ACRP
FACT SHEETS

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PROGRAM

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Deicing Practices

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FACT SHEETS

Deicing Practices #1–41

ACRP Report 14

Deicing Planning Guidelines and Practices
for Stormwater Management Systems

AIRPORT COOPERATIVE RESEARCH PROGRAM **2009**

Deicing Fact Sheets

These Fact Sheets are prepared for each of the identified deicing practices. They are organized into the five categories mentioned in "Deicing Practice Categories," Chapter 3: aircraft deicing source reduction; airfield pavement deicing source reduction; deicing runoff containment/collection; deicing runoff treatment/recycling; and deicing runoff system components.

Special note on costs: Where available, specific costs of equipment and other well-defined elements are provided in the Fact Sheets to give the reader a sense of the magnitude of costs. These estimated cost numbers should not be used for planning purposes without verifying current local costs.

Aircraft Deicing Source Reduction

The purpose of these practices is to reduce the amount of pollutants generated by aircraft deicing activities, either by using products with reduced environmental impacts or by reducing the amounts of deicing products required to achieve and maintain safe flight operations. It should be noted that U.S. aircraft operators must obtain FAA Flight Standards approval for certain proposed source reduction Fact Sheets prior to selection and implementation.

Fact Sheet 1. Aircraft-Deicing Product Selection

Fact Sheet 2. Storage and Handling of Aircraft-Deicing Materials

Fact Sheet 3. Proactive Anti-Icing

Fact Sheet 4. Blending to Temperature

Fact Sheet 5. Forced Air/Hybrid Deicing

Fact Sheet 6. Infrared Deicing Technology

Fact Sheet 7. Physical Removal

Fact Sheet 8. Hangared Parking

Fact Sheet 9. Hot Water Deicing

Fact Sheet 10. Enclosed Deicing Bucket

Fact Sheet 11. Enhanced Weather Forecasting

Fact Sheet 12. Holdover Time Determination Systems

Fact Sheet 13. Aircraft Deicer Use Tracking

Fact Sheet 14. Aircraft Reduced Operations

Fact Sheet 15. Tempered Steam Technology

Airfield Pavement Deicing Source Reduction

The purpose of these Fact Sheets is to reduce the amount of pollutants generated by airfield pavement–deicing activities, either by use of products with reduced environmental impacts or by reduction in the amounts of deicing products required to achieve and maintain safe flight operations.

Deicing Runoff Containment/Collection

The role of these Fact Sheets is to provide methods for isolating, collecting, and containing storm water runoff from deicing activities. In most instances, these practices are implemented to address aircraft deicing runoff.

Deicing Runoff System Components

These technologies represent components of systems that may be implemented in various locations, and serving different purposes, in any given system.

Deicing Runoff Treatment/Recycling

These practices provide alternatives for disposing of deicing runoff that has been collected and contained, and is not suitable for controlled discharge to receiving waters.

FACT SHEET 1

Aircraft-Deicing Product Selection

1. Description

Purpose

This practice considers opportunities to use alternative aircraft-deicing products that have a reduced environmental impact, primarily in terms of the biochemical oxygen demand (BOD) found in the freeze-point depressants and aquatic toxicity associated with additives required to meet certification specifications.

Product selection is typically the responsibility of aircraft operators and their contractors.

Technology

All aircraft deicing and anti-icing fluids (ADFs and AAFs) must be certified as meeting the following Aerospace Materials Specifications published by SAE:

- 1424 Deicing/Anti-Icing Fluid, Aircraft, SAE Type I
- 1428 Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian, SAE Types II, III, and IV

Each manufacturer of aircraft-deicing fluids has its own proprietary formulations, the environmental characteristics of which may vary from others. Currently, only ethylene glycol (EG)–based or propylene glycol (PG)–based aircraft fluids are used at a commercial level. Both of these glycols have a relatively high BOD content, with EG having a somewhat lower BOD than PG. The additive packages, which affect primarily the aquatic toxicity of each product, vary more significantly among the formulations. Guidance on the environmental properties is sometimes provided in manufacturer literature for each product, but it is not always consistent or comparable between products.

The fluid manufacturers have been steadily improving their products with respect to aquatic toxicity and elimination of toxic components in the additive packages. Therefore, it is important to get the most current product information on the deicers that are being used or considered.

There are several ongoing efforts to develop ADFs and AAFs with reduced environmental impacts. The Department of Defense’s Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) have been funding research into environmentally friendly aircraft deicers for the past decade. To date, three ADFs have come out of these programs, none of which has been fully qualified for use. The goal of ACRP’s ongoing 02-01 research project is to identify the sources of toxicity in currently available deicing formulations and develop alternatives with more environmentally friendly profiles. This project is expected to be completed in 2009 and produce several alternative formulations suitable for commercialization. It is uncertain if, or when, any of these fluids will become commercially available.

Documented Performance

The U.S. military and some airports have mandated the use of only PG-based aircraft fluids. This bias toward PG-based fluids seems counterintuitive given its BOD content, but other environmental considerations have driven the trend. Specifically, in the 1990s, industry and the military moved away from EG-based fluids because of ethylene glycol's mammalian toxicity and its listing as a hazardous air pollutant subject to release reporting under the Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA). In contrast to these industry trends, Dallas/Ft. Worth International Airport reported encouraging the use of EG-based fluids specifically to reduce BOD loading from aircraft deicing. This facility disposes of all collected runoff, so recycling is not a consideration.

At least one airport (Oslo) has taken the step of formally banning the use of ADFs and AAFs containing benzotriazoles because of Norwegian environmental regulations. These chemicals are used as corrosion inhibitors in some fluid formulations and have been implicated as a major source of aquatic toxicity in those fluids. There were no reports identified of North American airports taking similar steps.

2. Implementation Considerations

Applicability Assessment

The primary key to applicability of this practice is the ability of aircraft operators to purchase and use SAE-certified deicing products based on improved environmental characteristics. Flexibility in this regard will be dependent on site-specific weather and operational conditions, which require specific deicer characteristics, and organizational constraints that may affect procurement practices. Also, any change in deicers must be accompanied by revisions to the aircraft operator's FAA-approved snow and ice control plan.

The potential for benefits from changing aircraft deicers may be evaluated by comparing the environmental characteristics of products currently being used against available alternatives in the context of existing facility-specific environmental concerns.

Where glycol recycling is used or planned, there will be a strong economic motivation for using PG-based fluids because the value of recovered glycol from runoff containing only PG-based fluids is significantly greater than that of a mixed waste stream.

Regulatory Considerations

The primary regulatory considerations regarding this practice are: (1) choice of alternatives is constrained to SAE-certified products and (2) any changes in product use must be incorporated in revised FAA-approved snow and ice control plans as well as associated training and operational activities.

Planning and Design Considerations

Product selection by an aircraft operator begins with identifying certified products that are reliably available in the quantities required and within the time constraints. The identified list of products is then evaluated with respect to operator and industry experience with the product, ground support equipment fleet mix and compatibility with the product, and the need for and timing of employee retraining.

Other considerations include the following:

- Airport policies restricting the type of glycol that can be used at that facility.
- Implications to recycling programs that depend on using a PG-based fluid.
- Potential for increased management and reporting requirements associated with EG being regulated under Toxic Chemical Release and CERCLA reportable quantity regulations.
- 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 product.

Integration with Other Fact Sheets

Product selection can be combined with all other practices. There may be opportunities to reduce the need for collection and treatment through use of deicers with improved environmental characteristics (for example, lower BOD or reduced aquatic toxicity).

Operation and Maintenance Considerations

For this practice to be effective, the aircraft operator should plan on revising deicing plans to reflect the 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.

3. Costs

Capital Costs

The only capital costs that might be incurred would be if the new product is not compatible with existing storage and application equipment.

Operations and Maintenance Costs

The primary source of changes to operational and maintenance costs would be differences in cost of the new product compared to the previously used one.

FACT SHEET 2

Storage and Handling of Aircraft-Deicing Materials

SOURCE REDUCTION
Containment/Collection
System Components
Treatment/Recycling

1. Description

Purpose

This practice includes protocols or guidelines for the storage and handling of aircraft deicing materials, with the primary purpose of reducing the contamination of stormwater by deicing/anti-icing materials.

Aircraft operators or their deicing contractors are normally responsible for implementation of this practice.

Transfer operations provide an opportunity for inadvertent spills of deicing or anti-icing fluid.

Technology

Specific goals for the storage and handling of deicing/anti-icing materials include maintaining product integrity, using and storing products effectively, and minimizing exposure of the materials to stormwater. Personnel responsible for the storage and handling of these materials should be trained in stormwater pollution prevention and follow protocols and procedures consistent with the airport's stormwater pollution prevention plan (SWPPP) and deicer management program.

To maintain the integrity and effectiveness of deicing/anti-icing materials, they must be stored, handled, and applied in a manner consistent with chemical-specific instructions provided by the manufacturer on the material safety data sheet (MSDS). Materials with reduced effectiveness may require larger application volumes or frequent reapplication, thus increasing the potential for stormwater pollution.

In general, aircraft anti-icing fluid, or AAF (classified as either a Type II or a Type IV fluid by SAE), has more specialized requirements for storage and handling than does aircraft deicing fluid, or ADF (classified as a Type I fluid by SAE). The high viscosity of AAF may be damaged by improper handling or storage methods, which can potentially reduce the holdover time between applications. Thickeners in AAF may be damaged by ultraviolet light and certain metal ions and thus AAF requires storage in opaque tanks constructed of stainless steel, coated steel, polyethylene, or opaque fiberglass. AAF agents also require careful heating to protect fluid viscosity. Any transfer of deicers through dedicated pipes and pumping equipment should be accomplished according to manufacturers' specifications. Anecdotal information from one airport indicates that piping cannot contain 90° bends because they increase the likelihood of freezing.

Documented Performance

Quantified benefits of establishing storage and handling protocols for aircraft deicing materials have not been explicitly documented or measured. However, airports have reported reduced unexplained glycol releases during transfer and fewer unexplained occurrences of elevated deicer concentrations outside designated deicing areas with the implementation of this practice. Generally, benefits may be expected in terms of decreased deicer discharges to surface water and potentially decreased deicing stormwater management costs.

The success of this practice at an individual airport can be evaluated by comparing the frequency of unexplained or unexpected deicer releases before and after implementing storage and handling practices.

2. Implementation Considerations

Applicability Assessment

This practice is applicable to any airport where aircraft deicing occurs, although larger airports may experience more noticeable benefits because of the volumes of fluids being handled. Airports already may have some type of guidelines in place as a component of their SWPPP or deicer management program plan. Opportunities for improving existing deicing material storage and handling programs will arise where there is a problem with deicer runoff outside of designated deicing areas.

Regulatory Considerations

Storage and handling protocols are frequently incorporated as requirements of SWPPPs and written deicer management program plans, and may be explicitly required by National Pollutant Discharge Elimination System (NPDES) permit conditions.

Planning and Design Considerations

The following operational considerations apply when developing protocols for storing and handling aircraft deicing and anti-icing materials:

- Store, handle, and apply deicing and anti-icing materials only within designated contained areas.
- Maintain adequate supplies of spill response equipment and materials in locations accessible to and near areas where spills may occur.
- Provide employee education as appropriate in the following areas: material storage and handling, deicing procedures, spill response and prevention, and stormwater pollution prevention.
- Restrict deicing/anti-icing material storage and handling to trained personnel only.

- Take actions to prevent stormwater runoff onto deicing/anti-icing material storage and handling areas. Block storm drains during material handling operations to prevent runoff of deicing/anti-icing materials.
- Where possible, store deicing/anti-icing materials indoors or in a sheltered area.
- Perform and document frequent inspections of storm drains, deicer application equipment, deicer runoff controls, and storage tanks; perform maintenance as required.
- Follow chemical- and product-specific instructions and guidelines recommended by the material manufacturer to maintain the material's integrity and effectiveness.

Several airports have reported that employee training is key to the success of this practice. This importance is illustrated by an anecdotal report that operators were found to be allowing releases from hoses and overfills to enter secondary containment basins without realizing the costs associated with pumping out and disposing of contaminated precipitation in the basins.

The following features should be considered in designing new facilities or upgrading existing facilities, to aid the effective storage and handling of aircraft deicing and anti-icing materials:

- Pavement or flooring characteristics in material storage and handling areas that facilitate cleanup and containment of spills; slope pavement or flooring toward a sump to facilitate fluid collection
- Clearly designated aircraft deicer/anti-icer storage and transfer areas
- Secondary containment for aircraft deicing/anti-icing material storage areas
- Closed-loop recycling system at deicing stations, which could help with collecting spent or spilled deicer for recycling
- Consolidated glycol storage/dispensing system, which has the potential to reduce spillage caused from transferring the materials between storage tanks and dispensing equipment

Integration with Other Fact Sheets

This practice would be compatible with any other deicing practices with regard to pollution prevention. Following this practice will reduce overapplication and spillage and ultimately reduce the volume or concentration of deicing runoff that needs to be managed through other deicing practices. Storage and handling protocols may also be tailored to apply to specific deicer management practices, including alternative deicing materials, deicer application methods or equipment (for example, hybrid deicing trucks), and deicing stormwater collection and storage practices (for example, glycol collection vehicles; see Fact Sheet 23). Relevant storage and handling procedures and protocols should be considered during the development of standard operating procedures for those practices.

Operation and Maintenance Considerations

Operational requirements associated with this practice include regularly reviewing and updating deicing material storage and handling protocols as necessary prior to each deicing season. Employee training should occur prior to the start of each deicing season.

3. Costs

Costs associated with this practice include both capital and operation and maintenance components.

Capital Costs

Capital costs for this practice may include features added to material storage and handling equipment and areas to reduce spills and prevent contamination of stormwater. These features may include secondary containment for storage tanks or specialized dispensing equipment that reduces the opportunity for spillage during transfer operations.

Operations and Maintenance Costs

Operational costs associated with this practice include educational programs for employees involved in storage and handling of aircraft deicing/anti-icing materials, spill response materials, and performance of regular inspections of storage and handling equipment.

FACT SHEET 3

Proactive Anti-Icing

1. Description

Purpose

This practice 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 take-off.

Implementation of this practice would be the responsibility of the 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, this practice can reduce the overall volume of glycol-based deicing fluid applied to an aircraft when properly performed prior to the advent of icing conditions (EPA, 2000). Proactive anti-icing has been found to be most effective under freezing rain; it is less effective for heavy snow and severe icing conditions.

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.

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 (EPA, 2000). Out of concern for aircraft safety, aircraft that have been anti-iced are often deiced with Type I prior to take-off 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 practice would be most applicable for aircraft operators or fixed base operators (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 or severe icing 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 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 FAA 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

Aircraft operators and FBOs 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 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.

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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 these residues.

Integration with Other Fact Sheets

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, as well as conditions that will not result in the formation of a harmful residue.

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 practice may include removing residue that could form on aircraft from dried anti-icing materials.

3. Costs

Overall costs associated with this practice 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 associated with this practice 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.

Operations and Maintenance Costs

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

Reference

EPA. 2000. Preliminary Data Summary: Airport De-Icing Operations. *EPA-821-R-00-016*. From http://www.epa.gov/waterscience/guide/airport/.

FACT SHEET 4

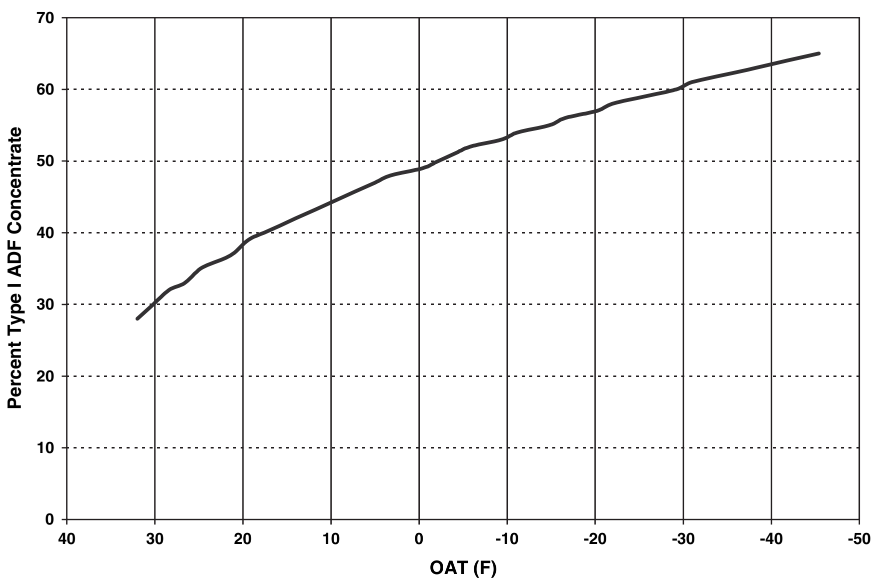
Blending to Temperature

1. Description

Purpose

Blending to temperature is a source reduction practice aimed at reducing the volume of Type I aircraft deicer fluid by optimizing the deicer concentration relative to the outside air temperature (OAT). This practice is not applicable to Type II or Type IV aircraft anti-icing fluids.

Aircraft operators or their contract 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 to their products to different outside air temperatures.

Technology

Manufacturers of aircraft deicing fluids (ADF) provide dilution charts describing the lowest operational use temperature for a range of mixtures. As the OAT rises, the mixture of glycol can be reduced instead of using a standard mixture. Examples of how blending calculations are conducted are commonly provided with the product literature.

Blending can be accomplished in a variety of ways, from manual mixing of ADF in a deicing truck's tank to the desired concentration, to the use of blending technology that either automates the tank mixture process (for example, blending stations) or provides for "blending on the fly" by adjusting the mix of concentrated

ADF and water fed to the deicing application nozzle. Recent developments in equipment technology have made the implementation of this practice more practicable and reliable, both with centralized blending stations and deicing vehicles.

Documented Performance

The success of this practice varies widely on the climate and temperature variations. The greatest potential for benefits exists at airports where deicing is conducted mostly at milder 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 savings reductions between 29 and 50 percent per season. The potential reduction is greatly influenced by facility specific factors, such as typical winter weather, aircraft mix, and times of day when aircraft deicing is conducted.

Many aircraft operators adopt a standard glycol-water mixture, typically between 45:55 and 60:40, to ensure consistent compliance with FAA 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.

2. Implementation Considerations

Applicability Assessment

This is an aircraft operator practice, so the first consideration will be the feasibility and acceptability of blending to temperature by the aircraft operators at the facility. 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 glycol storage and dispensing stations with automated blending equipment.

Blending may be considered 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) may elect to use a standard conservative blend on all aircraft because individual contracts with different carriers specify unique glycol 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 temperatures requires adherence to SAE Aerospace Recommended Practice (ARP) 4737 specification that residual Type I ADF on aircraft surfaces following deicing must have a freezing point at least 10°C (18°F) below the OAT or aircraft skin temperature. This is commonly referred to as the freezing point buffer.

In addition, the practice must be adequately described in an aircraft operator's FAA-approved snow and ice control plan.

Planning and Design Considerations

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

- Standard mixtures currently being used by aircraft operators;
- 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;
- Plans for glycol recycling, which can be undermined by the decreased concentrations of glycol in deicing runoff; and
- Effective training and quality assurance program.

Integration with Other Fact Sheets

Blending to temperature may be used in conjunction with most other practices in the source reduction, containment/collection, conveyance/storage, and treatment disposal categories. As noted above, integration with glycol recovery may be counterproductive because of reduced glycol concentrations in runoff.

Operation and Maintenance Considerations

The most significant operational consideration is how blending can be efficiently accomplished without affecting aircraft safety or operations. For example, it will be important to take care in managing 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 stations or blend-on-the-fly truck-mounted equipment is used, the added complexity of the technology will increase maintenance requirements.

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.

3. Costs

It is difficult to assess the capital costs of blending-to-temperature practices because most industry information contains total system or facilitywide costs rather than those of a particular facet of the system. Supporting evidence of substantial operations and maintenance savings does exist. 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 percent in glycol use with this practice, under relatively optimal climatological conditions (that is, deicing conducted primarily at temperatures between −2°C and more than 0°C).

FACT SHEET 5

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 by using a high-velocity stream of air to mechanically dislodge and remove snow and ice. In "hybrid deicing," aircraft-deicing fluid (ADF) is added to the air stream to aid in breaking loose snow and ice from aircraft surfaces.

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

Technology

Forced air/hybrid deicing employs specialized equipment to deliver high-pressure air and controlled Type I ADF mixtures to the aircraft surface. Some designs allow the use of air in applying Type IV anti-icing fluids, although certification tests on the equipment/fluid combination are required prior to use in this manner.

Forced air systems are often an optional item on larger, standard deicing vehicles and fixed boom configurations and, in some cases, can be installed as a retrofit. Some systems utilize a high-pressure air flow, while others are based on delivering large air volumes at low pressure. In some designs, nozzle arrangements deliver a columnar air stream that can be maintained over an extended distance to lengthen the effective reach of the stream. In all cases, the air stream may be warmer 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 Transport Canada-sponsored study evaluated forced air deicing systems in cleaning contamination from an aircraft test wing (APS Aviation Inc., 2000). The following study findings were reported:

- The increase in wing skin temperatures from forced air deicing (and, to a lesser degree, from fluid injected air) was less than observed with the standard application of heated ADF. This led to a significantly reduced time interval until refreezing occurred.
- The use of forced air alone was unable to free ice from the test-wing surface, in part because the heat of the air stream was insufficient to melt through the ice. An air/fluid combination melted the ice but required more than twice as much time as a standard nozzle to clean the wing.

- In tests to remove dry snow, the air/fluid combination and the standard fluid nozzle cleaned the test-wing in about the same time, but the air/fluid combination used about 80 percent less fluid.
- The short time-to-refreeze following forced air deicing precludes its use as a one-step deicing process, and undermines its suitability as the first-step in a two-step deicing process.

Reported experience indicates that performance in field operations is difficult to quantify with confidence and varies with the type of freezing precipitation. The technology has been found to be most effective under dry/powdery snow conditions and least effective in removing ice that has bonded to the aircraft surface. Table 1 below summarizes reported glycol reduction from facilities where this technology was found to be practicable. These results may be significantly better than what can be expected under less than ideal conditions. 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.

Table 1. Percent Glycol Reduction by User Type

User Type	Reduction	Note
Aircraft operator	85	Predominantly ideal conditions
Contract operation	65	Midwestern airport with centralized deicing pads
Medium 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 by properly trained personnel.
- A significant reduction in ADF usage over conventional trucks is possible under certain types of weather conditions, such as dry snow and frost.
- The potential source reduction benefits of the technology can assist facilities and airports with maintaining compliance with stormwater regulations.

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, or for the first step of a two-step deicing process unless 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 very effective in cleaning contamination from aircraft surfaces as a pre-step to standard fluid deicing, speeding up the deicing process and significantly reducing the amount of fluid needed to produce a clean aircraft.

The key factor in evaluating potential applicability of this technology is the type of winter precipitation commonly encountered. The technology is well-suited to dry, powdery snow, and least effective where icy conditions and heavy wet snow predominate.

A practical consideration is the age of existing deicing equipment. Equipment may not be scheduled for replacement for several years, thus reducing the near-term 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.

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

Planning and Design Considerations

The following success factors need to be considered prior to pursing a forced air/hybrid deicing system:

- Climate suited to the technology's strengths.
- Extensive operator-training program.
- Maintenance staff training.
- Phased procurement as part of regular deicing-truck replacement schedule.

Integration with Other Fact Sheets

Forced air/hybrid deicing can be integrated with virtually all of the other source reduction practices, with the exception of hangared parking (Fact Sheet 8). Significant reduction in the use of deicing fluids may undermine the economic viability of recycling programs.

Operation and Maintenance Considerations

The added complexity of the air blowers and delivery system will increase maintenance and repair requirements relative to conventional deicing vehicles or deicing booms.

Specialized operator training is critical to the effectiveness of this practice. The techniques are significantly different from conventional deicing trucks, and require more time to develop and maintain proficiency. It may be difficult for operators to maintain a high level of proficiency where local weather conditions result in infrequent use of the technology.

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

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 users of this technology indicates that the incremental cost associated with the forced air option on a deicing truck is in the neighborhood of $100,000, including a recommended enclosed cab feature.

Operations 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. Additional savings may be achieved through reductions in departure delays.

Reference

SAE G-12e Equipment Subcommittee. In progress. Forced Air or Forced Air/Fluid Equipment for Removal of Frozen Contaminants. Aerospace Information Report (AIR) 5633.

