ACRP

FACT SHEETS

AIRPORT COOPERATIVE RESEARCH PROGRAM

Sponsored by the Federal Aviation Administration

De/Anti-Icing Optimization

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

FACT SHEETS

De/Anti-Icing Optimization #42–57; 112

ACRP Report 45

Optimizing the Use of Aircraft Deicing
and Anti-Icing Fluids

AIRPORT COOPERATIVE RESEARCH PROGRAM **2016 (Revised)**

Fact Sheets for De/Anti-Icing Optimization

Introduction

During Phase I of ACRP Project 10-01, an extensive review of the literature on ground de/anti-icing of aircraft was conducted. This included:

- Specific industry technical reports;
- Manufacturer reports;
- Regulatory, government, and industry reports;
- Guidance materials and standards; and
- Technology patents and procedures.

The review produced a list of 34 potential de/anti-icing optimization technologies and procedures. Many of the potential technologies and procedures were deemed to possess technical or operational deficiencies, or to not offer an adequate environmental or operational enhancement, and were thus eliminated during the review process. The promising technologies and procedures were developed singly or in combination into 16 Fact Sheets that were given generic descriptive titles to eliminate commercial or competitive issues.

In 2016, as part of the ACRP Project 02-61 research, the 16 Fact Sheets were reviewed to assess if they reflected current technologies and practices in the industry. That review resulted in updates to Fact Sheets 45, 55, and 56, and the creation of a new Fact Sheet 112.

Documentation of Fact Sheets

This section includes Fact Sheets for the following 17 de/anti-icing fluid optimization technologies and procedures:

Fact Sheet 42: Physical Removal

Fact Sheet 43: Deicing-Only Fluid Buffer Reduction

Fact Sheet 44: First-Step Deicing Fluid Buffer Reduction

Fact Sheet 45: Blending to Temperature

Fact Sheet 46: Proactive Anti-Icing

Fact Sheet 47: Forced Air/Hybrid Deicing

Fact Sheet 48: Holdover Time Determination System

Fact Sheet 49:	Point Detection Sensors to Indicate Fluid Condition and Contamination on Aircraft Surfaces
Fact Sheet 50:	Remote Ice Detection Sensors to Scan Aircraft Critical Surfaces Before Departure Runway
Fact Sheet 51:	Spot Deicing for Frost Removal
Fact Sheet 52:	Tempered Steam Technology
Fact sheet 53:	Threshold Deicing
Fact Sheet 54:	Use of SAE Fluid Dilutions (Type I, II, III, IV)
Fact Sheet 55:	Type III Fluids
Fact Sheet 56:	Infrared Deicing Technology
Fact Sheet 57:	Enhanced Weather Forecasting
Fact Sheet 112:	Low Flow Nozzles

The Fact Sheets follow a format similar to that used in ACRP Project 02-02, "Managing Runoff from Aircraft and Airfield Deicing and Anti-Icing Operations," and presented in *ACRP Report 14: Deicing Planning Guidelines and Practices for Stormwater Management Systems.* This formatting enabled these Fact Sheets to be included within the overall compendium of ACRP Fact Sheets for optimizing the use of de/anti-icing fluids.

Each Fact Sheet includes (1) a description of the technology or procedure, (2) implementation considerations, and (3) cost information. The information included in each of the three sections is described below.

1) The Description section includes:
   - Purpose;
   - Technology; and
   - Documented performance.
2) The Implementation Considerations section includes:
   - Applicability assessment;
   - Regulatory considerations;
   - Planning and design considerations;
   - Integration with other Fact Sheets; and
   - Operation and maintenance considerations.
3) The Costs section includes cost information that in some cases is separated into:
   - Capital costs; and
   - Operation and maintenance costs.

FACT SHEET 42

Physical Removal

1. Description

Purpose

This Fact Sheet provides the opportunity to reduce the volume of conventional aircraft deicing equipment used in wintertime operations by physically (mechanically) removing snow or ice from aircraft. This is in lieu of using, and/or reducing the amount of deicing fluids needed. Manual methods of snow removal are useful in certain circumstances and can be used as long as safety is not compromised.

Physical removal techniques are the responsibility of the aircraft operator or its contracted service provider.

Technology

Physical removal of snow or ice involves manual labor and brooms, ropes, and/or brushes to remove accumulated snow from an aircraft. Hot-air-blast deicing systems may also be used. This requires that care be taken to avoid damage to the aircraft during the process of physically removing snow and ice.

Some of the more common types of physical contamination removal include:

- Brooms;
- Brushes;
- Ropes; and
- Scrapers.

Typically, after snow or ice has been physically removed, a deicing or anti-icing fluid will need to be applied to an aircraft to completely remove any remaining frozen contamination. The application of this fluid will also provide adequate holdover time prior to takeoff.

A Transport Canada (TC) Publication, "Guidelines for Aircraft Ground Deicing" (TP 14052), provides an excellent description of the safe use of brooms, ropes, and scrapers. It also discusses the use of portable forced-air heaters in the removal of frost. TP 14052 can be found on the following website: (http://www.tc.gc.ca/CivilAviation/publications/TP14052).

In addition to the devices described in TP 14052, some operators have employed portable leaf-blowers to remove dry contamination. This approach is particularly applicable and useful in the condition of cold dry snow that is not adhered to the aircraft surface. Fluid deicing can potentially be avoided entirely by blowing away the dry snow. The blown air must be cold to avoid melting of the snow onto the wing, with subsequent refreezing.

Brooms are very useful in cleaning windows and other sensitive areas. They can be used on radomes, static ports, pitot tubes, and other sensitive instruments where the application of hot liquid is best avoided or prohibited.

There is a separate set of technologies that serve to physically remove frozen precipitation during flight. "Boot" deicing systems are often used on smaller propeller aircraft. This technology employs an inflatable pneumatic or hydraulic

Deicing employs an inflatable boot installed on the leading edge of a wing to dislodge hardened ice.

boot, installed on the leading edge of aircraft wings, to crack and dislodge ice from the aircraft. Other mechanical means that have been evaluated on an experimental basis include electrical resistive heating on small aircraft (heating mats applied to the surface of the aircraft). These technologies have no impact on the use of deicing fluids.

Documented Performance

The performance of physical removal techniques is very site-specific, depending on factors such as the type of precipitation and the aircraft fleet mix.

There is a lack of documented performance of this practice. Anecdotal reports indicate that manual approaches to removing contamination are effective in particular circumstances. One such circumstance is the pre-deicing removal of large amounts of snow during early morning hours and removing small accumulations of dry cold non-adhered snow. This eliminates the need for fluid deicing.

2. Implementation Considerations

Applicability Assessment

Physical removal should carefully consider that safety is maintained and the technique used will not damage the aircraft in any way.

Physical removal is most successful with loose precipitation (e.g., dry powdery snow) and smaller aircraft with horizontal surfaces that can easily be accessed by ramp personnel. Larger aircraft, those with high wings, present access and safety issues that make physical removal impractical or unsafe. Protruding sensors or antennae on the surface of an aircraft may also make physically removing contamination impractical.

Items that should be evaluated prior to considering physical removal techniques include the size and configuration of the aircraft, the timeliness required prior to departures, traffic volumes, availability of suitable personnel, and the frequency of dry powdery snow.

Physical removal is more likely to be applicable at general aviation airports due to the smaller size of the aircraft involved. Aircraft operators may consider this process in conjunction with anti-icing protection to reduce the use of aircraft-deicing fluid.

Personnel performing mechanical deicing require training to ensure that they use proper equipment and methods to maintain safety and not damage the aircraft.

Regulatory Considerations

The primary regulatory consideration for the implementation of the physical/mechanical removal techniques is incorporation into the aircraft operator's approved snow and ice control plans. Safety guidelines related to labor (i.e., exposure to the elements, working under slippery conditions, etc.) should also be considered.

Planning and Design Considerations

The following factors should be considered in planning for physical removal:

- Frequency of snowfall that is subject to efficient physical removal;
- Size and configuration of aircraft;
- Staffing and labor requirements;
- Time requirements associated with physically removing snow or ice;
- Number of aircraft requiring the service at peak departure times;
- Equipment to provide personnel with safe access to aircraft surfaces is essential. This may take the form of the open bucket of a deicer or other high-lift vehicle, or a wing inspection ladder; and
- Personnel must be properly trained and should be provided with suitable equipment to avoid damage to highly sensitive and often fragile sensors and navigation antennae. Other such instruments vulnerable to damage are: pitot tubes, static ports, angle of attack sensors, and vortex generators.

Integration with Other Fact Sheets

Physical removal techniques may be employed prior to the application of aircraft de/anti-icing fluids in order to reduce the total amount of fluid required. In these cases, applicable practices (containment/collection, conveyance/storage, and treatment/disposal practices) can be implemented to further reduce the discharge of deicing agents into the stormwater system.

Operation and Maintenance Considerations

The primary operational considerations are worker safety and ensuring that no damage is incurred to the aircraft during the physical removal process.

Because manual methods of snow removal may be very time consuming, their application must be compatible with flight departure schedules.

3. Costs

Equipment costs for manually removing snow from aircraft are relatively small and generally would be covered under operating costs. Equipment acquisition generally would be limited to brooms, ropes, brushes, and access ladders.

Labor costs are the primary component of operation and maintenance costs. Personnel must be provided with suitable equipment for safe access to aircraft surfaces and be properly trained to avoid damage to aircraft components.

The equipment used is generally not sophisticated and does not introduce new or otherwise significant equipment maintenance requirements.

FACT SHEET 43

Deicing-Only Fluid Buffer Reduction

1. Description

Purpose

This Fact Sheet involves the procedure of using a reduced fluid freeze point (FFP) buffer in deicing-only conditions. The procedure is not currently approved by regulatory authorities at this time.

This procedure involves using a deicing fluid with a lower concentration of glycol for cleaning contamination from aircraft surfaces. It addresses the deicing condition when the only requirement is to clean contamination from the aircraft without the need for anti-icing protection. A typical example would be morning start-up following an overnight snowfall. A heated SAE Type I deicing fluid would typically be used for this cleaning operation.

A heated Type I deicing fluid applied to the port wing of a DC-9.

Because this condition is not specifically addressed in SAE Aerospace Recommendation Practice (ARP) 4737, field operators currently follow the guidelines that provide protection against ongoing precipitation. These guidelines require a one-step Type I deicing fluid to have a freeze point of not less than 10°C below ambient temperature. As a result, a higher-than-necessary concentration of glycol is employed in deicing-only conditions.

Application of a reduced fluid buffer for deicing-only conditions (i.e., no need for anti-icing protection) would provide cost savings and reduce environmental impact.

Technology

Many field operators use a more conventional method of fluid blending. Fluids are pre-mixed in holding tanks prior to being placed in truck tanks.

Some field operators are changing to deicing equipment with on-board fluid concentration blending systems. These deicers provide the best means of applying this procedure.

Alternatively, for deicers not equipped with fluid mixers, the deicing fluid would need to be pre-mixed to the required concentration. Guidelines for mixing fluids to specific freeze points are provided by fluid manufacturers.

Documented Performance

Research conducted to examine the results of applying fluid mixes having freeze points above outside air temperature (OAT) was reported in a TC publication entitled “Aircraft Deicing Fluid Freeze Point Buffer Requirements: Deicing Only and First Step of Two-Step Deicing” (TP 13315). Tests were conducted at various ambient temperatures and wind speeds. The research established experimental data to support development of a deicing-only table to serve as an industry guideline.

Initial test data indicated that for diluted Type I fluids (both ethylene and propylene glycol-based), fluid strength increased because of water evaporation following application of the heated fluid. As well, the test surfaces did not experience freezing when the applied fluid was mixed to a freeze point equal to the outside air temperature, regardless of wind speed.

A further detailed examination was reported in another TC publication, "Aircraft Deicing Fluid Freeze Point Buffer Requirements for Deicing-Only Condition" (TP 13478). This research examined how other variables affected fluid enrichment.

Specific recommendations were:

- The deicing-only concept should not be applied during active frost conditions;
- The deicing-only concept should not be applied for cold-soaked wing conditions in conjunction with a level of humidity that could cause active frost deposition on the cold surface;
- Type II propylene glycol-based fluids are unsuitable for the deicing-only procedure; and
- Procedures for the deicing-only concept should encourage the use of generous quantities of fluid, and the protection of heated fluid temperatures by locating the spray nozzle as near as possible to the wing surface.

2. Implementation Considerations

Applicability Assessment

Some larger operators are moving to deicing vehicles equipped with fluid strength blending systems. Such equipment provides the most satisfactory means of taking advantage of the potential of this procedure.

Operational concerns relate mainly to the spray equipment commonly in use, which are not equipped with on-board fluid blenders. To satisfy this procedure, fluid for these deicers would have to be pre-mixed to a specific concentration based on temperatures expected to occur during the operation. When a more dilute fluid is boarded in the truck tanks, there is a greater danger that falling temperatures could lead to freezing in the truck fluid system. Closer attention to forecast conditions is needed to prevent this. In the same vein, protection of fluid systems when the truck is taken out of use following the operation must be managed.

A deicing truck equipped with an on-board fluid blending system.

Many operators currently employ Type I fluid only at its delivered strength (50/50). Although current guidelines allow application of this fluid at lower concentrations both for deicing and anti-icing, these operators have yet to develop the local expertise needed to manage fluid mixes with fluid freeze points closer to ambient temperature.

Regulatory Considerations

This procedure does not have regulatory approval. Guidelines for its use have not been developed or published.

Guidelines for this procedure would need to be developed and must be approved prior to application in the field.

Planning and Design Considerations

For locations equipped with deicers having on-board fluid blending systems, the necessary fluid management systems and expertise would already be in place.

At other locations, local procedures, training, and fluid management controls would need to be developed.

Integration with Other Fact Sheets

This procedure integrates well with the Fact Sheet entitled *Blending to Temperature*. Three different Type I buffers can be considered:

1. First-step deicing fluid buffer of 3°C above ambient temperature (approved in current guidelines);
2. Anti-icing fluid buffer of 10°C below ambient temperature (approved in current guidelines); and
3. Deicing-only fluid buffer (no current guidelines and not approved).

Operation and Maintenance Considerations

Extra care must be taken to prevent freezing of the weaker fluid in truck plumbing systems.

3. Costs

Capital Costs

It is not expected that operators would modify their deicer fleet to on-board fluid blending solely to take advantage of this concept. Thus, additional capital costs are not expected. However, if this procedure was to be approved, it would assist in justifying the capital costs of moving to on-board fluid blending.

Operation and Maintenance Costs

This procedure provides the potential for lower deicing fluid costs as a result of lower concentrations of glycol.

FACT SHEET 44

First-Step Deicing Fluid Buffer Reduction

1. Description

Purpose

In a two-step deicing operation, a first-step heated deicing fluid is applied to clean the surface, and a second-step anti-icing fluid is over-sprayed to provide ongoing protection (holdover time).

This Fact Sheet relates to the limit on freeze point temperature for the first-step fluids. Current SAE ARP 4737 guidelines require that the second-step anti-icing fluid be applied before the first-step fluid freezes, typically within three minutes, and that the freeze point of the first-step deicing fluid be not more than 3°C above outside air temperature. This freeze point constraint may be more severe than necessary. It is possible that a different limit based on scientific research could provide the same levels of safety, while reducing the environmental impact and lowering the cost of the applied fluid.

In the past, some operators had deiced successfully using heated water at ambient temperatures as low as –7°C, applying a first-step fluid having a freeze point temperature 7°C above outside air temperature. At that time, the second-step fluid consisted of a heated application of Type I fluid. The heat from the second-step fluid may have corrected any early freezing. Currently, the second-step fluid is frequently a cold Type II or IV fluid, which would not offer the same inherent early-freezing correction. This past practice ended by industry adoption of SAE ARP 4737 in 1992, which introduced the 3°C limit. The value of the 3°C limit was obtained by consensus and was not based on scientific data.

