

COST EFFECTIVE AIRPORT AIRCRAFT DEICING FLUID MANAGEMENT

THERMOENERGY CORPORATION



THERMOENERGY

AIRPORT AIRCRAFT DEICING FLUID MANAGEMENT

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1.0 Background

The high and rising cost of airplane deicing coupled with final EPA aircraft deicing fluids (ADF) regulations are forcing airports to examine their deicing operations to reduce deicing costs and meet this new rule. The final rules are comprehensive directing airports to manage their spent ADF through specific data management, collection and treatment goals and guidelines.

Concurrently many airports are also streamlining aircraft deicing operations to improve efficiency and flight management. Once deicing operations were primarily done at the gate, today airports are constructing designated deicing pads (CDP) where planes can be quickly deiced and then moved to the flight line. There are many advantages to designated deicing pads in terms of cost effective deicing management including: ADF can be collected within a small surface area, and stormwater infiltration can be reduced. Where it is not possible to build a CDP, ground recovery vehicles (GRVs) can be used to collect the spent ADF and stormwater. Half of the largest 110 airports currently have CDPS, GRVs or both.

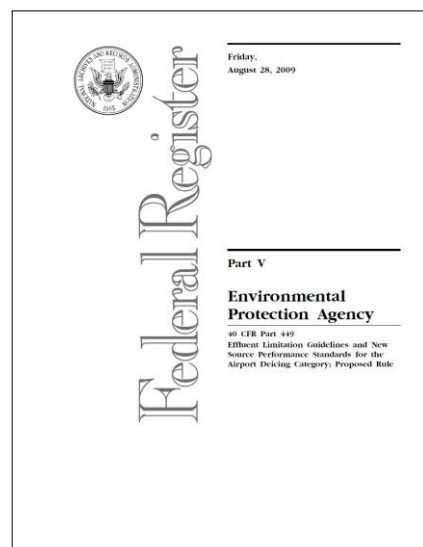
Combined these regulations and operational changes require more management of the treatment process for spent ADF. Collecting more spent ADF at higher spent ADF concentration increases treatment costs. Airports have limited choices for treatment that include disposal as a waste, discharge to a central or municipal wastewater treatment facility, onsite biological treatment and recovery of glycol in the spent ADF.

The purpose of this document is to examine airplane deicing management in today's regulatory and operational environment with the goal of reducing deicing costs. Based on data collected from several airports, the cost and benefits of five treatment options including do nothing, discharge to a sewer, disposal and biological treatment are analyzed and presented.

2.0 Regulatory Discussion

As a part of Airports' review of deicing policies and procedures, the impact of the Environmental Protection Agency's (EPA) Final Rule for Aircraft Deicing Effluent (April 25, 2012) on spent aircraft deicing fluid and stormwater collection and treatment must be considered. Within the context of this final rule, an Airport must review its deicing operations including spraying, collection, storage, and treatment of the spent ADF and stormwater to determine the most efficient, effective and lowest cost options.

For compliance with the final EPA rule limiting spent ADF in stormwater, Airports are regulated under the NPDES General Permit for Biological Oxygen Demand (BOD₅) Chemical Oxygen



Demand (COD), ammonia, pH and other contaminants of concern such as metals and hydrocarbons. Some airports are regulated under individual permits for stormwater and COD. For airports, the major requirements of the general permit usually are:

- Develop a stormwater pollution prevention plan (SWPPP), including a drainage area site map, documentation of measures used for management of runoff, an evaluation of runway and aircraft deicing operations, and implementation of a program to control or manage contaminated runoff, including consideration of various listed control practices;
- Implement deicing source reduction measures, including minimizing or eliminating the use of urea and glycol based deicing chemicals; minimizing contamination of stormwater runoff from runway and aircraft deicing operations; evaluating whether over application of deicing chemicals occurs; and consider use of various listed source control measures;
- For airports using over 60,000 gal. of glycol based deicing chemicals annually, monitor discharges quarterly for the first four quarters of the permit cycle, for the following pollutants: biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), ammonia and pH;
- If the average of the four monitoring values for any parameter exceeds its benchmark, implement additional control measures where feasible, and continue monitoring;
- Conduct an annual site inspection during the deicing season, and during periods of actual deicing operations if possible; and routine facility inspections at least monthly during the deicing season.

