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PILOT GUIDE



LARGE AIRCRAFT GROUND DEICING

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PREFACE

This advisory circular (AC) contains recommendations for ensuring the safe operation of large airplanes during icing conditions and guidelines for the development of adequate procedures for the deicing of large airplanes. It is designed for the use of flight crewmembers, maintenance and servicing personnel, and other aviation personnel responsible for ground deicing and aviation safety in general. The guidelines and procedures offered in this AC are advisory in nature and do not carry the force of a regulatory requirement. However, prudent operators will find that this information can further enhance safe operations and procedures.

In addition to a brief summary of the information contained in AC 20-117, "Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing," this AC contains recent information and guidance materials regarding advanced deicing and anti-icing fluids and procedures for their use. It recommends adherence to the clean aircraft concept which proposes "get it clean and keep it clean" during operations in adverse weather conditions.

This AC has been reproduced in a size and format that makes it easily added to flight manuals and checklists, or carried in flight cases. This AC does not change or interpret agency regulations and does not authorize deviations from regulatory requirements.



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CONTENTS

Page

Preface	i
Introduction	1
Clean aircraft concept	4
Practices for pilots to ensure a clean aircraft	5
Post-deicing/anti-icing check	7
Pretakeoff check	8
Need for a clean aircraft	9
Frozen contaminants	10
Deicing and anti-icing fluids	11
Traditional North American fluids	14
International Standards Organization (ISO) commercial fluids	14
U.S. military aircraft deicing fluids	16
Characteristics of Freezing Point Depressant (FPD) fluids	16
Temperature buffer	18
Current Federal Aviation Administration (FAA) recommendations	19
Variables that can influence holdover time	20
Health effects	21
Deicing and anti-icing procedures	21
Recommended use of deicing/anti-icing codes	23
Deicing of aircraft surfaces	24
Deicing the engine area	28
Clear ice phenomena	28
Central and remote deicing	29
Techniques for implementing the clean aircraft concept	29
 Appendix 1, Application guidelines tables	 (5 pages)

INTRODUCTION

Federal Aviation Regulations (FAR) prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, control surfaces, engine inlets, and other critical surfaces of the aircraft. This rule is the basis for the ***clean aircraft concept***. It is imperative that takeoff not be attempted in any aircraft unless the pilot-in-command (PIC) has ascertained that all critical components of the aircraft are free of frozen contaminants.

The clean aircraft concept is essential to safe flight operations. The ***PIC has the ultimate responsibility*** to determine if the aircraft is clean and that the aircraft is in a condition for safe flight. This requirement may be met if the PIC obtains verification from properly trained and qualified ground personnel that the aircraft is ready for flight. The general consensus of the aviation community is that a critical ingredient in ensuring a safe takeoff in conditions conducive to aircraft icing is visual and/or physical inspection of critical aircraft surfaces and components shortly before takeoff.

Common practice developed by the North American and European aviation communities is to deice and, if necessary, to anti-ice an aircraft before takeoff. This is accomplished most commonly by the use of heated aqueous solutions of Freezing Point Depressant (FPD) fluids for deicing, followed by anti-icing using cold, rich solutions that are thicker and have a lower freeze point. Several different types of FPD fluids have been developed during the past 40 years, and many are in common use today. Each of these various fluids has unique characteristics and requires handling unique to that particular fluid. More recently developed fluids, such as those identified as International Standards Organization (ISO) Type II and Society of Automotive Engineers (SAE) Type II, will last longer in conditions of precipitation and afford greater margins of safety if they are used in accordance with aircraft manufacturers' recommendations.

If improperly used, these fluids can cause undesirable and potentially dangerous changes in aircraft performance, stability, and control.

Ground deicing and anti-icing procedures vary depending primarily on aircraft type, type of ice accumulations on the aircraft, and FPD fluid type. *All pilots should become familiar with the procedures recommended by the aircraft manufacturer* in the Aircraft Flight Manual (AFM) or the maintenance manual and, where appropriate, the aircraft service manual.

FAA AC 20-117 provides a basic understanding of frozen contaminants and how they can affect aircraft performance and flight characteristics. Most aircraft manufacturers provide recommended procedures for deicing and anti-icing the aircraft. **The information contained herein is intended for basic understanding purposes and as a quick-reference guide for pilots and others. The pilot must refer to the specific procedures developed for the aircraft.**

The following list provides key points regarding aircraft deicing and anti-icing procedures.

- Most icing-related accidents have occurred when the aircraft was not deiced before takeoff attempt.
- The deicing process is intended to restore the aircraft to a clean configuration so that neither degradation of aerodynamic characteristics nor mechanical interference from contaminants will occur.
- The decision of whether or not to deice an aircraft is an integral part of the deicing process.
- The ultimate responsibility for the safety of the flight rests with the PIC of the aircraft.
- It is essential that the PIC have a thorough understanding of the deicing and anti-icing process and the approved procedures necessary to ensure that the aircraft is clean for takeoff.