A procedure using a first-step deicing fluid with a freeze point more than 3°C above outside air temperature would provide a potential means of lowering glycol usage.

Regulatory authorities do not approve such a procedure at this time.

Technology

Deicer manufacturers have developed on-board fluid proportioning systems that mix fluid and water to proportions designated by the operator. Fluid and water are withdrawn from truck tanks and mixed in the plumbing system leading to the spray nozzle. These proportioning systems are available as modifications to existing deicers or as delivered equipment on new units. These deicers provide the most effective means of applying this procedure.

On-board Proportional Blending System

Some deicers may be equipped with tank fluid blending systems that ensure water and fluids are quickly blended to a homogeneous mix.

Alternatively, for deicers not equipped with fluid proportioning systems or in-tank mixers, the deicing fluid may be pre-mixed to the required concentration, either in storage tanks or in the deicer tanks. Care must be taken, especially when mixing in the deicer tanks, to ensure that the fluid and water proportions are completely blended. Guidelines for mixing fluid and water to specific freeze points are provided by fluid manufacturers.

Documented Performance

Research on this subject was reported in the TC Publication entitled "Aircraft Deicing Fluid Freeze Point Buffer Requirements: Deicing only and First Step of Two-Step Deicing" (TP 13315E). This research examined freeze point temperature limits (buffers) for fluids used as the first-step of a two-step deicing operation. Various fluid strengths were tested in different precipitation and wind conditions.

Conclusions drawn from the research were:

- In calm wind conditions, all fluids tested delivered an interval of at least three minutes prior to initiation of freezing, at the lowest test temperature of –14°C;
- Wind exerts a major influence on the time interval available prior to freezing by causing more rapid cooling of the protected surface;
- Dilution of applied fluids occurs very rapidly. At the upper range of light freezing rain (25 g/dm^2/h), the applied fluid film is quickly replaced by rainwater:
  - Type I ethylene-based fluid mixed to –7°C freeze point: 4 to 5 minutes; and
  - Type I ethylene-based fluid at delivered strength (–43°C freeze point): 7 to 8 minutes.
- At the lower precipitation rate of 13 g/dm2/h, (the boundary demarcating freezing drizzle from light freezing rain), Type I ethylene-based fluid dilutes from a –43°C freeze point to a –10°C freeze point in about 3 minutes; and
- In precipitation conditions, the major contributor to the period of protection from the first-step fluid is the temperature of the aircraft surface, which has been heated above ambient by the applied heated fluid.

Several years ago, a European airline reported an incident where ice was found on a wing following takeoff. The aircraft had been deiced and anti-iced using this procedure, which led the operator to question the 3 minute assumption and the adequacy of the fluid freeze point buffer.

In response to the reported incident, APS reviewed data it had previously collected and undertook a research project in the winter of 2005–06 to determine the effect the FFP buffer of first-step deicing fluids has on protection time. This is reported in the TC draft report TP 14714E, "Evaluation of Fluid Freeze Points in First-Step Application of Deicing Fluids."

The status quo –3°C FFP buffer fluid generally provided protection for at least three minutes, but showed weakness in cold temperatures and under high precipitation rates. In conditions where it provided less than three minutes protection time, fluids with higher FFP buffers provided only minimal improvements. This supported the premise that an increased FFP buffer gives longer protection in conditions when it is not needed, but little increase in protection when it is needed.

It was recommended that the current application procedure (–3°C FFP buffer fluid) remain in place and that operators wishing to follow a more conservative approach may choose to increase the FFP buffer of first-step fluids.

2. Implementation Considerations

Applicability Assessment

Some larger operators are moving to deicing vehicles equipped with fluid strength blending systems. Such equipment provide the most satisfactory means of taking advantage of the potential of this procedure.

Operational concerns are mainly related to much of the spray equipment commonly in use, which are not equipped with on-board fluid blenders. To satisfy this procedure, fluid for these deicers would have to be pre-mixed to a specific concentration based on temperatures expected to occur during the operation.

When a more dilute fluid is boarded in the truck tanks, there is a greater danger that falling temperatures could lead to freezing in the truck fluid system. Closer attention to forecast conditions is needed to prevent this. In the same vein, protection of fluid systems when the truck is taken out of use following the operation must be managed.

Many operators currently employ Type I fluid only at its delivered strength (50/50). Although current guidelines allow application of this fluid at lower concentrations both for deicing and anti-icing, these operators have not developed the local expertise needed to manage fluid mixes with fluid freeze points closer to ambient temperature.

Regulatory Considerations

This procedure does not have regulatory approval, and guidelines for its use have not been developed or published.

Guidelines for this procedure would need to be developed and approved prior to application in the field.

Planning and Design Considerations

For locations equipped with deicers having on-board fluid blending systems, the necessary fluid management systems and expertise would already be in place.

At other locations, local procedures, training, and fluid management controls would need to be developed.

Integration with Other Fact Sheets

This procedure integrates well with the Fact Sheet entitled *Blending to Temperature*. Three different Type I buffers could be considered:

1. First-step deicing fluid buffer of 3°C above ambient temperature (approved in current guidelines);
2. Anti-icing fluid buffer of 10°C below ambient temperature (approved in current guidelines); and
3. Deicing-only fluid buffer (no current guidelines and not approved).

Operation and Maintenance Considerations

Extra care must be taken to prevent freezing of the weaker fluid in truck plumbing systems.

3. Costs

Capital Costs

It is not expected that operators would modify their deicer fleet to on-board fluid blending solely to take advantage of this concept. Thus, additional capital costs are not expected. However, if this procedure were to be approved, it would assist in justifying the capital costs of moving to on-board fluid blending.

Operation and Maintenance Costs

This procedure provides the potential for lower fluid costs with the use of lower concentrations of glycol.

FACT SHEET 45

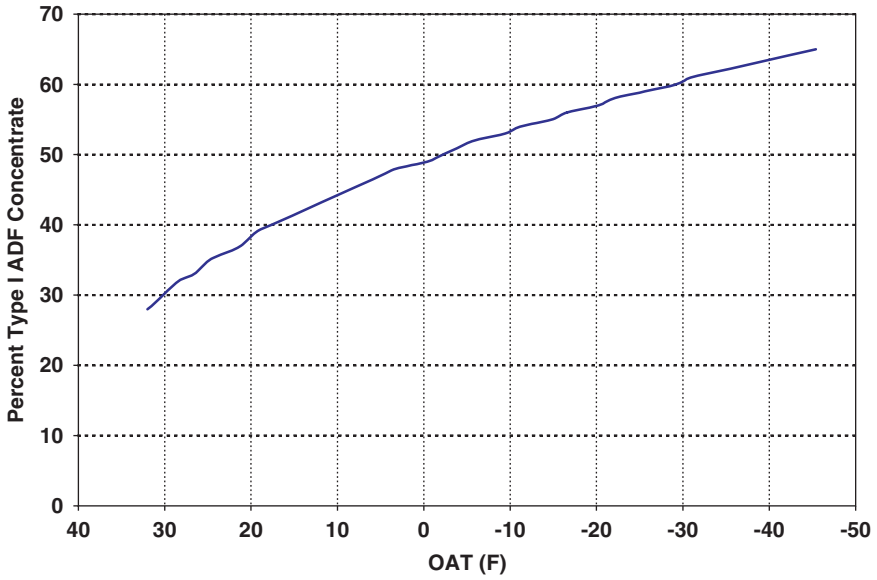
Blending to Temperature

1. Description

Purpose

Blending to temperature is a source reduction practice that reduces the volume of concentrated (or neat) Type I Aircraft Deicing Fluid (ADF) needed for deicing by optimizing the deicer concentration relative to the outside air temperature (OAT). As the OAT rises, a more diluted ADF may be applied without affecting aircraft operations safety. The result is a reduction in glycol use and potential discharge to the environment. This Fact Sheet is not directly applicable to Type II or Type IV aircraft anti-icing fluids because they are not typically diluted prior to use.

Aircraft operators or contracted service providers are normally responsible for the implementation of blending to temperature. Implementation of this practice throughout a facility can be facilitated through airport involvement and coordination of efforts.



ADF manufacturers provide specific guidance on blending their products to different outside air temperatures. (See example chart at left.)

Technology

Manufacturers of ADF provide dilution charts describing the lowest operational use temperature for a range of mixtures. As the OAT rises, a more diluted ADF mixture can be used instead of the standard mixture strength. Examples of how blending calculations are conducted are commonly provided with the product literature.

Any ADF to water ratio below the standard concentration will result in reductions in glycol usage.

Many aircraft operators adopt a standard ADF-water mixture, typically between 45/55 and 60/40, to ensure consistent compliance with regulatory criteria and prescribed safety factors under the full range of anticipated OATs. Any use of mixtures that can be accomplished below the standard concentration will result in reduced glycol use.

Blending can be accomplished in a variety of ways. The simplest involves manual mixing of ADF and water in a deicing truck's tank to the desired concentration.

Blending stations automate the mixing process at a central location and trucks are filled with a mixture strength that is determined to be appropriate for the current and anticipated OAT. The most advanced blending station technology enables deicing trucks to return unused blended deicing fluid to a mixing station. There, additional ADF or water can be added to adjust the ADF concentration as the temperature changes. "Blending on the fly" technology provides the ability to vary the mixture of concentrated ADF and water fed to the deicing application nozzle depending on OAT. These recent developments in equipment technology have made blending to temperature more practicable and reliable.

Documented Performance

The success of this practice varies widely depending on climate and temperature variations. The greatest potential for benefits exists at airports where deicing is conducted mostly at higher OATs.

Because blending to temperature is typically combined with other practices, specific documented performance data is not available. Various individual airport studies, as well as manufacturers' literature estimate reductions in ADF concentrate (and therefore glycol) usage of between 29 and 50% per season. The potential reduction is greatly influenced by facility specific factors, such as typical winter weather, aircraft mix, time of day, and when aircraft deicing is conducted.

2. Implementation Considerations

Applicability Assessment

This is an aircraft operator Fact Sheet, so the first consideration will be the feasibility and acceptability of blending to temperature by the aircraft operators, or contracted service provider, at the airport. The availability of blending technology greatly improves the feasibility of blending to temperature.

Airports may encourage this practice through environmental awareness programs and may go as far as providing central ADF storage and dispensing stations with automated blending equipment. Blending may be implemented in conjunction with centralized deicing systems; however, consideration must be made for infrastructure, such as a water supply, to support blending mixtures at the deicing facility.

Implementation may be constrained by the requirements of various air carriers. For example, fixed base operators (FBOs) or contracted service providers may elect to use a standard conservative blend on all aircraft because individual contracts with different carriers specify unique ADF blends.

Regulatory Considerations

There are no specific environmental regulations that apply to this practice, although reduction of deicing agents in stormwater will generally be viewed favorably by environmental regulatory agencies.

The use of blending to temperature requires adherence to the SAE ARP 4737 specification that residual Type I ADF on aircraft surfaces following deicing must have a freezing point at least 10ºC (18ºF) below the OAT or aircraft skin temperature, whichever is lower. This is commonly referred to as the freezing point buffer. In addition, the practice must be adequately described in an aircraft operator's approved snow and ice control plan.

Planning and Design Considerations

The following factors should be considered in planning implementation of blending to temperature:

- Standard mixtures currently being used by aircraft operators;
- Coordination with airlines and or contracted service provider to define acceptable practices moving forward;
- Distribution of air temperatures during periods of aircraft deicing;
- Suitability to aircraft fleet mix and operations;
- Availability of specialized blending equipment and land/space requirements, if any;
- Availability of water for blending accessible on site;
- Plans for glycol recycling, consideration should be given to efficiency, as it may be affected by the lower glycol concentration; and
- Effective training and quality assurance program.

Integration with Other Fact Sheets

Blending to temperature may be used in conjunction with most other Fact Sheets in the source reduction, containment/collection, conveyance/storage, and treatment disposal categories.

This BMP will reduce the concentrations of ADF in deicing stormwater, with reductions being proportional to the relative amount of aircraft deicing activity conducted at warmer temperatures and the level of implementation at an airport. Glycol recovery operations may be negatively impacted if the volumes of high-concentration runoff are reduced below the level that is critical to the economic viability of recycling.

Operation and Maintenance Considerations

The most significant operational consideration is efficient implementation without affecting aircraft safety. For example, it is important to manage trucks with various concentrations to ensure that the proper concentration is applied to the aircraft. Each facility and situation will present a unique set of opportunities and constraints in this regard.

Where blending is incorporated into a hydrant ADF delivery system, the operation and maintenance of separate service lines for the deicing fluids and water must be considered, along with other equipment and facilities that may be required.

When blending is done at a central station, the rate at which outside temperature changes will be an important consideration. Blending at a station inherently introduces a delay between when the fluid is mixed and when it is applied. This delay can make adjusting the mixture to rapidly changing weather conditions challenging. However, this can largely be avoided by using a larger temperature buffer than the regulatory freezing point buffer of at least 10ºC (18ºF) below the OAT or aircraft skin temperature.

The added complexity involved in blending stations and blend-on-the-fly truck-mounted equipment will increase maintenance requirements.

3. Costs

Capital Costs

It is difficult to assess the capital costs of blending-to-temperature practices because most industry information contains total system or facility wide costs rather than those of individual components of the system. The cost of a single fixed blending station can vary but has been reported by users at $300,000 for the entire unit including the glycol measuring equipment, pumps, etc. In this example the entire system including the concrete pad and electrical utilities cost approximately $480,000.

Operation and Maintenance Costs

Supporting evidence of substantial operations and maintenance savings does exist. The primary savings is through the reduction of glycol use. For example, an airline-sponsored study at a large hub airport concluded that savings of up to $2.5 million per year could be realized if blending-to-temperature mixtures were used. Other studies have suggested potential reductions of up to 30% in ADF use, under relatively optimal climatological conditions (deicing conducted primarily at temperatures above −2ºC). Finally, although it may be difficult to quantify, there is the potential for environmental improvements associated with lower levels of glycol use that may bring cost savings.

FACT SHEET 46

Proactive Anti-Icing

1. Description

Purpose

This Fact Sheet involves the application of aircraft anti-icing agents as a preventative measure, potentially resulting in a reduction in the volume of deicing agents required to ensure that aircraft are free of snow and ice contamination prior to takeoff.

Implementation of this practice would be the responsibility of aircraft operators.

Technology

Proactive anti-icing involves the application of anti-icing agents in advance of an anticipated frozen-precipitation event, therefore reducing the adherence of frozen precipitation on the aircraft and facilitating its removal. Aircraft anti-icing fluids (AAFs) are applied in significantly smaller volumes than deicing fluids, potentially resulting in cost savings to the aircraft operators, as well as reduced environmental impact due to glycol runoff.

Documented Performance

According to testing performed by the U.S. Air Force, proactive anti-icing can reduce the overall volume of glycol-based deicing fluid applied to an aircraft when properly performed prior to the advent of icing conditions. Proactive anti-icing has been found to be most effective under freezing precipitation; it is less effective for heavy snow.

Many airlines have experimented with post-landing application of anti-icing fluid.

Several aircraft operators have experimented with the preventative application of anti-icing agents to aircraft immediately after their landing. The purpose of this practice is to prevent the buildup of frozen precipitation while aircraft are at the gate and to reduce the deicing effort needed prior to their departure. Aircraft with short turnaround times generally require less deicing fluid application prior to departure, depending on weather conditions.

The key to proper implementation of this practice is access to accurate weather forecasts. When used with inaccurate weather forecasts, this practice can result in the application of otherwise unnecessary and excessive amounts of anti-icing fluid and deicing fluids needed to remove the AAF.

Proactive deicing requires an accurate assessment of weather forecasts.

