boots (to improve de-icing performance) for other purposes unless such uses are approved by the aircraft manufacturer.

– Use FPD fluid types and concentrations that will delay ice formations for as long as possible under the prevailing conditions.

## CRITICAL SURFACE INSPECTIONS

Critical surface inspections should be performed immediately after final application of the fluid to verify that the aircraft critical surfaces are free of contamination. (Refer to the *Ground Icing Operations Standards* if applicable to your operation.) Areas to be inspected depend on the aircraft design and should be identified in a critical surface inspection checklist. The checklist should include, at a minimum, all items recommended by the aircraft manufacturer. Generally, a checklist of this type includes the following items:

– Wing leading edges, upper surfaces, and lower surfaces;

– Vertical and horizontal stabilizing devices, leading edges, upper surfaces, lower surfaces, and side panels;

– High lift devices such as leading edge slats and leading or trailing edge flaps;

– Spoilers and speed brakes;

– All control surfaces and control balance bays;

– Propellers;

– Engine inlets, particle separators, and screens;

– Windshields and other windows necessary for visibility;

– Antennae;

– Fuselage;

– Exposed instrumentation devices such as angle of attack vanes, pitot-static pressure probes and static ports;

– Fuel tanks and fuel cap vents;

– Cooling and APU air intakes, inlets, and exhausts; and

– Landing gear.

Once it has been determined through the critical surface inspection that the aircraft is clean and adequately protected, the aircraft should be released for take-off as soon as possible. This procedure is especially important in conditions of precipitation or high relative humidity.

## REPRESENTATIVE AIRCRAFT SURFACES

Air carriers that have established a program in accordance with TC *Ground Icing Operations Standards* may have representative aircraft surfaces designated and approved for their aircraft. Representative surfaces that can be clearly observed by flight crew from inside the aircraft may be suitable for judging whether or not critical surfaces are contaminated. Guidelines for the approval of representative surfaces have been developed.

Many operators have painted a portion of the representative surface in a darker colour to aid in the visual detection of contamination. Some have designated representative surfaces on both sides of the aircraft in the event that, due to strong wind during taxi, one side of the aircraft becomes contaminated before the other.

Research has indicated that fluid failure occurs **last** at the mid chord sections of wings. Therefore, whether painted or not, areas located at mid chord sections of wings and previously used for checking fluid conditions are not suitable for evaluating fluid failure and should no longer be used exclusively as representative surfaces.

Pre-take-off contamination inspections should be concentrated on the leading edge in conjunction with the trailing edge of the wing. Dependent upon aircraft configuration, wing spoilers may also be used to provide an indication of fluid condition.

In addition to the representative surface, other aircraft critical surfaces which are visible from inside the aircraft should be inspected for contamination whenever possible.

While not recommended, if ground operations are to be conducted in freezing precipitation conditions, TC strongly recommends the use of Type II, III or IV anti-icing fluids (in accordance with the aircraft manufacturer's instructions) in order to take advantage of their superior protection characteristics.

**The decision to take off following the pre-take-off inspection is the responsibility of the PIC.**

## HELICOPTERS

For helicopters, ice exacts a very high performance penalty. Take-off with small quantities of ice on the rotor blades can also significantly reduce the autorotative capabilities of the rotor blades. Some of the special problems associated with helicopter operations in ground icing and other types of contamination conditions are outlined as follows:

- Footing during the external inspection, particularly on the upper deck, could be hazardous;

- Ice in inspection panel latches or doors may not allow access to critical areas. Attempting to force panels open may result in expensive damage;

- A coat of ice that has gone unnoticed on the main rotor blades or tips could result in asymmetric shedding during start up. The different blade weights and thrust characteristics results in a dramatic increase in vibration and poor control response. This could cause the aircraft to bounce off the pad and roll over or the pilot lose control on take-off. As well, ice is shed with a force that can be both destructive and deadly;

– An ice build up on the fuselage or moisture that has pooled inside of structures and frozen may cause an adverse shift in the centre of gravity;

– An ice build up on skids or wheels could result in dynamic rollover if only one side breaks free when power is applied;

– An ice build up around exposed hydraulic actuators, or pitch change linkages may bind the controls in one or more axes, causing loss of control on take-off;

– An ice build up on a tail rotor may result in a loss of yaw control when the aircraft is first lifted into the hover. Asymmetric shedding could also cause damage to the airframe or gearbox attachment area;

– An ice build up in the particle separator may partially thaw at low power and be released into the intake with the first high power application. This is likely to occur early in flight at low airspeed, or on climb out, with a restricted land back option.