- Heated solutions of FPD, water, or both are more effective in the deicing process than unheated solutions because thermal energy is used to melt the ice, snow, or frost formations.
- Unheated FPD fluids or aqueous solutions, especially SAE and ISO Type II, are more effective in the anti-icing process because the thickness of the final residue is greater.
- The freezing point of the final anti-icing coating should be as low as possible. The recommended minimum ambient temperature vs. freeze point buffers are shown below:

<i>Fluid Type</i>	<i>OAT** Range</i>	<i>Buffer</i>
SAE and ISO Type I	All	18°F
SAE and ISO Type II	above 19°F	5°F
SAE and ISO Type II	below 19°F	13°F

- Undiluted SAE and ISO Type II fluids contain no less than 50 percent glycols and have a freeze point of -32°C minimum (-25.6°F).
- SAE and ISO Type II fluids have a longer time of effectiveness (up to 45 minutes in light precipitation) than conventional North American or SAE and ISO Type I fluids.
- A post-deicing/anti-icing check should be performed during or immediately following the ground deicing and anti-icing process.
- A pretakeoff check may be required before takeoff roll is initiated. The pilot may need the assistance of qualified ground crews to perform pretakeoff checks.
- Ice, frost, or snow on top of deicing or anti-icing fluids must be considered as adhering to the aircraft. Takeoff should not be attempted.

** Outside Air Temperature (OAT)

- FPD fluids used during ground deicing are not intended for, and do not provide, ice protection during flight.
- Flight tests performed by manufacturers of transport category aircraft have shown that most SAE and ISO Type II fluid flows off lifting surfaces by rotation speeds (V_R). Some large aircraft experience performance degradation and may require weight or other takeoff compensation. Degradation is significant on small airplanes.
- 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.

CLEAN AIRCRAFT CONCEPT

Test data indicate that ice, snow, or frost 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 percent and increase drag by 40 percent.*

These 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, with the primary influence being surface roughness located on critical portions of an aerodynamic surface. These adverse effects on the aerodynamic properties of the airfoil may result in sudden departure from the commanded flight path and may not be preceded by any indications or aerodynamic warning to the pilot. Therefore, it is imperative that ***takeoff not be attempted*** unless the PIC has ascertained, as required by regulation, that all critical surfaces of the aircraft are free of adhering ice, snow, or frost formations.

More than 30 factors have been identified that can influence whether ice, snow, or frost may accumulate and cause surface roughness on an aircraft and affect the anti-icing abilities of FPD fluids. These factors include ambient temperature; aircraft surface (skin) temperature; deicing fluid type, temperature, and concentration; relative humidity; and wind velocity and direction. Because many factors affect the accumulation of frozen contaminants on the aircraft surface, FPD fluids used for deicing, anti-icing, or both should **not** be considered to have anti-icing qualities for a finite period. There is always a need for close inspection before takeoff.

Numerous techniques for complying with the clean aircraft concept have been developed by the aviation industry. The consensus of the aviation community is that the primary method of ensuring safe flight operations in conditions conducive to aircraft icing is through visual or physical inspection of critical aircraft surfaces to ascertain that they are clean before takeoff. This consensus is valid regardless of the deicing and anti-icing techniques used.

PRACTICES FOR PILOTS TO ENSURE A CLEAN AIRCRAFT

- Be knowledgeable of the adverse effects of surface roughness on aircraft performance and flight characteristics.
- Be knowledgeable of ground deicing 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.
- Do not allow deicing and anti-icing until you are familiar with the ground deicing practices and quality control procedures of the service organization.
- Be knowledgeable of critical areas of your aircraft and ensure that these areas are properly deiced and anti-iced.

- Ensure that proper precautions are taken during the deicing process to avoid damage to aircraft components and surfaces.
- Ensure that a thorough post-deicing/anti-icing check is performed prior to takeoff even though this may also be the responsibility of other organizations or personnel.
- Be knowledgeable of the function, capabilities, limitations, and operations of the ice protection systems installed on the aircraft.
- Perform additional post-deicing checks related to deicing or anti-icing as necessary or as required.
- Be aware that the time of effectiveness of FPD deicing or anti-icing treatments can only be estimated because of the many variables that influence this time (holdover time).
- Be knowledgeable of the variables that can reduce time of effectiveness (holdover time) and the general effects of these variables. See list on page 20 of this AC and AC 20-117.
- Ensure that deicing and anti-icing are performed at the latest possible time before taxi to the takeoff position.
- Do not start engines or engage rotor blades until it has been ascertained that all ice deposits have been removed. Ice particles shed from rotating components may damage the aircraft or injure ground personnel.
- Be aware that certain operations may produce recirculation of ice crystals, snow, or moisture.
- Be aware that operations in close proximity to other aircraft can induce snow, other ice particles, or moisture to be blown onto critical aircraft components, or can cause dry snow to melt and refreeze.

- Do not take off if snow or slush is observed splashing onto critical areas of the aircraft, such as wing leading edges, during taxi.
- Do not take off if positive evidence of a clean aircraft cannot be ascertained.

POST-DEICING/ANTI-ICING CHECK

Post-deicing/anti-icing checks should be performed during or immediately following the ground deicing and anti-icing process. Areas to be inspected depend on the aircraft design and should be identified in a post-deicing 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;
- Antennas;
- Fuselage;

- Exposed instrumentation devices such as angle-of-attack vanes, Pitot-static pressure probes, and static ports;
- Fuel tank and fuel cap vents;
- Cooling and auxiliary power unit (APU) air intakes, inlets, and exhausts; and
- Landing gear.

Once it has been determined through the post-deicing check that the aircraft is clean and adequately protected, the aircraft should be released for takeoff as soon as possible. This procedure is especially important in conditions of precipitation or high relative humidity (small temperature/dew point spread).

PRETAKEOFF CHECK

Shortly before the aircraft takes the active runway for takeoff or initiates takeoff roll, a visual pretakeoff check is strongly recommended. The components that can be inspected vary by 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 wings are in view. Undersurface of wings and the undercarriage are viewable 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 require the assistance of trained and qualified ground personnel to assist in the pretakeoff check.