A drawback of preventative anti-icing is that the application of AAF alone has been found to pose a safety risk to aircraft under certain conditions. If a dry period occurs in place of a predicted frozen-precipitation event, the AAF may dry into a residue, only to be rehydrated and refrozen during subsequent storm events. Several aircraft operators have expressed concerns that this refrozen

residue can degrade aircraft parts and limit flight controls. Out of concern for aircraft safety, aircraft that have been anti-iced are often deiced with Type I prior to takeoff in an effort to remove the Type IV residue, even in situations where deicing may not have been otherwise required.

2. Implementation Considerations

Applicability Assessment

This Fact Sheet would be most applicable for aircraft operators or fixed-base operations (FBOs) at airports that typically experience weather conditions during which proactive anti-icing would be an effective alternative or supplement to deicing (freezing rain, for example). Airports that frequently experience heavy snow conditions during the deicing season may not benefit as much from a proactive anti-icing program owing to the reduced effectiveness of anti-icing agents in those weather conditions. Deicing personnel should also consider whether the coordination of proactive anti-icing and deicing activities for arriving and departing flights would cause significant interference with airport operations and/or flight delays.

Regulatory Considerations

The FAA requires that an aircraft be clean prior to take-off in order to meet aircraft safety requirements. If proactive anti-icing is implemented, it must be performed with considerations for aircraft safety and regulations. In many cases, an aircraft will be deiced again prior to takeoff to ensure that all frozen precipitation has been removed and to prevent any buildup of anti-icer residue on the surface of the aircraft. Conservative deicing procedures required to ensure safety have the potential to reduce the documented performance levels of this practice.

Planning and Design Considerations

Application of Type IV anti-icer may result in the formation of a residue that poses a potential aircraft safety risk. The application of hot water or heated Type I fluid in the first step of a two-step process for subsequent deicing operations will minimize the formation of residues.

Aircraft operators and FBOs that are interested in proactive anti-icing should consider the following in their planning and implementation:

- Identify services or equipment for improving weather-forecasting abilities and thereby the accuracy of proactive anti-icing;
- Develop protocols for identifying conditions that are appropriate for proactive anti-icing;
- Develop standard operating procedures for proactive anti-icing, including weather forecasting, anti-icing equipment coordination, anti-icing agent application, and scheduling; and
- Integration with other practices.

The success of proactive anti-icing activities can be increased by using specialized weather-forecasting systems and procedures to identify opportunities for proactive anti-icing. Accurate weather forecasts can help aircraft operators and

FBOs identify weather conditions during which proactive anti-icing is expected to be more efficient than deicing alone and conditions that will not result in the formation of a harmful residue.

Integration with Other Fact Sheets

Proactive anti-icing has the potential to be integrated with most practices. The combination of proactive anti-icing and enhanced weather forecasting tools may be extremely useful to airports and aircraft operators.

Operation and Maintenance Considerations

Operational requirements associated with this practice include the regular monitoring of weather forecasts to identify weather conditions that would be appropriate for proactive anti-icing.

Maintenance requirements for this BMP may include removing residue that could form on aircraft from dried anti-icing materials.

3. Costs

Overall costs include the costs for anti-icing materials and equipment, as well as weather-forecasting or monitoring systems to accurately identify conditions that are beneficial for proactive anti-icing. Potential savings may be achieved where the net cost of all deicers and anti-icers used is reduced.

Capital Costs

The primary capital cost would be for the installation of a specialized weather forecasting system, if applicable. In some instances, additional deicing equipment may be required to meet air traffic demands.

Operation and Maintenance Costs

Operational costs may include additional aircraft anti-icing fluids used; costs associated with subscribing to a specialized weather-forecasting service, and specialized training. Other costs may include the labor and material costs to remove anti-icing material residue from aircraft. Potential cost savings may be achieved through any reduced use of aircraft deicing fluids.

FACT SHEET 47

Forced Air/Hybrid Deicing

1. Description

Purpose

Forced air/hybrid deicing reduces and in some instances eliminates the volume of aircraft deicers required to deice an aircraft. It does so by using a high-velocity stream of air to mechanically dislodge and remove snow and ice. In most applications of this concept, aircraft-deicing fluid can be added to the air stream to aid in breaking loose snow and ice from aircraft surfaces. This is commonly referred to as hybrid deicing.

Forced Air/hybrid equipped deicing truck

This practice is normally implemented by aircraft operators or their contract service providers.

Technology

Forced air/hybrid deicing requires specialized technology and equipment to deliver high-pressure air and controlled Type I ADF mixtures through booms/applicators to the aircraft surface. Some designs also allow the use of air in applying Type IV anti-icing fluids; although special tests on the equipment/fluid combination must first be conducted before the fluid can be applied in this manner.

Deicing trucks can be retrofit to include a force-air system.

Forced air systems are often an optional item on larger, standard deicing vehicles. Deicing vehicle manufacturers have developed forced-air deicing systems that can be installed either at time of manufacture or as a retrofit. The technology can also be employed in a fixed-boom configuration.

Some forced air deicing systems develop a high-pressure flow, while others are based on delivering large air volumes at low pressure. Some nozzle arrangements deliver air at a very high nozzle speed. 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. In all cases, the air stream exiting the nozzle may be hotter than ambient air because of the heat of compression.

SAE Aerospace Information Report (AIR) 5633 describes forced air technology including equipment, safety, operation, and methodology.

Documented Performance

A study to examine safety implications of forced air deicing systems documented the efficiency of cleaning contamination from an aircraft wing. Results were reported in the TC document TP 13664E, “Safety Issues and Concerns of Forced Air Deicing Systems”.

The study found that the increase in wing skin temperatures resulting from forced air deicing (and, to a lesser degree, from fluid injected air) was considerably less than that resulting from the standard nozzle application of heated fluid, and led to a reduced time interval until refreezing occurred.

Forced air tends to be ineffective in removing ice from a wing surface. An air fluid combination has proven to be effective in removing ice contamination.

In tests to remove ice, the use of forced air alone was unable to free the ice from a test-wing surface. The heat within the air stream was insufficient to melt through the ice. The air/fluid combination did melt through the ice but required over 7 minutes to clean the wing, using 174 L of fluid and giving a time-to-refreeze of just under 4 minutes. The standard fluid nozzle cleaned the wing in just over 3 minutes using 250 L of fluid, and time-to-refreeze was 8 minutes.

In tests to remove dry snow the air/fluid combination and the standard fluid nozzle cleaned the test-wing in about the same time. The air/fluid combination used 44 L of fluid and protected the wing from refreezing for less than one minute after deicing, while the standard fluid nozzle used 214 L and refreezing occurred at just under 3 minutes.

The short time-to-refreeze following forced air deicing prevents its use as a one-step deicing process, and raises a serious concern about its suitability as the first-step in a two-step deicing process.

Reported experience with this practice indicates that its performance in field operations is difficult to quantify with confidence and varies significantly with the type of freezing precipitation. The technology has been found to be most effective under dry/powdery snow conditions and least effective when attempting to remove ice that has bonded to the aircraft surface. The table below summarizes some reported results of using forced air/hybrid deicing from facilities where it was found to be practicable. These results should be considered reflective of optimum conditions and may be significantly better than what can be expected under less than ideal conditions.

It should be noted that reports on low effectiveness are generally not quantified, in part because interest in the technology disappears when it is found to not meet the aircraft operator's needs.

Percent Glycol Reduction by User Type.

User Type	% Glycol Reduction	Note
Aircraft operator	85	Predominantly ideal conditions
Contract operation	65	Midwestern airport with centralized deicing pads
Med. hub airport	46–67	Range reflects seasonal comparisons with varying weather

Aircraft operators who have adopted this technology cite the following reasons for the decision.

The time required to clean an aircraft of snow can be reduced under certain conditions:

- A significant reduction in ADF usage over conventional trucks is possible under certain types of weather conditions, such as dry snow and frost;
- There are times, such as during dry snow conditions, when very little ADF is required; and
- The potential source reduction benefits of the technology can assist facilities and airports with maintaining compliance with stormwater regulations.

It should be noted that there may be additional operational efficiencies due to the decreased frequency in refilling deicing fluid tanks.

2. Implementation Considerations

Applicability Assessment

Forced air systems are not approved for use as a one-step deicing process, as this application has not been demonstrated to produce endurance times that satisfy HOT guidelines.

Forced air systems are not approved for the first step of a two-step deicing process unless the use of the system has been tested and shown to be satisfactory. The SAE G12E Equipment Subcommittee has documented a test procedure for this purpose.

Forced air systems can be used very effectively to clean contamination from aircraft surfaces as a pre-step prior to standard fluid deicing. This can be done either with or without Type I fluid injection.

Using forced air to remove most of the snow in a pre-step deicing application prior to the actual deicing operation can speed up the deicing process and markedly reduce the amount of fluid needed to produce a clean aircraft.

Conditions are sometimes encountered where cold dry snow falling onto a cold wing can be seen to be swirled and moved by the wind across the wing surface. It is evident that the snow is not adhering to the wing surface. The application of fluid would result in the snow adhering to the wing, thus it may be counter-productive to spray fluids. However, if snow has accumulated at any location on the wing surface it must be removed prior to take-off. The removal of this snow with a stream of cold forced air may avoid the need to deice the aircraft with fluid, and may speed up the flight departure. A caution is necessary as the airflow from forced air systems typically retains some heat from the compression stage. The air stream temperature diminishes with distance, so it is important to determine how far from the wing the nozzle must be positioned in order to avoid melting of the snow onto the wing surface. This process does not provide a HOT. The surfaces must be checked after cleaning to ensure that no snow has melted and refrozen, adhering to the wing. If ice has adhered to the wing, the standard deicing process using heated deicing fluid must then be applied, followed by an anti-icing procedure producing a HOT.

The key consideration in evaluating potential applicability of this technology is the type of winter precipitation commonly encountered and the effectiveness of the technology in removing it. Dry, powdery snow provides the greatest opportunity in this regard, whereas the technology is least effective where icy conditions and heavy wet snow predominate.

A practical consideration is the age of existing deicing equipment. Newly purchased equipment may not be scheduled for replacement for several years, thus reducing the feasibility of changing to forced air/hybrid application technology.

Regulatory Considerations

There are no specific environmental regulations that apply to this practice, although increased air emissions may be an issue at some airports.

Forced air systems are not approved for use as a one-step deicing process.

Forced air systems are not approved for the first step of a two-step deicing process unless the use of the system has been tested and shown to be satisfactory.

The adoption of forced air/hybrid deicing requires that it be described in an aircraft operator's approved snow and ice control plan.

Planning and Design Considerations

The following items need to be considered prior to planning, designing, and implementing a forced air/hybrid deicing system:

- Climate suited to the technology's strengths;
- Extensive operator-training program, which is key to success;
- Maintenance staff training; and
- Phased procurement as part of regular deicing-truck replacement schedule.

Useful references on the use of forced air for deicing include Transport Canada TP 14052, SAE AIR 5633, and SAE ARP4737.

Integration with Other Fact Sheets

Forced air/hybrid deicing can be integrated with virtually all of the other source reduction Fact Sheets, with the exception of Hangared Parking (#8). This practice is compatible with all of the containment/collection, conveyance/storage, and treatment/recycling practices. Significant reduction in the use of deicing fluids may undermine the economic viability of recycling programs.

Operation and Maintenance Considerations

Standard operations and maintenance associated with deicing vehicles or deicing booms apply. The added complexity of the air blowers and delivery system will increase maintenance and repair requirements.

Specialized operator training and skill development are critical to maximizing the effectiveness of this practice. Specific operational concerns with this technol-

ogy cited by aircraft operators include the possible degradation of the fluids due to shear forces through the application process and excessive foaming, which obstructs the view of the aircraft skin. The techniques are significantly different from conventional deicing trucks, and require more training and practice time to develop and maintain proficiency. Where local weather conditions result in infrequent use of the technology, operators may be challenged to maintain a high level of skill.

Noise due to the high air stream velocity may necessitate hearing protection for operators and for nearby ground service personnel.

Care must be taken to:

- Ensure that ground service personnel are clear of the area before using forced air;
- Ensure that loose debris is not blown into engines or other intakes;
- Avoid blowing ice snow or slush into control surface hinge areas and other cavities. Apply the forced air stream from the wing leading edge to the trailing edge; and
- Ensure that ice removal does not result in impact damage to other surfaces or components.

If used to remove non-adhered cold dry snow, it is important to ensure that the air stream is cold enough to avoid melting of the snow. The surfaces must be checked after cleaning to ensure that no snow has melted and refrozen, adhering to the wing.

Operational efficiencies may result due to increased time intervals between deicing fluid resupply, in particular for deicing vehicles/equipment with deicer fluid tanks. Similarly, operational efficiencies can be realized by using forced air systems to remove accumulated snow versus physical/mechanical removal methods, and the opportunity for damage to the aircraft is minimized.

3. Costs

Capital Costs

The initial capital investment for forced air/hybrid deicing is dependent on the costs associated with the specialized equipment purchase. Anecdotal information from air carriers who use this technology indicates that the incremental cost associated with the addition of a forced air option on a deicing truck is in the neighborhood of $100,000, including a recommended enclosed cab feature.

Operation and Maintenance Costs

Additional maintenance costs may be expected because of the increased complexity of the machinery. Increased fuel consumption is required to operate the air blowers. However, aircraft operators have reported that overall the incremental cost of this technology above conventional equipment may be recovered in savings from reduced deicer usage within several seasons. Costs associated with delayed departures including aircraft operating costs, crew costs, and costs for inconvenienced passengers, may be reduced.

FACT SHEET 48

Holdover Time Determination System

1. Description

Purpose

The industry has long sought tools to assist flight crews in holdover time decision making in winter operating conditions.

The D-ICE A/S Deicing Information Support System (DIIS) is an example of a Holdover Time Determination System.

Holdover Time Determination Systems (HOTDS) record measurements of winter conditions at airports at pre-determined intervals. HOTDS compute a precipitation rate for any weather condition, enabling the calculation of a single-value de/anti-icing fluid HOT for any combination of fluid, ambient temperature, precipitation type, and precipitation rate. The HOT information can then be relayed electronically to crews in the flight deck. A complete report on this topic is available and is entitled "Holdover Time Variance Across an Airfield."

The result of this practice is vastly improved de/anti-icing fluid selection by flight crews, resulting in a wide array of cost savings, environmental benefits, operational efficiencies, and safety enhancements.

Technology

De/anti-icing fluid holdover time table values have been established through rigorous testing employing standardized, scientific test methodologies. Every HOT test is conducted at a precipitation rate that is specific for each winter precipitation condition, and the HOT for any test is determined as a function of this specific precipitation rate and ambient temperature.

Although strict test methodologies have been employed in the development of the HOT guidelines for numerous years, resulting in a significant improvement in the quality of the fluid HOT material available to flight crews, pilots still have little way to interpret the HOT values. The current tools employed by flight crews to assess the intensity of winter precipitation, Aviation Routine Weather Reports (METAR) and visibility tables, are subjective and inaccurate, and contain no quantitative data.

HOTDS contain sensors that measure the three parameters required for fluid HOT determination: rate of precipitation, type of precipitation and ambient temperature. The end result of each combined measurement of these three parameters is a scientific HOT for any given de/anti-icing fluid. A more precise assessment of fluid holdover time enables optimal de/anti-icing usage, consistent with actual measured onsite weather conditions and flight safety requirements.

A HOTDS was tested by APS Aviation at Montreal-Trudeau International Airport from November 2003 to April 2008. The system records ambient weather condition measurements every 10 minutes and calculates updated HOT

information based on quantitative data collected. The system includes weather sensors for precipitation type, precipitation intensity, ambient temperature, and wind speed. Weather measurements are analyzed by the dedicated PC-based software, which calculates HOTs based on the measured weather and ADF holdover time databases. The HOT databases are fluid-specific and represent the same information used to prepare conventional holdover timetables.

An HOTDS can provide real-time updates directly to the flight deck via Aircraft Communication and Reporting Systems (ACARS).