Following the Clean Aircraft Concept for helicopters is straightforward. The smart plan is to avoid surface contamination by placing the aircraft in a hangar whenever possible. Where operators do not have this option, other measures must be taken.

Here are some suggestions :

– Use waterproof material covers for the main and tail rotors and transmission deck. Ideally, covers will protect the windshield, the pitot static system and a good portion of the fuselage. As well, install inlet and exhaust plugs. Install covers and plugs at the end of each day or whenever the aircraft is not scheduled for use to ensure it is protected during periods of unexpected surface contamination conditions;

– Use a combustion heater with sufficient outlet hose to allow the application of heat to the transmission area, rotor components and engine compartment, and to assist in the removal of frozen covers;

– Remove the covers and then examine the fuselage for contamination to ensure ice or snow from the covers has not fallen onto the fuselage or into engine intakes;

– Remove any contamination adhering to the fuselage or tail boom by any of the procedures outlined for aeroplanes, subject to the aircraft manufacturers' recommendations;

– Free skids, wheels or any part of the landing gear that is frozen to the ground or snow cover

You're part of a flight safety team where every contribution helps. By giving pilots the information they need to make wise decisions you make aviation safer. When in doubt... do it.
.

## HEALTH AFFECTS

We should all be aware of the potential effect on health of de-icing and anti-icing fluids. Proper precautions must be taken during the de-icing and anti-icing process to ensure the well-being of passengers and flight crew. Passengers and crew should be shielded from all FPD fluid vapours by turning off all cabin air intakes during the de-icing and anti-icing process. Exposure to vapours or aerosols of any FPD fluid may cause transitory irritation to the eyes. Exposure to ethylene glycol vapours in a poorly ventilated area may cause nose and throat irritations, headaches, nausea, vomiting, and dizziness.

All glycols cause some irritation upon contact with the eyes or the skin. Although the irritation is described as "negligible", chemical manufacturers recommend **avoiding skin contact with FPD fluids and wearing protective clothing and equipment** when performing normal de-icing and anti-icing operations.

Ethylene and diethylene glycol are moderately toxic for humans. Swallowing small amounts of ethylene or diethylene glycol may cause abdominal discomfort, pain and dizziness, and can affect the central nervous system and kidneys. Because the glycol contained in FPD fluids is considerably diluted with water and other additives, it is unlikely that de-icing personnel could ingest a lethal amount accidentally in the normal performance of their duties. Detailed information on health effects and proper safety precautions for any commercial FPD fluid is contained in the material safety data sheet for that fluid. This sheet is available from the fluid manufacturer and should be on file with the operator providing the de-icing or anti-icing service.

## CONCLUSION

Ground de-icing and anti-icing procedures vary greatly depending primarily on aircraft type, type of contamination accumulation on the aircraft and FPD fluid type. Ground crew should become familiar with applicable Canadian Aviation Regulations and Standards, the procedures recommended by the aircraft manufacturer in the Aircraft Flight Manual, Maintenance Manual and, where appropriate, the aircraft service manual. As well, they should comply with all company operations manual provisions.

Copies of the current CBAACs may be obtained from your Regional Air Carrier representative.

The videos When in Doubt... Small Aircraft, When in Doubt... Large Aircraft, and When in Doubt... Ground Crew, and accompanying booklets, as well as the copies of the current CBAACs may be obtained from the Civil Aviation Communication Center at:

Toll Free : 1-800-305-2059
In the National Capital Area : (613) 993-7284
http://www.tc.gc.ca/aviation