If any aircraft surfaces have not been treated with FPD fluid, the PIC or another crewmember should look for, and examine any evidence of, melting snow and possible freezing. 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 fluids, aircraft

surfaces should appear glossy, smooth, and wet. If these checks indicate accumulations of ice, snow, or frost, the aircraft should be returned for additional deicing and, where appropriate, additional anti-icing.

Conducting a pretakeoff check in the manner described requires the PIC and other crewmembers to be knowledgeable of ground deicing procedures and danger signs. The post-deicing check should ensure that ground deicing and anti-icing were conducted in a thorough and uniform manner and that critical surfaces or components not in view from the cockpit or cabin are also clean. The pretakeoff check provides final confirmation for the pilot that the aircraft is free of frozen contaminants.

The decision to take off following pretakeoff check remains the responsibility of the PIC.

NEED FOR A CLEAN AIRCRAFT

FAR §§ 121.629, 125.221, 135.227, and 91.527 prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, or control surfaces of an aircraft. This is commonly referred to as the ***clean aircraft concept***. The degradation in aircraft performance and changes in flight characteristics when frozen contaminants are present are ***wide ranging, unpredictable, and highly dependent upon individual aircraft design***. The magnitude of these effects can be significant. It is imperative that ***takeoff not be attempted*** unless the PIC has ascertained, as required by the FAR, that all critical components of the aircraft are free of ice, snow, or frost formations.

Flight safety following ground operations in conditions conducive to icing encompasses the clean aircraft concept. Understanding the need for a clean aircraft requires a knowledge of:

- Adverse effects of ice, snow, or frost on aircraft performance and flight characteristics, which are generally reflected in the

form of decreased thrust, decreased lift increased stall speed, trim changes, and altered stall characteristics and handling qualities;

- Various procedures available for aircraft ground deicing and anti-icing, including the use and effectiveness of FPD fluids;
- Capabilities and limitations of these procedures in various weather conditions;
- Critical areas of aircraft such as the wings and tail; and
- Recognition that *final ensurance of a safe takeoff rests in confirmation of a clean aircraft.*

FROZEN CONTAMINANTS

Frozen contaminants in the form of ice, snow, or frost can accumulate on exterior surfaces of an aircraft on the ground. The type of accumulation on the aircraft surface is a key factor in determining the type of deicing/anti-icing procedure that should be used.

Ice, snow, and frost should be removed before takeoff. Dry, powdery snow can be removed by blowing cold air or nitrogen gas across the aircraft surface. Heavy, wet snow or ice can be removed by using solutions of heated FPD fluids and water or by mechanical means such as brooms and squeegees.

Frozen contaminants can also be removed from the surface of an aircraft by using FPD fluids. There are a number of FPD's available for use on commercial large transport category aircraft. The FPD's used most often are glycol-based fluids produced by a number of North American, European, and Russian chemical manufacturers.

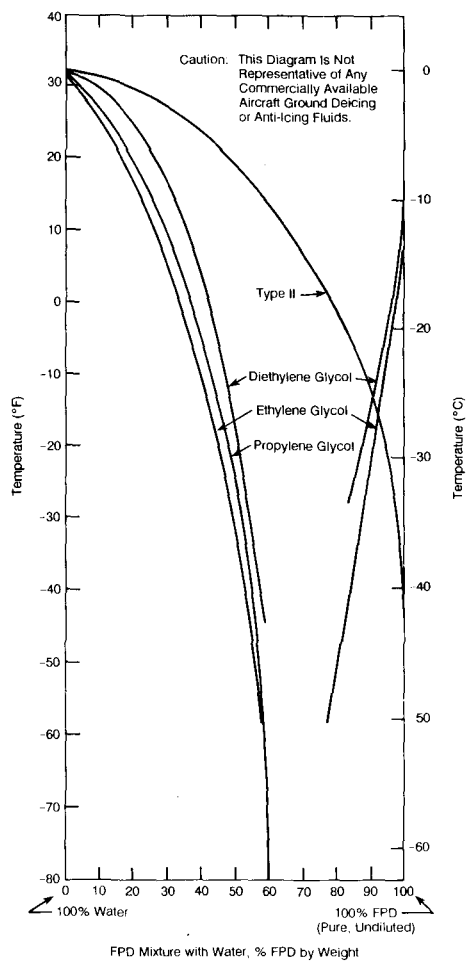
DEICING AND ANTI-ICING FLUIDS

Common practice, developed by the North American and European aviation communities over many years of experience, is to deice and anti-ice an aircraft before takeoff. Various techniques of ground deicing and anti-icing have been developed. The most common of these techniques is to use FPD fluids in the ground deicing process and to anti-ice with a protective film of FPD fluid to delay the reforming of ice, snow, or frost. Commercially available FPD fluids used for aircraft deicing are ethylene glycol or propylene glycol based. Today's FPD fluids have characteristics that are best defined by a phase diagram or freeze chart as shown in figure 1. The general characteristics of these fluids are described in table 1.

Note: Generally, the freeze characteristics of commercially available FPD fluids are based on the "neat" (undiluted premix) solution as furnished by the fluid manufacturer.

The basic philosophy of using FPD fluids for aircraft deicing is to decrease the freezing point of water in either the liquid or crystal (ice) phase. FPD fluids are highly soluble in water; however, ice is slow to absorb FPD or to melt when in contact with it. If frost, ice, or snow is adhering to an aircraft surface, the formation may be melted by repeated application of proper quantities of FPD fluid. This process can be significantly accelerated by thermal energy from heated fluids. 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. If all the ice is not melted, additional applications of FPD become necessary until the fluid penetrates to the aircraft surface. When all ice has melted, the remaining liquid residue is a mixture of water and FPD. The resulting film could freeze (begin to crystallize) with only a slight temperature decrease.