Calculated holdover times are displayed on the PC and can then be transmitted to the flight deck and ground crews. Holdover times are updated every 10 minutes with real-time weather data, and can be updated more frequently if multiple HOTDS units are used.

Other HOTDS products, including a liquid water equivalent system developed by the National Center for Atmospheric Research (NCAR), are currently in the development phase. The data collection intervals, sensor arrays, and specifics of the programming associated with these products may differ from the ones presented herein, but the system outputs are similar and serve the same objectives.

Documented Performance

A HOTDS was tested at Montreal-Trudeau International Airport over five winter seasons. Over 2,500 data points were collected with the system during this period in nearly 100 natural precipitation events, spanning the full range of ambient temperatures and precipitation types. Data from the HOTDS were compared to data collected using historical rate measurement procedures and human weather observations, and the correlation was excellent. In summer 2008, the HOTDS demonstrated compliance with the Minimum Performance Specifications and Quality Assurance Requirements established by TC for use of HOTDS outputs in Canadian air operations (see later section on Regulatory Considerations).

An operational assessment of the HOTDS was also performed at Montreal-Trudeau International Airport from 2004–06. The objective of this work was to compare actual flight crew decisions in winter operating conditions to optimal de/anti-icing fluid decisions that could be made if HOTDS were available. The operational data collection indicated that in 27% of all departures at the airport, flight crew selected to employ thickened Type IV fluids in conditions that did not warrant their use. An additional 4% of all departures took off with exceeded de/anti-icing fluid holdover times. The operational data collection, which was based on a sample of nearly 1,600 departures in a wide range of conditions, indicates the costs savings and safety enhancements that could be achieved through use of HOTDS outputs.

Additional HOTDS equipment is currently under development by other manufacturers, and testing of the systems is underway.

2. Implementation Considerations

Applicability Assessment

The potential cost savings, environmental benefits, operational efficiencies and safety enhancements associated with this practice render it applicable to all

airports and aircraft operators subjected to winter precipitation conditions and the use of fluid holdover time tables.

The benefits associated with the implementation of this practice will vary largely by the size of the operation and, therefore, the capital and operating costs of this practice may limit its widespread applicability to medium- and large-size airports and operations characterized by severe winter weather.

An HOTDS can provide significant cost savings, environmental benefits, and safety enhancements to all airports and aircraft operators.

Regulatory Considerations

TC and the FAA develop and publish the de/anti-icing fluid holdover time tables on an annual basis, and both organizations regulate the usage of the information by air carriers in their respective countries. The shift to automated provision of de/anti-icing fluid holdover time data will therefore require regulatory oversight.

In December 2007, TC issued a regulatory approval process for use of HOTDS in Canadian air operations. The regulatory approval process was based on an air carrier exemption from Canadian Aviation Regulation (CAR) 622.11, which pertains to the use of fluid holdover time tables in winter planning. As part of the regulatory approval process, TC developed Minimum Performance Specifications and Minimum Quality Assurance Requirements for HOTDS. The manufacturer of the HOTDS must demonstrate adherence to the minimum requirements established by TC prior to being approved by the regulator.

The manufacturer of the HOTDS tested in Canada has demonstrated compliance with the minimum requirements established by TC, and operational use of the system began in the winter of 2008–09.

The FAA is currently examining the development and adoption of a regulatory approval process for HOTDS, but it is believed that the process may still be a few years away.

Planning and Design Considerations

Numerous planning and design considerations need to be examined when implementing this practice:

- Airport siting issues with HOTDS: where to install the equipment on an airport site so that the system will provide outputs that are representative of conditions experienced by aircraft on the airfield;
- Determination of the desired data provision cycle time, which may impact the number of HOTDS systems that are ultimately installed at the airport;
- Space requirements for the physical installation of the system hardware; and
- Development of data communication pathways for system information (datalink, radio frequencies, wireless modems, etc.).

Integration with Other Fact Sheets

HOTDS technology has the potential to be integrated with most Fact Sheets, including all fluid-related Fact Sheets. The combination of real-time weather

measurement from the HOTDS and enhanced weather forecasting tools may be extremely useful to airports and aircraft operators.

Operation and Maintenance Considerations

Operational and maintenance requirements associated with this practice are not yet available because it has not been implemented at an operational level or tested over the long term.

Some operational considerations, such as how the holdover time information from the system will be employed by flight crews, will need to be examined in detail. The development of training programs for flight crews to ensure the transition from paper tables to electronic information is essential, as well as the need for calibration, maintenance, and verification programs for the HOTDS hardware, to ensure the validity of the system outputs.

3. Costs

Overall costs are not yet fully defined, as the technology has yet to be fully implemented in an operational environment.

Capital Costs

Capital costs are not fully defined, but are likely to consist primarily of costs of the installation, the location, as well as the hardware and software. Alternatively, capital costs of the installation may be incurred by a service provider who will sell the service to the airport/aircraft carrier community.

Operation and Maintenance Costs

Operational costs will be uncertain until the technology has been fully commercialized but are likely to include costs for personnel to oversee system operation and monitor results as well as costs for maintaining and testing the weather-monitoring equipment.

FACT SHEET 49

Point Detection Sensors to Indicate Fluid Condition and Contamination on Aircraft Surfaces

1. Description

Purpose

This Fact Sheet involves aircraft-mounted sensor systems that can be used prior to take-off to detect ice, frost, and snow and to monitor the remaining effectiveness of the applied de/anti-icing fluids.

Implementation of such systems could reduce the frequency of unnecessary returns for re-deicing when the holdover time is exceeded. They have a long-term potential for extending holdover times, eliminating the need for HOT guidelines, and for satisfying airworthiness directives for tactile checks on certain aircraft wing surfaces. Visual detection of contamination on critical surfaces by flight personnel from inside the aircraft is imprecise and impossible on high-wing aircraft.

These systems are still in the research and development phase and do not yet have regulatory approval for use in deicing operations. Guidelines for their use have not been developed or published.

Technology

Two aircraft-mounted sensor systems have been under development for some time. Thus far they are advisory systems only. They have not yet received regulatory approval to be used as the primary means of determining whether the airplane should be initially deiced or anti-iced, or to be used as the primary means of determining that the fluid has failed.

A C/FIMS™ sensor mounted on the leading edge of a Fokker F-100 aircraft.

C/FIMS™ is an aircraft wing-mounted sensor system developed by AlliedSignal Aerospace Canada in conjunction with Instrumar of St. John's, Newfoundland. It is designed for use on the ground prior to take-off for the detection of ice, frost, and snow and for monitoring the effectiveness of the applied de/anti-icing fluids. The sensors feed information to a cockpit display module to tell crews how well deicing and anti-icing fluids are working. C/FIMS sensors are designed to detect when the fluid is about to fail and to measure the wing skin temperature.

The Intertechnique Ice Detection Evaluation System (IDES) employs in-wing sensors using ultrasonic technology to detect ice. Based on the acoustic signals that are sent and received by the sensors, and several other data inputs, the system determines if there is ice or fluid on the surface of the sensor. If fluid is present, the IDES gives an indication of the fluid's condition. Other IDES outputs include fluid dilution, fluid thickness, and surface temperature

The Intertechnique Ice Detection Evaluation System (IDES) attempts to use acoustic signals to determine if there is ice or fluid present on the wing surface.

Documented Performance

a) C/FIMS™ System

An operational evaluation of a two-sensor C/FIMS™ system installation was reported in a TC publication (TP 2979E), "Final Report Operational Evaluation for the Two Sensor Contaminant/Fluid Integrity Measuring System (C/FIMS) Midway Airlines F-100 Aircraft."

The system was installed for evaluation on a Midway Airlines F-100 aircraft. Data was obtained from 82 take-off events. This included 8 events in which de/anti-icing fluids were used and 15 events in which the weather conditions were such that the FAA Airworthiness Directives (AD) called for a tactile check. Data collected by Midway pilots was obtained from two take-off events.

The results demonstrated that the two-sensor C/FIMS™ would enhance safety and provide operational benefits not available using existing manual inspection procedures. A further finding was that wing skin temperatures on average were 5.6°C (10°F) warmer than OAT.

The following year a four-sensor C/FIMS™ installation design was developed for the F-100, with the participation of Fokker Aviation Services. The evaluation was reported in the TC publication (TP 13254E), "Operational Evaluation for the Four Sensor Contaminant/Fluid Integrity Measuring System (C/FIMS) Midway Airlines F-100 Aircraft."

Data was collected from 63 take-off events on the Midway F-100 aircraft four-sensor system, from January to April 1997. This included four events in which de/anti-icing fluids were used and 11 events when the aircraft was within the weather conditions covered by the FAA AD applicable to F-100 aircraft.

C/FIMS™ will provide airline operators of the F-100 with the benefits of enhanced safety and improved operations in icing conditions.

From the collected data and analysis performed, it was concluded that a four-sensor production configuration of C/FIMS™ will provide airline operators of the F-100 with the benefits of enhanced safety and improved operations in icing conditions.

b) Intertechnique Ice Detection Evaluation System (IDES)

The ability of an IDES fluid failure sensor to replicate visual fluid failure calls was reported in the TC publication (TP 14382E), "A Sensor for Detecting Anti-Icing Fluid Failure: Phase I." If successful, the variability associated with human visual determination of failure during fluid endurance time tests could be eliminated by use of the sensor. It was concluded that the IDES was currently not able to duplicate the visual determination of failure. This may have been partially a result of the IDES system inability to match a human observation, rather than its inability to detect ice.

An improved IDES system (named WIDS) was tested in 2004–05 and results were reported in the TC publication (TP 4446E), "A Sensor for Detecting Anti-Icing Fluid Failure: Phase II." A limited number of tests were conducted with four fluids in natural snow, freezing drizzle, freezing rain, and freezing fog.

It was concluded that:

1. The Intertechnique IDES may be capable of being further refined to replicate visual endurance times in snow with Type II and Type IV fluids; and
2. Significant resources would be required to improve the technology to accurately replicate visual endurance times with Type I fluids or with all fluid types in simulated precipitation conditions.

IDEAS require more refinement to accurately replicate visual endurance times.

2. Implementation Considerations

Applicability Assessment

When such systems are approved, they would be applicable to all aircraft types.

It is expected that installation of these systems at time of aircraft manufacture would be less costly than retrofitting aircraft already in operation.

Successful systems could be integrated into the fluid holdover time test process to enhance the accuracy of fluid failure calls.

Regulatory Considerations

Some principal considerations in developing regulations on the use of this equipment are:

- System accuracy in identifying contamination in all weather and precipitation conditions and for all types of fluid applications;
- Ability to identify adhered contamination;
- Ability of point sensors to adequately represent condition of entire critical surface;
- Proven system reliability;
- Identification of numbers of point sensors and installation locations for best performance, by aircraft type;
- System indications versus published holdover time guidelines—which takes priority; and
- Once implemented, is the system included in the aircraft minimum equipment list.

These systems do not yet have regulatory approval for use in deicing operations and guidelines for their use have not been developed or published.

Planning and Design Considerations

It is expected that installation of such systems at time of aircraft manufacture would be the more efficient approach.

However, limiting implementation to new aircraft would dramatically extend the timeframe of implementation, given that many operators' fleets include relatively new aircraft that will be in service for some time.

When the systems receive regulatory approval for use in operations, interested operators will need to determine the most cost-effective approach to installing them, in conjunction with existing maintenance routines.

Flight operations procedures on the use and application of such systems and associated training would be required.

Integration with Other Fact Sheets

These systems complement other practices that address the reduction of glycol usage.

Operation and Maintenance Considerations

Operations considerations include integrating use of the sensor system into approved deicing programs and in flight operations manuals. The process of decision making based on sensor system information must be clearly defined and in accordance with regulatory guidance.

Potential inclusion of the implemented system in the minimum equipment list for commercial aircraft operation must be considered.

3. Costs

Costs include both capital and operating costs.

Capital Costs

Capital costs include purchase and installation of the system.

Operation and Maintenance Costs

Additional aircraft systems maintenance costs can be expected.

Implementation of the system may avoid some returns for re-deicing with their associated delayed operations costs as well as the additional deicing costs.

FACT SHEET 50

Remote Ice Detection Sensors to Scan Aircraft Critical Surfaces Before Departure Runway

1. Description

Purpose

This Fact Sheet involves the use of a Remote Ground Ice Detection System (GIDS) to scan the aircraft surfaces for freezing contamination at the entry point to the departure runway.

Remote Ground Ice Detection System (GIDS) is used to scan aircraft surfaces for contamination.

Such a system has potential for use at several points in the aircraft departure process during inclement weather.

GIDS may be used at the gate to assist in determining the need for aircraft deicing or may be used as a quality check following a deicing application. It may also reduce or eliminate the need for a tactile inspection of aircraft surfaces.

The Human Factors tests reported in FAA reports DOT/FAA/TC-06/20 and DOT/FAA/TC-06/21 have shown that, based on the particular conditions of the tests, remote on-ground sensors that meet the requirements of this standard perform more consistently and are more reliable than human visual, and/or tactile detection of clear ice on an aircraft critical surface in winter conditions. A Minimum Operational Performance Specification (AS5681) provides a standard for Remote On-Ground Ice Detection Systems (ROGIDS) for use in a post-deicing application.

This Fact Sheet addresses GIDS use at runway thresholds or as a final check to determine whether critical surfaces are still contamination free after taxi.

Implementation of such systems could reduce the frequency of unnecessary returns from end-of-runway for re-deicing. Visual detection of contamination on critical surfaces by flight personnel from inside the aircraft is imprecise, and impossible on high-wing aircraft.

These systems are still in the research and development phase and do not yet have regulatory approval for use in deicing operations. Guidelines for their use have not been developed or published.

Technology

Two prototype remote ground ice detection systems were developed in the 1990s.

There are currently two ground ice detection systems developed.

The Goodrich IceHawk® is a system initially developed by RVSI and subsequently purchased for further development by Goodrich Aerospace. The IceHawk system scans a surface by sending a beam of polarized infrared light. It detects ice by analyzing the polarization of the reflected signal. When ice is present, the

returned infrared signal is unpolarized. A picture of the scanned surface is computed and shown on the IceHawk display with patches of contamination highlighted in red. The system claims to have the ability to "see through" materials such as de/anti-icing fluid, hydraulic fluid, and fuel to detect frozen contaminant build-up underneath and to detect any frozen contaminant including snow, frost, slush or ice.

Ice Camera is a spectral camera system initially developed by Spar Aerospace and subsequently purchased for further development by MacDonald, Dettwiler and Associates Ltd (MDA). The system is based on a multi-spectral infrared camera employing a reflectance spectroscopy technique to detect ice.

Thus far, these systems have not received regulatory approval to be used as primary means of determining whether freezing contamination exists on aircraft surfaces.

Documented Performance

Field trials during 1998–99 winter deicing operations examined the feasibility of using remote GIDS to detect frozen contamination on the wings of aircraft just prior to entering the departure runway. These trials are reported in the TC publication (TP 13481E), "Feasibility of Use of Ice Detection Sensors for End-of-Runway Wing Checks."

Substantial field trials have been performed on aircraft to address both location alternatives and operating procedures.

Wings of departing aircraft were scanned with an ice detection camera installed on the mast of a communications company microwave truck, positioned near the departing runway. Appropriate sites for scanner locations and operating procedures were developed with the participation of airport and air traffic control staff.

The field trial conclusions were as follows:

- Selection of appropriate sites and operation of remote sensors is possible while respecting existing airport regulations;
- While scanning of stationary aircraft produced the best results, the remote sensor was capable of identifying contamination on a moving aircraft at some distance;
- The elevation of the sensor camera during the tests was suitable for scanning wings of aircraft up to narrow body in size. A camera height just below that of the B747 tail fin would enable satisfactory views of large wide body aircraft wings; and
- The GIDS had a number of performance issues for this application.

A further study conducted the following winter season was reported in the TC publication (TP 13662E), "Ice Detection Sensor Capabilities for End-of-Runway Wing Checks: Phase II Evaluation."