FACT SHEET 6

Infrared Deicing Technology

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. This is an emerging technology.

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

Some glycol use is still required for anti-icing after melting to provide holdover time during periods of active freezing or frozen precipitation.

Technology

Infrared energy can be produced in many different ways, but the systems typically have natural gas- or propane-fired emitters that are "tuned" to optimize the melting of frost, ice, and snow. One manufacturer has developed a drive-through structure with emitters where the aircraft is taken to be de-iced. Another manufacturer has developed a system, currently in the research and development phase, that places the emitters in large movable panels that can be mounted on stationary booms or a truck. The infrared energy applied to the aircraft does not heat the air, nor is it lost in the air before it hits the aircraft. The IR energy does not pass through the aircraft surface and has a negligible effect on aircraft cabin temperature.

Some glycol use is still required for anti-icing after melting to provide holdover time during periods of active freezing or frozen precipitation. Depending on the location of the system, some deicing of the aircraft may be necessary before it moves toward the infrared space.

Commercially operated infrared deicing currently uses the "drive-through" concept.

Documented Performance

Performance data on infrared deicing facilities are limited by the number and scale of facilities in commercial operation to date. Reductions in glycol use of up to 70 to 90 percent per individual aircraft deicing have been reported. Because all existing installations serve a small fraction of the total aircraft traffic at the airports where they are located, there are no data available on airportwide glycol use reductions.

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

- Angelo (2006) reported an 80–90 percent reduction per aircraft in glycol use at the Newark airport with the system installed there.
- An infrared installation at JFK Airport was operated during the 2006–2007 deicing season, which included two ice storms but was otherwise relatively mild. Glycol reductions of approximately 90 percent 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:

- 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 infrared 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 infrared 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.
- Some airports have been able to find productive uses (e.g., vehicle storage and maintenance) for the IR structures during the nondeicing 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 150/5300-14 CHG 2 ("Change #2 to Design of Aircraft Deicing Facilities") provides an appendix entitled "Design of Infra-Red Aircraft 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 infrared deicing facility. That is, consider the most constraining features of all of the various aircraft that are envisioned using the facility.

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, an IR facility may present a bottleneck during severe weather conditions. Under these circumstances, conventional deicing of aircraft may be required to ensure adequate throughput.

FAA publication AC 150/5300-14 CHG 2 ("Change #2 to Design of Aircraft Deicing Facilities") provides standards and recommendations for the design and construction of infrared aircraft-deicing facilities. In 2005, the FAA issued Advisory Circular AC 120-89 ("Ground Deicing Using Infrared Energy") to offer guidance to airlines on how to integrate infrared 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 need to be provided at the IR deicing facility. This localized collection and containment would be a likely opportunity for collection of high concentration of glycol.

Because this is a source control practice, 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. The 68,644-ft^2 facility at JFK is reported to have cost \$9.5 million. Final costs are dependent upon airport location and size, number of bays, and local geotechnical conditions.

Operations and Maintenance Costs

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

Reference

Angelo, W. F. 2006. New Deicing Technology May Save Groundwater. *Engineering News-Record.* May 8.

FACT SHEET 7

Physical Removal

1. Description

Purpose

This practice provides the opportunity to reduce the volume of aircraft deicers used in wintertime operations by physically (mechanically) removing snow or ice from aircraft. 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 brushes to remove accumulated snow from an aircraft. Hot-air-blast deicing systems may also be used. This practice requires that care be taken to avoid damage to the aircraft during the process of physically removing snow and ice.

Typically, after snow or ice has been physically removed, deicing or anti-icing fluid will need to be applied to an aircraft to remove any remaining frozen contamination, and to provide adequate holdover time prior to its takeoff.

A description of devices and associated procedures available to remove contamination is available in Transport Canada document TP 14052—Guidelines for Aircraft Ground-Icing Operations (http://www.tc.gc.ca/CivilAviation/publications/TP14052). This document describes the safe use of brooms, ropes, and scrapers, and touches on the use of portable forced-air-heaters to remove frost.

There is a separate set of technologies that serve to physically remove frozen precipitation during flight. "Boot" deicing systems, often used on smaller propeller aircraft, employ inflatable pneumatic or hydraulic boots, 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.

Anecdotal reports indicate that manual approaches to removing contamination are effective in particular circumstances, such as pre-deicing removal of large amounts of snow during early morning hours before operations start-up, and removing small accumulations of dry cold non-adhered snow, thereby avoiding the need for fluid deicing.

2. Implementation Considerations

Applicability Assessment

Physical removal is most successful with loose precipitation (e.g., dry powdery snow) and smaller aircraft with horizontal surfaces that can be easily accessed by ramp personnel. Larger aircraft and those with high wings present serious 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 precipitation 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 practice is incorporation into the aircraft operator's FAA-approved snow and ice control plans. Safety guidelines related to labor (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.
- Suitable equipment to provide personnel with safe access to aircraft surfaces.
- Provision of training and equipment to avoid damage to highly sensitive and often fragile sensors, antennas, vortex generators, and other aircraft surface features.

Integration with Other Practices

Physical removal techniques may be employed prior to the application of aircraft deicing or anti-icing fluids to reduce the total amount of fluid required. In those 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

The equipment costs to accomplish manual removal of snow from aircraft is relatively modest and generally would be covered under operating costs. Equipment purchases would be limited to brooms, ropes, brushes, and access ladders. Labor costs are the primary component of operation and maintenance costs.

SOURCE REDUCTION
Containment/Collection
System Components
Treatment/Recycling

FACT SHEET 8

Hangared Parking

1. Description

Purpose

Hangared parking seeks to reduce or eliminate the volume of aircraft deicers applied by avoiding accumulation of snow or ice on the aircraft. This practice is normally implemented by aircraft operators or their contract service providers.

Aircraft such as these F-16 Fighting Falcons are protected from the elements inside the hangar.

Technology

The application of this practice does not rely on technology. Hangared parking simply avoids exposing an aircraft to snowfall, freezing rain, etc., until just prior to its departure. Anti-icing may still be required to protect the aircraft from snow or ice accumulated during taxiing from the hanger to takeoff.

Documented Performance

The net reduction in deicer usage that can be achieved through this practice varies with climate, precipitation type, and characteristics of the aircraft operations. During periods of winter precipitation, this practice requires the application of anti-icing fluids to an aircraft to avoid snow or ice accumulation prior to the aircraft's takeoff.

2. Implementation Considerations

Applicability Assessment

The size of aircraft, the timeliness of departures, traffic volume, and the amount of suitable and available hangar space should be assessed prior to relying on hangared parking as an alternative to deicing operations. Where operations permit and adequate space is available, aircraft can be moved into hangars to warm up and melt off any freezing precipitation in advance of a scheduled departure. Generally, this practice is not suited to passenger or cargo operations where aircraft are loaded outside.

Smaller airports such as the Fort Collins–Loveland Municipal Airport can more easily implement this practice due to costs and size of the hangar space.

Smaller general aviation airports are more likely to implement hangared-parking alternatives due to the size of the aircraft involved. In addition, military installations are more likely to have hangar space for aircraft, especially smaller fighters.

Regulatory Considerations

The primary regulatory considerations concern FAA requirements and constraints on location and configuration of structures on the airfield.

Where significant taxiing to and from hangar locations is required, there may be regulatory concerns related to increased air emissions.

Planning and Design Considerations

The following factors should be considered in hangared parking:

- Availability, location, and adequacy of existing hangar space.
- Aircraft size.
- Nature of aircraft operations.
- Loading operations (indoor or outdoor requirements).
- Space for and cost of new hangar construction.

Integration with Other Practices

Not applicable.

Operation and Maintenance Considerations

Standard hangar space operation and maintenance need to be considered for this practice.

Operational considerations in utilizing hangared parking include the practicality of ground movement of aircraft to and from the hangars. Long taxi distances will increase fuel consumption and air emissions and potentially complicate airfield ground traffic management. It is also important to ensure that taxi routes are maintained so hangared aircraft do not become stranded in an area that is not a high priority for being cleared of snow during storm events.

3. Costs

Assuming hangared space is already available, there are few, if any, capital costs associated with implementing this practice. On the other hand, if hangar space is required, the associated capital investment will be relatively high, along with traditional operations and maintenance costs. In most instances, it will be cost-prohibitive to provide new hangar space for commercial aircraft.

Operating costs will vary with the specifics of the site. Reduced deicer usage will represent a reduction in operating costs, while additional labor required for moving aircraft in and out of the hangar and increased fuel consumption will increase operating costs. Maintenance costs will be largely associated with maintenance of the hangar and associated equipment.

FACT SHEET 9

Hot Water Deicing

1. Description

Purpose

Hot water deicing provides a specific opportunity to reduce or eliminate the volume of aircraft deicers applied by using hot water for deicing operations in lieu of deicer agents.

Aircraft operators or their contract service providers are normally responsible for the implementation of this practice.

Technology

Hot water deicing requires the appropriate technology to heat and distribute the water at the prescribed temperature (at least 60°C, or 140°F). Normally, this can be accomplished using conventional fixed or truck-mounted deicing equipment.

Hot water deicing is conducted as a two-step process: using a hot water spray to remove frozen material and then applying anti-icing fluid before the water has a chance to freeze.

Documented Performance

The success of this practice varies widely based on the suitability of the climate, with factors such as ambient temperature and wind speeds affecting the performance. Because this practice by itself does not provide holdover protection, it is employed as the first of a two-step process—being followed by the application of anti-icing fluids.

2. Implementation Considerations

Applicability Assessment

The primary factor determining applicability of this practice is local weather during the deicing season. Under relatively mild winter weather conditions, it has been successfully implemented by aircraft operators at a range of commercial airports.

Regulatory Considerations

The requirements for conducting hot water deicing are described in SAE's Aerospace Recommended Practice (ARP) 4737. The rules limit hot water deicing to ambient air temperatures above −3°C (27°F), specify a minimum application temperature of at least 60°C (140°F), and require that it be followed by application of an anti-icing fluid.

There are no environmental regulations that directly apply to this practice.

Planning and Design Considerations

The primary planning consideration is practicality of aircraft operators adopting hot water deicing under the ambient weather and operational conditions.

The procedures controlling the use of hot water must be very stringent because its application is dependent entirely on heat for protection against freezing. For this reason, this practice is recommended for use only at locations where there is supervision and dedicated deicing staff who are trained and proficient in its use.

Integration with Other Practices

Physical removal techniques may be used prior to using hot water deicing. In addition, practices associated with detecting the presence of snow or ice can be integrated with hot water deicing, such as aircraft ice detection sensors, enhanced weather forecasting, and ice detection and information systems. Forced air deicing (see Fact Sheet 5) may also be integrated with hot water deicing.

Because concentrations of glycol in runoff will be reduced with hot water deicing, this practice may undermine glycol recovery efforts (Fact Sheet 41).

Operation and Maintenance Considerations

Because existing deicing equipment can be used for implementing hot water deicing, the primary consideration will be how to integrate using hot water into overall deicing operations while ensuring safety and compliance with all FAA requirements.

Special care is needed to guard against the following operational risks:

- Decrease in ambient temperature below the accepted guideline during the deicing activity.
- High wind conditions that quickly rob heat from the treated surface.
- Freezing of inadequately protected deicing equipment plumbing following the deicing activity.
- Inadequate labeling and checking of deicer tank contents, leading to misunderstanding of strength of fluid being applied.
- Dangerous icing of ramp surfaces in the absence of freeze point depressant.

3. Costs

Where existing deicing equipment can be used or adapted for use, capital investment for hot water deicing would be negligible.

Cost savings from reduced deicing fluid use would be realized during operations.

FACT SHEET 10

Enclosed Deicing Bucket

1. Description

Purpose

This practice addresses the concept that equipment operators working in a comfortable environment and protected from the elements will be more efficient in their deicing usage and practices.

Aircraft operators or their contract service providers are normally responsible for the implementation of this.

Technology

Enclosed deicing buckets augment standard deicing trucks or booms. They consist of a weather-proof and climate-controlled enclosure for the deicing operator controls.

Enclosed deicing buckets offer operators a comfortable environment—protected from the elements and exposure to deicing fluids.

Documented Performance

There is currently no quantitative data on the performance of enclosed buckets in reducing deicer usage or improving the efficiency of deicing operations. However, it has been observed that equipment operators tend to be more conscientious and efficient during the application process when protected from the environment and from exposure to deicing fluid. Protection from back spray also encourages deicing closer to the aircraft, which may reduce overspray and increase efficiency.

2. Implementation Considerations

Applicability Assessment

This practice is applicable to any aircraft-deicing operation, but implementation is typically accomplished in conjunction with replacement of deicing trucks or boom-mounted equipment.

Enclosed deicing buckets are also part of centralized deicing facilities, such as this system at Pittsburgh International Airport.

Regulatory Considerations

There are no known regulatory requirements for enclosed deicing buckets. However, there are federal codes for exposure control and personal protective equipment related to the handling of propylene glycol, ethylene glycol, and other deicing agents. Chemical goggles, hand gloves, and clean body protection (rain suits) are required for handling of glycol; 29 CFR 1910.134 describes respiratory protection requirements for airborne exposure (specifically for ethylene glycol). Enclosed deicing buckets can reduce or eliminate some of those requirements.

Enclosed deicing buckets are offered as an option on various deicing vehicles.

Planning and Design Considerations

The primary factor to be considered in planning for enclosed deicing buckets is procurement of the equipment as part of regularly scheduled deicing vehicle replacement.

Integration with Other Practices

Enclosed deicing buckets are compatible with other practices, and can be used with forced air deicing (see Fact Sheet 5), hot water deicing (Fact Sheet 9), and blending to temperature (Fact Sheet 4) source reduction practices.

Operation and Maintenance Considerations

The operation and maintenance considerations for enclosed deicing buckets do not add significantly to the standard operation and maintenance for deicing vehicles.

Table 1.
Typical Equipment Costs

Equipment	$
Standard 2,200-gal open bucket deicing vehicle	220,000
Standard 2,200-gal enclosed bucket deicing vehicle	245,000

3. Costs

Most deicing equipment manufacturers offer enclosed buckets as an optional item for deicing vehicles, which increases the initial capital investment. However, anecdotal evidence suggests that savings in deicing fluid usage from more efficient application may offset this difference. The cost difference between open and enclosed buckets is demonstrated in the Table 1.

FACT SHEET 11

Enhanced Weather Forecasting

1. Description

Purpose

This practice 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

Enhanced weather forecasting 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 (Ecology and Environment, 1997). This real-time forecasting may assist in improving the efficiency of deicing and anti-icing practices. For example, if snowfall is classified as dry then an airport operator may be able to sweep snow from airfield pavement without the need for deicer application.

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

The Weather Support to De-Icing Decision Making System (WSDDM) 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 and moisture content plus current temperature, humidity, and wind speed and direction. FAA AC 150/5200-30 Airport Winter Safety and Operations provides a discussion of this system, and its safety and operational benefits. SAE Aerospace Standard AS #5537 provides guidelines for the components and configurations that define the four versions of the WSDDM system.

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 of this practice 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

This practice 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.
- Develop a training program for employees that will be using the weather-forecasting system.

Integration with Other Practices

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 (see Fact Sheet 5), tempered steam (Fact Sheet 15), hot-water deicing (Fact Sheet 9), proactive anti-icing (Fact Sheet 3), and deicer blending to temperature (Fact Sheet 4). Weather forecasts can also improve the preparation and coordination of deicer containment and collection equipment, including deicer collection vehicles (Fact Sheet 23) and catch basin inserts (Fact Sheet 33).

Operation and Maintenance Considerations

Operational requirements associated with this practice 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 associated with this practice 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.

Operations and Maintenance Costs

Operational costs associated 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.

Reference

Ecology and Environment, I. 1997. *Literature and Technology Review Report for Aircraft and Airfield Deicing Waste Management,* section 5, "Technology Review—Aircraft Deicing Waste Management." Lancaster, NY.

FACT SHEET 12

Holdover Time Determination Systems

SOURCE REDUCTION
Containment/Collection
System Components
Treatment/Recycling

1. Description

Purpose

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 holdover time for any combination of fluid, ambient temperature, precipitation type and precipitation rate. The holdover time (HOT) information can then be relayed electronically to crews in the flight deck for their use in HOT decision making in winter operating conditions.

The result of this practice is optimized selection of deicing/anti-icing fluid selection by flight crews, resulting in potential cost savings, environmental benefits, operational efficiencies, and safety enhancements.

This technology will be commercially available in winter 2008–2009.

Technology

Deicing/anti-icing fluid HOT table values have been established as a function of specific precipitation rate and ambient temperature. However, 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 employ sensors that measure the three parameters required for fluid HOT determination: rate of precipitation, type of precipitation, and ambient temperature. The result of each combined measurement of these parameters is a scientific holdover time for any given aircraft deicing fluid or aircraft anti-icing fluid. A more-precise assessment of fluid HOT enables optimal fluid usage that is consistent with actual measured onsite weather conditions and flight safety requirements.

A HOTDS was tested at Montreal-Trudeau International Airport from November 2003 to April 2008. The system records precipitation type, precipitation intensity, ambient temperature, and wind speed every 10 minutes and calculates updated HOTs based on the measured weather and ADF holdover time databases. The holdover time databases are fluid-specific and represent the same information used to prepare conventional holdover timetables. Calculated holdover times are displayed on the PC and can then be transmitted to the flight deck and ground crews.

The manufacturer of the HOTDS tested in Canada has demonstrated compliance with the minimum requirements established by Transport Canada, and operational use of the system was slated to begin in winter 2008–2009.

Other HOTDS products, including a liquid water equivalent system developed by the National Center for Atmospheric Research, 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 2500 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 Transport Canada 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 to 2006. The objective of this work was to compare actual flight crew decisions in winter operating conditions to optimal fluid decisions that would be made if HOTDS were available. The results indicated that flight crews selected to employ thickened Type IV fluids in conditions that did not warrant their use in 27 percent of all departures. An additional 4% of all departures took off with exceeded HOTs.

2. Implementation Considerations

Applicability Assessment

The potential cost savings, environmental benefits, operational efficiencies and safety enhancements associated with this practice make it potentially applicable to most airports and aircraft operators subjected to winter precipitation conditions and the use of fluid holdover timetables.

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 practical use to medium- and large-size airports and operations characterized by severe winter weather.

Regulatory Considerations

Transport Canada and the FAA develop and publish the deicing/anti-icing fluid HOT 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 generation of deicing/anti-icing fluid HOT data will therefore require regulatory oversight and approval.

In December 2007, Transport Canada issued regulatory approval for use of HOTDS in Canadian air operations. As part of the regulatory approval process, Transport Canada developed Minimum Performance Specifications and Minimum Quality Assurance Requirements for HOTDS. A HOTDS manufacturer must demonstrate adherence to the minimum requirements prior to being approved by Transport Canada.

The FAA is currently examining the development and adoption of a regulatory approval process for HOTDS.

Planning and Design Considerations

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

- Airport siting of the HOTDS 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 affect the number of HOTDS systems that are ultimately required.
- Space requirements for the physical installation of the system hardware.
- Development of data communication pathways for system information (data link, radio frequencies, wireless modems, etc).

Integration with Other Practices

HOTDS technology has the potential to be integrated with most practices, including all fluid-related practices. 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 HOT 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 associated with this practice are not yet fully defined, as the technology has yet to be fully implemented in an operational environment.

Capital Costs

Capital costs for this practice 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.

Operations 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.

SOURCE REDUCTION
Containment/Collection
System Components
Treatment/Recycling

FACT SHEET 13

Aircraft Deicer Use Tracking

1. Description

Purpose

This practice provides for quantifying the volumes of aircraft deicers and anti-icers used in wintertime operations. Accurate deicer use information can be critically valuable in understanding aircraft-deicing practices, supporting analysis and design of deicing management systems, and complying with environmental requirements.

Use tracking supports a quantitative understanding of deicing practices and provides critical information for the design of deicing management systems.

Tracking aircraft deicer use is never intended to promote unsafe or inadequate aircraft-deicing practices or conflict in any way with FAA-approved snow and ice control plans, which always take precedence.

Aircraft deicer use tracking is typically the combined responsibility of the aircraft operator (or its contracted service provider) and airport staff who track use across the entire facility.

Technology

Various methods may be used to track aircraft deicer use, depending on the availability of data from existing record-keeping and the nature of information needs driving the tracking effort. The simplest and most common approach involves manually extracting the information from deicing truck logs and entering it into a spreadsheet to facilitate management, tracking, and simple analysis of the data.

At the other end of the spectrum, where a high degree of accuracy or resolution is required, electronic instrumentation can be installed on deicing equipment to monitor and record use and even communicate it to a deicing dispatcher.

Documented Performance

There is no quantified description of the performance of this practice, and tracking deicer use is not by itself expected to affect rates of use or impacts to stormwater. Instead, tracking provides a basis for understanding and demonstrating the relationships among weather, airport operations, deicer use, and environmental impacts. Airports and aircraft operators have reported using detailed aircraft deicer application data for a wide range of purposes, including evaluating different deicing application technologies, quantifying deicer loading under different weather and operational conditions, assessing the performance of collection practices, and understanding the fate and transport of deicers.

2. Implementation Considerations

Applicability Assessment

This practice is applicable where quantitative information on aircraft deicer use is needed to support effective deicing runoff assessment, planning, design, and management. The complexity of the approach should be closely matched to the facility-specific data needs. Examples of factors that affect complexity include frequency and resolution of reporting (seasonal, monthly, weekly, daily, by aircraft), accuracy of reporting, spatial resolution (whole airport, by drainage area, by gate), and fluid type and concentration.

Regulatory Considerations

FAA AC 120-60B requires that deicing crews record the following details of each aircraft deicing:

- Fluid type (e.g., Type I, Type II, Type III or Type IV).
- Fluid–water mix ratio by volume for Types II, III, and IV. Reporting the concentration of Type I fluid is not required.
- Start time (hours and minutes) of the final fluid application.

Compliance with this requirement may facilitate more complete tracking of deicer usage.

There are no generally applicable environmental regulatory requirements for aircraft deicer use tracking. However, certain National Pollutant Discharge Elimination System (NPDES) permits for deicing discharges require some level of use reporting, and some permitting programs, such as the Multi-Sector General Permit, have tiered requirements based on annual aircraft deicer use.

Key to success: Clearly explain why use reporting is required, and work with the aircraft operators and their contractors to minimize their reporting burden.

Planning and Design Considerations

The following factors should be considered in planning for tracking aircraft deicer use:

- Tracking and reporting complexity should be chosen to produce data sufficiently accurate, representative, and complete to meet the intended use of the data.
- Taking advantage of existing aircraft deicer use recording activities provides a way to minimize additional burden.
- Clear explanation and communication of the need for tracking will facilitate cooperation by aircraft operators and their contractors.
- Reporting and tracking can be made easier using web-based reporting forms and software.
- Accountability for accurate and complete reporting will help minimize data gaps and errors.
- A simple quality assurance practice is the inclusion of end-of-season reconciliation checks to ensure agreement between deicers on hand at the begin-

ning of the season, purchased during the season, reported used, and on hand at the conclusion of the season.

Integration with Other Practices

Aircraft deicer use tracking can support the implementation, performance assessment, and refinement of a wide range of other practices.

Operation and Maintenance Considerations

Operational requirements associated with tracking aircraft deicer use are related to the methods of record-keeping and reporting. Primary considerations include the following:

- Employing commonly used software for data entry, management, and analysis.
- Building the tracking and reporting system around practices already in place—for example, compliance reporting required by FAA AC 120-60B.
- Minimizing data entry steps.
- Automating quality assurance checks.

Maintenance requirements consist of managing the database and generating tracking reports. In those rare instances where electronic tracking instrumentation is employed, some level of routine maintenance of that equipment should be expected.

3. Costs

The primary costs will be associated with both aircraft operator and airport staff time required for reporting and tracking activities. The magnitude of this effort will be a function of the incremental effort beyond that required by existing AC 120-60B reporting activities, the number of reporting entities, the complexity of the data being reported, and the types of data analyses and summary reporting required.

Capital costs for electronic instrumentation to measure, record, and report aircraft deicer use can be substantial. The Air Transport Association estimated a cost of $11,000 per deicing truck for a comprehensive instrumentation package that includes a flowmeter, GPS positioning, outside air temperature sensor, nozzle sensor, and inline refractometer.

FACT SHEET 14

Aircraft Reduced Operations

1. Description

Purpose

This practice involves reducing or eliminating deicer usage by curtailing flight operations during winter precipitation events. Reduced aircraft operations are the responsibility of aircraft operators.