Figure 1. Phase Diagram of Aqueous Glycol Solutions



FPD Mixture with Water, percent FPD by Weight

Table 1. General Characteristics of Commercially Available FPD's

Common Name	Primary Active Ingredients	Viscosity	Primary Use	Notes (see AC 20-117 for more complete information)
North American	Ethylene glycol propylene glycol	Low	Deicing	Includes AMS** 1425, AMS 1427, and Mil-A-8243 fluids. May not meet SAE nor ISO Type I specs.
SAE Type I ISO Type I	Propylene/diethylene ethylene glycol	Low	Deicing	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 Type II ISO Type II	Propylene/diethylene glycol with polymer thickener	High to Low	Deicing and anti-icing	For use on aircraft with $V_R > 85$ 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	Deicing	Less toxic to animals. Not to be used undiluted. Not similar to Mil-A-8243C Type I or II.
Mil-A-8243D Type II	3 parts ethylene glycol, 1 part propylene glycol	Low	Deicing	Similar to Mil-A-8243C Type I and II. Not approved as SAE or ISO Type II.
Arktika (Russia)	Ethylene glycol with thickener	High	Deicing and anti-icing	Not approved as SAE or ISO Type II. Considered thickened Type I. Effects on aerodynamics unknown to date.

**AMS - Aerospace Materials Specification

***AEA - Association of European Airlines

TRADITIONAL NORTH AMERICAN FLUIDS

As shown in table 1, there are various types of FPD's available. These fluids are produced by chemical manufacturers in North America and Europe. The FPD's used to deice aircraft in North America are usually composed of ethylene or propylene glycol combined with water and other ingredients. Users can purchase this deicing fluid in a concentrated form (80 percent-90 percent glycol) or in a solution that is approximately 50 percent glycol with 50 percent water by volume.

ISO COMMERCIAL FLUIDS

These fluids were originally known as AEA Type I and Type II. Specifications for these two types of FPD's are provided in the ISO guidelines as ISO #11075, "Aircraft deicing/anti-icing Newtonian fluids ISO Type I" and ISO #11078, "Aircraft deicing/anti-icing non-Newtonian fluids ISO Type II."

SAE Commercial Fluids.

SAE Type I and Type II fluids are very similar in all respects to ISO Type I and Type II fluids. The minor differences will not be presented in this AC. These FPD's, 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 anti-icing performance.

SAE and ISO Type I Fluids.

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

SAE and ISO Type II Fluids.

These fluids contain a minimum of 50 percent glycols and 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 takeoff. These fluids are used for deicing and anti-icing, and provide greater protection than do Type I fluids against ice, frost, or snow formation in conditions conducive to aircraft icing on the ground.

SAE and ISO Type II fluids are designed for use on aircraft with V_R ***greater than 85 knots***. As with any deicing 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. SAE and ISO Type II fluids are effective anti-icers because of their high viscosity and pseudoplastic behavior. They are designed to remain on the wings of an aircraft during ground operations or short term storage, thereby providing some anti-icing protection, but to readily flow off the wings during takeoff. When these fluids are subjected to shear stress, such as that experienced during a takeoff 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 anti-icing effectiveness of SAE and ISO Type II fluids is dependent upon the pseudoplastic behavior which can be altered by improper deicing/anti-icing equipment or handling. Some of the North American airlines have updated deicing and anti-icing equipment, fluid storage facilities, deicing and anti-icing procedures, quality control procedures, and training programs to accommodate the distinct characteristics of SAE and ISO Type II fluids. Testing indicates that SAE and ISO Type II fluids, if applied with improper equipment, may lose 20 percent to 60 percent of anti-icing performance.

SAE and ISO Type II fluids have been in the process of introduction in North America since 1985. Widespread use of SAE and ISO Type II fluids began to occur in 1990. Similar fluids, but with slight

differences in characteristics, have been developed, introduced, and used in Canada.

U.S. MILITARY AIRCRAFT DEICING FLUIDS

The U.S. Department of Defense has issued military specifications, "Anti-Icing and Deicing-Defrosting Fluids." These documents specify the following types of FPD's:

- MIL-A-4823C Type I—standard
- MIL-A-4823C Type II—standard with inhibitor
- MIL-A-4823D Type I (propylene glycol base)
- MIL-A-4823D Type II (ethylene and propylene glycol mix)

Military Types I and II fluids are essentially the same, except that Military Type II fluids contain a fire inhibitor. ***Military Types I and II fluids are unrelated to SAE and ISO Types I and II fluids*** (see table 1).

CHARACTERISTICS OF FPD FLUIDS

Chemical Composition of FPD Fluids

Commercially available FPD fluids are of the ethylene glycol or propylene glycol family. The exact formulas of various manufacturers' fluids are proprietary. It is important to understand that some commercially available FPD fluids contain either ethylene glycol or derivatives of ethylene glycol, such as diethylene glycol, with small quantities of additives and water. Various FPD manufacturers, upon request, will premix aqueous solutions of FPD for specific customer reasons. Before using a solution of FPD, it is imperative that the ingredients be checked by close examination of the stock number and by a quality control examination to ascertain that the fluid supply conforms to the customer need. FPD fluid

manufacturers can supply methodology and suggest equipment needed for quality control examinations. It is desirable that the pilot understand the criticality of effective quality control.

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 premixed (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 Strength When Applied

Fluid strength or the ratio of FPD ingredients, such as glycol, to water should be known if proper precautions, such as those outlined above, are taken before application. It is crucial to realize that fluid strength is a significant factor in deicing properties, as is the time that the FPD fluid may remain effective (holdover time).