The study had two objectives:

1. To evaluate the capabilities of GIDS systems under particular conditions; and
2. To further examine the feasibility of performing wing inspections with a remote ice detection camera system at the entrance to the departure runway (end-of-runway).

Objective 1 was met by conducting sensor capability tests, scanning ice of varying thickness formed with the use of Ice Detection Plates provided by the FAA.

Objective 2 was met by simulating an end-of-runway scanning operation at the central deicing facility at Montreal-Trudeau International Airport (YUL). Aircraft arriving for deicing were scanned prior to being cleaned, and an observer located in the bucket of a deicing truck sketched and photographed the actual pattern of contamination. Sensor indications of contamination were then compared to the actual contamination. Tests on a static test wing examined the accuracy of ice detector indications of known areas of applied contamination.

The conclusions from this study were:

Ice detection sensors should be further developed to address a number of concerns.

1. Further development of ice detection sensors is necessary for satisfactory operation in an end-of-runway application. The considerations that must be addressed include:
   - Distances and viewing angles obtainable when operating at typical end-of-runway sensor positions relative to departing aircraft;
   - Sensitivity to distance and angle of viewing complicates Go/No-Go decision making:
     - Detection of ice on the areas of the wing farther from the sensor is less precise than for parts of the wing that are closer; and
     - Detection of ice on aircraft with higher wings is less precise than on aircraft with lower wings due to the flatter angle of viewing.
   - At the distances governed by airport regulations, detection of contaminated areas is imperfect:
     - Need to be able to zoom-in to focus entirely on the suspect area.
   - Detection of contamination on the edge of a wing must not be obscured when viewed against a snow-covered ramp background;
   - Relative movement between aircraft and sensor must not produce false indications;
   - For nighttime operations, the system:
     - Must have the same sensitivity as in daylight;
     - Must not give false readings due to reflections from surface discontinuities;
     - Must be able to detect frost in an end-of-runway environment; and
     - Performance must not degrade due to changing levels of ambient light such as dawn and dusk.
2. Acceptable limits of contamination at takeoff must be defined by regulators in order for GIDS developers to proceed further with improved sensors.

2. Implementation Considerations

Applicability Assessment

When such systems are approved, they would be applicable to all aircraft types. They would provide improved information to the pilot regarding contamination on wings, leading to better decisions on the need to return for re-deicing, and enhanced aircraft safety.

Regulatory Considerations

Some principal considerations in developing regulations on this application follow:

Camera location:

- Selected in compliance with aerodrome regulations regarding the Obstacle Limitation surfaces (OLS).

GIDS system:

- System accuracy in identifying contamination in all weather and precipitation conditions and for all types of fluid applications;
- Proven system reliability;
- System accuracy in identifying contamination for all aircraft types at the distance and angles of viewing governed by the installations; and
- System indications versus published holdover time guidelines—which takes priority?

These systems do not yet have regulatory approval for use in deicing operations and guidelines for their use have not been developed or published.

Planning and Design Considerations

a) Selecting Scanner Locations

Considerations include aerodrome standards designed to minimize the dangers presented by obstacles to aircraft, local airport runway, taxiway, and deicing facility layout; how runways and taxiways are assigned during deicing conditions; and remote GIDS system limitations.

b) Aerodrome Standards

The height limitation of the sensor camera installation is controlled by the OLS. Fixed objects are not permitted above the surface except for frangible mounted objects. Mobile objects are not permitted above the surface when the runway is used for landing.

The location of aircraft taxi-holding positions also is controlled by the surface. Both the tail height and nose height are considered in establishing minimum distances from the runway centerline. This is of interest because scanning of static aircraft, as opposed to taxiing aircraft, produces superior results.

c) Airport Layout

The layout or geography of each airport influences the sensor positioning decision. Specific runways may be favored for departures during weather conditions requiring deicing and should be given prime consideration when designing GIDS installations. If these runways are also used for landing, the height of the sensor installation is then limited.

An escape route is necessary to allow the aircraft to return to the deicing facility following scanning of the wing for frozen contamination.

Departure-clearance holding-bays with more than one centerline to allow side-by-side aircraft positioning may interfere with the scanning of both wings. Bays that require immediate turning of the aircraft when departing may result in an unacceptably strong jet blast in the area where a GIDS camera might be located.

d) GIDS System Limitations

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

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

Increased sensor height and minimum separation distances produces enhanced results and better detection of contamination.

Scanning stationary aircraft awaiting clearance for departure produces better results than scanning moving aircraft.

e) Operating procedures

The nature of GIDS output dictates the need for an on-ground operator and controller, as opposed to direct communication from GIDS to pilot.

Procedures for such an application would involve a number of groups, including flight operations, airport and air traffic control, airline ground operations, and central deicing facilities operators.

Communications procedures must be developed and documented.

Integration with Other Fact Sheets

These systems do not conflict with implementation of other Fact Sheets.

Operation and Maintenance Considerations

Operations considerations include integrating use of the sensor system in current deicing programs. Responsibility for decision making based on GIDS system information must be clearly defined and in accordance with regulatory guidance.

3. Costs

Costs include both capital and operating costs.

Capital Costs

Capital costs include purchasing and installing a GIDS system and its ancillary systems (power supply, communications of GIDS output).

Operations and Maintenance Costs

Operation and maintenance costs include:

- Maintenance of the GIDS system and its installation;
- Manpower to monitor and communicate GIDS information; and
- Implementation of the system may avoid some returns for re-deicing with their associated delayed operations costs as well as the additional deicing costs.

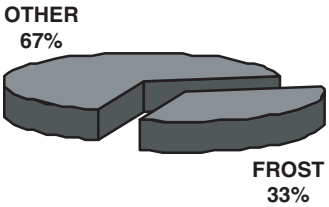
FACT SHEET 51

Spot Deicing for Frost Removal

1. Description

Purpose

Frost is an important consideration in aircraft deicing. The irregular and rough frost accretion patterns can result in a significant loss of lift on critical aircraft surfaces. This potential hazard is amplified by the frequent occurrence of frost accretion during winter airport operations. A survey of deicing activities at airports in North America, Europe, and Asia demonstrated that in regions with colder climates, up to 33% of deicing operations are frost related.



A recent survey indicated that 33% of all deicing operations are in frost conditions.

Fact Sheet 51 describes procedures and operational concerns for removing small patches of frost on aircraft upper wing surfaces in lieu of deicing the aircrafts entire upper wing surface as is currently practiced by many of the worlds airlines.

A complete report on this topic is available in *ACRP Report 45: Optimizing the Use of Aircraft Deicing and Anti-Icing Fluids.* This practice is usually implemented by the airlines or their deicing service providers (DSPs).

Technology

In conventional frost removal procedures, an aircraft's entire upper wing surface area is deiced using a heated glycol mixture of Type I, II, or IV fluid. The Type I fluids are typically applied with a 10°C buffer or a premix 50/50 or 55/45 concentrations. The Type II and IV fluids are typically applied in a premix concentration of 50/50 or 75/25 concentration.

This is mostly accomplished using the one-step deicing/anti-icing procedure whereby, in a single operation, the heated fluid mix is applied to aircraft surfaces in a sweeping motion in such quantities (about 1 liter per square meter) so as to leave a thin residual fluid layer on the wing upper surface. The heat in the fluid mix effectively melts the frost while the glycol in the mix prevents refreezing for a period of time. Another conventional defrosting method for non-active frost conditions is the use of high-pressure forced air in conjunction with the glycol fluid mixes. To a lesser degree, other non-active frost removal methods include infrared defrosting, forced air alone, mops impregnated with glycol, and mechanical methods such as scrapers, ropes, and squeegees. In addition, pretreatment of aircraft upper wing surfaces with glycol for overnight stays is routinely used when forecast/existing climatic conditions for the formation of frost were deemed imminent.

"Spot Deicing for Frost Removal" is a term that applies to using deicing fluids to treat small affected aircraft wing surfaces.

Spot deicing for frost removal applies to using deicing fluids to treat small, affected aircraft wing upper surfaces areas (patches of frost that are typically less than or equal to 20% of wing upper surface area) to remove (non-active) frost that may have formed during a ground overnight stay. The entire wing is not

treated; however both wings are treated symmetrically, whether both wings need to be defrosted or not. If any frost is observed on the leading edge of the wing(s), it must be removed. In non-active frost conditions, the wing does not require anti-icing and holdover times do not apply. The main thrust of using spot deicing is to reduce the amount of glycol used to achieve aerodynamically clean aircraft wings prior to takeoff, in comparison to amounts of glycol use in treating an entire upper wing surface. In addition, defrosting time may be reduced, depending upon the aircraft size, the extent of the frost, and the ambient conditions.

Many service providers are still using standard fluid applications for spot deicing. This can lead to significant glycol waste.

In performing spot deicing for frost removal, standard deicing fluid application procedures are typically employed, in which a fan spray nozzle setting is used. Also, Type I fluids are typically applied at a 60°C temperature (at the nozzle). Of the air carriers that have adopted spot deicing for frost removal procedures, it was indicated that this practice is performed on most current commercial aircraft, thus precluding the need for additional guidance from aircraft manufacturers.

Documented Performance

Recent Surveys have demonstrated 30–60% in monetary savings when using spot deicing for frost procedures.

In a recently conducted survey (summer 2008) of airlines and DSPs relative to aircraft deicing for frost removal it was revealed that:

- Although a reasonable number of operators are currently using spot deicing, there are still many operators who are not familiar with this methodology for frost removal;
- Spot deicing is seen to be a cheap and effective methodology for frost removal. Cost, fluid, and time savings are notable benefits of spot deicing compared to conventional deicing. Fluid savings are estimated to be between 30 and 60%;
- Spot deicing for frost removal is currently being employed using Type I fluid mixed to a 10°C buffer heated to 60°C and applied using a regular deicing vehicle;
- Training, lack of qualified individuals to make assessments about its usage, and asymmetrical application resulting in risks to safety, were identified as the key obstacles in employing spot deicing for frost removal; and
- The methodology was seen to be more suitable for operations at warmer temperatures.

2. Implementation Considerations

Applicability Assessment

This procedure is readily available for use by all airlines and DSPs. Frost removal prior to takeoff is a requisite safety requirement for all aircraft and conventional deicing procedures and equipments are in place to meet this requirement. Since the same equipment used for conventional defrosting is

available for spot deicing for frost removal, its applicability is straight forward. Implementation changes would entail:

- Additional training for deicing personnel in performing the spot deicing procedure;
- Additional checking following the application of the procedure; and
- Providing specific guidance material by industry professional groups and regulatory authorities.

Regulatory Considerations

There are no specific SAE guidelines in SAE ARP 4737, "Aircraft Deicing/ Anti-icing Methods" document that addressed procedures for spot deicing for frost removal. The general guideline for removal of frost and light ice (i.e., paragraph 6.1.2.2) simply states,

A nozzle setting giving a fan spray is recommended. NOTE: Providing that the hot fluid is applied close to the aircraft skin, a minimal amount of fluid will be required to melt the deposit.

Also, there were no specific SAE activities geared toward establishing guidelines for the use of spot deicing for the removal of frost. However there is a specific AEA recommended procedure to this effect in paragraph 3.9.1.3.2 of the AEA, "Recommendations for Deicing/Anti-icing of Aircraft on the Ground."

It states:

> AEA Paragraph 3.9.1.3.2 Local wing frost removal:
>
> For frost limited to a small patch on the upper wing surface only, and when no precipitation is falling or expected, 'local area' deicing may be carried out.
>
> Spray the affected area with a heated fluid/water mix suitable for a One-Step Procedure, and then spray the same area on the other wing. Both wings must be treated identically (same areas, same amount and type of fluid, same mixture strength), even if the frost is only present on one wing.
>
> The trained and qualified person releasing the aircraft must check that the treatment was done symmetrically and that all frozen deposits have been removed, and then report the details of the treatment to the Commander.

CAUTION: Holdover times do not apply.

However, changes to SAE ARP 4737 were proposed and accepted at the May 2009 meeting of the SAE G-12 Aircraft Ground Deicing Methods Subcommittee. These changes were adopted for the winter 2009–10 operating season, and will provide adequate guidance for operators wishing to implement this procedure.

In the aforementioned survey, the majority of the airlines and the DSPs (57%) indicated that they already use this procedure. These included major U.S.,

Canadian, AEA, and Russian air carriers. Most North American air carriers indicated that they already used this procedure. Several of the survey respondents that have not adopted spot deicing for frost removal procedures cite the need for further guidance from the SAE ARP 4737 document and FAA approval of their deicing program when this procedure is incorporated therein.

In turn, the FAA indicates, "Currently spot deicing is not prohibited by the FAA, however it is not specifically encouraged."

Planning and Design Considerations

There is no specific planning or design consideration for the adoption of this spot deicing for frost removal procedure. Current locations, deicing pads, and equipment and personnel used in conventional defrosting of aircraft are deemed adequate to effect the intent of this practice.

Integration with Other Fact Sheets

Integration with conventional frost removal procedures will help improve glycol usage and significantly reduce the amount of spent glycol that eventually finds it way into the environment. In addition, significant savings in overall aircraft deicing operation expenses have been reported.

Operation and Maintenance Considerations

These spot deicing for frost removal procedures would be incorporated into an air carriers deicing program for approval by appropriated authorities. Once approved, DSPs would then be able to offer/perform this procedure for their customer (the airlines).

There are no additional or new equipment required for this practice. Therefore, it does not introduce new or otherwise significant equipment maintenance requirements.

Spot Deicing for Frost does not require significant capital investment because the same deicing equipment employed in conventional deicing is also employed for spot removal.

3. Costs

The additional equipment costs to accomplish spot deicing for frost removal is deemed to be zero since the same deicing equipment used for conventional removal of frost would be used for spot deicing for frost removal. Additional training of deicing personnel and checking/inspection personnel on the spot deicing for frost removal procedures would be required.

However, this would add little material cost to the training syllabus or time to the annual deicing training requirement. In addition, flight crews would require some supplemental training on conducting post deicing checks following spot deicing for frost removal. Again, this supplemental training would be minimal and accomplished at the same time that training for pre-takeoff contamination checking is accomplished.

Labor costs would be the same or slightly less than that required for conventional deicing for frost removal.

In the future, new methodologies for spot deicing for frost removal may be adopted in which small transport aircraft could be spot deiced using a heated glycol mix carried in a bucket and applied by mops. In this case, a small cost associated with the procurement of mops and buckets would be appropriate.

Should the latter procedure of using mops and buckets for spot removal of frost be adopted, personnel must be provided with suitable equipment for safe access to aircraft surfaces and be properly trained to avoid damage to aircraft components.

FACT SHEET 52

Tempered Steam Technology

1. Description

Purpose

Tempered Steam Technology (TST) is an aircraft deicer application method nearing the completion of the research and development phase. This practice is most likely to be applicable to defrosting or predeicing of aircraft and thus potentially reduce the volumes of Type I fluid required to deice an aircraft. The practice could also be employed for engine deicing and for the first step of two-step de/anti-icing operations.

Currently, a truck mounted TST prototype is currently in the testing phase. Via an inflatable delivery head, this TST uses a mixture of water vapor and hot air to deice aircraft surfaces.

Technology

TST is a proprietary deicing technology being developed by one vendor. TST uses a mixture of water vapor and hot air to deice aircraft surfaces (Chaput 2006). An inflatable delivery head affixed to a vehicle boom ensures containment of the Tempered Steam and Hot Air over aircraft surfaces. No glycol is employed, and the technology is considered highly applicable to defrosting and predeicing applications.

Documented Performance

Promising results were reported after approximately 50 tests conducted during the winter of 2006–07. The technology has demonstrated an ability to defrost a test bed about the size of an executive jet in as little as 2 minutes, without producing any residual water whatsoever. As a predeicing tool, the technology has been demonstrated to effectively deice and dry large quantities of snow (up to 6 cm) and ice (up to 2 cm) in approximately 10 minutes. Tests were performed under a wide range of operating conditions, from +3°C to approximately –30°C.