Technology

There is no technology involved in this practice.

Documented Performance

There is no documented quantitative information on the performance of reduced aircraft operations in reducing deicer usage or deicing runoff discharges. However, reductions in both usage and discharges would be reasonably expected with reduced operations.

2. Implementation Considerations

Applicability Assessment

Reducing flight operations to reduce deicer usage and runoff has very limited applicability. In the general aviation and corporate flight communities, flight operations are flexible and flights are often delayed or cancelled to avoid flying in winter weather. Certain military aircraft operations are also discretionary, and may be scheduled around the weather.

Reducing flight operations to reduce deicer usage is not applicable to commercial airports.

This practice is impractical for any aircraft that operate on set flight schedules, operate on demand, or involve emergency services.

Regulatory Considerations

Where applicable, there are no regulatory considerations involved in reduced flight operations.

Planning and Design Considerations

The following factors should be considered in planning for reduced operations:

- Relative contribution of anticipated reduction in deicing to improved environmental compliance.

- Flexibility of flight operations.
- Acceptance by aircraft operators.
- Loss in revenue or other economic impacts from reduced flight operations.

Integration with Other Practices

This practice can be integrated with other deicing practices. Where reduced flight operations are feasible and result in reduced deicer usage, this practice should reduce requirements for collecting, storing, and treating deicing runoff.

Operation and Maintenance Considerations

Not applicable.

3. Costs

Costs will be associated with lost revenues or other lost opportunities associated with delayed or cancelled flights.

FACT SHEET 15

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 deicer required to deice an aircraft. This practice could also be employed for engine deicing and for the first step of two-step de/anti-icing operations.

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. 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 under a wide range of operating conditions during the winter of 2006–2007. 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.

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 promising, and plans are currently underway to implement the technology on a limited basis in winter 2008–09.

Residual water is created when melting large quantities of snow or ice contamination. Residual water presents a risk if it can re-freeze on the aircraft. In cases where residual water is created by the melting process, a simple application of Type I fluid subsequent to the TST operation will 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.

2. Implementation Considerations

Applicability Assessment

This practice would be most applicable to frost and predeicing applications in all climates. It 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.

The system may be employed at the gate, remote pads, or in centralized deicing operations.

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 2008–2009. Aircraft operators and FBOs that are interested in TST as a practice should consider testing the technology once it is available, to evaluate the technology's effectiveness under their operational conditions. Success of the technology at a particular airport will require that it be adopted by FBOs and air carriers. Because the technology is vehicle-mounted, infrastructure planning and design considerations applicable to this practice are minimal.

Integration with Other Practices

TST may be combined with nearly all other practices. The success of TST for defrosting or predeicing may be aided with additional practices that help to characterize when weather conditions will be appropriate for use of the practice.

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 practice 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 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 16

Airfield Pavement–Deicing Product Selection

SOURCE REDUCTION
Containment/Collection
System Components
Treatment/Recycling

1. Description

Purpose

This fact sheet considers opportunities to employ alternative pavement-deicing products that have a reduced environmental impact, primarily in terms of biochemical oxygen demand (BOD) and aquatic toxicity found in the freeze point depressants (and in very few cases, the aquatic toxicity associated with additives) required to meet certification specifications.

Product selection is typically the responsibility of airports and their contractors.

Technology

Prior to 1990, glycols and urea were the primary airfield pavement deicers used at airports. Since then, alternative pavement-deicing products that have lower BODs and no issues with ammonia toxicity or nutrient enrichment have been introduced to the market. These new products are available in both solid and liquid forms.

The primary environmental characteristics of potential concern are oxygen demand and toxicity.

Potassium acetate is supplied as liquid and can be applied either alone or as a wetting agent in conjunction with granular deicing materials to improve efficiency.

Potassium formate liquid pavement deicer is used at some airports in northern Europe, but is not currently used at any North American airports.

Sodium acetate and sodium formate are supplied in granular and prill form. Generally, manufacturers recommend applying these materials with liquid pavement deicers to improve adherence to ice surface and prevent the solid materials from being blown off the pavement. Granular products with irregular and sharp surfaces may be less susceptible to drift by wind or jet blasts than prill products.

Ongoing research and development results in the continual improvement of existing products and the introduction of new products. These efforts are being driven by both environmental considerations and materials compatibility issues.

Documented Performance

Product selection offers the opportunity to reduce loadings of BOD and ammonia (and possibly toxicity although the research is ongoing) associated with airfield deicing while providing the necessary operational and safety performance. The most common example of success from this practice is found in numerous reports from airports where the replacement of urea with another certified airfield pavement deicer has eliminated problems with excessive ammonia concentrations in stormwater discharges.

Table 1.

Pavement Deicer	Total Oxygen Demand*
Propylene glycol-urea	1.06 kg O_2/kg
Potassium acetate	0.4 kg O_2/kg
Sodium acetate	0.78 kg O_2/kg
Sodium formate	0.21 kg O_2/kg

*Please note that this information will be updated with the ACRP 02-01 Biodegradation Study results

The potential benefits of this practice at an individual airport will depend on the pavement deicer(s) currently in use, and the alternative products that are both available and meet all operational performance requirements. Table 1 provides representative total oxygen demand content for pavement deicing products. BOD and toxicity information for individual products may be found in the manufacturers' literature.

2. Implementation Considerations

Applicability Assessment

This practice is potentially applicable at any airport facility where airfield pavement-deicing agents are employed. The key to applicability will be the benefits that might be achieved by changing to an alternative product. Applicability will be greatest where airfield-deicing runoff is an environmental compliance concern and a change in pavement deicers offers the potential to significantly reduce pollutant loads.

Regulatory Considerations

The primary regulatory consideration in product is that all materials used for airfield deicing must be certified as conforming to SAE's specifications, described in AMS 1431 (solids) and AMS 1435 (liquids).

Planning and Design Considerations

The following factors should be considered before selecting the airfield-deicing product:

- Deicing products currently being used at the airport.
- Regulatory mandates and constraints regarding airfield-deicing materials.
- National Pollutant Discharge Elimination System (NPDES) permit language describing pavement-deicer requirements.
- Environmental characteristics of alternative airfield-deicing materials.
- Environmental impacts of primary concern and the relative contribution by airfield-deicing runoff.
- Compatibility of current and alternative pavement deicers with aircraft components and airfield infrastructure.

Guidance on the characteristics and proper handling and application of individual airfield-deicing materials are provided in manufacturer literature for each product.

Integration with Other Practices

Product selection may be integrated with most other source control practices, such as storage and handling and application of airfield-deicing materials (see Fact Sheet 17). Product selection that reduces airfield runoff pollutant loading may result in reduced needs for collection and treatment where this loading source is a significant compliance concern.

Operation and Maintenance Considerations

Deicing products may require specific storage and handling protocols to maintain their integrity and effectiveness. For example, some solid pavement deicers are hydroscopic and will cake if stored incorrectly. Product-specific requirements and instructions are typically provided by the manufacturer.

3. Costs

A representative range of costs typically associated with commercially available airfield-deicing products is provided in Table 2.

Table 2. Range of Unit Costs for Commercially Available Airfield-Deicing Products (circa 2007)

	Costs ($)		
Deicer	**Bulk**	**Tote**	**Drum/Bag**
Potassium acetate	2.50–3.00/gal	3.50–4.00/gal	3.75–4.25/gal
Sodium acetate	1,300–1,800/ton	1,430–2,150[a]	1,550–3,300[b]
Sodium formate	1,200–1,300/ton	—	—
Ethylene glycol (50%)	4.00–4.50/gal	—	—

Note: Costs were provided by commercial deicer providers.
[a] Per 2,205 lbs.
[b] Per pallet of 40 55-lb. bags.

FACT SHEET 17

Storing and Handling of Airfield Deicing/Anti-Icing Agents

Indoor storage and handling provides effective containment of solid pavement deicers.

1. Description

Purpose

This practice provides a means of preventing deicing and anti-icing agents from coming into contact with stormwater during their storage and handling prior to being applied.

Proper storage and handling of pavement deicing materials is normally the responsibility of any member of the airport community who uses these products.

Technology

Good housekeeping techniques, proper physical site usage, structural controls, regular maintenance, and the training of staff are typical activities related to storing and handling pavement deicers.

To maintain the integrity and effectiveness of pavement deicing materials, they must be stored, handled, and applied in a manner consistent with chemical-specific instructions provided by the manufacturer on the material safety data sheet (MSDS). Materials with reduced effectiveness may require larger application volumes or frequent reapplication, thus increasing the potential for stormwater pollution.

Proper storage is important to maintaining the integrity and effectiveness of pavement deicers.

Documented Performance

There is no quantitative data available on the performance of this practice. Generally, benefits may be expected in terms of decreased deicer discharges to surface water and potentially decreased deicing stormwater management costs.

The success of this practice at an individual airport can be evaluated by comparing pavement deicer consumption (rather than application) rates before and after implementing storage and handling practices. Any such comparison must, of course, consider comparability of weather conditions.

2. Implementation Considerations

Applicability Assessment

This practice is applicable to virtually any facility where airfield deicing materials are stored or handled prior to application.

Regulatory Considerations

Good housekeeping practices, including the proper storage and handling of deicing materials, are typically required under a National Pollutant Discharge Elimination System (NPDES) industrial stormwater permit as an element of an airport's Stormwater Pollution Prevention Plan.

Planning and Design Considerations

The following factors should be considered in planning for storing and handling airfield deicing/anti-icing agents:

Your NPDES permit may have specific requirements for storing and handling materials.

- Specific NPDES permit language describing requirements.
- Volume of deicing/anti-icing materials to be stored.
- Packaging of the deicing products (e.g., bulk, super-sacks, totes, or tanks).
- Methods used for transferring deicing materials to the application vehicles.
- Opportunities to upgrade existing facilities or construct new facilities for improved storage and handling.
- Indoor storage may offer an opportunity to incorporate heating of solid pavement deicers to enhance their effectiveness.
- Cost of storage and handling options.

Key approaches to storing and handling these products include the following:

- Store materials indoors or under cover, if possible.
- Store containers of material away from direct traffic routes to prevent accidental spills.
- Keep floors and ground surfaces clean and dry by using brooms, shovels, vacuum cleaners, or cleaning machines.
- Routinely inspect containers and tanks for leaks.
- Take actions to prevent stormwater run on to deicing/anti-icing material storage and handling areas. Block storm drains during material handling operations to prevent runoff of deicing/anti-icing materials.
- Provide a means of preventing spilled deicing materials from entering storm drain inlets.
- Clean areas following deicing/anti-icing material transfers.
- Maintain adequate supplies of spill response equipment and materials in accessible locations near operations.
- Emphasize the importance of these practices through personnel training.
- Restrict deicing material storage and handling to trained personnel only.
- Perform and document frequent inspections of storm drains, deicer application equipment, deicer runoff controls, and storage facilities; perform maintenance as required.

- Follow chemical-specific instructions and guidelines recommended by the material manufacturer to maintain the material's integrity and effectiveness.

Integration with Other Practices

This practice is compatible with all other deicing practices where pavement deicing materials are involved.

Operation and Maintenance Considerations

Operation and maintenance requirements related to materials' storage and handling are normally part of a facility's industrial NPDES compliance program. Deicing/anti-icing materials may require specific storage and handling protocols to maintain their integrity and effectiveness. These product-specific instructions are typically provided by the manufacturer. For example, solid materials require storage and handling that prevents clumping or dusting, either of which decreases effectiveness.

3. Costs

Capital and operation and maintenance costs depend on the amount of deicer materials to be stored and the locations and configurations of transfer areas. Higher costs will be incurred when covering or containing large loading/unloading areas is needed.

Pavement Deicer Materials Application Technology

1. Description

Purpose

This practice provides the opportunity to reduce the volume of pavement deicing materials (PDM) used in wintertime operations by facilitating efficient and optimum application of PDM.

PDM application techniques are generally the responsibility of the airport operator or its contracted service provider.

Technology

The simplest approach to efficient PDM application involves training and maintenance. Training airfield maintenance staff in appropriate techniques and application rates required to maintain safe operations and operators in the importance of disposing of excess deicers appropriately avoids unnecessarily exposing PDM to stormwater. Routine calibration and maintenance of PDM equipment ensures that application rates are accurately set.

Enhanced weather-forecasting systems can also improve the efficiency of deicing practices by airport operators. The quantitative information on the potential for freezing precipitation can help determine appropriate PDM application.

An increasingly common technology is the use of onboard computers to control application rates, with settings “locked out” of driver control to maintain consistent rates for the prevailing weather conditions.

One of the more advanced technologies for PDM application management integrates information from runway detection sensors and application vehicles. All runway clearing and deicing vehicles are equipped with GPS telemetry that transmits location and rate of runway deicer application to a central monitoring and logging system. Airfield maintenance staff can monitor the vehicles’ operations, along with runway and air temperatures in real time, and the information is stored in the system. Monitoring data are used to decide how much additional deicing is required. Additional benefits of this technology include the ability to detect when equipment is not operating to specifications (e.g., flow rates in booms, spreaders), providing in the event of an incident a detailed record of exactly where pavement deicers were applied.

Documented Performance

The performance of PDM techniques is site-specific, depending on factors such as the type of precipitation and the deicing mix. Up to 20 percent reduction in pavement chemical use has been reported by the Munich International Airport with the use of the most sophisticated telemetry and control systems (H. Pawlik, Flughafen München GMbH).

2. Implementation Considerations

Applicability Assessment

Sophisticated PDM application technologies are more likely to be applicable at facilities that regularly encounter ice and snow conditions and use significant quantities of PDM. The justification for this specialized equipment should be evaluated on a facility specific basis.

Personnel performing pavement deicing require training to ensure that they use proper equipment and methods to maintain safety. Training should also include techniques for ensuring appropriate application rates and avoiding overuse or waste.

Regulatory Considerations

The primary regulatory consideration for the implementation of this practice is its incorporation into an airport's ice and snow control plan. Safety guidelines related to labor (exposure to the elements, working under slippery conditions, etc.) should also be considered.

Planning Considerations

The following factors should be considered in planning for efficient PDM application:

- Frequency of ice or snowfall that is subject to use of efficient pavement deicing techniques.
- Size and configuration of airfield.
- Staffing and labor requirements.
- Time requirements associated with removing snow or ice.
- Costs for deicing application technology.

Integration with Other Practices

Mechanical methods, such as plows, brushes, blowers, and shovels for snow removal may be employed prior to the application of PDMs to reduce the total amount of fluid required.

Operation and Maintenance Considerations

The Stormwater Pollution Prevention Plan (SWPPP) for the airport typically requires the practicing for deicing/anti-icing practices. Generally, approaches for inspection or training, operation considerations, and contingency responses are provided.

Maintenance requirements vary with the type of equipment selected to use for pavement deicing application. Maintenance is either the responsibility of the airport operator or the contracted service operator.

3. Costs

Capital Costs

The most advanced control systems have capital costs that include vehicle and airfield telemetry packages, along with a control system and associated software. Costs for a complete package at a medium to large airport can range from $500,000 to more than $1,000,000.

Operations and Maintenance Costs

Labor and equipment maintenance costs are the primary components of operation and maintenance costs and depend largely on facility-specific details.

Depending on the type of enhanced weather forecasting system employed, reported annual operating costs for small, medium, and large airports nationwide can range from $2,400 to $8,400.

Reference

This was a personal communication with Mr. Pawlik who is with Flughafen München GMbH (http://www.munich-airport.de/de/consumer/index.jsp).

FACT SHEET 19

Heated Pavement

1. Description

Purpose

Heated pavement provides a means of deicing airfield pavement using electrical heating elements to minimize or eliminate the use of pavement deicing chemicals.

This practice is in the development stage. Implementation would be the responsibility of the airport.

Technology

The concept behind heated-pavement systems is that pavement surface temperatures are maintained above the freezing point of water, thus preventing accumulations of snow and ice from bonding with the pavement. Accomplishing this could facilitate the mechanical removal of frozen precipitation from paved areas, and could reduce the need for chemical deicing and anti-icing agents.

In the late 1990s, several manufacturers developed heated-pavement systems that could be applied to airfield pavement. Each of these took a different approach to the problem. One system consists of copper cables that are vertically embedded within a 2-inch-thick layer of conductive material installed below the paved surface. An electrical current passes through the conductive layer and acts as the heat source to the copper cables. A second system uses heated pipes to maintain the pavement temperature. A completely different approach uses a 120,000-BTU truck-mounted heating panel to melt ice on pavement.

None of the respondents to EPA's 2006 ELG questionnaire survey of more than 150 airports reported using heated pavement as a best management practice.

There are no known operational implementations of any of these approaches.

Documented Performance

Very limited documented information is available on any of these technologies. A prototype of the electrically conductive pavement system was tested at Chicago O'Hare International Airport in 1994 and 1995. Although the system was reported to have performed well at a testing level, it was also judged expensive to install and operate. There was no information available evaluating the potential cost savings from reduced use of airfield deicing agents using this practice.

Testing of the portable heating panel system at a general aviation facility demonstrated the ability to melt ice layers as thick as 1.5 inches without damaging paved surfaces or lighting.

2. Implementation Considerations

Applicability Assessment

Because this technology is not commercialized, this practice is unlikely to be applicable to airports at this time.

Regulatory Considerations

The primary regulatory considerations for this technology would be acceptance by FAA for installation and operation on an airfield.

Planning and Design Considerations

Not applicable at this time.

Integration with Other Practices

Not applicable at this time.

Operation and Maintenance Considerations

Not applicable at this time.

3. Costs

Not applicable at this time.

FACT SHEET 20

Airfield Deicers—Physical Removal

1. Description

Purpose

This practice provides the opportunity to reduce the volume of airfield deicers used in wintertime operations by physically (mechanically) removing snow or ice from the airfield in lieu of using deicing products for this purpose.

Technology

Physical removal of snow or ice involves using mechanized brooms and plows to remove accumulated snow from airfield pavement.

Under certain circumstances, especially in the case of dry snow, deicing products will not need to be applied to the airfield after the snow has been physically removed. Even when chemical deicing is needed after physical removal, less will be required to achieve safe operating conditions than would otherwise be the case.

Documented Performance

The performance of physical removal techniques is very site-specific, depending primarily on the type of precipitation encountered.

2. Implementation Considerations

Applicability Assessment

Physical removal is commonly conducted prior to application of pavement deicing products, and is widely applicable as a standard practice for airfield snow and ice removal. It is most successful in reducing the need to apply deicing products where loose dry precipitation, such as dry powdery snow, is involved.

Regulatory Considerations

There are no environmental regulatory considerations associated with this practice. Implementation must be consistent with all applicable FAA policies and approved airfield snow and ice control plans.

Planning and Design Considerations

Airports commonly employ physical removal procedures to make their use of deicing products more efficient. This fact sheet provides recognition that these typical procedures reduce the amount of deicing fluids applied and can therefore be considered as a source reduction practice.

Integration with Other Practices

Physical removal techniques are commonly employed prior to the application of deicing products to reduce the total amount of product required.

Operation and Maintenance Considerations

The primary operational consideration is ensuring aircraft safety.

3. Costs

Capital costs for physical removal are limited to purchasing brooms and plows. Labor costs are the primary component of operation and maintenance costs. However, because these practices are typically performed at airports regardless, there are no “new” costs in considering this action as a practice.

FACT SHEET 21

Centralized Deicing Facilities

1. Description

Purpose

This practice provides a means of concentrating deicing activities in one or more centralized deicing locations so that containment areas and runoff volumes are minimized.

Technology

Centralized deicing facilities can be simple aprons with deicer-laden runoff collection capabilities, or technologically advanced facilities with electronics that monitor everything from aircraft positioning to glycol concentrations in the runoff collection system. The complexity of each facility depends on the airports' or airlines' needs, and the sophistication required to meet operational and environmental needs.

Documented Performance

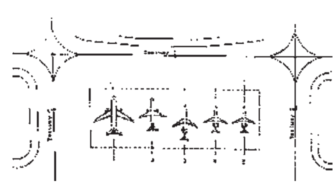
Centralized deicing facilities have the highest reported performance of available glycol collection practices. Because deicing activity is consolidated into one or more relatively confined areas, runoff volumes are reduced and relatively high concentrations of deicer-laden runoff may be collected. This feature is important when considering recycling of glycol in the runoff.

Airports employing centralized deicing facilities report repeatable seasonal collection performance in the range of 40–65 percent of glycols applied at the facilities.

2. Implementation Considerations

Applicability Assessment

Site-specific factors significantly affect the practicality of this practice. Centralized deicing facilities can vary from small apron or gate areas retrofitted with trench drains or asphalt curbs and frac tanks, to sophisticated off-gate facilities with queuing control, fixed deicing booms, blending to temperature, pumps, and recycling facilities. A key characteristic is that the facility provides an area where deicing activities are concentrated. Each airport and airline has to assess its needs and determine if one or more centralized deicing facilities is appropriate. U.S. EPA (1999) notes that centralized deicing may be impractical for all but the largest airport operations due to cost and size.



Typical centralized deicing facility.

The following factors are considered in determining whether a centralized deicing facility is a potentially suitable practice:

- Operational considerations such as peak hour traffic flow, gate availability, aircraft size, typical weather conditions, etc., will present opportunities and constraints. For example, it may not be economically feasible to construct a facility large enough to accommodate a large number of aircraft launched during a relatively short departure window. Conversely, if the flow of arrivals and departures is impeded by the availability of open gates, it may be beneficial to move deicing operations to a centralized facility, potentially reducing delays.
- The amount of site preparation required to construct a centralized deicing facility will affect cost. Large amounts of earthwork and drainage infrastructure may make the initial capital investment too large to justify the benefits of a centralized facility.
- Site-specific issues such as available area, drainage infrastructure, prevailing wind conditions, and jet blast will determine if a centralized deicing facility will fit within the confines of the airfield.
- Centralized deicing facilities may be established on existing aprons or gate areas if the areas are already graded favorably for collecting and containing deicing runoff. It may be feasible to deice smaller, regional jet–type aircraft at a centralized deicing facility while continuing to allow larger aircraft to deice at the gate.

Regulatory Considerations

Siting requirements for centralized deicing facilities are outlined in FAA Advisory Circular 150/5300-14. Centralized deicing facilities must also comply with the requirements of FAR Part 77, Objects Affecting Navigable Airspace, runway and taxiway safety area and object free area criteria, as well as TERPs surfaces such as precision obstacle free zones and W, X, and Y obstruction clearance surfaces. In accordance with FAA Environmental Handbook 5050.4A, a centralized deicing facility must not incorporate storage tanks or lagoons that may attract waterfowl.

Typically, the driving factor in considering centralized deicing is compliance with stringent environmental regulatory requirements embodied in the airport's NPDES permit. The decision to employ this practice to satisfy those requirements is made through a site-specific evaluation of alternatives, rather than a specific requirement for deicing pad technology as a compliance condition.

Planning and Design Considerations

FAA Advisory Circular AC 150-5300-14, "Design of Aircraft Deicing Facilities," provides guidance in planning and designing centralized deicing facilities and remote aircraft deicing facilities. There are separate chapters on sizing and siting the deicing facilities, designing aircraft deicing pads, aircraft access and vehicle service roads, and water quality mitigation.

The following factors should be weighed in planning and designing a centralized deicing facility:

- Consider departure rates and local conditions to determine the number of deicing positions needed.
- Consider aircraft fleet mix and queuing area in determining the size of the deicing pad. General guidelines require 2 acres per each medium or large aircraft. Aircraft movement simulation software may support the location, queue, and size of the deicing facility.
- Consider proximity of candidate locations to predominant take-off runway(s).
- Evaluate existing taxiways to and from the facility and the potential for additional taxiways to ensure efficient movement of aircraft.
- Incorporate drainage designs that capture deicer-laden runoff and segregate deicing runoff from "clean" runoff to minimize runoff volumes for treatment and disposal. Considerations should include wind dispersion and jet blast, grading, inlet locations, and underdrains.

Containment of flows in underdrains is often required to intercept glycol-laden runoff that has infiltrated through seams and cracks in the pavement surface of a deicing pad.

- Consider optimum method for deicing using either fixed-boom deicing equipment or deicing trucks.
- Allow sufficient capacity for spent deicer-laden runoff storage under design storm conditions.
- Ensure all structures, including support buildings, tanks, and lighting, comply with FAR Part 77 imaginary surfaces.
- Allow sufficient room for a support building, if desired. A clear view of the deicing positions is needed from the control room.
- Consider aircraft guidance lighting and marking to help pilots navigate into the deicing position.
- Consider enough room for aircraft to bypass other aircraft parking positions to facilitate traffic movement and avoid back-ups.

