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**Safety and Security** **Sécurité et sûreté**

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# When in Doubt...

## Small and Large Aircraft

## Aircraft Critical Surface Contamination Training

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Canada

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**CAUTION:**
This book 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.

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# PREFACE

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

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

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.**

Merlin Preuss
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 shall be made before take-off or attempted take-off. The type and minimum number of inspections indicated by the regulations, 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 no person shall conduct or attempt to conduct a take-off in an aircraft that has frost, ice or snow adhering to any of its 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 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 a qualified 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 a qualified 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 can produce 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 adhering to the fuselage. The exemption is subject to the following conditions:

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."

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

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.

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 Freezing Point Depressants (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.

Where conditions are such that ice or snow may reasonably be expected to adhere to the aircraft, it must be removed before take-off. In some circumstances, when the Aircraft Manufacturer recommends it, dry, powdery snow can be removed by blowing cold air or compressed nitrogen gas across the aircraft surface. In other 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 de-icing procedures.

**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 cannot be assumed to flow off the wing on takeoff and must be removed, as this layer can also hide a dangerous sheet of ice beneath.

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 contamination 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 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;

- a 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.

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**.

**Freezing Rain Conditions**

Aircraft anti-icing fluids Hold Over Times have not been evaluated under moderate and heavy freezing rain conditions and aircraft have not been certified to fly in freezing rain conditions. The ability of an aircraft to continue to fly safely in these conditions is questionable. Operation of an aircraft during freezing rain conditions should be avoided whenever possible.

**Freezing Drizzle**

Aircraft anti-icing fluids provide greater protection for freezing drizzle than for freezing rain, but similar caution should be exercised as high winds or high taxi speeds can increase the effective precipitation rate for freezing drizzle. Freezing drizzle can also be so light that it is almost imperceptible.

**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.

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) guidelines do not address ice pellet precipitation and the fluids have not been scientifically tested in such conditions. As a result, the HOT guidelines are not a reliable source of predicting fluid failure under ice pellets conditions. Thus, if ice pellets fall after anti-icing fluid has been applied to the critical surfaces of an aircraft, the fluid should be considered as failed.

**Snow Conditions**

Estimating Snowfall Rate

The meteorological approach to estimating snow rate has always been based on visibility alone. Scientific research has indicated that the use of visibility in snow as the sole criteria for establishing snowfall rate/intensity is invalid. The evidence indicates that a visibility and temperature pair needs to be used for establishing more accurate snowfall rates. The highest snowfall rates occur near 0° C. The Visibility in Snow versus Snowfall Intensity Chart contained in the Transport Canada HOT Guidelines document is based on Research sponsored by TDC and published as: "*TP14151E Relationship between Visibility and Snowfall Intensity;* Transportation Development Centre, Transport Canada; and "*Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility",* Transportation Development Centre, Transport Canada, November 1998.

For example, based upon the 2003 Transport Canada Visibility in Snow vs. Snowfall Intensity Chart, assume that the daytime visibility in snowfall is 1 statute mile and that the temperature is –7° C. Using the "Visibility in Snow vs. Snowfall Intensity Chart" (Table 1), for this example, we conclude that the snowfall rate is light. This snowfall rate will be used to determine which HOT Guideline value will be appropriate for the fluid in use.

**Table 1. Visibility In Snow vs. Snowfall Intensity Chart**[1]

| Lighting | Temperature Range | | Visibility in Snow (Statute Miles) | | | |
|---|---|---|---|---|---|---|
| | ºC | ºF | Heavy | Moderate | Light | Very Light |
| Darkness | -1 and above | 30 and above | ≤ 1 | >1 to 2½ | >2½ to 4 | >4 |
| | Below -1 | Below 30 | ≤ 3/4 | >3/4 to 1½ | >1½ to 3 | >3 |
| Daylight | -1 and above | 30 and above | ≤ ½ | >½ to 1½ | >1½ to 3 | >3 |
| | Below -1 | Below 30 | ≤ 3/8 | >3/8 to 7/8 | >7/8 to 2 | >2 |

1 Based on: *Relationship between Visibility and Snowfall Intensity* (TP 14151E), Transportation Development Centre, Transport Canada, to be published in November 2003; and *Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility* (TP 12893E), Transportation Development Centre, Transport Canada, November 1998.

**HOW TO READ THE TABLE**

Assume that the daytime visibility in snowfall is 1 statute mile and the temperature is -7°C. Based on these conditions, the snowfall intensity is light. This snowfall intensity is used to determine which holdover time guideline value is appropriate for the fluid in use.