A total of eight defrosting and deicing tests were also performed on behalf of TC in winter 2007 on a wing test bed and the results were excellent. The results of these tests were documented in a TC publication that has yet to be published.

In winter 2008, 18 tests were performed with TST on operational aircraft (Airbus A320, Embraer E175, B767) at Montreal-Trudeau International Airport (YUL). Testing focused on aircraft defrosting, engine deicing and delivery head positioning. The results were again very promising, and plans are currently underway to implement the technology on a limited basis in winter 2008–09.

The melting of frost accumulation on aircraft surfaces using TST is extremely efficient and does not result in any residual water being produced on the aircraft or in the wing quiet areas. Residual water is created when melting large quantities of snow or ice contamination. In cases where residual water is created by the

melting process, a simple application of Type I fluid could be applied subsequent to the deicing operation with TST to ensure the meltwater does not re-freeze. No other performance limitations have been documented to date, although use of this technology in active precipitation conditions would require anti-icing using conventional methods. Based on testing to date, the technology has no known limitations over conventional deicing methods.

TST has many applications including:
- Deicing in Frost Conditions
- Pre-deicing in all precipitation types
- First step of a two-step deicing application (alternative to Type I fluid)
- Engine Deicing

2. Implementation Considerations

Applicability Assessment

This practice would be most applicable to frost and predeicing applications in all climates, but could also be employed for engine deicing and for all deicing operations as a first step in two–step de/anti-icing. Anti-icing operations would require the use of glycol-based fluids. Airports that have limitations on glycol use at gate positions or airports that have a large number of frost deicing events may be most suitable for TST, although the technology has been proven to be effective across the entire spectrum of operation conditions. As TST is vehicle-based and can be employed at gate positions for defrosting, the use of this technology may enable aircraft to push back from the gate and taxi to the departure runway without having to undergo a glycol spray and the delays associated with it.

Regulatory Considerations

The primary regulatory consideration associated with TST would be its acceptance by regulators as an approvable component of an aircraft operator's snow and ice control plan.

Planning and Design Considerations

Although TST is not yet commercially available, it is likely to be implemented on a limited basis in winter 2010–11. As the technology is vehicle mounted, the planning and design considerations applicable to this practice are marginal.

Integration with Other Fact Sheets

One of the biggest benefits of TST is its potential ability to be combined with virtually all other Fact Sheets to streamline the cost and efficiency of de/anti-icing operations. The system is vehicle mounted, allowing it to be employed at the gate, remote pads, or in centralized deicing operations.

Operation and Maintenance Considerations

Because the technology is still under development and has yet to be fully implemented into airport operations, the operating and maintenance requirements of the BMP are not fully known at this point.

3. Costs

The practice is not yet commercially available at this time, and so definitive costs have not yet been established. It is believed that the technology costs will be considerably less than those associated with conventional deicing, especially when the cost benefits (glycol savings, operational efficiencies, aircraft fuel savings, environmental savings) associated with the technology are considered.

FACT SHEET 53

Threshold Deicing

1. Description

Purpose

Threshold deicing is based on the use of remote deicing pads located near the threshold of the departure runways, similar to those implemented at the Munich airport.

Technology

In threshold deicing, special areas are assigned for deicing of aircraft at each runway head. Aircraft are deiced at these special deicing areas just before takeoff. Deicing is typically conducted with engines running to minimize the deicing time of each aircraft and accelerate throughput.

Currently, a truck mounted TST prototype is in the testing phase. Via an inflatable delivery head, this TST uses a mixture of water vapor and hot air to deice aircraft surfaces.

Locating the deicing operation close to runway departure points has several potential benefits. These include:

- Limiting the need for application of thickened anti-icing fluids as a result of reduced time from end of deicing until actual aircraft takeoff. This would also result in reduced glycol being dispersed over the airport during the takeoff run;
- Reduced need for repeat deicing as fluid holdover times are less likely to be exceeded;
- Reduction of fluid drippage from wings of aircraft along taxiways as is the case when deicing is conducted at the airport apron; and
- Concentration of spent deicing fluid in a confined area, facilitating fluid containment and recovery.

Documented Performance

Aircraft ground deicing activities at threshold deicing sites have been proven to be operationally effective and provide numerous benefits to the aircraft operator community.

At Munich Airport in Germany, ground-deicing activities are the exclusive responsibility of Gesellschaft für Enteisen und Flugzeugschleppen am Flughafen München (EFM). Aircraft are deiced just before takeoff with their engines running at special deicing pads at the runway thresholds. There are three deicing pads for each takeoff direction on the north and south runways. Each deicing pad is equipped with several deicing vehicles. EFM is capable of up to 68 deicing operations per hour. The performance of the Munich airport deicing program is described on the website (http://www.efm.aero).

As much of the sprayed deicing fluid as possible is collected at the remote threshold areas in Munich. It is treated at the airport's recycling facility to produce new deicing fluid. Because of the proximity of the remote areas to the runway, aircraft can take off within the shortest possible time after being deiced. This minimizes the possibility that the holdover time for the deicing fluid will be exceeded, which necessitates a repeat deicing operation. Remote deicing ensures safety, saves time, reduces costs, limits the quantity of deicing fluid used, and protects the environment.

2. Implementation Considerations

Applicability Assessment

A number of principal factors apply when considering this approach:

- The availability of the large land areas at locations near runway thresholds, suitable for such operations;
- The large upfront infrastructure costs for such facilities; and
- The commitment of local commercial operators to use the facility, and to submit deicing operations to a single deicing operator.

Regulatory Considerations

Safe and efficient aircraft operations are of primary importance in the development of any aircraft deicing facility. FAA Advisory Circular (AC) No: 150.5300-14B *Design of Aircraft Deicing Facilities* discusses sizing, siting, environmental runoff mitigation, and operational needs of a deicing facility and how to maximize deicing capacity while maintaining maximum safety and efficiency.

TC publication (TP 14052), "Guidelines for Aircraft Ground-Icing Operations," contains information applicable to the Commercial Operation of Aircraft in Canada under Ground Icing Conditions. The information provided is derived from many sources and comes from operational experience, from scientific fact, from testing and evaluation, and from regulation.

All runoff from deicing operations must be contained, collected, and disposed of in accordance with regulations and guidelines of applicable governmental and municipal authorities. It is the responsibility of the user to assure that disposal is appropriate and is in compliance with legal requirements.

The operator's approved deicing program must provide a detailed description of the procedures related to the remote deicing site.

Planning and Design Considerations

The SAE Aerospace Division publication ARP 4902, *Design and Operation of Aircraft Deicing Facilities,* provides a list of operational issues that SAE recommends addressing. Each remote facility must be capable of handling the depar-

ture traffic expected for the associated runway without causing major delays to departures.

Each facility must have the capability of handling the locally operated aircraft with the most demanding characteristics, such as wingspan, tail height, etc.

The site location must be such that there is no interference with air traffic control or runway obstacle clearance requirements.

Remote sites will require electrical power, water, and potentially another energy supply.

Systems for spent fluid containment, collection, and disposal will be needed at each site.

Integration with Other Fact Sheets

Concentration of deicing operations at a few sites will offer the possibility of collecting a greater quantity of spent fluid as compared with deicing at the apron.

Minimizing taxi times to final takeoff will potentially enable greater use of only Type I fluids, reducing the need for thickened anti-icing fluids. Practices related to applying the lowest authorized fluid strength for Type I fluid could further reduce costs and environmental impact. The implementation of Holdover Time Determination Systems at threshold deicing sites may enable increased usage of Type I fluids.

Operation and Maintenance Considerations

Typically, such an operation would be controlled and managed by a single service provider.

Procedures for use of the facilities, especially standardized communications packages, will need to be developed in concert with aircraft operators, airport management, and air traffic control.

The standardized communications package is a vital key to safe and efficient use of the remote site.

- An efficient and reliable method of communication allows pilots to communicate their intentions to the service provider at the earliest possible time;
- Communication between the pilot and the service provider, as soon as possible in advance of the aircraft arriving at the deicing location, ensures that the deicing operation will be accomplished in the safest and most efficient manner, for both the flight crew and the ground crew;
- Once an aircraft has received permission to proceed to the deicing location and has begun taxiing, it is important that flight crews be able to receive prompt notification of any changes to the deicing operation or of problems that arise;
- The procedures used by the service provider for entry of aircraft into, and exit from the deicing pad must be made clear to the flight crews;

- Once an aircraft has reached the entry point to the facility, control must be transferred from Air Traffic Services to Pad Control. A communication link between the Pilot-in-Command and Pad Control must be established prior to the aircraft entering a deicing bay;
- Prior to commencement of the deicing/anti-icing operation, certain vital information will need to be shared and acknowledged to ensure that the aircraft is treated correctly, in a safe manner, and with a safe result;
- Following deicing, the pilot must be provided with standard information about the deicing anti-icing process used, prior to dispatch from the pad; and
- Emergency procedures must be clearly defined.

3. Costs

Significant capital, maintenance, and operating costs would be expected for such installations. The magnitude of these costs will be specific to each installation and location.

FACT SHEET 54

Use of SAE Fluid Dilutions (Type I, II, III, IV)

1. Description

Purpose

This Fact Sheet addresses the use of fluid dilutions in the deicing/anti-icing of aircraft prior to takeoff. A complete report on this topic is available in the main text of *ACRP Report 45: Optimizing the Use of Aircraft Deicing and Anti-Icing Fluids.* Many North American airlines continue to use Type I deicing fluids in ready-to-use mixtures and Type IV anti-icing fluids in the concentrated (undiluted) mixture, even when not required by prevailing weather and the associated holdover time requirements. Widespread use of fluids mixes diluted to the appropriate concentrations have been shown to offer significant savings in deicing/anti-icing fluid use while maintaining requisite levels of safety.

Outside Air Temperature[2]		Type II Fluid Concentration Neat Fluid/Water [Volume %/Volume %]
Degrees Celsius	Degrees Fahrenheit	
-3 and above	27 and above	100/0
		75/25
		50/50

This practice is normally implemented by the airlines or their DSP.

Technology

SAE aircraft deicing/anti-icing fluids are available from a number of fluid manufacturers. For a fluid to be used in deicing/anti-icing operations, it must meet requirement of SAE Standard AMS 1424 for Type I fluids and AMS 1428 for Type II, III, and IV fluids. Normally Type I fluids are considered to be deicing fluids and Type II and IV fluids are considered to be anti-icing fluids. However, any of these fluids can be used in the deicing and anti-icing role.

There are numerous fluid manufacturers that produce Type I fluids. These fluids are provided in a neat concentrate 100/00 or in diluted blends as requested by the airlines or DSPs. These blend are typically 50/50 (50% glycol and 50% water) or 55/45; however, other blends such as 60/40 are available if requested. To a lesser extent, there are several manufacturers which produce the Type II, III, or IV fluids. The preponderance of these fluids are provided in the neat concentrated 100/00 blend, but can be made available in the other blends of 75/25 and 50/50 if requested.

The SAE ARP 4737 states that SAE Type I fluids used for either one-step deicing/anti-icing or as the anti-icing fluid in a two-step operation must have a fluid freeze point (FFP) at least 10°C (18°F) below the ambient temperature. (This is referred to as the 10°C buffer). Type I fluid holdover times are determined using fluids mixed to this buffer. With some exceptions, the general industry practice when deicing/anti-icing with Type I fluid has been to apply Type I fluid at the standard, as delivered, fluid concentration of 50/50. Although Type I fluid mixes

are required to have only a 10°C buffer, the Type I fluid 50/50 mixes typically have FFP ranging from –20°C to –35°C depending upon the type of glycol used. These FFPs provide greater buffers than the 10°C buffer required for most prevailing temperatures during aircraft deicing operations. Thus, this practice results in dispensing much more glycol content than is necessary, and leads to unnecessary operational costs and increased stress on the environment.

Similarly SAE Types II, III, and IV anti-icing fluids are available at fluid dilutions/concentrations of 100/0, 75/25, and 50/50. Fluid endurance times are measured for several temperature bands using fluids mixed to these concentrations and the corresponding holdover time guidelines are published. Some 75/25 anti-icing thickened fluid concentrations have holdover times similar to 100/0 fluids, and many 50/50 thickened fluid concentrations have holdover times well in excess of SAE Type I fluid, where applicable. Despite the opportunity to employ lower fluid concentrations, anti-icing operations in North America have been based almost exclusively on 100/0 Type IV fluid concentrations. As a result, there is a considerable opportunity to reduce the amount of glycol dispensed by applying fluid at lower, already approved, concentrations.

A proportioning/blending unit consists of a pumping system (including a pump, valves, piping, and a controller) that pumps ADF from one tank and water from another tank into a blend tank at a selected concentration. The blend tank is normally fitted with a refractometer to measure the FFP of the mixture. The blend tank may be fitted with heaters, to allow application of the blend mix at required temperatures. For Type II, and Type IV fluids, special pumps such as diaphragm pumps may be required. This technology is well established.

Several manufacturers of deicing equipment produce units with proportional blending capabilities that can readily blend glycol and water to produce the required Type I fluid 10°C buffer mix. In addition some units have blending capabilities that dilute the 100/0 Type II, III, and IV fluid concentrations to blends of 75/25 and 50/50 concentrations. The sizes of these units vary from less than 1,000 gallon capacity to over 3,000 gallon capacity. Although newer units with proportional blending are available, many airlines opt to continue to use the older conventional units which do not have proportional blending capabilities. In this case, ready-to-use mixes of Type I in the 50/50 or 55/45 concentration and Type IV fluids in the 100/0 concentration are usually used.

Documented Performance

Several equipment manufacturers have cited case studies in which proportional blending of Type I fluids to the required 10°C buffer have resulted in savings of 30 to 70% over that of conventional deicing/anti-icing operations using a manufacturers supplied ready-to-use mix of 55/45 concentrations. In many of these cases, the temperature and prevailing weather conditions were such that only a 20/80 mixture was required to achieve the required 10°C buffer. This was common at the warmer temperatures where the aircraft were defrosted early in the morning at the start of the day's operations.

2. Implementation Considerations

Applicability Assessment

Two significant factors apply when considering the use of fluid dilutions for deicing and anti-icing. They are:

- Costs associated with the procurement of deicing equipment with a proportional blending capability or cost required to add this capability to existing deicing equipment; and
- The willingness of deicing operators to not use ready-to-use Type I fluid mixtures with 50/50 or 55/45 concentrations, or Type IV fluid neat concentrations (100/0) when prevailing climatic conditions and Holdover-time requirements can be met by Type I fluids with appropriate 10°C buffers or Type IV 50/50 or 75/25 fluid dilutions.

Regulatory Considerations

Current industry and regulatory guidelines are in place, which allow the efficient use of fluid dilutions to effect deicing and anti-icing of aircraft surfaces. There are specific SAE Guidelines in SAE ARP 4737 that addressed procedures for the application of Type I, II, III, and IV fluids and their dilutions in both the one-step and the two-step deicing/anti-icing procedures.

Similar tables are contained in the guidance documents published yearly by the FAA, TC, and the AEA. In a recent survey on this topic, both the airlines and DSPs indicated that these guidelines were adequate to effect safe and timely use of fluid dilutions in the deicing and anti-icing operations.

Planning and Design Considerations

The following items need to be considered when planning, and implementing a deicing/anti-icing system that uses proportional blending to effect the required 10°C buffer for Type I fluids or are used to dilute Type II, III, or IV 100/0 anti-icing fluids to 75/25 or 50/50 concentrations:

- Climate suited to the technology's strengths;
- Additions to the operators training program to address operational characteristics, limitations, and safety concerns associated with the use of dilutions;
- Maintenance staff training; and
- Upgrade of existing conventional deicing units vs. phased replacement of entire deicing units on a scheduled basis.