In addition, the final EPA ADF rule would require the Airport to:

- Collect at least a specified proportion of spent ADF based on the permit writer's best judgment of available ADF and impact on airport operations;
- Meet a specified numeric effluent limit for COD in wastewater collected and discharged to the waters of the United States of a maximum daily load of 271 mg/l and weekly average load of 154 mg/l
- Certify that it uses airfield pavement deicers that do not contain urea.

The airport will also have to keep detailed records of ADF consumption, collection and treatment to show regulators that they are meeting permit conditions.

EPA regulations for the treatment of the spent ADF and stormwater requires at a minimum the treatment performance of the best available technology (BAT) which is anaerobic fluidized bed technology. The BAT performance goals are the removal of 98% of BOD₅, 97% of the COD and 99% of the propylene glycol in the stormwater before discharge. If the treated water is sent to a POTW after treatment; the discharge conditions for the Airport's treatment system may be less. Specific treatment discharge limits will be negotiated with the local regulatory agencies and the POTW.

3.0 Deicing and Spent ADF Collection Operations

Effective and low cost management of spent ADF and stormwater treatment begins with the deicing operation. ADF concentration in stormwater and the volume of stormwater treated are the major drivers of treatment costs. There are two factors that impact the volume of spent ADF/stormwater, the amount of ADF sprayed on planes and the amount of stormwater that is allowed to mix with the spent ADF. Both factors can be controlled to reduce the volume of stormwater to be treated. The amount of

deicing fluid consumed can be limited by using the latest technology in deicing equipment and limiting the amount of stormwater can be accomplished by using more efficient collection systems.

As an example how spent ADF/stormwater volumes impact treatment costs, assume that the collected spent ADF concentration in stormwater is 5%; if an airport uses 150,000 gallons of ADF per season it would need to dispose of 3,000,000 gallons of spent ADF and stormwater. If the concentration of normalized ADF in the stormwater is 20% instead of 5% then the quantity of stormwater to be collected and treated would decrease to 750,000 gallons from 3,000,000 gallons. This would result in a significant decrease in treatment costs since less volume would need to be treated. Therefore, a goal of the deicing operation in addition to improving airport flight management would be to attain the highest ADF concentration by preventing dilution with stormwater.

3.1 Deicing Operations-Deicing Equipment

By using modern deicing equipment such as the Global ULTIMATE 2100 deicing trucks, the volume of ADF sprayed per plane will decrease. These high efficiency deicing trucks not only spray less ADF per plane to achieve the same level of deicing as traditional trucks they also have a tighter spray distribution pattern that will result in higher concentration of the spent ADF around the footprint of the aircraft. A comparison of traditional and highly efficient deicing trucks at several airports show a 35% reduction in deicing fluid



Figure 1: High Efficiency Deicing Trucks showing spray pattern.

consumed. This reduction in the consumption of ADF is due to over spraying the ADF on a hot air stream with the hot air providing both improved mixing as well as heating the accumulating ice and snow on the plane. As Figure 1 illustrates, high efficiency deicing trucks spray both above the wing and along the wing edge and fuselage. Thus the distribution pattern and the highest concentrations of the ADF will be around the footprint of the plane. Concentrations of ADF of between 20-35% are typically found in these areas. If spent ADF can be collected around the plane then the amount of stormwater collected with the ADF will be significantly reduced.