Tables 1 and 2 in appendix 1 present guidelines for holdover times achieved by SAE and ISO Type II and SAE and ISO Type I fluids respectively as a function of weather conditions and OAT.

Do not use pure (100 percent) ethylene glycol or pure propylene glycol fluids in nonprecipitation conditions. The reasons for this caution are explained below.

- The freezing point of pure ethylene glycol is much higher than that 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, ambient temperature cooling, wind effects, and lowered temperature during development of wing lift. If the freezing point of the remaining film is found to be insufficient, the

deicing/anti-icing procedure should be repeated before the aircraft is released for flight.

- Full strength (undiluted) propylene glycol, having a strength of about 88 percent glycol at temperatures less than -10°C ($+14^{\circ}\text{F}$), is quite viscous. In this form, propylene glycol based fluids have been found to produce lift reductions of about 20 percent. Propylene glycol FPD fluids are not intended to be used in the undiluted state unless specifically recommended by the aircraft manufacturer.

TEMPERATURE BUFFER

American Practice

The practice developed and accepted by the North American air carrier industry using traditional North American fluids is to ensure that the remaining film has a freeze point of at least 20°F below ambient temperature.

European and Canadian Practice

The practice developed by the European air carrier industry has been to ensure that the freezing point of residual SAE and ISO Type I fluids is at least 10°C (18°F) below ambient temperature. This is similar to the North American practice, except for metric conversion differences. For SAE and ISO Type II fluids, the freeze temperature should be at least 7°C (13°F) below ambient temperature. This temperature difference between SAE and ISO Type I and SAE and ISO Type II FPD fluids is primarily to accommodate differences in fluid dilution rates which occur in freezing precipitation. Type II fluids, which are thicker, will not dilute to the same extent in a given period of time.

CURRENT FAA RECOMMENDATIONS

Generally the holdover time is increased with an expansion of the temperature buffer. Therefore, if the choice is available, use the maximum buffers. 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 traditional North American and Type I SAE and ISO Fluids, the freeze point buffer of the anti-icing fluid should be as great as possible but not less than 10°C (18°F).

For SAE and ISO Type II Fluids, the freeze point buffer should not be less than those recommended by the SAE and ISO which is currently 7°C (13°F) at ambient temperatures below -7°C (19°F) and 3°C (5°F) at ambient temperatures above -7°C (19°F).

AC 20-117 Recommendation

The FAA's recommendation, published in AC 20-117 in December 1982 and reissued in 1988, is to ensure that the fluid freeze point is at least 20°F (11°C) below the colder of the ambient or aircraft surface (skin) temperature. The reasons for this differential are to delay refreezing of the anti-icing fluid and to take into consideration such factors as:

- **Temperature reduction** during climb or in the production of aerodynamic forces, and the possibility that residual fluids (on surfaces, in balance bays, etc.) will freeze at altitude;
 - **Freezing potential** in conditions conducive to icing. As freezing precipitation or moisture from any source contacts and is absorbed by the residual anti-icing fluid, the freeze point is
-

increased. A greater temperature buffer provides a longer holdover time due to this effect; and

- **Quality control** margin for error.

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. The influence of these variables on the FPD fluids' time of effectiveness is described in detail in appendix 3 of AC 20-117. These major variables include:

- 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 other aircraft, equipment, and structures;
- Operation on snow, slush, or wet ramps, taxiways, and runways;
- Precipitation type and rate;
- Presence of FPD fluid;
- Radiational cooling;
- Residual moisture on the aircraft surface;
- Relative humidity;
- Solar radiation; and
- Wind velocity and direction.

HEALTH EFFECTS

Pilots must be aware of the potential health effects of deicing and anti-icing fluids in order to ensure that proper precautions are taken during the deicing and anti-icing process and to better ensure the well-being of passengers and flightcrew. Passengers and crew should be shielded from all FPD fluid vapors by turning off all cabin air intakes during the deicing and anti-icing process. Exposure to vapors or aerosols of any FPD fluid may cause transitory irritation of the eyes. Exposure to ethylene glycol vapors 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 and wearing protective clothing when performing normal deicing operations.

Ethylene and diethylene glycol are moderately toxic for humans. Swallowing small amounts of ethylene or diethylene glycol may cause abdominal discomfort and pain, dizziness, and effects on the central nervous system and kidneys. Because the glycol contained in FPD fluids is considerably diluted with water and other additives, it is highly unlikely that deicing personnel would ingest anything close to a lethal amount (3 to 4 ounces of pure glycol). 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 which is available from the fluid manufacturer and should be on file with the operator providing the deicing or anti-icing service.

DEICING AND ANTI-ICING PROCEDURES

Depending on the type of accumulation on the surface of the aircraft and the type of aircraft, operational procedures employed in aircraft ground deicing and anti-icing vary. 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, the SAE and ISO. Tables 3 and 4 in appendix 1 relate guidance suggested by the SAE based upon SAE and ISO recommendations.

Pilot training can be accomplished through the use of manuals, films, and, to a limited extent, onsite observation. It is essential that the PIC fully understand effective deicing and anti-icing procedures. An annual review of these procedures by all pilots is required to maintain current knowledge of deicing and anti-icing methods, since the **PIC is responsible** for ensuring that critical aircraft surfaces are free from ice, snow, or frost formations before takeoff. An aircraft may be deiced by any suitable manual method, using water, FPD fluids, or solutions of FPD fluids and water. Heating these fluids increases their deicing effectiveness; however, in the anti-icing process, unheated fluids are more effective. SAE and ISO Type II fluids are more effective for providing anti-icing protection than are traditional North American fluids and SAE and ISO Type I fluids.