Integration with Other Practices

Centralized deicing facilities may incorporate virtually any source control practice.

Centralized deicing pads are often implemented on a limited scale and operated in conjunction with other collection/containment practices. These facilities may be used just for heavy snow events while defrosting or light deicing continues at the terminal gates or freight ramps.

Because centralized pads tend to result in the collection of concentrated runoff, they can facilitate recycling programs.

Operation and Maintenance Considerations

Operational requirements associated with centralized deicing facilities can be quite extensive, depending on the sophistication of the facility and local conditions. Some facilities are operated by the tenant airlines, whereas others are run by the airport through a private operator or using airport employees.

Maintenance requirements also vary with the degree of sophistication, but at a minimum include: annual maintenance of diversion valves and pumps, inspection/repair of pavement joints, and cleaning of the deicing runoff collection and storage system. Fixed booms are disassembled and serviced annually.

3. Costs

Capital Costs

Due to the high capital costs, centralized deicing facilities are generally impractical for all but the largest airports. The largest components of the capital costs include site preparation and excavation, paving and drainage infrastructure, and containment facilities. Additional costs include the deicing delivery method (fixed booms or truck-mounted deicers), as well as the glycol delivery piping costs and costs for a building to house the mixing/blending equipment and the truck-mounted deicing vehicles. Representative reported capital costs for centralized deicing facilities are shown in Table 1. It should be noted that each facility is unique to the context within which it is designed, and they are often constructed as part of larger airfield projects. It would be inadvisable to estimate costs for a new pad based on the data in the table.

Operations and Maintenance Costs

Reported operating costs for centralized deicing facilities are shown in Table 1. These costs typically include land and/or facility leases; labor; taxes; insurance and overhead; electricity, water, and gas utilities; and potentially a surcharge fee to the airport for the applied fluid, similar to a fuel flowage fee.

Table 1. Examples of Capital and O&M Costs for Centralized Deicing Facilities

Airport	Capital* ($M)	Annual O&M* ($K)
Akron-Canton, OH	10	200
Atlanta, GA	8.1	80
Baltimore, MD	30	800
Cincinnati, OH	33	500
Cleveland, OH	45–50	3.5
Dallas-Forth Worth, TX	100	No data
Dayton, OH	23	300
Detroit, MI	80	1,500
Fairbanks, AK	5.75	15–20
Hartford, CT	34	500–600
Pittsburgh, PA	42	~ 700–1,100

*All costs are approximate.

FACT SHEET 22

Apron Collection Systems

1. Description

Purpose

This practice provides a means of collecting deicer-laden runoff from terminal and freight apron surfaces by modifying existing drainage infrastructure or installing new conveyance infrastructure to allow deicing runoff to be diverted to containment and storage.

Apron trench drain near deicing operations.

Technology

Apron collection systems for deicing material control generally use conventional collection technology with special features to separate deicing runoff from ordinary stormwater. Watertight standards that are similar to sanitary sewer technology are applied to reduce infiltration or dilution of the collected material and to prevent exfiltration of the collected material into the ground and potentially the groundwater. Some form of diversion valve technology (see Fact Sheet 31) is used to separate deicing from nondeicing runoff. Other surface runoff technologies may be used to promote effective containment and collection of spent deicing materials.

Documented Performance

A wide variety of airports has implemented apron collection systems, either as a stand-alone collection approach or in combination with other collection practices, especially mobile collection vehicles (see Fact Sheet 23). Reported collection performance data from these facilities show a high level of variability, with collection efficiencies that range from about 10 percent to 60 percent of applied glycol. The performance is very dependent on local conditions, especially the weather during deicing events and the configuration of drainage infrastructure. Examination of reported data suggests that long periods of consistently cold weather support higher collection efficiencies.

2. Implementation Considerations

Applicability Assessment

The primary considerations in evaluating the potential applicability of apron collection are the configuration of existing apron drainage, especially storm sewers, and the ability to store and treat the deicing runoff that will be collected.

Drainage configurations will define the size of the area collected and opportunities for implementing diversions. Ideally, the drainage system will provide opportunities to divert deicing runoff with minimal dilution from nondeicing areas through surface runoff or converging storm sewer lines. Apron renovation or new construction projects may offer opportunities to incorporate optimized apron collection features, such as isolation of deicing drainage areas from non-deicing areas, placement of inlets close to deicing positions, and installation of diversions at optimal locations.

Because apron collection tends to involve larger areas of pavement than more-targeted collection practices, the volumes of deicing runoff collected tend to be greater, and the concentrations of deicers in that runoff tend to be lower. Adequate storage, coupled with a suitable treatment practice must be available for apron collection to be a practical option.

Regulatory Considerations

The placement and configuration of apron drainage features must comply with FAA requirements for taxiways and aircraft aprons (FAA Advisory Circular 150/5300-13, "Airport Design"). Apron drainage features must also comply with runway and taxiway safety area and object-free-area criteria, as well as terminal instrument procedure surfaces such as precision obstacle-free zones and W, X, and Y obstruction clearance surfaces.

Planning and Design Considerations

FAA Advisory Circular 150/5320-5C, "Surface Drainage Design," provides general guidance in planning and designing apron collection systems. Separate sections are included on sizing facilities and drainage and collection methods. The goal of the apron collection system for deicing runoff control is to maintain as much of the deicing runoff in the system as possible and reduce the loss of material to uncontrolled areas. The following factors should be considered in planning and designing an apron collection system to achieve this goal:

- Consider the geometry of the system. For simple retrofits, look for nodes where diversions can be installed to isolate subdrainage networks that serve the deicing areas with minimal inflow from nondeicing areas. For major apron renovation or new construction, a drain layout that reduces the surface travel distance for deicing runoff improves the potential for capture. Do not locate the drain under the aircraft if fueling operations are planned for the deicing position.
- For larger deicing areas, consider segmenting the surface drainage to minimize dilution during limited deicing operations.
- Consider slope and surface roughness to reduce the loss of fluid off the apron containment area due to jet blast.
- Seal pavement joints to reduce infiltration and deicing runoff loss through the pavement section.
- Consider service vehicle routes and taxi lanes when designing surface flow paths to avoid tracking deicing runoff out of the collection system.

- Use single- or multiple-grate inlets for simple construction and low maintenance.
- Consider trench drains in low points when necessary to meet minimum surface grade requirements. Avoid using trench drains to create drainage divides on slopes.
- Require watertight inlets and drain structures and pipe penetrations.
- Require watertight pipe material and joints.
- Provide periodic trench flow check material to control subsurface flow in pipe bedding material.
- Provide underdrains for controlling deicing fluid and stormwater infiltration and high groundwater. Allow diversion of the underdrains to the deicing fluid collection system.
- Design the system using controls equipment that is suited to the system objectives and the capabilities of the operations staff.

Integration with Other Practices

Apron collection systems can be implemented alone or in combination with other collection practices. Mobile collection vehicles (Fact Sheet 23) may be used to collect concentrated deicing runoff, to support recycling for example, with the apron collection system serving to contain the more dilute runoff. Apron collection system features may be used in managing the melt-off from deicer-laden snow and in providing spill control capabilities.

Operation and Maintenance Considerations

Operational and maintenance requirements associated with an apron collection system vary significantly depending on the sophistication of the system. The requirements are significant in a system that includes pumping, diversion valves, monitoring, and storage in addition to conveyance to a treatment or recycling process. In areas with winter weather that fluctuates between freezing precipitation and rainfall, manually operated systems will require a higher level of attention and operation. A gravity flow system may have requirements as modest as periodic observation and annual flushing.

Most apron collection system elements are underground and should be designed with low maintenance in mind to avoid excavation, repair, and replacement costs and the costs of surface restoration and disruption of airfield operations.

Apron collection systems may be operated by the tenant airlines (for example, a freight apron operator, the dominant air carrier, or largest fixed base operator), or by the airport through a private operator or using their own employees. Each facility needs to consider the best method of operating the apron collection system with the interests of all users in mind.

Pavement joints on the apron surface need to be inspected annually. Any joints showing signs of defective sealant should be resealed, and any cracks in the pavement should be sealed to reduce migration of the deicing runoff into the subsurface drainage. Finally, storage tanks associated with the drainage system should be maintained and cleaned during the off-season to avoid odor and prevent corrosion or attack from residual deicing materials.

3. Costs

Capital Costs

The capital costs for apron collection systems using existing infrastructure and surface drainage techniques can be very low. Larger aprons require underground drains and piping and may become significantly more costly. If mechanical control and monitoring are required, the capital cost of conveyance facilities can be even higher.

Operations and Maintenance Costs

Though it may have a high capital cost, a large pipe gravity conveyance system can have nearly no operation and maintenance costs. Mechanical systems add significantly to the O&M costs because of the more complex nature of the facilities, the need for monitoring and data collection, and the ability to develop and implement control strategies.

FACT SHEET 23

Glycol Collection Vehicles

1. Description

Purpose

This practice provides for active collection of aircraft deicing runoff from pavement surfaces using specialized vacuum-type collection vehicles.

Glycol collection vehicles are commonly referred to by a variety of names, including “sweeper-vacs,” “glycol recovery vehicles” (GRVs), and “mobile collection units.”

Technology

These collection vehicles are commonly referred to by a variety of names, including sweeper-vacs, glycol recovery vehicles (GRVs), and “mobile collection units.” Collection vehicles may be used for removing spent aircraft deicing fluid from the pavement virtually anywhere that aircraft are deiced and vehicles can have access. Glycol collection vehicles are often used in conjunction with other, passive collection practices.

There are two basic design approaches in commercial glycol collection vehicles: truck chassis or trailer mounted. The truck chassis designs are adaptations of the street sweeper concept, with a vacuum unit, vacuum/sweeper head, and storage tank all mounted on a single self-propelled vehicle. Typically, a separate engine powers the vacuum system. Trailer-mounted designs have the vacuum unit, collection head, and storage tank on a towed platform with power provided by either an engine mounted on the trailer chassis or a power take-off from the tow vehicle, typically a tractor.

Truck chassis design

Documented Performance

Glycol collection vehicles can be operated to collect as much aircraft deicing runoff as possible, or to just target the most concentrated runoff, depending on the objectives of the collection program. Performance data on glycol collection vehicle operations from several airports report glycol recovering between 23 and 53 percent of glycol applied in the collection area on an annual basis. The upper end of this reported range should be considered as reflecting optimal conditions.

Trailer-mounted collection unit

The overall effectiveness of glycol collection vehicles varies based on the number of vehicles used relative to the areas and deicing activities served, and whether they are used in conjunction with other collection methods, such as apron collection systems (see Fact Sheet 22), central deicing facilities (Fact Sheet 21), automated diversion valves (Fact Sheet 31), etc.

2. Implementation Considerations

Applicability Assessment

Vehicle-based glycol collection is generally well suited to situations where the following conditions are present:

- Aircraft deicing is conducted at various locations around the airfield.
- Collection of relatively high-concentration runoff is desired.
- Catch basins and storm sewer inlets can be blocked to prevent deicing runoff from entering the storm sewer prior to collection.

Other considerations include the following:

- Mobile glycol collection will increase the volume of vehicular traffic around gates and apron areas.
- Some temporary ponding of deicing runoff on the apron surface will occur. Coordination of collection operations will minimize the occurrence of this ponding.
- To the greatest extent possible, apron surfaces should be cleared of snow and heavy slush prior to mobile collection activities to avoid clogging the machinery. This can be a significant operational constraint on the effectiveness of this practice.
- Adequate staff must be available to operate the collection vehicles, open and close the catch basin valves, and manage the collected runoff.
- It is essential to maintain close communication and coordination between the glycol collection vehicle operators, aircraft deicing crews, and ramp coordinators.

Regulatory Considerations

There are no direct regulatory considerations associated with operation of glycol collection vehicles, other than compliance with all regulations regarding airside vehicle operations.

At some facilities, there may be concerns over increased air emissions.

Planning and Design Considerations

Glycol collection vehicles work best where deicing runoff remains on the ramp surface and is accessible for collection. As such, the following must be considered in developing an implementation plan:

- The capacity of the collection vehicle will be dictated by the amount of deicing fluid used at the facility during peak deicing events. Generally, larger capacity vehicles are more efficient, while smaller vehicles are able to operate in more confined areas.
- Some method of blocking storm sewer inlets to keep deicing runoff on the surface prior to its collection is essential to optimal performance. The most

reliable methods involve mechanical blocks installed within the inlets. Rubber mats may be used, but these are prone to being picked up by the collection vehicle and displaced by jet blast and prop wash.

- Pavement surfaces and joints must be maintained in good condition because the collection vehicle vacuum can suck up loose pavement and joint material.
- Stations for transferring collected runoff from the collection vehicles to storage should be located close to the collection areas to minimize transit distances.
- Solids collected with the deicing runoff must be managed and disposed of appropriately.
- Provisions are required for efficient transfer of the collected runoff from the vehicle to storage. On-board pumps can be used to transfer runoff to above-ground tanks. An in-ground sump with a heavy grate can be used for rapidly offloading collection vehicles equipped with a dump body design.
- Collection vehicles are prone to clogging with snow and slush and require a relatively clear surface for optimal effectiveness. Coordination with snow removal operations and operator training will minimize the impact on collection operations.

Some method of blocking storm sewer inlets to keep deicing runoff on the surface prior to collection is essential to optimal performance.

Dump feature enables rapid emptying of collected runoff

Integration with Other Practices

Glycol collection vehicles may be combined with block-and-pump systems (Fact Sheet 24), apron collection (Fact Sheet 22), and centralized deicing pads (Fact Sheet 21). Often, this is done to target runoff from defrosting operations or to intercept high-concentration runoff. The relatively high concentrations that can be collected facilitate reduced storage requirements and support recycling.

Operation and Maintenance Considerations

Effective operation of glycol collection vehicles requires trained staff and close coordination with aircraft-deicing operations. Vehicle operators need to be available at all times when aircraft deicing is conducted, and especially when heavy events occur. Staffing of glycol collection vehicle programs can be by airport staff or use contractor personnel. Training and supervising operators is key to success with this practice. Typically, a designated coordinator who tracks aircraft schedules and deicing operations, and directs the operations of the collection vehicles will result in optimum performance.

The maintenance of the collection vehicles is similar to other ground-based vehicles.

3. Costs

Capital Costs

Glycol collection vehicle costs depend on the type and capacity of vehicle. Purchase prices for purpose-built vehicles range between $85,000 and $350,000.

Lease plans are often offered by glycol collection contractors, either alone or as part of a program package.

Less-expensive alternatives may be suitable for some applications. Retrofit kits are available for certain street sweepers to adapt them to glycol collection. These kits are significantly less expensive than purchasing a new piece of machinery, although performance may not equal that of a vehicle that has been specifically designed for deicing runoff collection.

Operations and Maintenance Costs

Operating costs depend on the size and frequency of use of the vehicle.

FACT SHEET 24

Block-and-Pump Systems

1. Description

Purpose

This practice provides a means of intercepting deicing stormwater near the source. Implementation and operation of this practice is typically the responsibility of an airport, but tenants may consider implementation within their leasehold.

Technology

The primary objective in employing block-and-pump systems is to intercept deicing runoff close to the source, often using existing storm sewers for temporary inline storage. This approach facilitates cost-efficient collection of runoff and can improve the economy of glycol treatment/recovery systems. Block-and-pump systems are often supplemented with glycol recovery vehicles (GRVs) to collect a higher concentration deicing runoff.

Drainage blocks, consisting of valves (refer to Fact Sheet 31 Manual and Automatic Diversion Valves) or inflatable sewer plugs, are installed within the drainage infrastructure to prevent concentrated deicing stormwater from discharging to surface water through the drainage system. Upstream of the blocking mechanism, detention is provided in the form of pipe storage, surface flooding, or storage within other drainage structures. Deicing stormwater is collected periodically using pumps or GRVs, and transported elsewhere for treatment or processing. Blocking mechanisms are generally opened or removed during nondeicing periods to allow normal drainage of nonimpacted stormwater.

Documented Performance

The performance of a block-and-pump system for preventing the discharge of deicing stormwater depends upon the effective operation of the drainage blocks and collection of deicing stormwater during deicing events.

There are little available performance data specific to block-and-pump installations, but the practice is popular among smaller airports. Twenty-one airports (15 percent of those surveyed) reported to EPA that they use such a system. Of those airports reporting, all but seven were small-hub or nonhub-type airports.

2. Implementation Considerations

Applicability Assessment

The following factors should be considered when deciding whether a block-and-pump system is applicable to a deicing stormwater management system:

- Block-and-pump systems can typically be easily deployed and quickly operational. This practice is often a precursor to more-advanced collection systems.
- Block-and-pump systems may provide a means for collecting relatively high concentrations of spent aircraft deicer in applications where other high-concentration practices (e.g., deicing pads, GRVs) are not practicable.
- Block-and-pump systems are more favorable if the size of the drainage area and complexity of the storm sewer system are relatively low.
- A significant level of coordination may be required to operate and maintain the block-and-pump system to avoid interference with airport operations.
- Inflatable sewer balloons can be simple and effective as blocks but do require secure anchoring within the storm sewer system. Balloons may require replacement after 2–4 seasons.
- Drainage blocks may need to be custom fabricated for individual drainage systems.
- Ponding areas should be easily accessible by collection equipment to avoid interference with airport operations.
- Block-and-pump systems may cause flooding during heavy precipitation and impede safe aircraft operation.
- Effectiveness of block-and-pump systems is directly affected by pavement or drainage system cracks (leaks points), drainage area size, porous storm sewers, pipe material (e.g., corrugated metal), and the potential transport of deicer to other areas by vehicles that pass through ponded areas.

Sewer balloons may be installed almost anywhere there is access to the storm sewer.

Regulatory Considerations

Block-and-pump systems will not generally require permits, however they should be operated in compliance with any National Pollutant Discharge Elimination System (NPDES) (or equivalent) surface water discharge permit and FAA regulations. Ponding has the potential to interfere with airport and aircraft operations, and FAA Advisory Circular (AC) 150/5320-5c (“Surface Drainage Design”) recommends that ponding above apron catch basin inlets be limited to a depth of 4 inches. Standard operating procedures should establish upset conditions for the removal of drainage blocks when a potential for hazardous flooding occurs. OSHA regulations regarding confined space entry may be applicable where entry into the sewer system is required for installation or maintenance.

Planning and Design Considerations

The following factors should be considered in planning to implement a block-and-pump system:

- Identify potential locations in the drainage system where blocks would be most effective for capturing deicer runoff, and which would not cause significant upstream surface ponding or interference with airport operations.
- Develop standard procedures for preparing, inspecting, monitoring, operating, and maintaining the block-and-pump system, including upset conditions.
- Estimate time intervals and staffing required to operate, inspect, and maintain the system during and between deicing events.
- The collection location should be accessible by recovery vehicles or vacuum trucks, if applicable. The offloading location should be similarly convenient.
- This practice requires that joints or cracks in the pavement and within the drainage infrastructure be sealed to prevent infiltration or exfiltration. Because storm sewers are typically not designed to be watertight, frequent pumping of collected stormwater will minimize losses to exfiltration. The integrity of the block-and-pump system can be directly examined through regular visual inspections and/or tightness testing.

Integration with Other Practices

Commonly, a block-and-pump system is operated in conjunction with GRVs (see Fact Sheet 23) or a tanker truck with pumps, which collect the deicing stormwater that builds up behind the drainage block during deicing events. GRVs can also be used in conjunction with block and pump systems to collect higher concentration runoff

Operation and Maintenance Considerations

Operational requirements associated with a block-and-pump system include the manual operation of the drainage blocks, periodic testing of the ponded stormwater, pumping the collected deicing stormwater, and hauling it to storage and treatment. Maintenance tasks associated with block-and-pump systems include regular inspections of the systems to ensure proper operation, removal of debris that may interfere with drainage block operation, repairs to maintain watertight seals, and replacement of worn sewer balloons and valve parts.

3. Costs

Overall costs associated with block-and-pump systems depend upon the type of system employed, the number and size of drainage blocks required, the type of collection equipment selected, and the need for modifications to the existing drainage system to maximize effectiveness.

Capital Costs

Capital costs for block-and-pump systems may include drainage blocks, pumps or other collection equipment, vehicles for transport, additional detention structures, and modifications to the existing drainage infrastructure. Other initial costs may include repairs to existing infrastructure and surrounding pavement to ensure an adequate watertight seal.

Operations and Maintenance Costs

Operational cost items for block-and-pump systems include labor associated with operating the blocking and collection mechanisms, transportation of collected fluid, and monitoring and analysis. At some airports sewer balloons are removed at the end of each deicing season and reinstalled at the beginning of the next.

Maintenance costs may include the following:

- Repairs to seals within drainage infrastructure and surrounding pavement;
- Regular inspection of the block-and-pump system;
- Repairs to maintain proper system operation; and
- Periodic replacement of sewer balloons, if used.

Airfield Drainage Planning/ Design/Retrofit

1. Description

Purpose

The primary purpose of airfield drainage design is to divert stormwater from airfield operations areas in order to provide a safe and stable surface for movement of aircraft and support equipment. A secondary purpose is to reduce stormwater contaminants before they are discharged to the surface water system. For cold-weather airports, the most significant contaminant is uncollected spent deicing fluid. Considering the unique aspects of deicing runoff in the airfield drainage design process can improve overall control efforts.

Technology

Most existing airfield drainage systems benefit from some passive control of deicing materials in stormwater. Mass balance monitoring at various airports shows significant losses of deicers between point of application and stormwater discharge, and published research demonstrates that substantial biodegradation occurs on apron surfaces, even at low temperatures (Revitt and Worrall, 2003). Degradation of deicers in runoff can be enhanced by applying basic stormwater management principles, such as increasing the time that the materials remain in the system and controlling the conveyance surfaces that the deicing contaminants are exposed to. Systems that maintain drainage on the ground surface and maximize contact with vegetation and soil are expected to get the greatest removal benefit, while systems that promote rapid drainage with hard ditches and conduits are likely to get the least.

There are two processes that work to control stormwater contaminants: (1) biological reduction, which uses bacteria and nutrients in soil and vegetation to break down dissolved organic materials such as deicers, and (2) filtration in soil and vegetation, which intercepts suspended material in stormwater. Filtration is most applicable to non-deicing pollutants, but may provide benefits in intercepting granular pavement deicers and sand, as well as particulates unrelated to deicing runoff. Both processes can be designed into a drainage system by increasing the time or the flow path that deicing runoff takes to travel through the system and by providing contact with soil and vegetated surfaces.

Documented Performance

There is no documented performance data on this practice, although published research indicates that significant biodegradation of deicers occurs on airfield surfaces at low temperatures (Revitt and Worrall, 2003). The common occurrences of bacterial growth along airfield drainage ways is further evidence of biological activity under wintertime conditions. Significant documentation exists on the performance of stormwater practices, which employ the same underlying principles. Although quantitative performance cannot be extrapolated from the stormwater context, there is good reason to conclude that some level of deicing pollutant reduction will occur if favorable conditions are provided in the airfield drainage system.

2. Implementation Considerations

Applicability Assessment

This practice is intended to use buffer space or separation space that is not designed for aircraft operation or safety purposes. Thus this practice is appropriate for airfields that have considerable buffer and separation space; it may be less applicable at airfields where space is limited.

The biological degradation process is sensitive to temperature. Cold region applications will tend to see lower biological reduction rates. There is also typically less runoff during cold periods, reducing the flow-through times and loading factors. There may be no significant benefit in extremely cold regions.

In arid regions where vegetation is sparse, the filtering benefit of vegetation, which would reduce the containment of pollutants in particle form, is reduced. For areas with pervious soils and high groundwater, the drainage design should consider options to protect the groundwater from surface water impacts.

Regulatory Considerations

Design and construction of airfield drainage systems is subject to considerable regulations. Most significant are environmental regulations that are covered in other sections of this document. FAA's advisory circular AC-150/5320-5C for airfield drainage has recently been updated to cover both the quantity and quality of airfield runoff. There are allowances for stormwater practices that are consistent with drainage design principles for deicing runoff control.

Planning and Design Considerations

The following general airfield drainage practices are effective to varying degrees in controlling deicing runoff in airfield drainage systems, and can be applied individually or in combination to improve effectiveness.