Integration with Other Fact Sheets

Use of dilutions of SAE Type I, II, III, and IV fluids can readily be integrated with other source reduction BMP where fluids are used. This practice is compatible with all of the containment/collection/conveyance/storage, and treatment/

recycling practices. This practice may not be compatible with those airport-recycling programs where captured spent deicing fluids must contain a minimal amount of glycol to prove economically viable.

Operation and Maintenance Considerations

Operational requirements associated with this BMP include proportioning/blending equipment that will allow fluid blending and the associated training for deicing personnel to use the equipment safely.

The added complexity of the technology may increase maintenance requirements.

3. Costs

Moderate capital, maintenance, and operating costs would be expected for the situations in which conventional deicing equipment without proportional blending capabilities are replaced or upgraded with the installation of blending systems. These costs would be governed by the sophistication of the upgrade to the deicing equipment and could vary between $30,000 to $60,000 depending upon the capabilities, condition, and age of the equipment being upgraded. A new deicing unit/equipment (a single deicing vehicle) with proportional blending capability could vary from $230,000–400,000 for moderate sized (1,800 gallon units) to well over $600,000 for larger capacity (3000 + gallon) high reach units.

There would be similar cost increases ($30,000 to $60,000) associated with the addition of proportioning blending to dilute Type IV fluids from the 100/0 concentrations to 50/50 or 75/25 dilutions as appropriate. Studies have shown potential saving in the long run whenever adequate and not excessive dilutions are used.

FACT SHEET 55

Type III Fluids

1. Description

Purpose

Type III fluid has a much lower viscosity profile than other thickened de/anti-icing fluids. Type III fluid is designed for heated application in a one-step de/anti-icing operation using the same equipment employed to dispense Type I fluids, providing improved holdover time performance in comparison to Type I fluid. Because most of the applied fluid drains off the aircraft surfaces shortly after application, spent fluid can be readily collected at the deicing location. This practice can potentially reduce the volumes of anti-icing fluids applied to aircraft, as well as the time required to de/anti-ice aircraft, as the entire operation can be completed in one step.

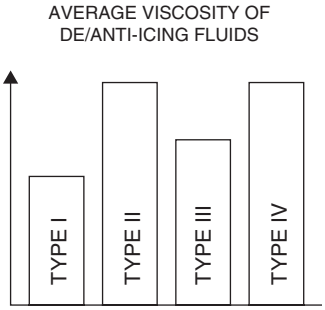
Many operators of commuter aircraft received penalties for the use of Type II and IV fluids. These fluids are not designed for slow rotation speed aircraft.

Technology

Due to the holdover time restrictions of Type I fluid, many operators of commuter aircraft were historically forced to use Type II or Type IV anti-icing fluids, despite the fact that these fluids were not recommended for use on commuter aircraft with slow rotation speeds and short takeoff rolls. Many airlines incurred regulatory penalties as a result of the use of Type II or Type IV fluid in icing conditions.

Type III is a de/anti-icing fluid designed for aircraft with lower rotation speeds and shorter takeoff rolls. Type III fluid has a viscosity profile in between that of Type I and Type II fluid. It is designed for heated application in a one-step de/anti-icing operation using the same conventional equipment employed to dispense Type I fluids.

Two Type III fluids were tested in the 1990s for endurance times. One fluid was produced commercially but later discontinued; the other fluid was never produced commercially. In 2003–04, a propylene-glycol based Type III fluid was certified to SAE Aerospace Material Specification (AMS) 1428 and was tested for holdover time performance. The endurance times of this fluid were much longer than the Type I holdover times. Based on these positive results, the fluid was produced by the manufacturer and has been commercially available since this time.



Type III fluid is a lightly thickened de/anti-icing fluid with a viscosity profile located in between that of Type I and Type II/IV fluids.

Transport Canada (TC) and the FAA produced holdover time tables for the new Type III fluid (neat) and included them in their operator guidance material for use in 2004–05 winter operations. Subsequent test results of 75/25 and 50/50 mixture ratios (Type III/water) from the same manufacturer have been included in the holdover time guidelines for Type III fluids.

Because the holdover time performance of the new Type III fluid is far in excess of Type I fluid in all conditions, the fluid can also be employed in de/anti-icing

larger aircraft at airports where queue times post-deicing are low and the holdover times for Type II or Type IV fluids are not required.

As of the last update of this factsheet in 2016, Type III fluid is not thought to be regularly used in the United States, although it still sees limited use in Canada. Because air carrier traffic is generally increasing in capacity and size, the rotation speed of aircraft is increasing, which reduces the advantages of Type III use.

Documented Performance

Field trials were performed in 2003–04 during the development of Type III fluids. These tests were documented in the TC publications (TP 14152E) "A Potential Solution for De/Anti-icing of Commuter Aircraft" and (TP 14379E) "Development of Holdover Time Guidelines for Type III Fluids."

TP 14152E presented the results of a preliminary study aimed at determining the feasibility of a new, simulated Type III formulation based on a lightly thickened anti-icing fluid. The conclusions presented in TP 14152E were:

- Despite having a very low viscosity, the simulated Type III fluids provided vastly superior holdover time performance than Type I fluid;
- The holdover times provided by the simulated Type III fluids could provide the industry with operationally useful holdover times;
- Type III fluids could potentially be used in one-step de/anti-icing operations, as Type I fluids currently are;
- The low viscosity of undiluted Type III fluid provides freezing point protection across the holdover time table;
- Type III fluid could likely be applied with Type I fluid spray equipment; and
- Due to the lower viscosity, the fluid would likely provide improved aerodynamics for commuter aircraft and alleviate current penalties imposed on operators.

American Eagle Saab 340 commuter aircraft

Subsequent to the preliminary study (TP 14152E), and prior to the onset of the fluid endurance time tests with the new Type III fluid, a series of spray tests were performed at Dallas-Fort Worth (DFW) using an American Eagle Saab 340 aircraft. The objective of these tests was to spray heated Type III fluid through a Type I spray nozzle and to compare the viscosities of the sprayed and virgin fluids to determine the appropriate viscosity for this fluid for endurance time testing.TP 14379E presented the results of the spray test at DFW, as well as the results of endurance time testing with the Type III fluid (neat) in natural and simulated precipitation conditions.

The spray tests performed at DFW demonstrated that it is possible to heat a Type III production sample and spray it through a Type I nozzle with enough pressure to deice and anti-ice an aircraft. The consistency of the Type III fluid that was applied with the Type I spray equipment was excellent. The measured viscosities of the fluid sprayed on the wing in the two tests were used by the fluid manufacturer to determine the appropriate delivery viscosity for the Type III fluid that was sent to the testing laboratory for endurance time testing.

The endurance time tests performed with new Type III fluid provided very good results. The endurance times were all much longer than the Type I holdover times. TC and the FAA produced similar Type III holdover time tables for inclusion within their operator guidance material for use in 2004–05 winter operations. Subsequent incarnations of the Type III holdover time guidelines from TC and FAA have included values for 75/25 and 50/50 Type III fluids.

The Type III fluid has been endorsed by most airframe manufacturers, and Bombardier and Embraer have performed takeoff tests on operational aircraft with the Type III fluid. Aerodynamic testing with the Type III fluid limited its use to −16.5°C (2°F) with slow rotation speed aircraft and −29°C (−20°F) with high rotation speed aircraft.

In the early 2000s, air operators in the United States and Canada began employing Type III fluid in winter operations, but its use has not been widespread. The fluid was reported to have performed well in all operations, and no deficiencies have been noted to date.

The fluid, as designed, may be used heated in a one-step operation. Use of heated, thickened anti-icing fluids for deicing has resulted in cases of fluid residue re-hydration in the past. As the viscosity profile of the fluid is greatly reduced in comparison to other thickened fluids, it is believed that fluid residues will be greatly reduced with Type III fluid. A verification program may need to be implemented if Type III use is initiated.

2. Implementation Considerations

Applicability Assessment

This practice would be primarily applicable to aircraft operators or FBOs at airports with commuter aircraft traffic or with short queue times following de/anti-icing. This practice would be readily applicable for spray-and-go deicing operations. As the fluids provide holdover times well in excess of Type I fluids, this practice would enable improved operational flexibility at many airports and improved safety. In addition, the use of Type III fluid could sizably reduce volumes of fluids applied at airports that have mild winter operating conditions.

Regulatory Considerations

The fluid currently resides on the TC and FAA lists of approved de/anti-icing fluids, and holdover time guidelines for the products are provided by the regulators. There are no other regulatory considerations that hinder the use of Type III fluid.

Planning and Design Considerations

The following factors should be considered in planning implementation of Type III fluids:

- Aerodynamic performance and freeze point limitations of the Type III fluid versus the operating environment at the airport;

- Holdover times required for operations at the airport in all winter operating conditions;
- Queue times of aircraft post-deicing;
- On-site fluid storage facilities;
- The logistics of product substitution, which will include consuming or disposing of existing stockpiles of old fluids and cleaning tanks and refilling them with the new product;
- Modifying and distributing deicing plans to reflect the new product and training employees on the new plan and product;
- The environmental characteristics of the Type III product; and
- Effective training and quality assurance program.

Integration with Other Fact Sheets

Type III fluid could be employed with many other practices.

Operation and Maintenance Considerations

For this practice to be effective, operators should plan on revising deicing plans to reflect new product and providing product-specific training to deicing personnel.

With the exception of changes required to the deicing plans, equipment operation and maintenance requirements should not change significantly.

A maintenance program may need to be initiated to verify that gel residue issues are not created by the use of Type III fluids in a heated one-step deicing operation.

3. Costs

The initial costs for implementing Type III ADF would be for the purchase of the fluid and any additional storage capacity that may be required.

The cost of Type III fluid is similar to that of Types I and IV. However, Type III fluid is applied at higher concentrations than Type I, which makes it more expensive per gallon applied for deicing. Additionally, Type III fluid offers shorter holdover time protection than Type IV fluids. Therefore, cost savings are generally realized only when Type III fluid can be used in a one-step deicing/anti-icing process that replaces both Type I and Type IV fluids. Because business jets are smaller than commercial airliners and often operate from smaller airports where long holdover protection is not necessary, they are the most likely to benefit from Type III fluid application. A reduction in environmental costs would also occur.

Costs may also be incurred development and monitoring of a maintenance program to verify that gel residue is not an issue with the use of Type III fluids in a heated one-step deicing operation.

FACT SHEET 56

Infrared Deicing Technology

This Fact Sheet is structured in two parts: Part I describes the use of fixed facilities for infrared deicing and Part II describes the use of mobile infrared deicing systems.

Part I Fixed Infrared Deicing Facilities

1. Description

Purpose

This practice utilizes infrared (IR) energy to melt frost, snow, and ice from the surface of an aircraft, greatly reducing the need for deicing fluids.

Responsibility for implementation and operation is by a specialized service contractor in coordination with an airport.

Some deicer or anti-icer application may be required after IR deicing to provide holdover time during periods of active freezing or frozen precipitation.

Technology

The technology for infrared deicing utilizes natural gas- or propane-fired emitters that are tuned to optimize the melting of frost, ice, and snow. The IR energy from the emitters does not heat the air nor is it lost in the air before it contacts the aircraft. The IR energy does not pass through the aircraft surface and has a negligible effect on aircraft cabin temperature.

Some deicer or anti-icer application may be required after snow and ice have been removed by the IR to provide holdover time during periods of active freezing or frozen precipitation. Depending on the weather conditions and location of the system, some deicing of the aircraft using aircraft deicing fluid may be necessary before it can be moved to the IR deicing location.

One manufacturer has developed an IR deicing system that consists of a drive-through structure with emitters mounted from the ceiling that aircraft pass through to be deiced. Four facilities were constructed in the United States between 1997 and 2006 at Buffalo Niagara, Rhinelander–Oneida County, Newark International, and JFK International airports. However, as of 2016, none of these facilities are currently in regular use. Another facility was opened in Oslo, Norway in 2006 and was used as a testing facility for two deicing seasons before it was shut down.

Documented Performance

Performance data on IR deicing are limited by the number and scale of facilities in commercial operation to date. When they were operating, all of the existing

installations served a small fraction of the total aircraft traffic at the airports where they are located. For that reason, there are no data available on airport wide glycol use reductions.

Data is available for two facilities in the New York metropolitan area:

- An 80–90% reduction in per aircraft glycol use was reported using the system installed at the Newark airport;
- The JFK Airport IR facility was operated during the 2006–2007 deicing season. With the exception of two ice storms, this was a relatively mild deicing season. Glycol reductions of approximately 90% per aircraft were reported under snow and ice conditions. Defrosting operations were reported as having used no glycol.

2. Implementation Considerations

Applicability Assessment

The following factors should be considered in evaluating the potential applicability of this technology to a particular airport:

Although the technology is still available, IR deicing facilities are not in active production.

- All of the existing IR deicing facilities were implemented by a single manufacturer. Since that time, this manufacturer is no longer actively offering this product and service. While there are other companies that offer IR heating equipment and may have the capability to install IR deicing hangars, none are actively pursuing IR deicing at the time of this factsheet;
- The IR system provides aircraft deicing, but does not provide any holdover time. Supplemental application of aircraft deicers or anti-icers is likely to be required for safe flight operations;
- With the current drive-through designs, land requirements and siting of an IR facility are key determinants regarding basic feasibility. See Regulatory Considerations and Planning and Design Considerations;
- Substantial upfront infrastructure costs are associated with construction of an IR facility. In most cases, some level of commitment by aircraft operators to use the facility would be required to prove the business case for a new installation; and
- It may be possible to find productive uses (e.g., vehicle storage and maintenance) for the IR structures during the non-deicing season.

Regulatory Considerations

The FAA has produced several guidance documents related to the use of IR energy for deicing and encourages the development and use of this technology. IR facilities need to meet the criteria of FAA AC 120-89, “Ground Deicing Using Infrared Energy.” Use of IR energy for deicing can be approved as part of any Part 121, 125, or 135 certificate holder’s deicing/anti-icing program or plan. FAA publication AC 150/5300-14C, “Design of Aircraft Deicing Facilities,” Chapter 5 covers the design of infrared deicing facilities.

Air emissions issues and applicable regulations should be considered with this practice. Aircraft movement to the deicing facility may increase air emissions. In addition, the power generation and gas used by the infrared emitters may have emissions ramifications.

These issues need to be examined at the airport level before a decision is made to employ this practice.

Planning and Design Considerations

The location and design of the IR system structure is critical to its acceptance and success. IR facility placement must take into consideration the aircraft launch area and allow for adequate approach and egress. These facilities can be land intensive. The structure itself must conform to FAA Part 77 and be approved for tower sightlines and runway object-free areas. Part 77 includes imaginary surfaces that define navigable airspace with specific height and construction restrictions. Basic electrical, water, and gas utilities are required.

The size and type of aircraft operating at the facility must be considered to determine if they can be accommodated by the IR system. In most cases, it will be advisable to consider a "composite" aircraft when designing an IR deicing facility. That is, consider the most constraining features of all of the various aircraft that are envisioned using the facility. One facility in the United States ceased operations because the air carrier it typically served increased the size of its aircraft.

A screening-level traffic analysis will provide an estimate of the number of facilities that would be required to serve a given portion or subset of an airport's deicing needs. If the airport operates with significant "pushes" each day where a large number of aircraft are departing during a relatively short period, the IR facility must be sized with enough throughput capacity to prevent bottlenecks during severe weather conditions. Under these circumstances, conventional deicing of aircraft may be required to ensure adequate throughput.

FAA publication AC 150/5300-14C, "Design of Aircraft Deicing Facilities," provides standards and recommendations for the design and construction of IR aircraft-deicing facilities. In 2005, the FAA issued AC 120-89, "Ground Deicing Using Infrared Energy" to offer guidance to airlines on how to integrate IR deicing operations into their operating plans.