**Snow Column Cells in the HOT Guidelines.**

The capability of anti-icing fluid to tolerate a heavy snowfall rate has not been evaluated, therefore holdover times for heavy snow conditions have not been generated. In continuous heavy snow, operations should be suspended as the holdover times are extremely short and inspections of the surfaces cannot guarantee safety. Operations during occasional 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 regardless of the time that has elapsed since anti-icing occurred. Such an inspection can only be carried out when the applicable moderate snow holdover time is a minimum of 20 minutes. There must be at least 5 minutes of moderate snow holdover time remaining after the inspection has been accomplished. The take-off needs to be initiated within five minutes of completion of the inspection. Further delay after inspection should result in a return for de-icing/antiicing.

Type I fluid is particularly vulnerable to sudden failure and therefore must not be used as an anti-icing fluid during heavy snow conditions. During light to moderate snow conditions a take-off may be initiated without inspection provided that the lowest number/value in the appropriate snow cell range has not been exceeded. During variable snow conditions the most conservative HOT table cell time should be utilized, which means, the lowest time.

## 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 2, 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 formulations 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.

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. The general characteristics of these fluids are outlined in Table 2.

**Table 2. General Characteristics of Types I, II and IV FPDs**

| Common Name | Colour | Primary Active Ingredients | Viscosity | Primary Use | Notes |
|---|---|---|---|---|---|
| SAE Type I<br><br>ISO Type I | Orange | Propylene/ diethylene ethylene glycol | Low | De-icing | 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. |

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

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.

The de-icing process can be sped up considerably by using the physical energy of high-pressure spray equipment and heat, 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 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 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)**

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

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.

SAE and ISO Type II fluids 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, 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, refer to the fluid manufacturer or supplier for compatibility information. As well, the use of Type II fluid over badly contaminated Type I fluid will reduce the effectiveness of Type II fluid.

**Type III Fluids (No Colour Defined Yet)**

Type III is a thickened FPD fluid that 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. 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. Although the Type III HOT table has been published, at the time of printing this document there were no qualified Type III fluids available.

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

Type IV anti-icing fluids meet the same fluid specifications as the Type II fluids and have a significantly longer HOT. Therefore, SAE and ISO Type IV fluids should be used on aircraft with rotation speeds ($V_r$) above 100 knots. In recognition of the above, holdover time guidelines are available for Type IV fluids.

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.

**<u>Research has indicated that if the fluid is not applied correctly, the HOT guideline values are not achievable.</u>**

**Qualified Fluids**

A list of *Qualified* de-icing and anti-icing fluids is included on the TC website in the Transport Canada HOT guidelines. 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 and to confirm aerodynamic acceptability during simulated take-off conditions.

**When HOT guidelines are used in determining safe take-off criteria the operator of the aircraft is ultimately responsible for ensuring that only qualified fluids are used.**

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 that do not currently appear in the Transport Canada HOT guidelines. However, the operator will be required to prove that fluids not on the qualified 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.

**FPD Fluid Strength When Applied**

The ratio of FPD fluid 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).

**<u>Do not</u> 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.

## LOWEST OPERATIONAL USE TEMPERATURE (LOUT)

Just as an aircraft has a specific operating envelope within which it is approved to be operated, de/anti-icing fluids are also tested and qualified for operation within a specific envelope. The qualification of de/anti-icing fluids, also called freezing point depressants (FPD), is a complex and thorough process, which evaluates a multitude of fluid properties and characteristics. The one of particular interest in this case is the lowest operational use temperature (LOUT).

The LOUT for a given fluid is the higher of:

- The lowest temperature at which the fluid meets the aerodynamic acceptance test for given aircraft type, or
- The actual freezing point of the fluid plus its freezing point buffer of 10°C, for a Type I fluid, and 7°C for a Type II or IV fluid.

What does the aerodynamic acceptance test for a given aircraft type mean?

Laboratory tests are conducted on fluids to determine their characteristics as their temperatures are lowered. Typically the colder the fluid the more viscous it becomes and the more difficult it will be for the fluid to flow off the lifting surfaces. The aim of the aerodynamic acceptance test is to determine the coldest temperature at which the fluids have acceptable aerodynamic characteristics as they flow off the lifting surfaces.
There are two types of aerodynamic tests, one is called a high speed aerodynamic acceptance test which is applicable to fluids used on large transport jet aircraft with rotation speeds in excess of 100 knots and ground acceleration times greater than 23 seconds. The low speed aerodynamics test is applicable to fluids used on aircraft with rotation speeds in excess of 60 knots.