- **Drain paved areas on the surface to vegetation.** This is the conventional method for runways and taxiways. In many situations, it can also be applied to paved apron space.
- **Slope safety areas for positive sheet flow drainage.** Safety areas must be capable of supporting aircraft and safety vehicles. A stable vegetated surface and positive drainage should be provided for these areas.

- **Slope buffer areas for sheet flow drainage over time.** Rapid and effective drainage is not as critical in buffer areas because maintenance activities can be scheduled during dry periods.
- **Provide vegetated swales for shallow concentrated flow rather than earthen or paved ditches or storm sewers.** This practice tends to increase the cross-sectional area of the flow path, thereby increasing short-term storage and reducing flow velocity and peak flow rates.
- **For concentrated flow where velocities are higher and flow durations longer, provide gravel and cobble armor in ditches rather than using paved ditches or storm sewers.** This approach adds roughness to the conveyance system, thereby reducing velocities and providing filtration, greater surface area for biological reduction, and opportunity for infiltration.
- **Allow sheet flow over vegetation upstream of field inlets.** Drains and storm sewers are needed in internally drained infield areas. A vegetated buffer area filters out sediment and attached pollutants before the stormwater enters the storm sewer for discharge to surface waters.
- **Consider temporary stormwater retention in areas not related to airfield operations.** This can provide flood control, contaminant filtration, sedimentation, and biological degradation. Avoid long-term standing water areas that may provide habitat for birds and ground animals.
- **Divert unimpacted surface drainage away from deicing areas.** This practice tends to reduce the volume of deicing runoff that requires treatment.
- **Consider potential impacts on shallow groundwater.** This practice will help avoid unintended transport pathways and water quality impacts.

Certain airfield situations may preclude the use of some of these practices, and practices should never compromise the function of safety areas.

Integration with Other Practices

This practice is compatible with all other deicing practices. Drainage design practices are especially important downstream of deicing areas, where fugitive deicing materials are present in stormwater. They are also beneficial where pavement-deicing materials may be present in stormwater.

Operation and Maintenance Considerations

The following considerations pertain to operation and maintenance associated with this practice:

- Airfield drainage systems should be designed to minimize operation and maintenance incursions into the operations area.
- Features that reduce maintenance requirements—such as self-cleaning inlets and remotely or automatically operated pumps, valves, and gates—are recommended.

- Surfaces and surface slopes should be compatible with normal maintenance and mowing equipment.
- Specialized procedures should be developed for nonstandard drainage and deicing fluid control features.

3. Costs

Capital Costs

Airfield drainage design to improve deicing runoff management is typically less costly than traditional drainage practices. The focus is on reducing more costly paved surfaces and underground drainage structures, and incorporating less costly vegetated and armored earthen surfaces and detention areas that reduce the size of drainage features. These practices do require more space than conventional designs, but the space is usually in buffer areas that do not serve a critical aviation function and have little or no commercial value.

Operations and Maintenance Costs

Periodic inspection is required to identify vegetated surfaces that have accumulated sediment and conveyance areas where erosion has compromised vegetated or armored surfaces. Annual removal of accumulated sediment and repair of eroded surfaces may be required, especially after initial installation or after subsequent construction activity. These operation and maintenance activities may be somewhat more costly than those for a system incorporating concrete surfaces and that does not control sediment.

Reference

Revitt, D. M., P. Worrall. 2003. Low temperature biodegradation of airport de-icing fluids. *Water Science and Technology,* 48(9), 103–111.

FACT SHEET 26

Deicer-Laden Snow Management

1. Description

Purpose

Management of snow containing aircraft or pavement deicers (sometimes called “pink” snow because of the color imparted by high concentrations of entrained aircraft deicers) is important for reducing deicer-laden discharges to surface water. Within deicer application areas and along runways and taxiways, deicer may runoff into or become entrained in clean snow. During snow-clearing activities, deicer-laden snow may be mixed or stockpiled with clean snow, resulting in further contamination. If containment actions are not taken, runoff from snow stockpiles with significant amounts of entrained deicers has the potential to enter the storm drainage system and discharge to surface water or infiltrate into groundwater.

Airports are typically responsible for the implementation of this practice.

Technology

Snow management has two primary objectives that address the concerns associated with deicer entrainment: minimizing the volumes of deicer-laden snow generated and managing deicer-laden snow and the associated meltwater to meet environmental requirements. Snow management includes a variety of practices and techniques to achieve these objectives.

Techniques for minimizing the amount of snow that is subject to being mixed with aircraft deicers may be accomplished in several ways. A common approach is clearing accumulations of clean snow from designated aircraft deicing areas prior to deicing operations. This requires good coordination between snow removal crews and aircraft deicing crews. Another approach is reducing the size of designated deicing areas, which may have additional benefits to deicing runoff collection and treatment or recycling.

Management of deicer-laden snow may be accomplished by plowing operations that distinguish between impacted and clean snow and the use of separate disposal areas for impacted snow that provide for containment of high-concentration meltwater.

Documented Performance

Performance data on this practice were not identified during the development of this guidance document. However, published U.S. Geological Survey research on the glycol content of airfield snow piles at one airport reported that 0.2 to 11 percent of applied aircraft deicers was contained in snow banks. The

The keys to managing deicer-laden snow are (1) reducing the volumes generated and (2) keeping it separate from clean snow.

following factors affect achievement of this level of performance from a snow management program:

- Comprehensiveness of efforts to minimize and segregate deicer-laden snow piles.
- Deicer content in the managed snow piles.
- Degradation of deicers in the snow piles prior to meltwater collection.
- Effectiveness in separating deicer-laden meltwater from relatively “clean” meltwater.
- Timeliness of snow melting and collection activities after snowfall event to avoid losses to soil or surface drainage.

2. Implementation Considerations

Applicability Assessment

Deicer-related snow management is not a widespread practice across the airport industry. This practice is typically implemented in response to evidence that (1) primary deicing runoff controls are not meeting requirements, (2) a significant amount of uncollected deicing runoff is bound up in deicer-laden snow, and (3) the deicers in the meltwater from that snow represent an unacceptable discharge to the environment.

This practice is typically not applicable where snow rarely accumulates, where apron collection or other widespread runoff collection efforts include snow disposal areas, where other deicing practices adequately control deicing runoff discharges, or where there is no practical alternative for disposing of the meltwater.

Requirements for successful management of deicer-laden snow include adequate manpower and equipment for separate plowing and handling of snow from designated deicing areas, suitable land for separate storage/disposal, and a suitable destination for the treatment or discharge of deicer-laden meltwater.

Regulatory Considerations

Management of deicer-laden snow must be consistent with all pertinent FAA regulations, including heights of snow piles allowed in different areas of the airfield. Lining of impacted-snow disposal areas may be required to avoid regulatory requirements associated with discharges to groundwater. Where snow melters are being considered, their impact on air emissions may have regulatory implications.

Planning and Design Considerations

The following factors should be considered in planning a successful snow management program to contain entrained deicers:

- There should be a well-defined justification for snow management to meet environmental requirements.

- Adequate and suitable space must be available for deicer-laden snow storage; it must be readily accessible for equipment transporting deicer-laden snow.
- Controls on meltwater from the storage area(s) should consider both surface runoff (via grading and curbing) and infiltration of the deicer-laden snowmelt into the ground (via a suitable impermeable lining).
- A suitable method for disposing of deicer-laden meltwater is required, with adequate capacity to handle the expected concentrations and volumes; strategies for diverting deicer-laden water to treatment and clean meltwater to the stormwater system should be considered.
- Standard operating procedures (SOPs) should be developed to provide unambiguous guidance for plow operators and truck drivers in identifying, collecting, transporting, and disposing of deicer-laden snow. Development of the SOPs should begin early in the planning process and with the explicit commitment and collaboration of staff who conduct snow-clearing operations.
- Snow melters can be used to significantly reduce the land requirements for managing deicer-laden snow.
- If snow melters are considered, details on their placement, operating costs, emissions, and method of disposal of meltwaters should be evaluated early in the planning process.

Integration with Other Practices

This practice is readily integrated as an element of a comprehensive deicing runoff management program. Disposal of deicer-laden meltwater will require adequate and suitable treatment capacity for the relatively dilute streams involved.

Management of deicer-laden snow generally enhances overall system collection performance. In addition to controlling a fraction of deicing runoff that would otherwise not be collected, snow removal from designated deicing areas prior to deicing operations benefits collection by reducing sources of dilution.

Operation and Maintenance Considerations

Operation and maintenance requirements will be facility-specific. The following general guidelines are provided:

- Some incremental increase in time and effort will be required to implement this practice; in many cases, deicer-laden snow management may be implemented with existing staff and equipment.
- Development of unambiguous guidance for plow operators and truck drivers is essential for success.
- Regular attention will be required during periods of warm weather to monitor the quality of the meltwater and manage its disposition.
- Maintenance at the end of the deicing season will consist of cleaning up accumulated debris and sediment from the storage areas, and inspecting, and repairing as needed, runoff controls and liners to ensure their integrity.

3. Costs

Costs for implementation of deicer-laden snow management will be very site specific. The following information provides guidance on possible cost elements.

Capital Costs

Capital cost elements may include additional snow plows and trucks, site preparation for a contained snow disposal area, and drainage controls and conveyance for managing meltwater. Snow melters, if purchased, can add significantly to capital costs, with prices in the area of several hundreds of thousands of dollars, depending on capacity.

Operations and Maintenance Costs

Possible operational cost elements may include labor and fuel for additional equipment operations and coordination, monitoring of snow disposal areas, lease and fuel costs for snow melters, and treatment for meltwater above concentrations that can be discharged to stormwater.

Maintenance cost elements include incremental increases in maintenance of snow plows and trucks, snow disposal area monitoring and control equipment, and snow melters, if owned by the airport. Annual maintenance of the snow disposal area(s) will also be required.

FACT SHEET 27

Portable Tanks (Frac Tanks)

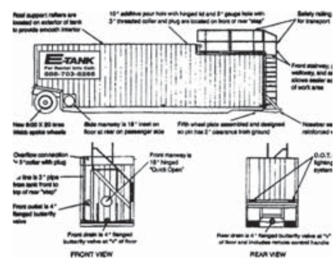
1. Description

Purpose

This practice provides a means of temporary storage for deicer-laden stormwater runoff prior to transporting for treatment or disposal. These tanks are commonly known in the industry as frac tanks.

Technology

Frac tanks are portable tanks, generally 21,000 gallons in size, that are delivered when and where needed by conventional semi-tractor trucks. These tanks are easily placed and removed and may be rented for any time period desired.



A conventional Frac tank schematic (provided by E-Tank).

Documented Performance

Frac tanks have been used successfully for a wide variety of storage applications for many years. The use of frac tanks for reliable and flexible deicing runoff storage applications dates back to at least the early 1990s at some of the first deicing pads established in the country.

2. Implementation Considerations

Applicability Assessment

Temporary storage using portable tanks is employed where the runoff volumes to be contained are relatively small and deicer concentrations are relatively high. Multiple tanks can be placed at a single location to meet storage capacity needs, and tanks can be distributed around the airport to serve multiple deicing locations. Additional tanks can be brought in if additional capacity is required.

Regulatory Considerations

Frac tanks themselves are not regulated since they are not designed for fluid transport. However, because Frac tanks may be used to store a variety of materials, including hazardous materials, the cleaning of the tanks is regulated according to the product that has been contained within the tank. Some frac tank rental companies will require an MSDS for the material stored as well as analytical results to certify that the tank is fully cleaned and free of the materials that were stored within.

In some instances, secondary containment may be required to prevent spills from entering stormwater systems.

Placement of frac tanks on the airfield must be in compliance with all applicable FAA regulations.

Planning and Design Considerations

The following factors should be considered when planning for the use of frac tanks for storage of deicer-laden stormwater runoff:

- Location of the tanks near the deicing area to simplify transfer into the tanks and minimize transport costs.
- Ease of transfer from the tanks to tankers for treatment or disposal.
- Assurance that the location of the frac tanks does not violate FAR Part 77 imaginary surfaces (A landside location may be preferable to an airside location for easier tank delivery/removal and tanker transfer.).
- Close coordination with the airport operations department to ensure that the location of the tanks does not affect other airfield operations.
- Provision of a level surface to take advantage of the full 21,000-gallon storage capacity (Gravel or other material may be required to stabilize the surface.).
- Advance coordination with the frac tank company well before the tanks are needed onsite to ensure availability. (Better rates are often available for long-term rentals, i.e., those longer than 4 months.)

Integration with Other Practices

Portable frac tanks offer great flexibility in placement, being small enough to locate around apron areas for short-term storage of runoff collected by glycol collection vehicles or block-and-pump systems. Frac tanks may also be used as a temporary storage option while permanent tanks are being constructed or undergoing maintenance activities or until the runoff can be transported for disposal.

Operation and Maintenance Considerations

Maintenance requirements are primarily associated with tank cleanout prior to movement at the end of a lease term. Some manufacturers or providers offer cleaning as a service included with the rental agreement. In this case, maintenance on a rented frac tank is negligible.

Frac tanks are not meant for transporting liquids and should be moved only when empty.

3. Costs

Although they can be purchased, frac tanks are generally procured as rented facilities.

Capital Costs

Frac tanks are not typically purchased, and therefore are not normally classified as a capital cost. Permanent, aboveground storage tanks (not frac tanks) are recommended for long-term storage, so frac tank purchase costs are not provided here.

Frac tanks are typically rented because they are used for temporary storage. As such, they can be leased for whatever time period they're needed. However, the best rates are obtained when tanks are rented for at least 4 months. Typical rental fees are provided in Table 1.

Operations and Maintenance Costs

Frac tanks require little in terms of operations and maintenance. However, one potential cost is cleaning the tanks upon completion of their use. Frac tank manufacturers require that the tanks be returned clean, and will charge a nominal fee for cleaning the tanks themselves or will require analytical results indicating that the tanks have been cleaned of the materials that were stored within them. Typical frac tank rental and cleaning fees are shown in Table 1.

Table 1. Typical Frac Tank Rental Fees

Fee	Typical Range
Daily	$45/day
Monthly	$1,350/mo
Long-term	Up to 20% discount
Cleaning	$200/hr including pressure washer, confined space entry, etc.

FACT SHEET 28

Modular Tanks

1. Description

Typical modular tank. (Courtesy of Modutank, Inc.)

Purpose

This practice provides a temporary or semipermanent means of storing deicer-laden stormwater runoff prior to its processing or transport.

Technology

Modular tanks are typically constructed of metal frames with membrane liners and floating covers. They can be purchased or leased and configured in a variety of shapes and sizes to suit the needs of the specific application. Modular tanks are a relatively economical, semipermanent solution to storing deicer-laden runoff that can be procured and installed in a relatively short period of time. Tanks vary in size from hundreds of gallons up to 2 million gallons and are available in square, rectangular, or circular configurations. Square and rectangular tanks are offered in sizes up to 2 million gallons with wall heights of 4 feet, 9 inches or 6 feet, whereas circular tanks are generally limited to a wall height of 20 feet and 800,000 gallons.

Documented Performance

Modular tanks have been used successfully for a wide variety of storage applications for many years. As with frac tanks, their use dates back to the earliest deicing pads established in the early 1990s. Compared to permanent tanks, they can be procured and assembled in a relatively short time period.

2. Implementation Considerations

Applicability Assessment

Storage using modular tanks is employed where deicing storage is needed and permanent tanks may not be an available option for budget or height restriction reasons. Modular tanks are often viewed as an interim step before permanent tanks can be programmed in a capital plan and implemented.

Regulatory Considerations

Modular tanks are typically constructed with double membrane liners and may be equipped with leak detection. The cleaning of the modular tanks is regulated according to the product that has been contained within the tank. Annual cleaning may be required, based on the disposition of the deicer-laden runoff, and may require a material safety data sheet (MSDS) for the material that was stored as well as analytical results to certify that the tank is fully cleaned and free of the materials that were stored within.

In lieu of double liners in a single modular tank, two single-liner tanks may be nested one within the other and still comply with primary and secondary containment requirements.

Placement of modular tanks on the airfield must be in compliance with all applicable FAA regulations.

Planning and Design Considerations

The following factors should be examined when considering the use of modular tanks to store deicer-laden runoff:

Typical modular tank construction.

- Need for the modular tanks to be located near the deicing area(s) to minimize transport costs.
- Ease of transfer from the tanks to the onsite processing facility or tankers for offsite treatment or disposal.
- Assurance that the location for the modular tank(s) does not violate FAR Part 77 imaginary surfaces (A landside location may be preferable to an airside location for easier tank delivery/removal and tanker transfer.).
- Need for a level surface to place the modular tank on so that full storage capacity can be taken advantage of.
- Need for a sand or felt layer under the secondary liner to protect the liners from puncture.
- Fact that water may accumulate on the floating covers of these tanks, thus possibility attracting waterfowl.
- Prevailing wind direction and proximity to occupied buildings because odors from stored deicer-laden runoff may be an issue.
- Stainless steel bolts, nuts, and washers should be specified to aid in annual maintenance and inspection.
- Weight adequate to hold down the liners prior to the tank being filled with fluid (Strong winds may float the liners out of place and potentially damage them.).

Integration with Other Practices

Modular tanks offer great flexibility in placement, being flexible enough to configure around apron areas for short-term storage of runoff collected by glycol collection vehicles (see Fact Sheet 23) or block-and-pump systems (Fact Sheet 24). Modular tanks may also be used as storage while other, permanent tanks are being constructed or undergoing maintenance.

Operation and Maintenance Considerations

Maintenance should be performed at least annually for the modular tank components and more frequently for the floating cover and liners. The steel components should be inspected annually for corrosion or sharp edges that may abrade or puncture the liner. The liners and floating cover should be inspected annually for leaks, punctures, or tears. Water accumulating on the surface of the tanks may be pumped off and disposed of as stormwater assuming an analytical test is conducted that confirms that the water is free of deicer-laden runoff.

3. Costs

Modular tanks may be purchased for long-term use or leased for shorter-term use. The costs vary with the size of the tank, and also with the options chosen for the tank.

Capital Costs

Modular tanks are available with different liner materials and different hardware types (galvanized vs. stainless steel), etc. Typical purchase prices, excluding assembly and site preparation, are shown in Table 1.

Table 1. Typical Modular Tank Purchase Fees

Size (gal.)	Typical Cost* ($)
50,000	40,000
100,000	50,000
245,000	80,000
500,000	130,000
1,000,000	225,000
2,000,000	375,000

*Excluding shipping, site preparation, and installation which could be significant (more than 10% of tank cost) depending on the facility location and site conditions.

Operations and Maintenance Costs

Modular tank components should be inspected annually for repair or replacement. The liners are the most important component of the modular tanks, and they may need to be replaced every 3 to 5 years on average, possibly more frequently. There are costs associated with the annual inspection and cleaning; however, these would vary greatly with tank size. Once these tanks are erected, the operational costs are relatively low, primarily involving monitoring of any tank valves and fluid levels during periods of active filling or discharge.

FACT SHEET 29

Ponds

1. Description

Purpose

Ponds provides for the onsite storage of collected deicing stormwater in open ponds for subsequent release to onsite treatment, sanitary sewer, or surface water in accordance with permit limitations.

Technology

Ponds (alternatively called basins or lagoons) provide a method for storing deicing runoff prior to treatment or surface water discharge. In some cases, these facilities also serve as nondeicing stormwater quantity and quality controls.

Although the primary function of ponds in deicer management systems is temporary detention of deicing runoff, ponds can also provide the benefits of solids settling and some degree of equalization. Ponds may provide a treatment benefit relative to deicing materials if detention time exceeds several weeks and the ponds are aerated.

Aerated ponds may be used for pretreating deicing stormwater prior to its discharge to treatment, or treatment to achieve concentrations that can be discharged to surface waters in accordance with applicable permits. Removal efficiency is primarily a function of detention time, temperature, nutrient load, dissolved oxygen concentration, and the concentration of deicers in the stormwater.

Documented Performance

There is no performance metric to reflect storage. Treatment efficiency data are not readily available.

2. Implementation Considerations

Applicability Assessment

Ponds are often considered by airports because they generally represent the most cost-effective means of storage available. There are, however, potential constraints to be evaluated.

Ponds offer the following advantages:

- Generally represent the least costly alternative for storage of large volumes of stormwater.

- Generally do not pose the height restriction concerns that may be encountered with aboveground tanks, although this will depend on berm height and pond location relative to the aircraft operating area.
- The storage capacity of a pond can often be increased much less expensively than can other types of storage.

Potential constraints related to ponds include the following:

- Degradation of deicers is more likely to occur in an open basin than in a closed tank because of wind mixing and the increased availability of oxygen. For facilities that recycle glycol, this degradation could reduce yields of recoverable product. Unaerated and poorly mixed ponds may experience significant odor problems from the anaerobic degradation of deicing compounds.
- Uncovered ponds may expose collected deicing stormwater to local surface runoff, sediment, and debris, which could interfere with treatment operations.
- Ponds used for storing deicing stormwater will typically require a liner to prevent impacts to groundwater. Drainage layers (e.g., geocomposites) below the liner may also be required to capture any leakage from the pond and, in some cases, to ensure that the pond liner will not "float" during periods of high groundwater.
- Uncovered ponds may present a wildlife attraction hazard, especially when constructed close to the airfield. Floating covers or other mitigation measures may be required to satisfy FAA requirements. Covers that have the appearance of open water, such as black floating covers, may still attract wildlife and may require camouflaging.

Other issues with ponds that should be considered:

- Ponds typically require a significantly larger footprint than other storage options, which may restrict potential locations.
- It is often more difficult to efficiently mix the contents of a pond than the contents of a storage tank.
- Synthetic liners can be subject to damage from equipment and animals, necessitating repairs.
- Locating a pond in an area with a high groundwater table or numerous high-yield sand seams can make construction difficult due to dewatering requirements.

Regulatory Considerations

FAA Advisory Circular 150/5200-33 ("Hazardous Wildlife Attractants on or Near Airports") provides guidance on placement and design of stormwater detention ponds near airfields. Ponds may require a permit to install or a construction permit in some states. In many states, a dam permit is required if the pond berms are certain heights above the lowest local discharge route. Compliance with groundwater regulations (including separation distance from groundwater) should be carefully evaluated before design and construction activities occur.

Planning and Design Considerations

Pond design needs to be site-specific, with special consideration given to the proximity to aircraft operating areas, wildlife deterrence, odor generation and control, solids removal, lining, and groundwater dewatering.

The following factors should be considered in pond design:

- In systems with onsite treatment, cost savings may be achieved by finding a balance between storage volume and treatment capacity. One aspect of determining the storage volume is the volume required for the "design" storm event, as well as the volume required for unforeseen circumstances when discharge rates may be restricted. Other considerations for pond design are discussed in Section 2.4.3 of the guidance document.
- Specialized outfall structures may be required to control the rate of discharge more precisely and consistently than would be required for an ordinary stormwater pond.

Integration with Other Practices

Storage is often a central component in an airport's overall deicing runoff management strategy, bridging the gap between collection and disposal by detaining collected deicing stormwater until it can be discharged to a glycol recovery system, onsite or offsite treatment, or surface water. Ponds can also play a role in an airport's overall stormwater management system, providing flow attenuation and water quality benefits to stormwater during nondeicing periods.

Operation and Maintenance Considerations

Operational and maintenance requirements will vary from minimal to significant, depending on the site, pond design, and integration with treatment operations. Requirements may include the operation of gates, pumps, mixers, valves, aerators, and monitoring equipment, depending on the specifics of the facility.

Ponds have low capital and annual costs relative to other storage options

Most basins will require periodic sediment and debris removal and maintenance of basin vegetation. Basins with a geosynthetic liner may require occasional repairs. Associated mechanical equipment will also require routine and preventative maintenance.

3. Costs

Overall costs associated with ponds will vary by individual airport site, depending on the design features selected. In general, ponds have low capital and annual costs relative to other storage options (e.g., underground detention and aboveground storage tanks).

Capital Costs

Capital costs for constructing ponds consist of excavation of the basin itself, outlet structures, and associated pump stations and piping. Pond costs may significantly

Table 1. Representative Ranges of Unit Costs for Open Storage Ponds

Volume	Cost per Gallon
<10 MG	$0.20–$0.40
>10 MG	$0.15–$0.35

increase if designs incorporate control systems with associated mechanical equipment, including pumps, aerators, mixers, and monitoring equipment. Costs will also increase if the basin must be lined with geosynthetic liner and geocomposite drainage fabric.