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

The **one-step procedure** is accomplished using a heated or, in some cases, an unheated FPD mixture. In this process, the residual FPD fluid film provides a very limited anti-icing protection. This protection can be enhanced by the use of cold fluids or by the use of techniques to cool heated fluid during the deicing process. A technique used commonly in the past is to spray on a final coat of deicing fluid using a very fine mist, applied in an arched trajectory so as to cool the fluid before contact. This produces a thicker fluid film which will have slightly enhanced anti-icing effectiveness. **Exercise caution when using this technique to ensure that freezing has not occurred within the fluid previously applied.**

The **two-step procedure** involves both deicing and anti-icing. Deicing 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 deicing fluid to use. The second (anti-icing) step involves applying a mixture of SAE or ISO Type II and water to the critical surfaces of the aircraft.

When heated water alone is used in the deicing process, the second step must be performed before refreezing occurs--generally within 3 minutes after the beginning of the deicing step. If necessary, the process is conducted area-by-area. As with any deicing or anti-icing fluid, SAE and ISO Type II fluid should not be used unless the aircraft manufacturer has approved its use. SAE and ISO Type II fluids are designed for use on aircraft with V_R in excess of 85 knots. This is to ensure sufficient flowoff of the fluid during the takeoff.

Table 3, appendix 1, contains recommendations developed by SAE and ISO.

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

- Pitot heads and angle-of-attack sensors;
- Control surface cavities;
- Cockpit windows and nose of fuselage;
- Lower side of radome underneath nose;
- Static ports;
- Air inlets; and
- Engines.

The freezing point of residual fluids on aircraft surfaces resulting from FPD fluids mixing with precipitation or melted ice should be at least the values presented in tables 3 and 4, appendix 1. FPD freezing points can be determined by using a refractometer or other similar techniques.

RECOMMENDED USE OF DEICING/ANTI-ICING CODES

Following ground deicing, anti-icing, and inspection by qualified personnel, information supplied to the flightcrew should include the

type of final fluid coating applied, the mixture of fluid (percent by volume), and time of application. This may be transmitted to the pilot by a four element code, such as the following.

Element A	specifies Type I or Type II fluid;
Element B	specifies the percentage of fluid within the fluid/ water mixture (e.g., 75/25 = 75 percent fluid and 25 percent water);
Element C	specifies the local time of the beginning of the final deicing/anti-icing step (e.g., 1330); and
Element D	specifies date (day, written month, year) (e.g., 20 April 1992).

These elements are recommended for use in recordkeeping, and are optional for flightcrew notification.

Examples of the Deicing/Anti-icing Information Format are as follows:

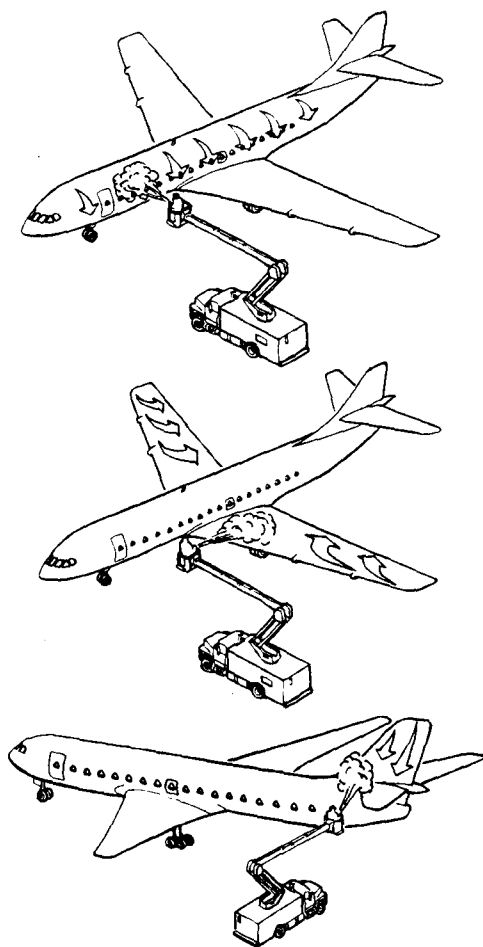
Type II - 100/0 - 1100h - 16 Mar 1991
Type II - 75/25 - 1330h - 20 Apr 1992
Type I - 70/30 - 0942h - 17 Feb 1992

DEICING OF AIRCRAFT SURFACES

An aircraft must be systematically deiced and anti-iced in weather conditions conducive to icing (figure 2). Each aircraft surface requires a specific technique to achieve a clean aircraft.

The wings are the main lifting surfaces of the aircraft and must be free of contaminants to operate efficiently. An accumulation of upperwing frost, snow, or ice changes the airflow characteristics over the wing, 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.

Figure 2. Systematic Deicing of Aircraft in Conditions Conducive to Icing



On most aircraft, deicing of the wing should begin at the leading-edge wing tip, sweeping in the aft and inboard direction. This process avoids increasing the snowload 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.

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 the trailing edge.

The extendable surfaces of the wing (i.e., leading-edge slats and trailing-edge flaps) should be retracted to avoid accumulating frost, snow, or ice during time at the gate or in overnight storage. A surface that is extended in weather conditions requiring deicing and anti-icing should be visually inspected to ensure that the surface, tracks, hinges, seals, and actuators are free of any contaminants before retraction. Flaps and slats retracted during anti-icing will not receive a protective film of FPD fluid and may freeze in precipitation or frost conditions. Consult the aircraft manufacturer to ascertain the most appropriate slat and flap management procedures.