3.2 Collection of Spent ADF and Stormwater

An Airport has two alternatives other than runoff for the collection of spent ADF and stormwater. The first alternative is to use a drainage system around the deicing areas. Figure 2, shows a typical deicing pad with a drain in the center. Common to most deicing pads is the large surface area that collects and retains stormwater. The stormwater runs by gravity to the storm drain. The drain connects to a drainage system that may collect stormwater from elsewhere on the airport. The drainage system



Figure 2: Deicing Pad with Drain

can then be discharged to the sanitary sewer, a retention pond or a tank. The large surface area results in stormwater with very low concentrations of ADF. When mixed with high concentration areas around the footprint of the plane the overall concentration of ADF stormwater is greatly reduced. Typically



Figure 3: Drain Cover

concentrations of spent ADF in the drainage water are from 1% to 7%. To prevent the spent ADF/stormwater from entering the drainage system and increase the concentration of spent ADF drain covers (Figure 3) are placed over the drains. Concentrations of spent ADF will be 7%-20% depending on the surface area drained. The drains are removed at the end of the deicing season.

The second alternative to collect spent ADF and stormwater is to use Ground Recovery Vehicles (See Figure 4). Using GRVs to collect the

spent ADF/stormwater can limit dilution by collecting around the aircraft footprint where the highest concentrations and volumes of spent ADF are located. Also by frequently collecting stormwater during a storm event, dilution can be limited and concentrations of spent ADF higher. The capacities of GRVs are typically 750 to 2,000 gallons.

3.3 Storage

After collection by either the GRVs or storm drain the spent ADF and stormwater could be sent to a temporary or permanent holding tank (Figures 5 and 6). After the storm event, the GRV's could be used to transfer the spent ADF and stormwater to a larger storage facility either near the treatment facility or within the airport. A typically large storage tank of 100,000 gallons capacity might look like the picture in Figure 6. The tank is a simple pre-stressed concrete construction. The costs of storage range from a monthly fee of \$1,100 (\$0.05 per gallon per month) for temporary storage to \$1.00 per gallon to build a permanent holding tank.



Figure 4: Global Ground Recovery Vehicle with 2,000 gallon tank



Figure 5: 21,000 gallon temporary storage tank

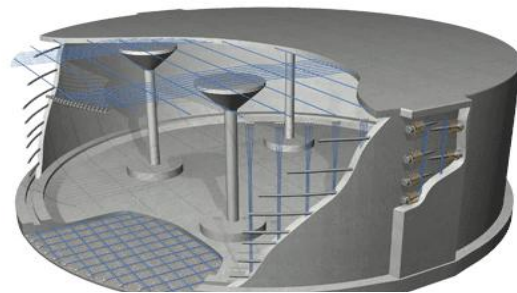


Figure 6: Concrete Storage Tank

4.0 Treatment Options

After collection and storage of the spent ADF and stormwater there are five treatment options available to an Airport: 1) do nothing and let the spent ADF runoff, 2) transport to an offsite treatment and disposal facility, 3) discharge to a sanitary sewer wastewater treatment plant, 4) onsite biological

treatment, 5A) dewatering the spent ADF/stormwater and selling a 50/50 mix of ADF and water and 5B) recovery of the glycol portion of the spent ADF.

4.1 Option 1: Do Nothing Allow ADF to Run Off into Soil

Historically, spent ADF was carried off by the stormwater to the edge of the runway or gate area where it seeped into the soil and groundwater or ran into rivers. Glycol, a major component of ADF, increases the chemical oxygen demand in ground and surface water depleting oxygen that is necessary to support aquatic life. Some glycols such as ethylene glycol are also toxic to humans when ingested. The proposed EPA regulations address the environmental damage that can result from uncontrolled releases of glycol and ADF additives to the environment. Most airports recognize the environmental impact of spent ADF and are looking at alternatives to runoff. While doing nothing may have the lowest costs of any option regulatory agencies will prohibit its use in the future.