Table 1 provides some representative ranges of unit costs for basic pond construction, assuming an HDPE liner and earthen berms. These costs exclude land, which may be significant, conveyance infrastructure to/from the pond, and any covering that may be required.

Operations and Maintenance Costs

Operational costs associated with ponds may include regular sediment removal, liner repairs (if applicable), and maintenance of mechanical equipment. If the ponds are aerated, additional costs will be associated with power consumption by aerators, nutrient addition, aerator maintenance, and periodic solids removal and disposal.

FACT SHEET 30

Permanent Tanks

1. Description

Purpose

This practice provides a means of storing deicer-laden stormwater runoff in permanent aboveground or underground storage tanks.

Prestressed wire-wound concrete tank. Permanent concrete tanks can be aboveground or underground.

Technology

The design of permanent tanks follows conventional tank design principles, and sizes vary from thousands of gallons to multi-million gallon tanks. They typically offer long-term solutions for higher-strength deicer-laden runoff destined for onsite or offsite treatment or recycling. Permanent tanks can be constructed of concrete, steel, or fiberglass in square, rectangular, or circular configurations with varying wall heights.

Documented Performance

Storage in permanent tanks offers a number of advantages. Provisions for mixing can be incorporated to provide concentration uniformity and minimize solid deposits. Odor problems are significantly less of an issue with permanent tanks than with open basins or ponds. Finally, permanent tanks do not present a wildlife attractant problem.

2. Implementation Considerations

Applicability Assessment

Storage tanks are typically required for flow balancing and uniformity of deicing agent concentrations. Permanent tanks are used where there are higher-strength deicing agents that go on to be treated or recycled. Considerations of budget and height restrictions are key in assessing whether to implement permanent tanks or modular or frac tanks, or even a pond or basin.

Regulatory Considerations

Leak detection and cleaning are the primary concerns related to permanent storage tank regulations. Generally speaking, state regulations are more stringent when it comes to aboveground and underground storage tanks requirements, regardless of the agent. Title 40 of the Code of Federal Regulations governs and establishes minimum environmental protection standards. Permanent steel tanks are typically fabricated with double walls and are equipped with leak detection systems. The cleaning of the tanks is regulated according to the product that has been stored within the tank. Annual cleaning may be required, based on the disposition of the deicer-laden runoff, and may require a material safety data sheet for the material that was stored as well as analytical results to certify that the tank is fully cleaned and free of the materials that had been stored.

Planning and Design Considerations

The following issues should be examined when considering the use of permanent tanks to store deicer-laden runoff:

- Land availability and suitability.
- Site's not violating FAR Part 77 imaginary surfaces (aboveground tanks).
- Geotechnical suitability, especially for larger tanks.
- Accurate sizing.
- Accessibility for future cleaning and removal of solids.
- Costs.

Integration with Other Practices

Permanent tanks are implemented as part of a glycol collection system, which typically incorporates a number of other practices from source reduction to containment and collection and to treatment and disposal.

Operation and Maintenance Considerations

Permanent storage tanks generally have lower maintenance requirements than ponds or basins. Maintenance should be performed at least annually for the tank and its components. Steel components as well as leak detection system components should be inspected annually.

3. Costs

Permanent tanks are the most costly form of nonportable storage. The costs vary with the size of the tank, and also with the materials (concrete, steel, or fiberglass) and options chosen for the tank.

Capital Costs

Permanent tank prices vary widely based on the size and materials. Steel tanks generally have a lower construction cost compared to tanks constructed of other materials. Tables 1 and 2 provide some basic guidance on unit costs for different permanent tank configurations.

Table 1. Aboveground Storage Tank Capital Costs

Size (gal.)	Typical Cost ($/gal.)
250,000	1.50–2.00
500,000	1.25–1.75
1,000,000	1.00–1.50
2,000,000	0.80–1.00
4,000,000	0.60–0.80

Note: Costs are for the tank and a shallow foundation; exclude pumps, piping, design costs, etc.

Table 2. Underground Storage Tank Capital Costs

Size (gal.)	Typical Cost ($/gal.)
3,000–6,000	2.50–4.00
10,000–20,000	2.00–2.50

Operations and Maintenance Costs

Operations and maintenance costs associated with permanent tanks include annual inspection, cleaning, and solids removal. These costs vary greatly based on the size of the tank. Although steel tanks typically have a lower construction cost, they have higher operating costs associated with inspection and maintenance of the coating system (paint).

FACT SHEET 31

Manual and Automated Diversion Valves

1. Description

Purpose

This practice provides controlled routing of deicing stormwater flows for the purpose of collection, storage, treatment, and discharges. Diversion valves may be automatic or manual.

Technology

Diversion valves provide flexibility in managing stormwater with varying deicer concentrations. Diversion valves may be used to direct stormwater to one of several destinations, including treatment, storage, or discharge. Installations vary in complexity from manually operated valves to automated diversion systems that operate based on real-time monitoring.

Manual diversion valves are typically operated based on deicing conditions or weather observations (e.g., diversion to storage during deicing events and to surface water between events). Automated valves may allow flows to be managed more precisely during deicing events. These valves may be actuated by a supervisory control and data acquisition (SCADA) system, which may make diversion decisions based on online monitoring or management system information.

Several valve types are suitable for use in deicing runoff containment systems. In general, resilient gate valves or plug valves are preferred. Ultimately, any valve used for deicing runoff must have zero leakage and be chemically compatible.

Documented Performance

Although data on the performance of diversion valves alone have not been collected, a number of airports have implemented successful apron collection systems with manual and automated diversion valves. These airports include, but are not limited to, Portland International Airport, Detroit Metropolitan Wayne County Airport, Baltimore Washington International Thurgood Marshall Airport, Ted Stevens Anchorage International Airport, Seattle Tacoma International Airport, and Dallas–Ft. Worth International Airport.

2. Implementation Considerations

Applicability Assessment

Although most airports will have some form of diversion valve for deicing stormwater management purposes, the appropriate type of valve may vary depending on the application. The variability of concentrations in the flows, as well as storage, treatment, and operational requirements, are major considerations in deciding upon the level of complexity for diversion systems.

Advantages of automated valves include the following:

- Reduced manpower requirements for valve operation;
- Ability to be integrated into a SCADA system in conjunction with online monitoring for automatic, real-time diversion decisions and centralized operation of diversions throughout the system; and
- Improved National Pollutant Discharge Elimination System (NPDES) permit compliance by reducing the chance for human error and improving the precision of diversion decisions.

Advantages of manual valves include the following:

- Lower costs for valves and overall diversion systems;
- Retrofitting into existing storm sewer systems may be easier; and
- Simpler operation and maintenance.

Simple, manual diversion systems are appropriate for airports with relatively simple deicer management systems that are operated infrequently or do not require changes often, and airports that collect and discharge all deicing runoff to a single destination.

More sophisticated and costly automated approaches may be justified at airports with management systems where operation can be optimized using concentration-based flow segregation. Automatic valves are often used in applications requiring frequent diversion.

Regulatory Considerations

If diversion valves are central to environmental compliance, operating conditions for collection or surface water discharge should be approved by regulators and incorporated into an airport's NPDES (or equivalent) surface water discharge permit. Permit conditions may stipulate valve locations, threshold concentrations for collection or discharge, operation schedule, valve operation protocols, and emergency upset conditions for valve operation.

Planning and Design Considerations

The following factors should be considered in planning and implementation of manual or automated diversion valves:

- Diversion locations should be carefully selected with regard to collection efficiency, potential dilution, and integration with other system components such as online monitoring.
- The selection of appropriate threshold concentrations for concentration-based diversion is essential to success.

- The complexity of the diversion valve system should be matched to the airport's application, and the design of the diversion system should be coordinated with the overall deicing management system to optimize benefits.
- When selecting a valve type, airports should consider operation and maintenance, as well as cost. Key considerations for valve selection should include suitability for the application, reliability, and resistance to clogging and corrosion.
- Vaults containing diversion valves should be protected from water intrusion, which may require sump pumps.

Integration with Other Practices

Diversion valve operation is typically integrated with a variety of practices. Valves can be used to divert flows to storage units, treatment systems, glycol recovery systems, or discharges to surface water or a sanitary sewer. If automated, valves may be tied into an overall deicer management control system. Control systems or airport personnel may use information from online monitoring or sampling, as well as storage and treatment system data, to make diversion decisions that comply with effluent limits.

Operation and Maintenance Considerations

Manual diversion valve systems are relatively straightforward to operate; however, they may require significant manpower, especially if the valves are operated frequently. Manual valves should be installed such that they can be operated easily by one person during the deicing season, without interfering with airport operations. Manual valve operating procedures may require only that valves at deicing areas be diverted toward onsite storage or treatment prior to the start of a deicing event. More complex manual systems may divert flows to different destinations, depending on deicing and monitoring observations.

Automated diversion valve systems generally require less manpower to operate than manual systems. Personnel are still required to occasionally remotely monitor and verify automated monitoring results and diversion decisions. Automated diversion systems can provide a factor of safety by ensuring the proper operation of the diversion system when it is not normally staffed by an operator. Operating costs can be reduced if this automation enhances the ability of personnel to multitask and attend to other components of the deicer management system.

Effective performance of this practice requires that the valves and valve structures be maintained regularly. In general, regular inspections are required to verify functionality and to remove debris or address other potential hazards. Maintenance of automated systems may be more complex if it also involves the maintenance of integrated practices.

3. Costs

Overall costs associated with manual diversion valve systems are low compared to those of automated diversion valve systems. Diversion valve costs include the valves themselves, additional practices and infrastructure, and costs to operate the valves manually or automatically.

Capital Costs

Capital costs include the valves themselves, in addition to associated equipment and infrastructure, including diversion structures, piping, online monitoring equipment, and PLCs. Capital costs may vary significantly depending on the type of valve, valve actuation, and valve size. Available data suggest that cost may fall within the range of $5,000–$100,000 per valve.

Operations and Maintenance Costs

Annual costs include wages for personnel to operate and inspect the diversion valves, as well as maintenance costs for cleaning and repairing the valves and diversion structures.

FACT SHEET 32

Real-Time Monitoring Technology

1. Description

Purpose

This practice provides the opportunity to more precisely manage aircraft and airfield deicers in runoff through real-time monitoring of key water quality constituents that reflect deicer content. This capability may be employed to selectively route flows to different destinations based on concentration ranges, and track loads in flows and to manage publicly owned treatment works (POTWs) and surface water discharges to meet concentration or load limits.

Technology

Sensor technology has advanced to the point where real-time monitoring of biochemical oxygen demand (BOD), total organic carbon (TOC), or other surrogate parameters in stormwater flows is both feasible and practical. The use of an online monitor provides near instantaneous measurement of water quality, reduces the error associated with characterizing and managing continuous discharges based on a series of discrete measurements, and reduces the risk of missing high-concentration, low-duration spikes of deicer concentrations that may occur in the runoff. It is these capabilities that make concentration-based diversions possible by linking real-time monitoring to automated valves.

Different types of sensors can be used for this purpose. Several manufacturers sell instrumentation that measure biological, physical, or chemical oxidation parameters, providing output that is analogous to laboratory-measured BOD, TOC, or chemical oxygen demand (COD). Each of these can be used as a surrogate for the organic content of deicers. Online refractometers calibrated to glycols have been used for this purpose as well, although their detection limits are generally higher than those of the other technologies.

Documented Performance

The most appropriate performance metrics for this technology are detection limit and range. Table 1 provides representative information on the most commonly used real-time monitoring technologies.

2. Implementation Considerations

Applicability Assessment

Several aspects of the application should be evaluated and understood when real-time monitoring technologies are being considered. First is the actual requirement

Table 1. Real-Time Monitoring Technologies

Parameter	Detection Limit*	Range*
BOD	5 mg/L	5–100,000 mg/L
TOC	2 μg/L	0.0–5.0 mg/L
COD	10 mg/L	10–100,000 mg/L
Refractive index	0.5% glycol	0.5–70.0% glycol

*Obtained from manufacturers' literature.

for real-time monitoring, which is typically driven by runoff flows with concentrations that vary significantly over relatively short timeframes (minutes to hours) and the need to selectively manage those flows at a similarly fine scale. This ability to divert flow continuously can significantly reduce stormwater storage volume as well as treatment costs and enhance recycling programs.

Second, once it has been determined that real-time monitoring is needed, consideration should be given to the specifics of the intended application, including the intended target parameter(s) (BOD, TOC, etc.), the expected operational range of runoff concentration(s), the location(s) where monitoring is to be conducted, and the availability of staff to maintain the instrumentation.

Third, the physical constraints of the site will have to be considered to ensure the technology is a realistic option. In most cases, infrastructure will be required, including a shelter structure and utilities (electricity, water). The specifics will depend on the nature of the implementation.

Trained personnel are required to calibrate and maintain the sensors.

Regulatory Considerations

There are no specific regulatory considerations for this practice. It should be noted that use of this technology for compliance monitoring requires obtaining formal acceptance by regulatory staff. Many regulatory personnel may be unfamiliar with this new technology, and obtaining their explicit acceptance can be a very expensive and time-consuming process.

Planning and Design Considerations

The following factors should be considered in planning for real-time monitoring:

- The costs of real-time monitoring can be significant.
- The capabilities of the technology should be matched to the data needs in terms of parameter, concentration range, precision, and accuracy.
- The instrumentation is sophisticated and requires a trained operator to provide routine maintenance and care. As an example, BOD-sensing technology measures dissolved oxygen consumption in a bioreactor to estimate BOD. To accomplish this, the bacteria in the reactor must be acclimated to the mix of

deicers in the runoff and properly maintained during periods when runoff does not contain deicing materials.

- The airport or aircraft operator must be committed to maintenance of the equipment on a 24/7 basis during the deicing season to ensure consistent and accurate readings.
- Installations require protective housing and utilities in a location that is readily accessible for routine maintenance.
- Use for compliance monitoring requires gaining regulators' acceptance.

Integration with Other Practices

Real-time monitoring technology is always implemented as part of an integrated deicing runoff practice system. Most commonly, it is used in combination with an automated control system and motorized diversion valves to allow continuous stormwater segregation by concentration in the absence of a full-time operator.

Operation and Maintenance Considerations

Proper operation and maintenance is essential for this technology to be effective and reliable. Requirements include the following:

- An experienced or trainable operator with good troubleshooting skills.
- Operation of the equipment within clearly defined conditions and ranges.
- Regular maintenance and calibration of all installed sensors.

3. Costs

Capital Costs

Available BOD and TOC sensors can measure a wide range of concentrations but are relatively expensive, with installed costs ranging between $50,000 and $150,000 per unit, which includes enclosures, utilities, and other supporting equipment.

Operations and Maintenance Costs

These technologies are relatively sophisticated and require regular maintenance, calibration, and troubleshooting by operators to ensure accuracy and reliability. The costs for training and maintenance will depend on the type of sensor and the level of training required for the individual maintaining the system.

FACT SHEET 33

Catch Basin Inserts/Valves

1. Description

Purpose

This practice provides a means of intercepting deicing stormwater before it can enter the storm sewer system and facilitating collection by glycol collection vehicles.

Technology

Catch basin inserts provide a physical barrier for containing deicing stormwater on the surface of the apron to allow time for collection or for testing prior to its release. Inserts are typically installed in catch basins that receive surface drainage from aircraft deicing areas and are capable of being readily closed prior to the start of the deicing event and opened subsequently to allow clean runoff to enter the storm sewer system.

Different types of physical barrier are available. The simplest method consists of a molded plastic drop-in panel with a depression in the bottom that serves as a sump. These have limited practicality because they require that the storm grate be lifted to install or remove the barrier. A more sophisticated and practical approach employs a metal sump installed under a catch basin grate and fitted with a butterfly valve that can be operated with a T-handle from the surface. (See Figure 1.)

Figure 1

Inserts typically remain closed during the deicing event, although many operators keep them closed longer to prevent dry weather discharges of deicer. Depending on test results, the stormwater may then be released to the storm sewer or collected by a glycol recovery vehicle or vacuum truck.

Documented Performance

The performance of catch basin inserts for preventing the discharge of deicing stormwater depends largely on the effective operation of the stoppers or valves and the integrity of the water-tight seal. The integrity of the catch basin structure beyond the insert needs to be assessed prior to implementation. Some airports have reported that catch basins leak if not properly sealed or maintained, and that maintaining seals that are exposed to sand and other debris can be problematic. In addition, any system that promotes ponding on the apron surface requires that pavement joints be sealed to prevent infiltration under the increased head (Switzenbaum et al., 1999). Performance is also affected by how quickly fluids can be collected from the surface.

2. Implementation Considerations

Applicability Assessment

Catch basin inserts are beneficial for use with a glycol recovery program employing mobile collection vehicles. They allow the collection of deicing stormwater near the source, before it enters the storm sewer. This approach has the potential to minimize the overall volume of deicing stormwater that must be managed. They are also effective in preventing the unauthorized discharge of deicers under dry weather conditions (frost, for example).

The following factors should be considered when deciding whether catch basin inserts are appropriate and applicable for an airport deicing stormwater management system:

- Operation and inspection of catch basin inserts, as well as glycol recovery activities, may require dedicated operators.
- Catch basin inserts must be custom-fabricated for individual catch basins, and cost varies with catch basin size.
- Catch basins need to be accessible by collection vehicles without interfering with airport operations.
- Catch basin inserts and glycol recovery activities may result in the following situations, which could significantly interfere with airport safety and/or operations:
  - Potentially dangerous ponding during heavy precipitation if catch basin insert drains or valves are left closed.
  - Added vehicular traffic in congested gate areas.
- The effectiveness of catch basin inserts and glycol recovery activities may be limited by the following airport characteristics:
  - Irregular ground surfaces, which may prevent effective collection.
  - Cracks or joints in pavement and catch basins, which could allow leaks to the stormwater drainage system.
  - Aircraft deicing areas with drainage areas that are large or not well-defined.
  - Exposure of catch basins to debris, including sand and gravel.

Note: It is important to perform regular inspections to verify that catch basin inserts are operating properly.

Regulatory Considerations

Installation and operation of catch basin inserts must be performed in compliance with FAA regulations. Ponding has the potential to interfere with airport and aircraft operations, and FAA Advisory Circular 150/5320-5C ("Surface Drainage") recommends that ponding above apron catch basin inlets be limited to a depth of 4 inches. Standard operating procedures should include upset conditions for opening valves when hazardous flooding occurs.

Planning and Design Considerations

The following factors should be considered by airports in planning the implementation of catch basin inserts:

- Appropriate locations for inserts or valves, including the likelihood or impact of ponding at those locations;
- Appropriate level of complexity for catch basin inserts;
- Inserts or valves must be sized to allow peak flows to pass without unacceptable flooding;
- Standard procedures and protocols for preparation, inspection/monitoring, operation, and maintenance of the catch basin inserts, including threshold concentrations and upset conditions associated with hazardous flooding;
- Time and staffing required to operate inserts/valves and to collect ponded deicing stormwater at each installation;
- Accessibility of catch basin insert locations by glycol recovery vehicles or vacuum trucks; and
- Plan to address potential leak points, including cracks in pavement or within drainage infrastructure;

Integration with Other Practices

Most commonly, catch basin inserts are installed in designated deicing areas and operated in conjunction with collection vehicles, which collect the deicing stormwater that ponds above the inserts during deicing events. Catch basin inserts may also be used for controlling deicer-laden snowmelt runoff or for applications where the management of runoff is facilitated by keeping it out of the storm sewer system.

Operation and Maintenance Considerations

Operational requirements associated with catch basin valve inserts include manual operation of the valves, periodic testing of the ponded stormwater, and tracking of the status of inserts during the deicing season. Maintenance tasks associated with catch basin inserts include regular inspections of the catch basin structures and inserts or valves to ensure functionality, removal of debris, and repairs to maintain watertight seals. In some applications, removal of inserts or valves is required at the end of the deicing season if non-deicing runoff rates exceed the flow capacity of the insert.

3. Costs

Overall costs associated with catch basin valve insert systems depend upon the number and sizes of catch basins that will require inserts as well as the initial condition of the catch basins.

Capital Costs

Capital costs for catch basin valve inserts consist primarily of the insert itself, which must be custom fabricated to fit a catch basin. Vendors have indicated that the cost of a single catch basin insert will vary with the size of the catch basin. Rough unit costs are reflected in one vendor's quoted costs that range from $3,500 for a smaller catch basin to $5,500 for a larger catch basin (2007 prices). Installation of the inserts is often provided by the vendors as a separate cost item. Other initial costs may include repairs to existing catch basins and surrounding pavement to ensure an adequate water-tight seal.

Operations and Maintenance Costs

Operational costs for catch basin inserts are those associated with monitoring and manual operation. Maintenance costs may include the following:

- Regular inspection of catch basin structures and inserts;
- Repairs to maintain proper operation and integrity of seal within catch basin; and
- Repairs to pavement surrounding catch basins to prevent infiltration of ponded deicing stormwater.

Reference

Switzenbaum, M. S., Veltman, S., Schoenberg, T., Durand, C., Mericas, D., & Wagoner, B. 1999. *Best Management Practices for Airport Deicing Stormwater*. USA: University of Massachusetts/Amherst Water Resources Research Center.

FACT SHEET 34

POTW Discharge

1. Description

Purpose

This practice provides a means of disposing of deicer-laden stormwater.

Discharging to a POTW can be beneficial to both the airport and the POTW.

Technology

Publicly owned treatment works (POTWs) use biological processes to break down biodegradable organic compounds in domestic, commercial, and industrial wastewaters. Glycols and other organic constituents of deicing runoff are generally amenable to biological treatment, and access to a POTW can represent a convenient and cost-effective offsite option for disposing of deicing runoff that cannot be discharged untreated to the environment.

Discharge to a POTW can be accomplished in various ways. Some airports have been able to connect directly to a suitable sanitary sewer, while others have found over-the-road tanker transport to an offsite discharge location to be cost effective.

Documented Performance

Biochemical oxygen demand (BOD) loadings in deicing discharges to sanitary sewers are typically in the range of several thousands to tens of thousands of pounds per day. However, allowable BOD discharge rates are always site specific and depend on the relative magnitudes of the airport discharges and POTW capacity. The success of the practice at an individual airport can be evaluated by assessing the airport's ability to fully utilize hydraulic and BOD-loading allowances, the number of exceedances of those allowances, the number of instances in which the POTW restricts discharges to below those allowances, the need to seek out alternative disposal practices on a short-term or long-term basis, and the extent of unplanned increases in discharge fees imposed by the POTW.

2. Implementation Considerations

Applicability Assessment

POTWs are generally willing to accept discharges of airport deicer-laden stormwater under rate structures that apply to industrial discharges. The POTW operator typically must consider the following technical and regulatory factors in determining the conditions under which these discharges are accepted:

- Hydraulic capacity of the sanitary sewers, including the timing of other batch discharges to the affected sewer lines;

- Hydraulic capacity of the treatment plant;
- BOD load capacity of the treatment plant;
- The variable and seasonal nature of the discharges as it affects plant performance and revenue streams;
- Limitations on POTW capacity during wet weather events;
- The potential effect of deicer additives on plant performance and the ability of the plant to meet its own NPDES permit limitations; and
- Established policies, such as maximum fraction of POTW capacity that can be allocated to a single discharger, and prohibition on stormwater discharges to the plant.

Application for a POTW discharge permit will require characterization of the volumes and constituents in the proposed discharges, and may include requirements for bench-scale or pilot-scale treatability studies to demonstrate that the discharge will not negatively impact the POTW's operations or compliance with its own NPDES permit.

It is important to identify short- and long-term contingencies in case the discharge authorization is revoked by the POTW.

POTWs have the ability to revoke discharge permits. This introduces a level of risk for the airport if POTW discharge is the primary disposal practice. When planning a POTW discharge, it may be prudent to identify short- and long-term disposal contingencies that can be implemented if access to the POTW is terminated or restricted.

An airport's decision to discharge to a POTW is typically based on the adequacy of treatment capacity offered by the POTW operator to meet the airport's needs, capital costs for implementation, user fees, and reliability of service.

Regulatory Considerations

An industrial discharge permit is typically required for discharging deicing stormwater to a sanitary sewer. These permits are issued by either the POTW operator or a state agency that regulates POTWs. The permit will define the conditions and limits under which the wastewater will be accepted by the POTW. Limits are typically based upon the treatment and hydraulic capacity of the POTW, the ability of the POTW to process the airport stormwater without causing a plant upset, and possibly on the hydraulic capacity of the sanitary sewer being used. A construction or tap-in permit may also be required from local or state regulators to access the existing sanitary sewer with a new sanitary sewer pipe.