Integration with Other Fact Sheets

As discussed earlier, some level of deicing or anti-icing will still need to be performed on aircraft under many conditions. Additional collection and containment of the resulting glycol-laden runoff may be required at the IR deicing facility. This localized collection and containment would be a likely opportunity for collection of relatively small volumes of high concentration of glycol.

Because this is a source control BMP, its use will likely reduce the volume of deicing stormwater requiring collection and treatment, with reductions being proportional to the level of implementation at an airport. Glycol recovery operations

may be negatively impacted if the volumes of high-concentration runoff are reduced below the level critical to economic feasibility.

Operation and Maintenance Considerations

Operation and maintenance of the IR facility are typically provided by a service contractor with specialized skills and training.

Ground traffic coordination may impose new operational requirements.

3. Costs

As with performance data, cost data are limited on the IR deicing facilities because of the few installations to date. The most recent implementations have been installed under cooperative agreements between the airport and the technology provider.

Capital Costs

The range of costs for construction of a single-bay deicing facility was reported as $1 million to $4 million in 1997 ($1.5 million to $6.0 million in 2016 dollars). The 68,644 ft^2 facility at JFK is reported to have cost $9.5 million ($12.1 million in 2016 dollars). Final costs are dependent upon airport location and size, number of bays, proximity to required utilities, and local geotechnical conditions.

Operation and Maintenance Costs

Operating costs for infrared deicing have been cited as being significantly lower than conventional deicing with fluids.

Part II Mobile Infrared Deicing Systems

1. Description

Purpose

A mobile IR deicing system has the potential to be an alternative to standard glycol deicing, with the flexibility to operate at the gate or other locations where environmental restrictions could prohibit the use of glycol.

This practice is not yet a proven technology, but has been examined as a potential alternative technology in the research and development phase. As of 2016, Trimac Industries is still capable of producing the truck as described below although they are not actively pursuing its production.

Technology

Trimac Industries, LLC of North Kansas City, Missouri, developed a mobile aircraft deicing system designed around flameless IR heat emitters. The system is known as the Infra-Red Technologies Ice Cat™ system.

The Ice Cat aircraft deicing system is designed around IR heat emitters using natural gas, propane or butane fuel. The IR heat is created through a catalytic process that doesn't emit nitrous oxides or carbon monoxide associated with combustion processes.

A microprocessor based temperature control system manages the IR energy transmitted to the aircraft surfaces. The control system allows the operator to pre-set the desired maximum aircraft skin temperature by continuously adjusting the amount of propane fuel being fed to the heaters.

The Ice Cat's emitters are installed on mobile vehicles equipped with articulating boom extensions, which lift and position the panels over the aircraft surfaces.

Documented Performance

A study conducted to examine the effectiveness of a mobile system in removing different types of frozen contamination from a wing surface in terms of time and quality and to assess the potential for future use was reported in the Transport Canada document (TP 13489E), "Deicing with a Mobile Infrared System."

The research team evaluated the effectiveness of the Ice Cat IR deicing system on Fokker F28 and Boeing 737 aircraft. The time required to clear an entire wing of wet snow or frozen precipitation for the prototype system was found to be unacceptably long. The researchers concluded that deicing times would need to be reduced for the unit to be operationally viable.

Although the system's effectiveness in natural frost conditions was not examined, it is expected that the deicing time should be much shorter than that experienced with natural snow and may be operationally acceptable.

2. Implementation Considerations

As of 2016, this technology is not commercially available. Nonetheless, the following general guidance on implementation considerations is provided if the status should change in the future.

Applicability Assessment

As a mobile unit, the system could be used in two possible modes:

- At the gate, to remove overnight frost, ice, or snow contamination following termination of precipitation; and
- Off-gate deicing or in conjunction with off-gate deicing, to deice the aircraft prior to application of anti-icing fluid.

The time required to deice an entire wing of wet snow or frozen precipitation for the prototype unit, as demonstrated, was found to be unacceptably long. Deicing times would need to be reduced for the unit to be operationally viable.

Although the system's effectiveness in natural frost conditions was not examined, the deicing time should be much shorter than that experienced with natural snow, and may be operationally acceptable.

There may be an opportunity to develop the system as a solution for frost removal. Incorporation of blowing fans could be considered to assist in removing melt water from the surface to prevent it from running into wing cavities. Defrosting constitutes a relatively large part of winter deicing operations. When viewed on the basis of the amount of contamination being removed, fluid defrosting is a relatively high-cost operation.

Regulatory Considerations

The system must produce results that comply with ARP 4737.

Approval by regulatory authorities is required prior to implementation in field operations.

FAA AC 120-89, "Ground Deicing using Infrared Energy" offers more information on the subject.

Planning and Design Considerations

Some prime objectives that must be considered for successful application are:

- The mobile equipment must be adaptable to use on aircraft parked at passenger terminals;
- The deicing/defrosting process must be sufficiently rapid to avoid delays to aircraft departures; and
- Wing surface temperatures must conform to aircraft manufacturer's limitations.

Integration with Other Fact Sheets

This practice is viewed as being an alternative technology to the use of glycol deicing fluids, but could also be employed to eliminate a portion of the contamination on the aircraft prior to the use of glycol-based fluids. Therefore, it could be integrated with other practices.

Operation and Maintenance Considerations

Specialized operator training would be required for the safe use of such equipment, particularly if employed in the congested passenger terminal parking areas.

Maintenance support and training would be required for the mobile IR system.

3. Costs

Capital Costs

A significant capital cost would be associated with purchasing such systems, which include the mobile vehicles and articulating booms for mounting the IR panels.

Operation and Maintenance Costs

Maintenance costs would be associated with the mobile vehicles and IR systems. Operational costs for the vehicle operation and the IR panel fuel must be considered. Savings could accrue from reduced use of glycol fluids.

FACT SHEET 57

Enhanced Weather Forecasting

1. Description

Purpose

This Fact Sheet involves the use of advanced weather forecasting systems to improve the accuracy of deicing and anti-icing material application, as well as for the preparation and operation of deicing practices.

Airports, aircraft operators or deicing service providers may be responsible for implementing this practice.

Technology

This practice utilizes real-time weather forecasting to improve the efficiency of deicing and anti-icing practices by giving pilots and airport operators relevant qualitative and quantitative information on the potential for wintertime precipitation. This real-time forecasting may assist in improving the efficiency of deicing and anti-icing practices.

Several technologies have been developed and implemented at several airports to achieve improve weather forecasting.

One popular technology uses regional area Doppler radars, surface weather stations, and snow gauges situated in terminal areas to measure weather characteristics. The National Center for Atmospheric Research (NCAR) developed an integrated display system that uses this information to depict accurate, real-time nowcasts of snowfall rate plus current temperature, humidity, and wind speed and direction.

A second technology provides forecast services ranging from terminal forecasts to written or oral system route briefings. Terminal forecasts are short-term, 18-hour forecasts of ceilings, visibilities, winds, and weather in or near airports, all of which dictate weather restrictions on arriving aircraft. If airport conditions improve earlier than originally forecasted, an amendment is issued as soon as possible. Route system briefing forecasts provide weather conditions over longer periods and over larger areas than the terminal forecasts. Briefings consist of a written summary of weather features and events that are likely to impact aviation operations. Generally, they include a discussion of the pertinent weather features forecasted to affect the route system during the next 8 to 24 or 48 hours. Potential weather trouble spots including timeframes and impacts are identified as specifically as possible. These reports are intended for use by systems operation controllers and others who work with the various components of flight operations.

Documented Performance

The performance has not been directly measured. If used successfully, this practice can optimize the selection of deicing or anti-icing materials and methods for

a particular deicing event. When used in conjunction with other deicing practices, enhanced weather forecasting may also improve the accuracy of practice selection, coordination, and operation, thereby potentially reducing concentrations or discharge volumes of deicer- or anti-icer-impacted stormwater.

A limitation associated with this practice is that forecasts are often inaccurate, even with advanced weather systems and equipment. Deicing personnel are tasked with making real-time deicing decisions that are conservative with respect to aircraft safety. As such, deicer application rates may not be significantly decreased because of enhanced weather forecasts.

2. Implementation Considerations

Applicability Assessment

Enhanced weather forecasting would be applicable to any airport or aircraft operator that performs aircraft or pavement deicing because it can improve the accuracy of deicer or anti-icer application rates and methods. The practice could be especially beneficial at airports with deicer management systems and deicer application practices that could be optimized by more accurate weather forecasts.

Accurate weather forecasts can help to identify weather conditions that are optimal for alternative deicing methods such as forced air deicing, tempered steam, hot water deicing, proactive anti-icing, and deicer blending to temperature. Weather forecasts can also improve the preparation and coordination of deicer containment and collection equipment, including deicer collection vehicles and catch basin inserts. Airports with fewer operations may not realize significant benefits when compared to the costs for installation and operation. Medium and large airports in northern climates are more likely to achieve the most benefits from this practice.

Regulatory Considerations

The primary regulatory consideration for this practice is complete compliance with all FAA requirements for effective deicing and safe flight operations.

Planning and Design Considerations

Airports, aircraft operators and deicing service providers interested in enhanced weather forecasting as a practice should consider the following in their planning and implementation:

- Identify the service or equipment that can provide enhanced weather forecasting services that best meet the needs of the airport and aircraft operators;
- Consider the following:
  - Capital and operational cost for each service or equipment; and
  - Types and accuracy of forecasts provided through each system and their applicability to existing airport deicing procedures and practices.

- Determine how enhanced weather forecasts will be incorporated into standard operating procedures for deicing/anti-icing and deicer management;
- Develop protocol for identifying weather conditions that are appropriate for existing deicer or anti-icer application methods and deicer management practices; and
- Develop a training program for employees that will be using the weather-forecasting system.

Integration with Other Fact Sheets

The success of many deicer application and deicer management practices may be enhanced by more-accurate and relevant weather forecasts. Enhanced weather forecasts may enable an airport or aircraft operator to identify opportunities for using alternative deicing practices, including alternative deicing materials and application equipment. Accurate weather forecasts can help to identify weather conditions that are optimal for alternative deicing methods such as forced air deicing, tempered steam, hot-water deicing, proactive anti-icing, and deicer blending to temperature. Weather forecasts can also improve the preparation and coordination of deicer containment and collection equipment, including deicer collection vehicles and catch basin inserts.

Operation and Maintenance Considerations

Operational requirements depend on the technology employed. If a service provider is used, the primary operational issues will be incorporating the information into standard operating procedures and training of personnel. If the technology is to be operated by the airport or aircraft operator, regular maintenance of equipment associated with sensors and forecasting technologies will be required, as prescribed by the manufacturer.

3. Costs

Costs consist of the costs of the weather-forecasting service or system as well as the time for the airport/airline staff to interpret the data.

Even with enhanced weather systems, forecasts are sometimes inaccurate.

Consequently, deicing decisions that are conservative with respect to aircraft safety must be made.

Capital Costs

Capital costs include installation of specialized weather-forecasting equipment onsite. Costs may be significant if the airport or aircraft operator chooses to own and operate the instrumentation. Using a forecasting service will entail no capital costs if dedicated instrumentation is not required.

Operation and Maintenance Costs

Operational costs may include costs associated with subscribing to or accessing a specialized weather-forecasting service, or costs for maintenance of onsite enhanced weather-forecasting sensors and equipment.

FACT SHEET 112

Low Flow Nozzles

1. Description

Purpose

This Fact Sheet discusses the use of low flow Aircraft Deicing Fluid (ADF) application nozzle technology that uses a reduced amount of ADF as compared to standard nozzles. Low flow nozzles may be used on most existing deicing trucks as an immediate low cost method of improving the efficiency of ADF application to aircraft, and reducing ADF usage.

Low flow nozzles range from 11 gpm to 40 gpm, often with the ability to vary flow settings.

Technology

Although specific models will vary, a typical low flow nozzle has flow rates that can be varied between 11 and 40 gallons per minute (gpm), compared to conventional fixed flow nozzles which typically are between 50–60 gpm. Some variants of the low flow nozzles maintain a constant pressure over a range of flow settings. Low flow nozzles that change the pressure to regulate the flow can result in higher pressures that are not applicable for all aspects of deicing.

Documented Performance

Low flow nozzles, particularly constant pressure variable flow nozzles, have been shown to deice aircraft in the same amount of time and as effectively as conventional nozzles. Constant pressure low flow nozzles are able to maintain a useable stream while flow is being adjusted. An additional benefit is that it moderates fluctuations in flow due to truck systems.

Nozzles that decrease flow by increasing pressure (similar to placing your thumb over the end of a garden hose) have been shown to be useful to penetrate more resilient snow and ice, such as refrozen snow.

Some nozzles deliver flows as low as 11 gpm, which are applicable to aircraft defrosting operations. This has been reported to result in a considerable reduction of ADF compared to conventional nozzles.

Specific glycol savings are difficult to estimate because it varies for each user depending on flow rates used and fleet make up. However, since low flow nozzles are generally capable of deicing an aircraft in the same amount of time as higher flow nozzles, operators should be able to estimate their glycol savings by estimating glycol use as a function of flow and time taken to deice an aircraft.

2. Implementation Considerations

Applicability Assessment

This technology is directly applicable to operators who have the responsibility for selecting and using ADF application technology that meets all requirements for maintaining aircraft safety.

Low flow nozzles are often cited as low hanging fruit when considering glycol use reduction options.

Older generation trucks with original nozzles may have flow rates as high as 50–60 gpm. Some trucks also have the capability of using multiple nozzles and switching between them. Using low flow nozzles as either the sole nozzle or as an option on a multi-nozzle truck allows for a reduction in applied gpm and hence a reduction in applied volume. This option is often cited as low hanging fruit when considering options for reducing glycol consumption. This technology is particularly applicable to improving the efficiency of older generation trucks.

Regulatory Considerations

There are no regulatory considerations that directly affect this practice. However, aircraft must be free from contamination before takeoff, and the exclusive use of low flow deicing nozzles may make it difficult to meet these requirements in a timely manner under severe winter conditions.

Planning and Design Considerations

The following factors should be considered in planning for low flow nozzles:

- Existing deicing equipment that can accommodate low flow nozzles;
- Size and configuration of aircraft;
- Time requirements associated with reduced flow nozzles (particularly during severe weather conditions); and
- Additional training for personnel.

Integration with Other Fact Sheets

Low flow nozzles may be employed in association with technologies described in other Fact Sheets involving the use of ADF blending or dilution. Low flow nozzles can be integrated with forced air or blending to temperature to further reduce ADF use.

Operation and Maintenance Considerations

Low flow nozzles are often easily installed on existing trucks.

Low flow nozzles are compatible with the majority of existing trucks and their installation is generally uncomplicated. Trucks with the capacity to measure ADF use in real time should ensure compatibility with low flow nozzles before switching/supplementing low flow nozzles to ensure accuracy. Pumping systems for trucks may have to be adjusted to meet flow and pressure ratings for specific nozzles.

Higher pressure low flow nozzles may be impractical for use in anti-icing operations because the higher pressure results in uneven fluid application.

Care should be taken when using low flow nozzles in conjunction with blending to temperature or hybrid air technologies to ensure that temperature buffers are met. Holdover time is a function of volume of fluid on the aircraft and the temperature of the fluid. Therefore, if the volume of the fluid is reduced (and subsequently the inherent total heat), holdover time will also be reduced. This problem may be amplified when deicing aircraft where the skin of the aircraft is colder than normal, for example from having flown long distances.

3. Costs

Capital Costs

The primary cost associated with this technology is the initial purchase of the nozzles, which is on the order of $200 each. While installation is moderately simple, it varies with the make and model of the trucks and selected nozzles. Total initial costs will depend on fleet size. Truck pump modifications may be necessary depending on the specific truck and nozzle pairing. Additional system adjustments may add to the initial cost.

Operation and Maintenance Costs

Beyond initial cost to purchase and install this technology, there are not considered to be any significant additional costs. This procedure provides the potential for savings through reduction in deicing fluid usage.