The tail surfaces require the same caution afforded the wing during the deicing procedure. The balance bay area between moveable and stationary tail surfaces should be closely inspected. For some aircraft, positioning the horizontal stabilizer in the leading-edge-down position allows the FPD fluid and contaminants to run off rather than into balance bays. For some aircraft, the horizontal stabilizer must be in the leading-edge-up position during deicing.

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 impeding the movement of the control surface.

The fuselage should be deiced 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., antennas) while deicing. Spraying the upper section with heated FPD fluid first allows the fluid to flow down,

warming the sides of the fuselage and removing accumulations. This is also effective when deicing the windows and windshield of the aircraft, since direct spraying of the surfaces can cause thermal shock resulting in cracking or crazing of the windows. The FPD fluid must be removed from the crew's windows to maintain optimal visibility.

Deicing the top of the fuselage is especially important on aircraft with aft-mounted centerline and fuselage mounted engines. The ingestion of ice or snow into an engine may result in compressor stalls or damage to the engine.

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

Also, special precautions are necessary to ensure that residual fluids do not enter sensitive instrumentation or flow over the cockpit windows during taxi or takeoff.

The cargo and passenger doors must also be deiced and anti-iced in order 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 hatches.

Sensor orifices and probes along the fuselage require caution during the application of FPD fluid. Direct spraying into these openings and resulting fluid residue can result in faulty instrument readings. Also, when protective covers used during applications are not removed, faulty instrument readings can result.

DEICING THE ENGINE AREA

Minimal amounts of FPD fluid should be used to deice the engine area and APU. FPD fluids ingested in the APU can cause smoke and vapors to enter the cabin. Engine intake areas should be inspected for the presence of ice immediately after shutdown. Any accumulation 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. A light coating of deicing fluid applied to the plug may prevent the plugs from freezing to the nacelle.

Fluid residue on engine fan or compressor blades can reduce engine performance or cause stall or surge. In addition, this could increase the possibility of, or the quantity of, glycol vapors entering the aircraft through the engine bleed air system.

Most turbojet and turboprop engine manufacturers recommend, and some AFM's require, that thrust levers be periodically advanced to an N1 rpm of 70 percent to 80 percent during ground operations. This practice prevents ice buildup that can result in reduced thrust, dynamic imbalance of the fan or compressor, or excessive induction of shed ice. The pilot must be aware of these operating procedures and should comply with procedures established for the aircraft.

CLEAR ICE PHENOMENA

Some aircraft have experienced formations of clear ice on the upper surfaces of wings in the vicinity of integral fuel tanks. Such ice is difficult to see and **in many instances can not be detected other than by touch** with the bare hand or by means of special purpose ice detector. These phenomena typically occur on aircraft that have flown high altitude missions for a sufficient time to cold soak the fuel in tanks, and the fuel remaining in wing tanks at the destination is sufficient to contact upper wing skins when rain or high humidity is present. Upperwing frost can also occur under conditions of high relative humidity.

In either case, ice or frost formation on upper wing surfaces must be removed prior to takeoff. Skin temperature should be increased to preclude formation of ice prior to takeoff. This is often possible by refueling with warm fuel.

Clear ice formations of this type can cause aircraft performance changes and can break loose at rotation or during flight, causing engine damage on some aircraft types, primarily those with rear mounted engines.

CENTRAL AND REMOTE DEICING

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

- Reduces the time between deicing/anti-icing and takeoff;
- Facilitates the recycling of FPD in the deicing 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 where adequate facilities exist and if performed by qualified personnel. It should not be substituted for a pretakeoff check unless performed just prior to takeoff.

TECHNIQUES FOR IMPLEMENTING THE CLEAN AIRCRAFT CONCEPT

- Establish training programs to continually update pilots on the hazards of winter operations, adverse effects of ice formations on aircraft performance and flight characteristics, proper use of ice protection equipment, ground deicing and anti-icing procedures, deicing and pretakeoff procedures following ground

deicing or anti-icing, and operations in conditions conducive to aircraft icing.

- Establish training programs for maintenance or other personnel who perform aircraft deicing to ensure thorough knowledge of the adverse effects of ice formations on aircraft performance and flight characteristics, critical components, specific ground deicing and anti-icing procedures for each aircraft type, and the use of ground deicing 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 deicing 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 deicing 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 maintenance service contracts.
- Monitor weather conditions very closely to ensure that planning information remains valid during the ground deicing or anti-icing process and subsequent aircraft operations. Type or concentration of FPD fluids, deicing or anti-icing procedures, and departure plans should be altered accordingly.
- Deice or anti-ice areas that are visible from the cockpit first so that during pretakeoff check the pilot may have assurance that other areas of the aircraft are clean. Areas deiced or anti-iced first will generally freeze first.
- Use the two-stage deicing 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 coordination of the ground deicing and anti-icing process so that final treatments are provided just prior to takeoff.

- When feasible, provide and use remote sites near the takeoff position for deicing, anti-icing, final inspection, and to reduce the time between deicing and takeoff.
- Use multiple aircraft deicing 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 deicing 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.

APPENDIX 1**APPLICATION GUIDELINES TABLES**

This appendix contains guidelines (in tabular format) for the application of Type I and Type II FPD fluids and advisory material on holdover times. These tables were developed by the SAE ad hoc committee on Aircraft Ground Deicing in conjunction with the ISO committee on "Aerospace Aircraft Deicing and Anti-icing Methods With Fluids." This information will continue to be refined as additional data is acquired. These guidelines should only be used by air carriers as a part of, or in conjunction with, an approved ground deicing/anti-icing program.