Planning and Design Considerations

The following factors should be considered in planning a successful POTW discharge system:

- The airport's flow rates and BOD loads requiring disposal under a variety of weather conditions;

- The available POTW hydraulic (flow) and BOD-loading capacity;
- Flow or loading restrictions that the POTW may consider during special circumstances (e.g., high flow conditions, plant upsets);
- User fee calculations for industrial discharges, including both volume and "high-strength" charges;
- Projections for changes in user fees in the next 10 years;
- Permit requirements;
- Potential sewer access points near the airport and the capacity of the sewers at those locations;
- Storage requirements to contain large storm events under the constraints of flow and loading to the sanitary sewer;
- pH adjustment in collected deicing runoff discharges to the sanitary sewer may be required if the runoff is held for an extended period of time; and
- Alternative disposal options if the allowable discharges are decreased or the actual loadings are larger than expected.

Integration with Other Practices

Hydraulic restrictions in the sanitary sewers or at the POTW, and the difference between airport discharge BOD concentrations (typically 500–50,000 mg/L) and POTW design influent concentrations (typically about 200 mg/L) almost always require onsite storage and controlled release of deicing runoff discharges as part of an integrated system. These site-specific constraints and interrelationships will define how POTW discharge is used to meet the airport's program needs. The following practice system components are frequently required to implement the POTW discharge practice:

- Online monitoring/diversion systems to segregate low- and high-BOD concentration stormwater;
- Onsite storage to equalize discharge flows and loads; and
- Monitoring and metering procedures to control the flow or BOD-loading rates of discharges to the sanitary sewer.

Operation and Maintenance Considerations

Operational requirements associated with POTW discharges are associated primarily with monitoring (e.g., pollutant concentrations, flow rates, storage volumes) at key locations in the system, and metering (flow rates and BOD loads discharged to the sanitary sewer). Monitoring and metering can be achieved either manually or automatically, depending on the system requirements and budget.

Adjusting pH may be required where deicing runoff is stored for extended periods and anaerobic degradation lowers pH below that allowed in discharges to the POTW.

Maintenance requirements are primarily associated with sediment cleanout in the storage facilities, as well as preventive and emergency maintenance on mixing, monitoring, pumping, and metering equipment.

3. Costs

In general, POTW discharge offers lower capital costs and higher operating costs relative to other disposal options.

Capital Costs

Capital costs for discharge to a POTW may include storage tanks or ponds, real-time BOD (or equivalent) monitoring equipment, metering pumps or control valves to regulate sanitary sewer discharges, and new conveyance to the local sewer system. The costs depend on site-specific factors, including the airport's deicer use, weather conditions, storm sewer infrastructure, available space, as well as the proximity and accessibility of the local sanitary sewers.

Operations and Maintenance Costs

Table 1. Typical POTW Discharge Fees

Fee	Typical Range
Flow	\$4.00–5.50/1,000 gals
Surcharge	\$0.20–\$0.30/lb BOD_5

There will typically be a charge for use of the POTW and sanitary sewer (see Table 1). Commonly, the fee is based on the flow volume discharged, plus a surcharge fee for BOD concentrations in excess of some maximum (for example, 275–300 mg/L). Often, the elevated BOD concentrations in deicer-laden stormwater discharges result in significant annual surcharge fees.

POTW fees have risen significantly in recent years, and are expected to continue to increase in the future as municipalities seek funding to replace aging infrastructure and to manage combined sewer overflow discharges. Because of the volatility of sewer fee rates, airports should obtain details on expected rate changes prior to completing the financial analysis on potential discharges to a POTW.

FACT SHEET 35

Anaerobic Fluidized Bed Reactor

1. Description

Purpose

This practice is a biological system for treating collected deicer-laden stormwater. The system is typically installed onsite and may be used for treating deicing runoff to concentrations acceptable for discharge to surface waters or the sanitary sewer.

The installation and operation of this practice is normally the responsibility of the airport operator.

Technology

Anaerobic fluidized bed reactor system.

The anaerobic fluidized bed reactor (FBR) system is an attached-growth biological treatment process. Treatment occurs in reactor vessels whose diameters range typically from 10 to 14 feet and whose heights range typically from 30 to 35 feet. Anaerobic bacterial films form on inert medium, such as granular activated carbon (GAC), inside the reactor vessel. Collected deicing runoff is cycled through the reactor from the bottom, resulting in a suspension (fluidizing) of the medium. Fluidizing the medium bed maximizes the surface area and conditions for bacterial growth and optimizes treatment efficiency.

The reactor influent must be heated to a constant elevated temperature (typically around 90°F) to promote optimum bacterial activity. However, energy needed for heating may be obtained through the capture and combustion of methane generated by the anaerobic process, at minimal cost. The anaerobic FBR reactor is supported by a chemical feed system, heating and heat recovery system, a solids removal system, and a gas collection system.

Documented Performance

This practice has been successfully used to treat deicer-laden stormwater at two airport locations in the United States. The Albany International Airport (ALB), in Albany, N.Y., has been operating a 3,100-lb biochemical oxygen demand (BOD)/day anaerobic FBR since 1998. The Akron-Canton Regional Airport (CAK) in North Canton, Ohio, constructed and started up a 2,000-lb BOD/day anaerobic FBR in 2007.

The anaerobic FBR has demonstrated the capability to remove more than 99 percent of influent propylene glycol (PG), and more than 95 percent of influent BOD. This technology has also been observed to degrade triazole compounds. The systems generate sufficient methane to heat the influent water following each season's startup period.

2. Implementation Considerations

Applicability Assessment

The following characteristics of anaerobic FBR systems should be considered when evaluating the potential applicability of the practice to a particular airport:

- The system is well suited to treating high-concentration stormwater (the existing systems have been designed to treat concentrations as high as 50,000 mg/L of BOD).
- The system is highly applicable to airports where effluent limits are in terms of PG or ethylene glycol (EG), because the glycols are almost completely destroyed in the treatment process.
- The anaerobic FBR can produce effluent with BOD concentrations as low as 200 mg/L under typical design conditions.
- The system has a relatively small footprint, typically less than 0.1 acres, making it potentially appealing to airports with significant space constraints. Height restrictions may apply, depending on the system's proximity to the airfield.
- The self-generation of methane to heat the water makes this practice a more attractive option in climates where low temperatures may affect the efficiency of open-air biological treatment systems.
- The system has shown the ability to degrade tolyltriazoles as well as petroleum products. The ability to remove other aircraft-deicing fluid additives has not been studied.

Regulatory Considerations

Construction of an anaerobic FBR system may require a permit-to-install or construction permit in some states. Approvals from the local fire marshal may also be required because of the methane handling system. Air permits for excess methane emissions are not required.

Modifications to the facility's National Pollutant Discharge Elimination System (NPDES) permit may be required to reflect appropriate monitoring requirements for treatment system effluent, as well as new outfall locations if applicable.

Planning and Design Considerations

The following factors should be considered in the planning and implementation of an anaerobic FBR system:

- Performance data from existing systems can be used for a design basis, if expected influent loads are well-characterized. An onsite pilot-scale system may be used to optimize system performance and minimize cost.
- The system requires a continuous supply of an alkaline chemical to maintain neutral pH, as well as nutrient addition to maintain a healthy bacterial community (as with other biological systems).

- Although sludge generation is low compared to aerobic systems, the means for sludge dewatering and offsite disposal (e.g., landfill disposal) should be considered.
- The system requires multiple utility connections, including potable water, electricity, and natural gas. Thus, the system may not be suitable for rural sites with limited utilities.
- A minimum 2-year window should be allocated for design, bidding, construction, and startup of an FBR system. Additional time may be necessary for other system components.

Integration with Other Practices

The concentration and flow ranges suitable for the anaerobic FBR are compatible with the ranges of runoff concentrations associated with apron collection systems (see Fact Sheet 22), centralized deicing facilities (Fact Sheet 21), glycol collection vehicles (Fact Sheet 23), block-and-pump systems (Fact Sheet 24), and snow melt systems (Fact Sheet 26). Diversion valves can be used with real-time concentration monitoring to optimize the influent loading to the system, which can enhance system performance and reduce costs.

Storage capacity upstream of the system is essential for effective system operation. Designers can consider different combinations of storage and treatment capacities to achieve the most cost effective balance.

Operation and Maintenance Considerations

Airports with anaerobic FBR systems typically have utilized existing staff with maintenance backgrounds as system operators. Staff should be trained by operators experienced with an FBR system.

Adequate flow management controls built into the supervisory control and data acquisition (SCADA) system reduce the likelihood of system upsets resulting from spike loadings. Because of the methane generation, it is recommended that the facility be staffed on all shifts or have an alarm callout and a SCADA system capable of remote monitoring and control.

Initial startup of the system can take 2 to 3 months, while the startup time for subsequent seasons is typically 2 to 3 weeks. The anaerobic FBR is a low-maintenance system. Following the annual system shutdown at the end of the deicing season, operators perform preventative maintenance on pumps and other system components. A 2,000-lb BOD/day system can be expected to generate approximately 10 cubic yards of solids per year of dry solids that will require offsite disposal.

3. Costs

Capital and operating costs for the anaerobic FBR treatment system are site specific, depending upon the deicer load to be treated, stormwater flow rates, upstream storage capacity, and the effluent limit required in the discharge permit.

Capital Costs

Significant capital cost items for this practice include a building to house the treatment system, the reactors and media separation units, pumps, piping, online and offline monitoring equipment, and SCADA system components. Capital costs per pound of BOD treated decrease as the required treatment capacity increases, making the systems more cost effective at higher loadings. Data from the two existing systems suggest that capital costs may be in the range of $2.5–$10 million.

Operations and Maintenance Costs

Operational cost items for this practice include power consumption, monitoring and analysis, solids disposal, and routine maintenance and repairs, with chemical addition (caustic, nutrients) as the largest cost item. Energy costs can be reduced through the use of methane generated by the system to heat the influent stormwater, as well as for heating the treatment building and other uses if excess methane is available. There may be minimal costs associated with occasional GAC replacement over time, however GAC regeneration is not required.

As an example, the estimated O&M cost of the AFBR system at Akron is $95,000, not including operators' wages.

FACT SHEET 36

Reciprocating Subsurface Treatment

Source Reduction
Containment/Collection
System Components
TREATMENT/RECYCLING

1. Description

Purpose

This practice provides for the onsite biological treatment of collected deicer-laden stormwater. The system may be used to treat the stormwater to concentrations acceptable for discharge to surface waters or sanitary sewer.

Schematic cross-section of a reciprocating subsurface system.

Technology

The reciprocating subsurface treatment system is an attached-growth aerobic biological treatment process. "Subsurface" refers to the fact that the stormwater remains below the surface of the gravel-filled treatment cells, avoiding open water exposure. "Reciprocating" refers to the cyclical process by which water is pumped back and forth between gravel-filled basins. Bacteria are exposed to atmospheric oxygen in the first phase of the cycle and are exposed to deicing stormwater in the second phase of the cycle, eliminating the need to supply supplemental oxygen.

Documented Performance

This practice has been successfully implemented to treat deicer-laden stormwater at one U.S. airport. Two separate systems were constructed in 2000 at DHL's Wilmington Air Park (ILN) in Wilmington, Ohio. Each of the 5 acre treatment systems was designed to treat 50 to 300 gpm of flow at influent biochemical oxygen demand (BOD) concentrations ranging from 300 to 5,000 mg/L. The systems are designed to produce effluent with propylene glycol (PG) and BOD concentrations of 10 mg/L to 200 mg/L. The actual effluent concentrations depend upon the influent BOD loading. Seasonal removal rates have averaged 93 percent. The ability to remove deicer additives has not been evaluated.

As with any biological treatment system, removal efficiencies are a function of temperature, with efficiencies improving as water temperatures increase. BOD removal efficiency at any particular point in time is dependent upon the design capacity of the treatment system, influent BOD loadings, water temperature, and air temperature.

2. Implementation Considerations

Applicability Assessment

The following factors should be considered when evaluating the applicability of a reciprocating subsurface treatment system to a particular airport:

- The system is best suited for applications with high flows of low-concentration (<5,000 mg/L BOD) stormwater (e.g., widespread deicing collection areas), rather than low-flow, high-concentration applications (e.g., deicing pads). It can accommodate higher flow rates per pound of BOD or PG removed than many other treatment systems.
- The system is best suited for winter climates where water temperatures typically vary between 36°F and 60°F, to avoid needing to heat the influent. At colder temperatures, treatment efficiency is reduced. At warmer temperatures, solids generation becomes excessive.
- If the influent loading to the system is optimized, effluent BOD, PG, and ethylene glycol (EG) concentrations less than 10 mg/L can be achieved at water temperatures above 40°F. Low effluent concentrations become difficult to achieve at lower temperatures as treatment efficiency decreases.
- The system requires a larger footprint than other deicer treatment systems (typically several acres).
- Bird attraction is minimized if the system is designed to have the water level remain below the gravel surface.
- Odors are minimal during winter months, but may become problematic with increasing temperatures.

Regulatory Considerations

Construction of a reciprocating subsurface treatment system may require a permit-to-install or construction permit in some states. Modifications to the facility's NPDES permit may be required to reflect appropriate monitoring requirements for treatment system effluent, as well as new outfall locations if applicable.

Planning and Design Considerations

The following factors should be considered in the planning and implementation of a reciprocating subsurface treatment system:

- A system's footprint can be reduced by increasing the depth of the treatment basins, as long as the functionality and effectiveness of the system is maintained.
- The size and cost of a system can be minimized by using storage and a SCADA system to optimize influent loadings to the system based on water temperature.
- Storage capacity upstream of the system is essential for effective system operation. Designers can consider different combinations of storage and treatment capacities to achieve the most cost effective balance.

- As is the case with other biological treatment systems, nutrients must be added to the treatment system to maintain a healthy bacterial community.
- The treatment system bacterial population can develop from bacteria present in stormwater, so there is no need for purchased bacterial seed. Design performance levels can be reached in two to four weeks, depending on water temperatures and loading rates.
- A minimum 2-year window should be allocated for schematic design and pilot testing of the system. An additional 2-year period should be allocated for design, bidding, construction, and startup.

Integration with Other Practices

A reciprocating subsurface system is compatible with the range of deicing runoff concentrations associated with apron collection systems (Fact Sheet 22) and airfield drainage systems (Fact Sheet 25). The technology is also compatible with systems where diversions separate low- and high-concentration streams, allowing load to be optimized by blending these streams.

Operation and Maintenance Considerations

One to three full-time operators are required to run and maintain a reciprocating subsurface treatment system, depending upon the size and complexity of the system. As with other systems, management of flow rates in and out of the system are critical and can be complex at times. The required degree of active operator involvement is dependent upon the degree of automatic controls integrated into the system design.

Reciprocating subsurface treatment system.

Maintenance tasks typically include annual preventative maintenance on pumps and weed control. Solids buildup can be managed if operational ranges are met, or else significant effort may be needed to clean or replace the media.

3. Costs

Capital and operating costs for the subsurface reciprocating treatment system are site specific, depending upon design load and flow rates, upstream storage capacity, degree of SCADA control, climate, and effluent limits.

Capital Costs

Significant capital cost items for this practice include treatment cell construction, gravel media, pump stations, monitoring equipment, and SCADA system components. For lower concentration, higher flow rate stormwater streams, the reciprocating subsurface treatment system can have a significant cost advantage over other treatment technologies. Available data from the existing system at ILN suggests a potential capital cost range of \$2 million to \$8 million.

Operations and Maintenance Costs

Operational cost items for this practice include nutrient addition, power consumption, monitoring and analysis, and routine maintenance and repairs. Power costs are relatively low because pumps typically run 15–25 percent of the time in winter and are off in the summer. Major maintenance cost items include yearly pump preventative maintenance. Available data from existing systems suggests an annual cost range of $20,000–$50,000, not including labor.

FACT SHEET 37

Moving Bed Bioreactor Treatment System

Source Reduction

Containment/Collection

System Components

→ **TREATMENT/RECYCLING**

1. Description

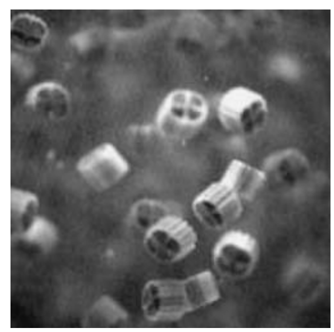
Purpose

This practice is a biological treatment system for treating collected deicer-laden stormwater. The system is typically installed onsite and may be used for pretreating stormwater prior to discharging it to a sanitary sewer, or to treat the stormwater to concentrations acceptable for discharging it to surface water.

The installation and operation of this fact sheet is normally the responsibility of the airport operator.

Technology

The moving bed biofilm reactor (MBBR) is an aerobic attached-growth biological treatment process. In the MBBR system, biomass grows on a polyethylene carrier (media element) that is shaped to maximize biofilm growth and reduce the reactor size needed for a given level of treatment.



Plastic media.

The carriers are suspended in the reactor tank liquid through the buoyant action of air pumped through a network of diffuser manifolds in the bottom of the reactor. The air provides the aerobic conditions necessary for the bacteria to grow. The system will not function under anaerobic conditions.

Biosolids are formed in the MBBR system when the biofilm thickness increases to the point that the bacteria closest to the media can no longer get oxygen and the film sloughs off the media. The solids are carried out of the reactor with the treated wastewater and must be removed, which typically is accomplished through a dissolved air flotation system.

Documented Performance

The MBBR process has been implemented at one European airport and bench-scale tested at one U.S. airport.

The Oslo Airport uses an MBBR plant to treat stormwater with influent concentrations of up to 2,000 mg/L of glycol. The system was constructed in the spring of 2004. Geothermal energy is used to heat the influent stormwater stream by routing it through underground caverns prior to treatment. The system removes about 90 percent of the glycol in the influent stream and is reported to remove oxylates associated with surfactant additives. The Pittsburgh International Airport has bench-scale tested a three-stage MBBR system for treatment of dilute airfield runoff. In general, bench-scale tests using stormwater from the airport spiked with aircraft and pavement deicer have demonstrated the potential to achieve an effluent BOD concentration as low as 10 mg/L. However, achievement of this concentration was observed to be highly temperature-dependent. Effluent concentrations of 10 mg/L BOD at temperatures typical of winter stormwater were inconsistent.

2. Implementation Considerations

Applicability Assessment

The following characteristics of an MBBR should be considered when evaluating the potential applicability of this treatment fact sheet at a particular airport:

- The system is best suited to treatment of lower biochemical oxygen demand (BOD) concentration stormwater (less than 1,000 mg/L).
- The MBBR process is capable of achieving low effluent concentrations (as low as 10 mg/L) in bench-scale testing.
- Heating influent stormwater will improve performance, but it is not necessary to achieve treatment, if the relationship between temperature and removal efficiency is understood and accounted for in the system design. The cost associated with system size requirements to achieve 10 mg/L BOD versus the cost of heating the influent should be evaluated. Further, the ability of the system to consistently achieve 10 mg/L BOD effluent limits at very low temperatures should be considered with respect to associated permit limits in which exceedence of 10 mg/L may be considered a permit violation.
- The system has a relatively small footprint, typically less than 0.1 acre.

Regulatory Considerations

Construction of a MBBR system may require a permit-to-install or construction permit in some states.

In some instances, system effluent may discharge to the receiving waters through new outfalls, necessitating modification to the facility's National Pollutant Discharge Elimination System (NPDES) permit.

The monitoring requirements, including frequency and types of samples, that are included in the NPDES permit for a treatment system discharge should be considered carefully, as they may vary from the monitoring requirements associated with an untreated stormwater discharge.

Planning and Design Considerations

The following factors should be considered in the planning and implementation of an MBBR system:

- Pilot testing is recommended to establish treatment rates, achievable effluent concentrations, and temperature effects on deicer-laden stormwater from the site.

- The treatment process will produce sludge that requires dewatering and disposal. The expected quantity of sludge produced and its moisture content, density, and settling characteristics should be determined in the pilot-testing stage.
- Two operators are typically recommended, with the operators trained by experienced operators of existing MBBR systems.

Integration with Other Practices

The MBBR system is effective at treating lower concentration influent, making it compatible with apron collection systems (see Fact Sheet 22) and airfield drainage systems. The technology is also compatible with systems where diversion valves separate high- and low-concentration streams, and performance can be optimized by blending these streams to maintain a constant load to treatment. Storage capacity upstream of the treatment system in the form of ponds (Fact Sheet 29) or permanent tanks (Fact Sheet 30) is essential for effective and efficient operation. The required storage capacity can be accurately determined if the temperature-loading rate relationship is integrated into the system operation and the variation in stormwater flow rates and BOD-glycol concentrations in the collected stormwater are understood.

Operation and Maintenance Considerations

As is the case with other biological systems used to treat deicer-laden stormwater, nutrients must be added to the treatment system to maintain healthy bacterial communities. Oxygen must also be provided to the reactor to maintain aerobic conditions. The operators are responsible for maintaining the correct nutrient balance and oxygen supply.

The MBBR system will produce biosolids that require dewatering and disposal. Dewatering system requirements will vary depending on the characteristics of the sludge produced by the system.

A wastewater treatment background is not necessary for a treatment system operator as long as training can be provided by operators experienced in operating an MBBR system.

Adequate flow management controls built into the supervisory control and data acquisition system (SCADA) reduce the likelihood of system upsets resulting from spike loadings.

Initial startup of the system can take several months, depending upon the degree to which the reactor is seeded with bacteria.

3. Costs

Capital and operating costs for the MBBR treatment system are site specific, depending upon the deicer load to be treated, stormwater flow rates, upstream storage capacity, the effluent limit parameters, and the numeric effluent limits.

Capital Costs

Significant capital costs for this fact sheet include a building to house the treatment system, reactors, blowers or oxygen generation equipment, sludge-dewatering equipment, sludge storage, pumps, piping, online and offline monitoring equipment, and SCADA system components.

Operations and Maintenance Costs

Operational costs for this fact sheet include chemical addition, power consumption, monitoring and analysis, and routine maintenance and repairs.

Maintenance cost items include yearly preventative maintenance and transport/ disposal of dry sludge to a landfill.

FACT SHEET 38

Sequencing Batch Reactor

1. Description

Purpose

This practice is a biological treatment system for treating collected deicer-laden stormwater onsite. The system may be used for pretreating stormwater prior to its being discharged to a sanitary sewer, or it may be used to treat the stormwater to concentrations acceptable for discharging it to surface water.

The implementation and operation of this practice would typically be the responsibility of an airport authority.

Although this treatment technology is proven, its application to winter stormwater is a recent development. As a result, this practice should be considered an emerging technology.

Technology

A sequencing batch reactor (SBR) is an aerobic biological treatment system that represents a variation of the activated sludge process typically used at municipal publicly owned treatment works (POTWs). As other activated sludge processes do, the SBR works by developing a mixed culture of bacteria suspended in the wastewater. However, where the typical activated sludge system is a continuous flow-through process, the wastewater in an SBR is treated in batches that undergo a sequence of steps of filling, holding, settling, and decanting. The advantage of SBR is that at lower flow rates, it is typically more cost effective than conventional activated sludge because the equalization, aeration, treatment, and sludge-settling steps are all carried out in a single reactor. An SBR can be sized to process flows up to several hundred gallons per minute. SBR systems are often designed so that the concentration is stepped down in a series of reactors, rather than having all treatment performed within a single, larger-scale reactor. Using a series of reactors allows for smaller-scale, more-cost-effective system components. Having multiple treatment units also provides the operator with greater flexibility and control over the treatment process, allowing the process to be adjusted for variations in influent flow rates and concentrations.

Documented Performance

Initial studies evaluating the SBR for treatment of deicer-laden stormwater were performed in 1997 for Chicago's O'Hare International Airport. The studies indicated that the SBR technology reduced influent biochemical oxygen demand (BOD) concentrations of 7,000 mg/L to less than 10 mg/L, making it a potentially viable technology for deicer treatment. The studies also identified problems with slime buildup and elevated suspended solids.

A full-scale SBR was operated at the Cincinnati/Northern Kentucky Airport in 2004 and 2005. This facility was designed to treat dilute stormwater flows at the headwaters to one of the airport's two receiving streams. The design flow rate was 1,040 gpm, and the design influent and effluent BOD values were 1,200 mg/L and 50 mg/L, respectively. Although the system performed well during moderate conditions, maintaining the bacterial population during periods of high-BOD and low-BOD loading and low temperatures was difficult. Because the system did not perform well under variable load scenarios, it was abandoned and has been turned into sludge basins.