4.2 Option 2: Disposal of Spent ADF and Stormwater to an Offsite Treatment and Disposal Facility

Spent ADF is a non-hazardous waste that can be treated and disposed of in a licensed treatment facility. Concentrated ADF is typically composed of 88% propylene glycol and 2% of an additive package that contains a coating agent, a filming agent and an anti-corrosion agent and 10% water. Although some ADF formulations contain ethylene glycol; ADF based on ethylene glycol is being phased out of use because of its greater environmental impact. Once the spent ADF and stormwater is collected in temporary storage tanks, it is transported by a 5,000 gallon licensed tank truck to a treatment facility. Transporting and disposing spent ADF and stormwater is expensive costing \$0.50-\$1.00 per gallon. Temporary or permanent storage will also be necessary to hold the spent ADF and stormwater until it is transported. Costs for storage are explained in Section 3.3 Storage. If an airport collects 200,000 gallons of spent ADF and stormwater a season then disposal costs will range from \$100 thousand to \$200 thousand per season. In addition, over 150 tanker loads per season will be necessary to remove the spent ADF and stormwater to the treatment facility. At the treatment facility, the spent ADF/stormwater is dewatered and the glycol burned or used in lower value applications such as compressors as a coolant.

4.3 Option 3: Discharge to a Municipal Wastewater Treatment Plant

Spent ADF/stormwater from tanks, retention ponds or a storm drain can be discharge to the sanitary sewer. Generally wastewater treatment plants will accept glycol concentrations less than 1000 mg/l in stormwater. However, some wastewater treatment plants will accept higher glycol concentrations generally up to 1% if they need the carbon source. If stormwater infiltration is uncontrolled the expected glycol concentration is usually between 1-7% higher than the typical wastewater treatment plant can take. If GRV's are used to collect the spent ADF/stormwater there will be a 20% to 35% concentration of ADF in the stormwater discharged. At these high concentrations, the glycol portion of the ADF has high BOD and COD impact of 1,000,000 mg/l as compared a typical municipal wastewater COD level of 500 mg/l and it is likely that the stormwater will be metered to the sanitary sewer and that a maximum ADF concentration in the effluent be established. The amount metered depends on the amount of COD in pounds per day allowed by the wastewater treatment facility. Therefore, there will have to be enough on-site storage to handle all of the seasonal stormwater. There also may be a cost

based on the flow and the quantity of ADF discharged as well. For example, Philadelphia International Airport discharge fees for 2.9 million gallons at 3-7% glycol concentration per season are \$561,000 or \$0.19 per gallon of spent ADF/stormwater treated.

4.4 Option 4: On-Site Biological Treatment

On-site anaerobic biological treatment of spent ADF/stormwater is used at several airports. Similar to municipal wastewater treatment systems a film of anaerobic microorganisms coat the surface of a matrix where they convert the glycol into byproducts of the assimilation process: methane, carbon dioxide and a biosludge. Effluent from an anaerobic treatment system can be discharged to the municipal wastewater treatment plant or to the surface waters. Anaerobic treatment is expensive and has a large footprint. Rhode Island's Theodore Francis Green airport for 200,000 gallons of concentrated ADF per season will install an anaerobic treatment system at a capital cost of \$8.5 million. Biosludge disposal will also be required at a cost of \$50-\$100 per dry ton. EPA estimates that anaerobic treatment of spent ADF would cost \$1,659 per pound of COD removed per day with an annual operating cost of \$77.72 per pound of COD removed per day.