Table 1. Guidelines for Holdover Times Anticipated by SAE Type II and ISO Type II Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION! THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY AND IT SHOULD BE USED IN CONJUNCTION WITH PRETAKEOFF CHECK PROCEDURES.

OAT		Type II Fluid Concentration Neat-Fluid/Water [% by Volume]	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours: minutes)				
°C	°F		FROST	FREEZING FOG	SNOW	FREEZING RAIN	RAIN ON COLD SOAKED WING
0 and above	32 and above	100/0	12:00	1:15-3:00	0:25-1:00	0:08-0:20	0:24-1:00
		75/25	6:00	0:50-2:00	0:20-0:45	0:04-0:10	0:18-0:45
		50/50	4:00	0:35-1:30	0:15-0:30	0:02-0:05	0:12-0:30
below 0 to -7	below 32 to 19	100/0	8:00	0:35-1:30	0:20-0:45	0:08-0:20	CAUTION! clear ice may require touch for confirmation
		75/25	5:00	0:25-1:00	0:15-0:30	0:04-0:10	
		50/50	3:00	0:20-0:45	0:05-0:15	0:01-0:03	
below -7 to -14	below 19 to 7	100/0	8:00	0:35-1:30	0:20-0:45		
		75/25	5:00	0:25-1:00	0:15-0:30		
below -14 to -25	below 7 to -13	100/0	8:00	0:35-1:30	0:20-0:45		
below -25	below -13	100/0 if 7°C (13°F) Buffer is maintained	A buffer of at least 7°C (13°F) must be maintained for Type II used for anti-icing at OAT below -25°C (-13°F). Consider use of Type I fluids where SAE or ISO Type II cannot be used.				

THIS TABLE DOES NOT APPLY TO OTHER THAN SAE OR ISO TYPE II FPD FLUIDS.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER.

Table 2. Guidelines for Holdover Times Anticipated by SAE Type I and ISO Type I Fluid Mixtures as a Function of Weather Conditions and OAT.**CAUTION! THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY AND IT SHOULD BE USED IN CONJUNCTION WITH PRETAKEOFF CHECK PROCEDURES.**

Freezing Point of Type I fluid mixture used must be at least 10°C (18°F) below OAT.

OAT		Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)				
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING RAIN	RAIN ON COLD SOAKED WING
0 & above	32 & above	0:18-0:45	0:12-0:30	0:06-0:15	0:02-0:05	0:06-0:15
below 0 to -7	below 32 to 19	0:18-0:45	0:06-0:15	0:06-0:15	0:01-0:03	CAUTION! Clear ice may require touch for confirmation
below -7	below 19	0:12-0:30	0:06-0:15	0:06-0:15		

THIS TABLE DOES NOT APPLY TO OTHER THAN SAE OR ISO TYPE I FPD FLUIDS.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER.

Table 3. Guidelines for Application of SAE and ISO Type II Fluids as a Function of OAT

OAT		Minimum Concentration, Heated - Fluid/Water Ratio (% by Volume)		
		One-Step De/Anti-Icing Procedure with SAE OR ISO Type II Fluid	Two-Step Procedure	
°C	°F		First Step Deicing	Second Step Anti-Icing**
above -3	above 27	50/50 heated Type II	Water heated to 60°C (140°F) minimum at the nozzle or a heated mix of Type I or II and water	50/50 Type II
-3 to -7	27 to 19		50/50 heated Type II or heated suitable mix of Type I with freeze point not more than 3°C (5°F) above OAT	
-7 to -14	19 to 7	75/25 heated Type II	75/25 heated Type II or heated suitable mix of Type I with freeze point not more than 3°C (5°F) above OAT	75/25 Type II
-14 to -17	7 to 1	100/0 Type II fluid not suitable for deicing. Consider use of suitable mix of Type I or the two-step procedure		100/0 Type II
-17 to -25	1 to -13			
below -25	below -13	TYPE II used for anti-icing below -25°C (-13°F) must meet aerodynamic acceptance test of AMS 1428, and maintain a buffer of at least 7°C (13°F). Consider use of SAE or ISO Type I where Type II cannot be used.		

Heated fluid - Fluid temperature not less than 60°C (140°F) at the nozzle

Note: FOR OVERNIGHT PROTECTION USE TWO-STEP PROCEDURE, SECOND STEP ANTI-ICING

** To be applied before first step fluid freezes, typically within 3 minutes.

Caution: Aircraft skin temperature and OAT may differ

Table 4. Guidelines for Application of SAE and ISO Type I Fluids as a Function of OAT

OAT		Minimum Concentrations, Heated - Fluid/Water Ratio (% by Volume)		
°C	°F	One-Step De/Anti-Icing Procedure with Type I Fluid	Two-Step Procedure	
			First Step Deicing	Second Step Anti-Icing**
above -3	above 27	Freeze point of heated Type I fluid mixture should be at least 10°C (18°F) below OAT***	Water heated to 60°C (140°F) minimum at the nozzle, or a heated mix of Type I fluid and water	Freeze point of heated Type I fluid mixture should be at least 10°C (18°F) below OAT
below -3	below 27		Freeze point of heated Type I fluid mixture should not be more than 3°C (5°F) above OAT	

Heated fluid - Fluid temperature not less than 60°C (140°F) at the nozzle

Note: FOR OVERNIGHT PROTECTION USE TWO-STEP PROCEDURE, SECOND STEP ANTI-ICING

** To be applied before first step fluid freezes, typically within 3 minutes.

*** Clean aircraft may be anti-iced with cold fluid

Caution: Aircraft skin temperature and OAT may differ