What is the implication of having a freezing point buffer?

The freezing point of a fluid is normally a function of the glycol concentration. An assessment of the fluid concentration can be performed in the field by measuring the refractive index of the fluid. The magnitude of refraction (how much light bends) is related to the concentration of glycol in the solution and hence the freezing point.
Fluid manufacturers provide fluid specification charts that correlate refraction index, also called BRIX, versus fluid freezing point. Since there could be some error in reading the BRIX, or the skin temperature could be lower than the outside air temperature, it was decided to add a safety buffer to all the calculations, and a value of 10°C was agreed for Type I fluids, by the SAE G-12 Fluids sub-committee, and 7°C for Types II & IV fluids.

An example of establishing a LOUT.

Lets take as an example a Type I fluid that has met the aerodynamics acceptance test down to –45°C. The reported freezing point of the fluid (as measured by the service provider) is –43°C.

The OAT is –39°C.

Can this fluid be used to de-ice the aircraft under these conditions?

The LOUT for a given fluid is the **higher** of:

- The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type, in this case –45°C**;** or
- The actual freezing point of the fluid plus a freezing point buffer of 10°C, in this case - 43°C + 10°C = -33°C.

The LOUT is –33°C and since the OAT is –39°C, **this fluid as is, can't be used**.

**Manufacturers state that a fluid must not be used when the outside air temperature or skin temperature is below the LOUT of the fluid.**

## TYPE II and TYPE IV FLUID DRYOUT

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.

There have been reported incidents of restricted movement of flight controls surfaces, while in flight, which has been attributed to fluid dryout. Further testing has shown that diluted Type II and Type IV fluids can produce more of a gel residue than neat fluids.

Dryout may occur with repeated use of Type II and Type IV fluids without prior application of hot water or without a heated Type I fluid mixture. The result can be that fluid will collect in aerodynamically quiet areas or crevices. The fluids do not flow out of these areas during normal take off conditions. These residues have been known to re-hydrate and expand under certain atmospheric conditions, such as during high humidity or rain. Subsequent to re-hydration, the residues may freeze, typically during flight at higher altitudes. The re-hydrated fluid gels have been found in and around gaps between stabilizers, elevators, tabs and hinge areas. The problem can be exacerbated for aircraft without powered controls. Pilots have reported that they have had to reduce their altitude until the frozen residue melted, which restored full flight control movement.

A number of European Air Operators have reported this condition when they have used a diluted Type II or Type IV fluid as a first step and then a concentrated Type II or Type IV as a second step, in their de/anti-icing procedure. North American Air Operators, to date, have not reported this situation. It is suggested that the use of heated Type I fluid/water high pressure washing may alleviate the occurrence of fluid dryout. Such routine procedures may result in the requirement for more frequent lubrication of components. Special attention should be paid the aerodynamically quiet areas such as: gaps between stabilizers, elevators, tabs, and hinge areas.

## DE-ICING AND ANTI-ICING PROCEDURES

**CAUTION:**

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

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. Pilots may call ATC and request information about anticipated delays before de-icing and anti-icing is commenced. Controllers can assist pilots by giving them the best available information about delays, so the pilot may arrange to have the aircraft de-iced and anti-iced as closely as possible to the actual departure time.

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. SAE ARP4737A has been issued and recommends de-icing and anti-icing procedures.

### 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 guidelines 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.

Figure 1 demonstrates how an aircraft must be systematically and symmetrically 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.