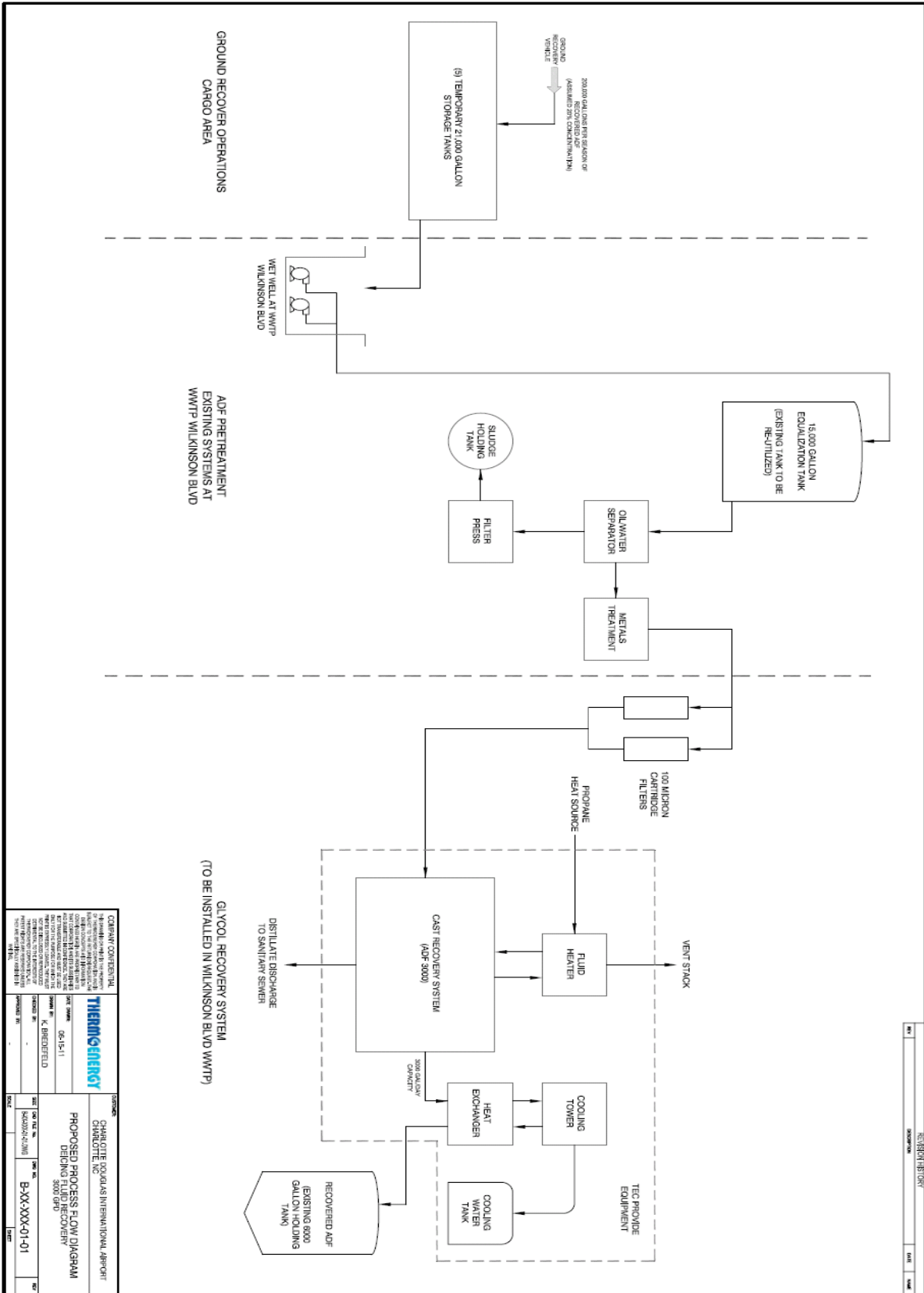
4.5 Option 5A and 5B: Dewatering or Recovery of Glycol Portion of Spent ADF for Reuse or Recycling

The glycol portion of spent ADF has economic value and can be easily recovered for resale or reuse through mechanical vapor recompression or distillation. Mechanical vapor recompression (MVR) with reverse osmosis is used to dewater the low concentration spent ADF/stormwater to lower transportation costs and raise the energy content of the spent ADF/stormwater. With an ADF concentration in stormwater of 1-7% then an MVR will increase the concentration of spent ADF to 50%. The higher concentration of ADF allows it to be used as a fuel in waste incinerators or as a coolant in compressors. EPA estimates the capital cost of an RO/MVR is \$4.08 per gallon treated with an operating cost of \$0.10 per gallon treated. The recovered value of the spent ADF is on the order of \$2.50-\$3.50 per gallon of concentrated ADF because the spent ADF still contains the additive package. While lowering the costs of transport and disposal the MVR does not recover the entire value of the spent ADF.