2. Implementation Considerations

Applicability Assessment

The SBR process is potentially applicable to situations where low-effluent BOD concentrations are required; however, achievable effluent concentrations will depend upon site-specific conditions and influent characteristics. Successful application requires that a relatively constant BOD load be maintained, along with water temperatures greater than 41°F, in order to optimize the biological population. As with other biological treatment practices, frequent variations in the BOD load may result in unreliable treatment efficiency if the biological population is unable to respond accordingly.

Regulatory Considerations

Construction of an SBR system may require a permit-to-install or construction permit in some states.

SBR systems may need to comply with industrial discharge permit requirements if they are used for pretreating stormwater that is being discharged to a POTW. Alternatively, if the system discharges to surface water, it would need to meet all NPDES permit (or equivalent) surface water discharge requirements, including discharge-monitoring requirements. The monitoring requirements, including frequency and types of samples, that are included in the NPDES permit for a treatment system discharge should be considered carefully, because they may vary from the monitoring requirements associated with untreated stormwater discharges.

In some instances, system effluent may discharge to the receiving waters through new outfalls, which would require modification to the facility's NPDES permit.

Planning and Design Considerations

Airports interested in an SBR system as a practice should consider the following in their planning and implementation:

- SBR systems require that the BOD load be maintained relatively constant throughout the season to maintain the bacterial population. This requirement may be met using a system that segregates stormwater by concentration and then blends the streams to maintain an optimal loading throughout the season.

- Because the system requires that temperature be maintained above 41°F, a means of heating the influent stream should be considered.
- Typical operating conditions should be identified to support the design of the system, including influent loads, concentrations, and flows, as well as desired effluent concentration.
- Construction and operation of a pilot-scale system will allow examination of the applicability of this treatment system for a particular airport and stormwater stream.
- Successful operation of the SBR system requires support equipment in the form of storage tanks, online monitoring, and potentially a blending system.
- A means for disposing of sludge produced during treatment operations will be required.
- Standard operating procedures for use of SBR should be developed in conjunction with an overall deicer management system.
- A training program for system operators will be required. It is recommended that operators be trained by experienced operators of SBR systems.

Integration with Other Practices

Because an SBR is best suited to treating lower-concentration stormwater, it may be used in conjunction with apron collection systems (Fact Sheet 22) or airfield drainage systems (Fact Sheet 25). The technology is also compatible with systems where high- and low-concentration streams are separated.

An SBR may be used to pretreat stormwater prior to its discharge to a POTW. It also may be paired with treatment or recycling technologies that are capable of handling higher-concentration influent streams.

Operation and Maintenance Considerations

The SBR system may require one to two full-time operators. Licensed operators may not be required, although requirements may vary from state to state.

Operational and maintenance issues to consider include sludge processing and disposal, and regulation of stormwater temperature and loading. Additional maintenance may be required to address any slime buildup that occurs within the reactor.

3. Costs

Capital and operating costs for an SBR system will be site specific and depend upon the deicer load to be treated, stormwater flow rates, upstream storage capacity, climate, and the effluent limits.

Capital Costs

Significant capital cost items for this practice include construction of the reactor structures, blowers, and diffuser system; supervisory control and data acquisition (SCADA) system components; solids handling; and sludge dewatering.

Operations and Maintenance Costs

Operational cost items for this practice include full-time operator(s), nutrient addition, power consumption, monitoring and analysis, sludge disposal, and routine maintenance and repairs.

FACT SHEET 39

Natural Treatment Systems

1. Description

Purpose

Natural treatment systems (NTSs) are used to treat runoff impacted by aircraft and airfield deicers.

Technology

Wetland at Edmonton International Airport

NTSs use soil, water, and plant ecosystems to remove pollutants through physical, chemical, and biological processes. Deicing chemicals are removed by microbial communities in the soils, root zones, and surface sediments that use the organic compounds as a food source.

Natural treatment systems fall into three broad categories:

- **Aquatic** systems include ponds, lagoons, and floating aquatic plant systems.
- **Terrestrial** systems include land application to herbaceous or forested systems, overland flow, and soil aquifer treatment approaches.
- **Wetland** systems are broadly characterized as
  - Constructed marshes with water flow aboveground;
  - Subsurface flow systems with water flow belowground through planted gravel or soil media; and
  - Naturally occurring wetlands designed to receive a low loading of effluent.

The most common NTS implementations at airports are constructed subsurface-flow wetlands and land application systems. These technologies are often combined or enhanced to meet specific treatment needs. Specific configurations are marketed as patented processes.

Documented Performance

Available performance data are limited to the following sites:

- Since 2002, Heathrow International Airport (LHR) has operated a series of aerated detention ponds, subsurface flow wetlands, and floating wetlands to supplement offsite treatment capacity. The system is designed to reduce biochemical oxygen demand (BOD) from 240 mg/L to less than 40 mg/L at water temperatures varying between 6°C and 20°C (Revitt et al., 2001).
- Toronto's Lester B. Pearson International Airport (YYZ) constructed a three-cell NTS consisting of a sedimentation basin, vertical subsurface

flow system, and surface flow marsh for storing and treating runoff designed to achieve a 73 percent reduction in BOD (Flindall and Basran, 2001).

- A pilot-scale NTS was implemented at the Airborne Air Park in Wilmington, Ohio (ILN) with six gravel-bed cells totaling 0.12 acres. Results indicated BOD removal rates of greater than 90 percent with reciprocation of the water between cells to periodically expose the bacterial film to the atmosphere (USEPA, 2000). A 6-acre system designed for an average loading of 3,200 lbs CBOD/day was subsequently installed (USDOD, 2004).
- The Westover Air Reserve Base in Massachusetts has operated a demonstration subsurface flow wetland since 2002. During 10 monitored deicing events, this system reduced the BOD concentrations in runoff by 11–78 percent and tolerated peak concentrations of 974–15,098 mg/L (USDOD, 2004).
- Edmonton International Airport (EIA) operates 6.7 acres of horizontal subsurface flow wetlands from April to September to treat stored deicing runoff. The system is designed to treat 0.34 mgd of 1,400-mg/L ethylene glycol to 100 mg/L ethylene glycol and 25 mg/L BOD (Higgins and MacLean, 2002).
- Buffalo Niagara International Airport (BUF) is constructing a 13.6-acre system of aerated horizontal subsurface flow wetlands. Pilot studies indicated greater than 95 percent BOD removal and a 10-fold improvement in removal rate constants (3.8 d^{-1} aerated vs. 0.4 d^{-1} unaerated) at 4°C using the proprietary design (Higgins et al., 2006).

2. Implementation Considerations

Applicability Assessment

Land requirements are the major consideration in assessing the potential applicability of natural treatment. Land requirements depend on the type of technology, influent runoff quality, required effluent quality, and drainage area treated. Representative sizes and types of NTS implementations are provided in Table 1.

Table 1. Examples of NTS Size and Type

Airport	Construction
Edmonton CN	6.7 ac, horizontal subsurface flow
Toronto CN	1.0 ac, vertical subsurface flow 3.4 ac, surface flow
Heathrow UK	5.1 ac subsurface flow 2.5 ac, floating mat
Wilmington OH	6.0 ac, reciprocating subsurface flow
Westover ARB MA	0.6 ac, horizontal subsurface flow
Buffalo NY	13.6 ac, aerated subsurface flow

It is also important to consider the existing drainage infrastructure to determine if an NTS will fit within the confines of the airport, and if the flow must be pumped or conveyed by gravity.

Available information indicates that deicing treatment wetlands are designed for runoff concentrations of up to 1,353 mg/L ethylene glycol (Edmonton) and up to 5,000 mg/L BOD (Toronto). Measurements of inflow concentrations to the Westover ARB showed peak inflow concentrations during spring events of 15,098 mg/L. Design concentrations are typically lower, ranging from 108 mg/L BOD (Heathrow) and 500 mg/L (Toronto). Design criteria are based upon pilot study results (e.g., Buffalo, Heathrow, Wilmington) or in the case of Toronto and Westover, from the general literature on treatment wetlands for wastewaters of high organic strength (Kadlec and Knight, 1996).

Regulatory Considerations

Bird airstrike hazards (BASHs) are a critical safety consideration at airports. Available data indicate that deicing treatment wetlands are not necessarily an attractive habitat, and that wildlife populations can be managed effectively.

Many local municipalities are beginning to require low-impact development (LID) stormwater management on development within their purview. Incorporating an NTS as a deicing and stormwater practice may be viewed as an LID-type practice.

Planning and Design Considerations

Sizing and estimating performance for these systems are generally accomplished using accepted empirical first-order BOD removal sizing models (e.g., Kadlec and Knight, 1996). No standardized model exists for the design of treatment wetlands for aircraft and airfield deicer removal.

The need for reliable performance during cold weather and minimized wildlife hazards poses significant challenges to NTS applications at airports. However, methods are available to address these concerns. Vegetation species can be chosen that pose minimal or less desirable waterfowl food sources. Surface water drawdown durations within the treatment system can be reduced to minimize habitat value to water fowl. Finally, the vegetation in some NTS may be mowed regularly to avoid forming large stands that could represent attractive habitat.

Hydraulic surface flow routing is a critical design factor in delivering runoff to the NTS. To avoid pumping, it is best to site the NTS downgradient of the sources of runoff to be treated. Existing drainage systems typically require modification to accommodate this practice.

Pilot-scale testing is generally recommended to account for site-specific variations in climate, site characteristics, storm water runoff characteristics, and the general lack of standard design guidelines for natural treatment systems.

Integration with Other Practices

NTSs can be combined with other practices as part of an integrated system. Frequently, the highest-strength runoff is isolated and collected for recycling or other suitable treatment, and lower strength runoff is routed to the NTS. Conveyance design may also provide opportunities to incorporate benefits such as solids settling or actual BOD removal.

Operation and Maintenance Considerations

NTSs typically require much lower maintenance than other treatment practices. With favorable conditions and proper design, there are very few moving parts in these systems.

A trained operator who understands the operating principles and conditions of the system will be required. Typically, water level adjustments will be required a few times a year based on seasonal changes in runoff.

Storage in winter and treatment in summer may be an option. The subsurface flow wetland at Edmonton only operates outside of frozen conditions and must impound water or collect contaminated snow in winter. During very cold weather, cold air drawn into the beds of the wetland cells at Wilmington freezes the bacteria, and water must be impounded during these periods of no biological activity.

Vegetation management may be required to minimize BASH, or to maintain appropriate hydraulic flow conditions. Mowing or hand cutting during the summer may be required.

3. Costs

Construction costs of full-scale wetlands to treat de-icing fluids vary depending upon size, flow, and operating season. Cost data presented here are for preliminary guidance only.

Capital Costs

Table 2 summarizes available capital cost data. Per-acre costs vary from $543,000 to $2,000,000. Conveyance and pumping systems and site infrastructure installation typically make engineered media systems more costly than wetland projects.

Table 2. Examples of NTS Capital Costs

Airport	Construction
Edmonton	$1,800,000
Toronto	$2,000,000
Heathrow	$20,000,000
Westover	$326,000

Operations and Maintenance Costs

Average annual reported operating costs for an NTS facility are about $3,000 per year. General cost data from the treatment wetland literature indicate an average range of operation and maintenance costs of $1,000 to $2,000 per acre per year (Kadlec and Knight, 1996). Maintenance activities may be included with other site operation activities with negligible cost effect.

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FACT SHEET 40

Membrane Filtration

1. Description

Purpose

Membrane filtration refers to a number of related physical treatment processes that can be applied to segregate deicer-laden stormwater into dilute and concentrated streams.

The implementation of this practice is typically by an airport or a glycol recovery contractor.

Technology

Membrane filtration physically separates dissolved substances on the basis of molecular size. The membranes have pores that allow water molecules to pass through while blocking larger molecules, such as glycols and other deicer constituents. The result is increased concentrations of glycols and other deicers in the "concentrate (reject)" stream and a "dilute (permeate)" stream.

Ultrafiltration (UF) and reverse osmosis (RO) are applications of the membrane filtration principle. In UF, relatively low hydrostatic pressures (less than 100 pounds per square inch, or psi) are employed to separate relatively large molecules. In contrast, RO uses significantly higher pressures to remove relatively smaller molecules, such as metal ions, aqueous salts, and organic compounds.

Components of a membrane treatment system include pretreatment to remove suspended solids and hydrocarbons, chemical feed for pH adjustment and scale control, the RO treatment train, and a system for membrane cleaning. The influent may be heated to optimize the removal efficiency.

RO is usually operated as a staged system. The concentrate from the first stage feeds the second stage, which further increases the concentration in the reject stream and reduces the stream's volume. The concentrate volume from a two-stage RO system is typically from 5 to 25 percent of the feed volume.

Membrane filtration systems at airports are used primarily to support glycol recovery from runoff with deicer concentrations greater than 1%. In these applications, the stream from a two-stage RO system is often further concentrated by additional processing to obtain a saleable product.

Membrane filtration systems can also be used in nonrecycling applications to achieve a low concentration dilute stream potentially suitable for surface water discharge. In these applications, disposal of the concentrate stream via public owned treatment works (POTW) discharge or other means is required. Munich International Airport has tested RO to reduce the volume of airfield runoff discharged to the POTW.

Documented Performance

RO performance is defined by contaminant removal, permeate recovery, and flux. Contaminant removal can range from 90 to 99 percent depending on the parameter. Typical permeate recovery (i.e., the ratio of the permeate volume to the feed volume) for a two-stage system is 75–85 percent. Flux, the volume of water passing through a unit area of membrane per unit time, is selected during the design process based on feed characteristics, effluent targets, and permeate recovery targets.

Membrane filtration performance depends on adequate pretreatment processes to remove suspended solids and hydrocarbons. Pretreatment or chemical addition to control mineral or biofouling of the membrane.

Dallas-Fort Worth International Airport employs membrane filtration of deicing runoff to meet surface water discharge limits for glycol. The system has achieved permeate glycol concentrations of less than 30 mg/L and up to 15 percent glycol in the concentrate stream (R. Wick, personal communication, 2006). Membrane filtration units at Bradley International Airport produce permeate glycol concentrations of less than 100 ppm and 8–10 percent glycol concentrate. Testing at Bradley indicates over 99 percent removal of the additives tolyltriazole and phenol (EPA, 2000).

2. Implementation Considerations

Applicability Assessment

An initial applicability screening for membrane filtration can be conducted with information on the sources of deicing runoff; the cations, anions, alkalinity, and hardness of the expected stream; and the permeate treatment targets and concentrate management approach.

The following should be considered when evaluating applicability of membrane filtration at a particular airport:

- Membrane filtration is best suited where effluent discharge limits are stringent or glycol-recycling is being pursued.
- Membrane filtration systems can be started quickly, even after an extended period without use.
- Membrane filtration systems can operate over a relatively wide range of influent concentrations.
- The technology provides the opportunity for a high quality effluent, including reduction of deicing fluid additives.
- Membrane replacement costs can be high.
- Reject ratios for pollutants of concern can be limited by the presence of other pollutants such as silica.
- Proper pretreatment is essential to manage biofouling and avoid impacts on system efficiency and costs.

- Relatively high levels of operator skills are required.
- If the concentrate stream is not recycled, disposal of the concentrate can be a significant factor in assessing applicability.

Regulatory Considerations

The only regulatory implication of membrane filtration systems is that they need to comply with applicable discharge permit requirements.

Planning and Design Considerations

The following should be considered in planning and implementing a membrane filtration system:

- Laboratory and pilot testing are typically required to confirm treatment effectiveness, select membrane type, and develop design parameters.
- "Design" conditions must be identified, including influent loads, concentrations and flows, and desired effluent quality.
- Modular, skid-mounted designs may provide adaptability to future changes in treatment capacity needs.
- The performance of some membrane filtration systems is enhanced by a heated influent.
- Installation should be in a heated building. Required utilities include electricity, potable water, hot water, natural gas (if influent is heated), and a sewer connection.
- Pretreatment requirements need to be determined to optimize performance and minimize costs.
- Standard operating procedures need to be developed in conjunction with the overall deicer management system.
- Additional system components, such as storage and on-line monitoring, should be identified.
- The destination for the concentrate, and a means for disposing of the permeate need to be identified.
- If the system will be operated by airport personnel, a training program for system operators should be developed.

Integration with Other Practices

A membrane filtration system is typically implemented as a component of a deicer management and treatment system, most often as part of a glycol-recycling program.

Operation and Maintenance Considerations

Operation of a typical membrane filtration treatment system and the associated pretreatment systems requires one or two skilled operators per shift. Actual staffing requirements depend on the system size, number of unit processes, and number of treatment trains. System operation is often contracted out to a glycol recovery company.

Maintenance requirements include routine backflushing of the pretreatment processes. Media filters are typically backwashed daily with filtered effluent, and UF systems are cleaned weekly with caustic and detergent solutions. Membrane cleaning is based on the type of fouling experienced and can include use of acids, bases, detergents, or enzymes. Proper system cleaning and shutdown for the off-season is critical for prolonging membrane life (typically 3–5 years).

3. Costs

Costs associated with this practice will depend on site-specific factors and constraints including responsibility for equipment ownership, and system operation and maintenance.

Capital Costs

Capital cost items could include the membrane filtration units, storage tanks, pump stations, pretreatment equipment, control systems, and a building. Capital costs increase with influent flow rate and decreasing effluent concentrations. Available capital cost data for existing membrane filtration systems ranges from $1 million to $8 million.

Operations and Maintenance Costs

Operating and maintenance cost items may include chemicals, power, natural gas, solids disposal, and membrane replacement. Costs for POTW discharge or transport of the concentrate to an offsite treatment facility can be significant. Available data for existing membrane filtration systems suggest annual operating costs from $150,000 to $800,000.

Reference

EPA. 2000. Preliminary Data Summary: Airport De-Icing Operations. *EPA-821-R-00-016.* From http://www.epa.gov/waterscience/guide/airport/.

FACT SHEET 41

Glycol Recovery

1. Description

Purpose

Glycol recovery and recycling is a disposal practice aimed at recovering the glycol in aircraft-deicing runoff for some type of productive reuse. The market value for propylene glycol is significantly higher than that of ethylene glycol, which results in a focus on propylene glycol in all airport glycol-recycling programs. Mixed streams of recovered glycol have limited utility and a very low market value.

Recovered glycol may be used as "feed stock" for products such as coolants, coatings, paints, and plastics. In Europe and at some U.S. airports, recovered glycol is reformulated as aircraft-deicing fluid after certification that it meets all SAE AMS 1424 specifications. Other airport uses for recovered glycol include anti-freeze for maintenance trucks and aircraft lavatory fluid.

Technology

Recovery of glycol to economically viable concentrations requires a series of steps to remove water and suspended solids, surfactants, corrosion inhibitors, and other additives from aircraft-deicing runoff. The processing may include filtration to remove suspended solids, ion exchange to remove dissolved solids, nanofiltration or flocculation to remove polymer-based additives (e.g., thickening agents, corrosion inhibitors, and surfactants), and reverse osmosis, evaporation, or distillation to remove water and concentrate the glycol.

In many cases, recovery is accomplished partly onsite to get concentrations high enough to economically transport the material to an offsite recycling facility for final processing.

A new technology has been described in the literature for recycling/recovering deicing fluids using polymeric/ceramic composite membrane-based vapor permeation technology and low-cost, high-performance ceramic ultrafiltration. However, it is unclear if this technology has been commercially implemented.

Documented Performance

Glycol application and recovery data were obtained from Denver International Airport (DIA) and Detroit Metropolitan Wayne County Airport (DTW), which have two of the most aggressive and expensive deicing runoff management systems in the United States that incorporate extensive glycol recovery programs. Table 1 summarizes the performance of these two systems expressed as percent of applied glycol recovered by recycling.

Table 1. Annual Recycled Fraction of Applied Glycol

Airport	Average	Range
DIA	29	10–44
DTW	39	25–53

It is important to note that differences in winter weather among the reporting years was identified by both airports as being a major factor in glycol recovery.

2. Implementation Considerations

Applicability Assessment

The feasibility of glycol recovery is dependent on collecting sufficient volumes of adequately high concentrations of glycol in runoff to reach an economically sustainable scale.

Five percent is a common lower limit for economically recoverable glycol, but at least one program (T. F. Green Airport) operates with a threshold concentration of 3 percent.

- Mixed-glycol streams are generally impractical to recycle because the resulting product has a very low market value. This means that only propylene glycol–based aircraft deicing fluid (ADF) and aircraft anti-icing fluid (AAF) may be used in the areas where deicing runoff is to be recycled to ensure the highest value of the recovered material.
- A critical criterion for recycling is collection of runoff with glycol concentrations that are high enough to make recovery economical. Minimum concentrations should be in the range of 3 to 5 percent, whereas average concentrations should be significantly higher.
- The volume of high-concentration runoff that is collected will determine the feasibility of onsite processing versus offsite transport for processing. Only the largest airports are likely to generate the volume of concentrated runoff necessary to support onsite-processing facilities.
- Smaller airports may be able to implement recycling if they are able to transport collected runoff economically to a recycling facility that serves other airports and/or industries. If the runoff volumes are large enough, limited onsite processing to reduce water content may make transport more economically feasible.
- It is technically feasible to recover glycol to concentrations in excess of 98 percent, although energy requirements and cost increase significantly with concentrations. Therefore, glycol is concentrated only as much as necessary to meet the needs of the reuse application.

Regulatory Considerations

Waste streams from the recycling process, if performed on airport grounds, must be properly permitted and handled. This may require an industrial discharge permit for sanitary sewer discharges, and/or pretreatment and solids disposal.

Air emissions from onsite processing and over-the-road transport may be of regulatory concern, depending on location.

Planning and Design Considerations

Several airports in North America have active glycol-recycling programs. The strategies and scales of these recycling operations vary significantly, determined by site-specific factors such as volume and reliability of ADF usage, glycol concentrations in collected runoff, volume of high-concentration runoff, and proximity to processing facilities.

Practical onsite glycol recycling is generally restricted to the largest airports, where large volumes of glycol are used annually.

Airports with Active Glycol Recycling Programs

- Detroit Metropolitan Wayne County
- Toronto’s Lester B. Pearson International
- Denver International
- Cincinnati/Northern Kentucky International
- Pittsburgh International
- Minneapolis–St. Paul International
- Newark International
- Salt Lake City International
- Washington Dulles International
- Bradley International
- T. F. Green

At smaller airports, access to an offsite recycling facility is necessary, and costs for transporting collected runoff may be a significant limiting factor.

Typically, a glycol-recycling contractor implements this practice under an agreement with either the airport or an air carrier (or group of air carriers). The details of the contractual arrangements vary significantly. In the simplest cases, the contractor serves as a waste hauler, transporting collected runoff to an offsite processing facility. In the largest programs, the contractor may be responsible for all onsite collection, storage, handling, and processing activities. An innovative glycol harvesting agreement has been established at the Detroit Metropolitan Wayne County Airport, where the contractor pays an annual fee for access to all deicing runoff above a certain concentration, and additional monies for recovered glycol above a set annual total volume.

Integration with Other Practices

Glycol recovery and recycling relies on a collection system that is capable of consistently capturing significant volume of deicing runoff at or above 3 to 5 percent glycol.

The economic feasibility of recycling may be undermined by source control practices that reduce the volumes of ADF used and thereby reduce volumes and concentrations of deicing runoff generated.

Operation and Maintenance Considerations

For implementations that involve offsite processing, the primary operation and maintenance considerations will involve temporary onsite storage and tracking of high-concentration runoff prior to its transport offsite.

Onsite glycol processing is typically operated by a contractor, who is responsible for setting up, operating, and maintaining the onsite equipment, facilities, and programs.

3. Costs

Costs for implementing recycling are very site-specific, depending on the scale. Factors that affect cost include volume and glycol concentration of collected material and proximity and access to a processing facility.

There are some unique cost considerations when evaluating this practice. The benefits of employing glycol recovery as a practice for managing collected deicing runoff include reduced costs for public owned treatment works (POTW) treatment, reduced dependence on POTW capacity, and the potential for cost recovery in the form of income from the value of the recovered glycol. As mentioned earlier, at DTW, a contractor pays the airport an annual fee for the right to “harvest” glycol from runoff collected at centralized deicing facilities, plus additional fees for harvested glycol above a stipulated minimum volume recovered for the season. However, the potential income from recovered glycol also relies on market forces of how valuable that glycol continues to be.