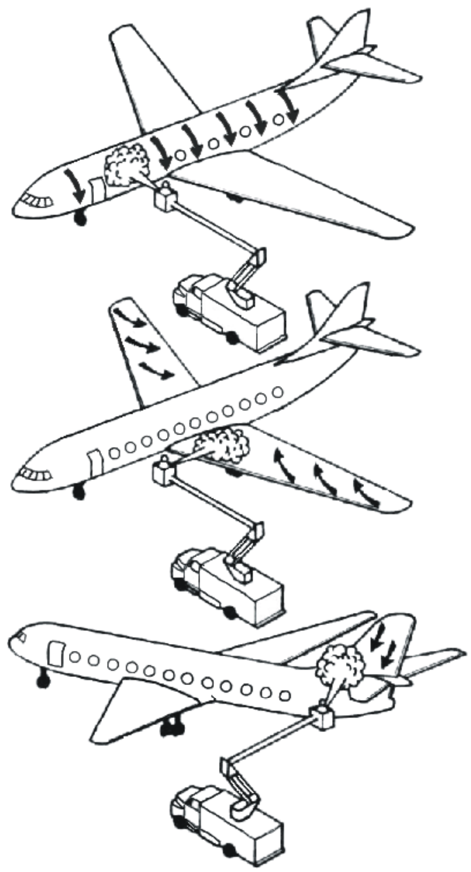

**Figure 1. Systematic and symmetrical de-icing of aircraft.**

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.

**CAUTION: taxiing in wet/slush conditions, even after de/anti icing, may contaminate flap/slat and landing gear door/sensor surfaces and may cause takeoff and/or after takeoff problems. Most Manufacturers recommend that flap/slat devices be deployed just prior to takeoff and taxi speed reduced to minimize splashed contaminants from freezing to landing gear door/sensor surfaces.**

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 engine damage.

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 manufacturers recommended procedures established for their aircraft.

**Ground De-Icing/Anti-Icing With Main Engines and/or APU 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:

- Configure the aircraft in accordance with Manufacturers specifications;
- 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, flameout 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”

## FORCED AIR DE-ICING

Airlines have shown increased interest in the use of forced air deicing to blow frozen contaminants off an aircraft surface, corresponding to the development by several manufacturers of forced air systems mounted on conventional deicing vehicles.

Some forced air deicing systems use high-pressure air or an air/fluid mix, while others are based on delivering large air volumes at low pressure. Some nozzle arrangements deliver air at a very high speed from the nozzle. A columnar air stream can be maintained over an extended distance to lengthen the effective reach of the high-speed air stream. Other designs demonstrate a very rapid decrease in speed of the air stream after it exits the nozzle. The air stream exiting the nozzle may be hotter than the ambient air because of the heat of compression.

Because the use of forced air systems is a relatively new process, no firm recommendations on operational use of those tested systems can be made. Some operators have been authorized to utilize forced air deicing to remove dry snow.

## CENTRAL and REMOTE DE-ICING

Some facilities employ remote deicing that is conducted near the end of the active runway. This practice has diminished in the last few years in favour of central facilities that can capture and recycle spent fluid, for environmental reasons.

Certain large airports have created highly automated and efficient Central Deicing Facilities that can accommodate many aircraft at one time. They employ the latest technology to expedite and control the flow of aircraft from the gate area to the deice pads which in turn minimizes takeoff delay time after the de/anti-ice procedure.

State of the art deice vehicles along with highly trained crews ensure that deicing operations are conducted efficiently and safely. The facilities have underground storage tanks that house fluid reserves and capture the runoff fluid from the aircraft for recycling purposes. They have the ability to adjust the amount of FPD in deicing fluid, called ”Proportional Mixing” or “Variable Blend”, for the given conditions. This process utilizes the automation of these facilities to adjust the fluid concentrations for the given weather conditions, which in turn become a cost savings for the operators. One operator has developed a program where all “Remain Over Night” (RON) aircraft are deiced with forced air, when dry snow conditions exist, during quiet hours. This minimizes the amount of deicing operations the next day as well as reducing the amount of deicing fluid utilized.

Voice and data transmission are conducted via set procedures and controlled by centralized operations centers. Controllers here can view each aircraft in the deice bay and its current stage of deicing, as well as maintain contact with each aircraft and the individual deice vehicles. Computer displays installed in the control centers and the deicing vehicles display updated information on aircraft status throughout the entire deice process. Electronic message boards advise Air Crews of their status in the deice pads such as, the type of fluid being utilized, posting the time when final application of fluid commenced, the completion of spraying operations, and radio frequencies to contact ATS when deicing operations has ceased and all deicing crews are clear.

## VARIABLES THAT CAN INFLUENCE HOLDOVER TIME

This section provides a listing of some of the major variables that can influence the effectiveness of FPD fluids, especially when the fluids are being diluted by precipitation:

- Aircraft component inclination angle, contour, and surface roughness;
- Ambient temperature;
- Aircraft surface (skin) temperature;
- FPD fluid application procedure;
- FPD fluid aqueous solution (strength);
- FPD fluid film thickness;
- FPD fluid temperature;
- FPD fluid type;
- Operation in close proximity to aircraft, equipment or structures;
- Operation on snow, slush or wet ramps, taxiways or runways;
- Precipitation type and rate;
- Presence of FPD fluids;
- Radiation cooling;
- Residual moisture on the aircraft surface;
- Relative humidity;
- Solar radiation; and
- Wind speed and direction.

Holdover time guidelines are given in standard tables for different types of fluids, as a function of precipitation type and rate, and temperature to assist pilots (see page 29 for access to current HOT tables).

## 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.

- At non-centralized locations, 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 the aircraft manufacturer approves such uses.

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

## PRACTICES FOR PILOTS TO ENSURE A CLEAN AIRCRAFT

- Be knowledgeable of the adverse effects of surface roughness on aircraft performance and flight characteristics.

- Do not allow de-icing and anti-icing until you are familiar with the ground de-icing practices and quality control procedures of the service organization.

- Be knowledgeable of the function, capabilities, limitations, and operations of the ice protection systems installed on the aircraft.

- Be aware the FPD fluids used during ground de-icing and anti-icing are not intended for, and do not provide, ice protection during flight.

- Be knowledgeable of ground de-icing and anti-icing practices and procedures being used on your aircraft, whether this service is being performed by your company, a service contractor, a fixed base operator, or others.

- Be knowledgeable of critical areas of your aircraft and ensure that these areas are properly de-iced and anti-iced.

- Ensure that proper precautions are taken during de-icing process to avoid damage to aircraft components and surfaces.

- Ensure that de-icing and anti-icing are performed at the latest possible time before taxi to the take-off position.

- Ensure that the mandatory critical surface inspection is performed following the final application of FPD fluid.

- Be aware that the time of effectiveness (holdover time) of FPD de-icing or anti-icing treatments can only be estimated because of the many variables that influence this time.

- Be knowledgeable of the variables that can reduce holdover time and the general effects of those variables

- 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.

- Do not start engines or engage rotor blades until it has been determined that all ice deposits have been removed and that all ground personnel and equipment are clear. Ice particles shed from rotating components may damage the aircraft or injure ground personnel.

- Be aware that certain operations, such as power back, may produce recirculation of ice crystals, snow, or moisture.

- Be aware that operations in close proximity to other aircraft can cause snow, ice particles or moisture to be blown onto critical aircraft components, or can cause dry snow to melt and refreeze.

- When aircraft are operating on slush or wet surfaces, ground crew should be particularly alert for contamination of the wheel wells, the underside of the belly and the control surfaces. Do not take-off if snow or slush is observed splashing onto critical areas of the aircraft, such as wing leading edges, during taxi.

- Be aware that SAE and ISO Type II and Type IV fluids should be used on aircraft with rotation speeds ($V_r$) above 100 knots.

- Do not take-off if you cannot positively ascertain that the critical surfaces are clean.

## 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.

## PRE-TAKE-OFF CONTAMINATION INSPECTION

As required by regulations, immediately prior to take-off, a pre-take-off inspection shall be made to determine whether frost, ice or snow is adhering to any of the aircraft critical surfaces, except where the operator has established a program in accordance with the *Ground Icing Operations Standards* and complies with that program. The pilot may need the assistance of qualified personnel to perform this inspection.

Unless other procedures have been specifically approved, a tactile external inspection must be conducted on all aeroplanes without leading edge devices (i.e., hard-wing), such as the DC9-10, the CRJ-50 and the F-28.

The components that can be inspected vary according to aircraft design. In some aircraft, the entire wing, and portions of the empennage are visible from the cockpit or the cabin. In other aircraft, these surfaces are so remote that only portions of the upper surface of the wing are in view. The under surface of wings and the landing gear are visible only in high wing type aircraft. A practice in use by some operators is to perform a visual inspection of wing surfaces, leading edges, engine inlets, and other components of the aircraft that are in view from either the cockpit or cabin, whichever provides the maximum visibility. The PIC may call upon the assistance of other qualified personnel. The pre-take-off inspection should concentrate on the leading edge in conjunction with the trailing edge. The trailing edge control surfaces and/or spoilers usually provide an early indication of imminent fluid failure on the leading edge. **If, under any circumstances, the PIC cannot ascertain that the critical surfaces are free of any adhering frost, ice or snow, take-off must not be attempted**.

If any aircraft surfaces have not been treated with FPD fluid, the PIC or another crew member should look for and examine any evidence of melting snow and possible refreezing. In addition, any evidence of ice formation that may have been induced by taxi operations should be removed. If the aircraft has been treated with FPD fluid, aircraft surfaces should appear glossy, smooth, and wet. Frost, ice or snow on top of de-icing or anti-icing fluids must be considered as adhering to the aircraft and take-off must not be attempted. In this case, the aircraft should be returned for additional de-icing and, where appropriate, anti-icing.

Conducting a pre-take-off inspection in the manner described requires the PIC and other crew members, including flight attendants, to be knowledgeable of ground de-icing and anti-icing procedures and danger signs. This inspection should ensure that ground de-icing and anti-icing were conducted in a thorough and uniform manner and that critical surfaces not in view from the cockpit or cabin are also clean.

## REPRESENTATIVE AIRCRAFT SURFACES

Air Operators 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.

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. Tests have shown that first fluid failure occurs in the areas of the leading and trailing edges on aircraft with leading edge devices and that first fluid failure occurs in the areas of the spoilers, wing tip and the trailing edges on hard wing aircraft. (Note: The leading edges should always be checked because they are critical to aircraft performance.)

Pre-take-off contamination inspections should be concentrated on the leading edge close to the fuselage (the wing high lift area) and ahead of the aileron (the roll control area) where these are visible. 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.

The operational advantage of a check from inside the aircraft is obvious in this circumstance. However, as stated in the TC standard, the operator's program must specify the conditions, such as weather, lighting and visibility under which such an inspection may be conducted. In some cases, even the presence of residual de-icing and anti-ice fluid on cabin windows may make a proper visual check difficult or impossible.

In any event, flight crew personnel should be aware that the use of a representative surface for contamination detection might not be feasible in some circumstances. A return to the de-icing facility will be the only safe alternative, if any doubts exist, regarding the condition of the aircraft.

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.**

## TAKE-OFF AFTER HOLDOVER TIMES HAVE BEEN EXCEEDED

In accordance with the operator's program, take-off may occur after holdover time has been exceeded only if a pre-take-off contamination inspection is conducted and it is determined that critical surfaces are not contaminated.

Subparagraph 602.11(4)(a)(i) of the *Canadian Aviation Regulations* (CARs) states: "The aircraft has been inspected immediately prior to take-off to determine whether any frost, ice or snow is adhering to any of its critical surfaces".

Section 622.11 (6.3) of the *Commercial Air Service Standards* (CASS) states, in part: "When holdover time tables are used as decision making criteria, take-off after holdover times have been exceeded can occur only if a pre-take-off contamination inspection is conducted, or the aircraft is de-iced/anti-iced again".

Transport Canada's interpretation of the phrase "inspected immediately prior to take-off", in the ground icing context, is that the inspection must be conducted within **five minutes prior to beginning of the take-off roll.**

Fluid testing has indicated that this procedure must not be applied to Type I fluids. Type I fluids have very short HOT performance and fluid failure occurs suddenly. The procedure should only be applied to Types II, III and IV anti-icing fluids and then only when the pertinent minimum holdover time equals or exceeds 20 minutes.

**If after conducting the contamination inspection it is not possible to take-off within five minutes, the aircraft must return for de-icing/anti-icing.**

## HELICOPTERS

For helicopters the PIC must remember that 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 loses control on take-off. As well, ice is shed with a force that can be both destructive and deadly;

- Above normal torque may be required to hover and taxi;

- 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.

## HEALTH AFFECTS

Pilots must be aware of the potential health effects 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 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. Pilots 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.

You may reproduce this guide as required and it can be found at:
**http://www.tc.gc.ca/civilaviation/general/exams/guides/menu.htm**

Copies of the current Transport Canada Ground Icing Operations Update (TP 14052) and the Holdover Time Guidelines may be obtained from your Regional Commercial and Business Aviation representative or the following website:
**http://www.tc.gc.ca/CivilAviation/commerce/HoldoverTime/menu.htm**

NASA Glenn Research facility has developed numerous in-flight icing media, which address problems, encountered while in-flight such as, tailplane stall, Supercooled Liquid Drops (SLD), aircraft icing certification criteria plus computer based icing training sessions. They are available from: **http://icebox-esn.grc.nasa.gov/**

Or by writing to the following address:
Icing Branch
NASA GRC
21000 Brookpark Rd.
MS 11-2
Cleveland, OH 44135
216-433-3900
216-977-7469 (fax)

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 CBAAC's may be obtained from the Civil Aviation Communication Center at:

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