A distillation recovery system can remove all of the water and separate the propylene glycol from the additive package. The recovered propylene glycol is 99% pure and it can be reused as ADF by mixing it with an ADF additive package or it can be sold in such applications as coolants. It will meet ASTM specifications for virgin and recovered glycol. Pure recovered glycol is worth \$5.00-\$8.00 per gallon. Distillation of the spent ADF/stormwater will generate the highest value for the glycol. It should be noted that ThermoEnergy has developed a distillation system specifically for spent ADF/stormwater based and a comparison of treatment alternatives will be made based on this proprietary technology.

ThermoEnergy's ADF Recovery Process has two distillation stages. In the first stage, the spent ADF and stormwater is transferred from the temporary collection tank (See Figure 6: Process Flow Diagram) to a pretreatment step where the stormwater is filtered to remove any grit or sand. If treatment for hydrocarbons and metals is required the stormwater will be sent through an oil water separator and coagulants, flocculants and precipitants will be added as needed. Sludges will be filtered from the stormwater and sent to a filter press for dewatering. In addition, some ADF's contain siloxanes or other

Figure 6: ADF Process Flow Diagram



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<p>DATE:</p> <p>06-15-11</p>	<p>DESIGNED BY:</p> <p>K. BRODEUR</p>	<p>SCALE:</p> <p>AS SHOWN</p>	<p>PROJECT NO.:</p> <p>B-XXX-XXX-01-01</p>
<p>PROPOSED PROCESS FLOW DIAGRAM DESIGNING FLUID RECOVERY 8000 GPD</p>			

stormwater is then sent to the ADF treatment unit (See Figure 7). As the stormwater enters the ADF treatment vessel, the water is separated through flash distillation from the ADF. The water is collected in a condenser. Depending on how the system is operated a small amount of glycol may be found in the distillate. This can be removed with an RO and returned to the ADF Recovery System. The water is of distillation quality at this point and can be discharged to a sanitary sewer. The spent ADF which now consists of propylene or ethylene glycol and an additive package moves to the second flash distillation stage. In the second stage, the glycol is separated from the additive package and is collected as pure glycol and can be recycled or reused. The recovered glycol has an approximate value of \$6-\$8 per gallon under current market conditions. The additive package is collected as a still bottom and is sent for disposal. If the water needs to be pH adjusted caustic or acid will be added after the CAST unit; then the water is discharged to the sanitary sewer.



Figure 7: Single Stage 3000 gallon per day ThermoEnergy Glycol Recovery Process

ThermoEnergy's CAST platform technology is the primary treatment component of its ADF Recovery Process. Based on vacuum assisted flash distillation, the CAST technology is an effective and efficient solution for recovering spent ADF from stormwater for recycle or reuse. ThermoEnergy's ADF Recovery Process is able to meet the proposed EPA ADF regulations. As Table 1 illustrates for an antifreeze application pure glycol can be recovered at 99% purity and meets ASTM specifications. In addition, water discharged to the sanitary sewer will meet EPA wastewater permit conditions since it is distillation quality.

Table 1: Typical ThermoEnergy Glycol Recovery Performance

Variable	First Stage	Second Stage	Discharge Water
Glycol	45%	> 99%	ND
Water	55%	> 1%	ND
Ash	1-250 PPM	< 5 PPM	ND
Chloride	> 100 PPM	< 5 PPM	4 PPM
Silicon	> 150 PPM	< 5 PPM	ND
Phosphorous	> 5000 PPM	< 5 PPM	ND
Boron	> 500 PPM	< 5 PPM	ND
Organic Acids	> 50 PPM	< 0.5 PPM	ND
Metals	> 300 PPM	ND	ND

ThermoEnergy ADF System come in five sizes to meet any airport stormwater flow as Table 2 shows:

Table 2: ADF System Sizes

ThermoEnergy System	Gallons Processed per 220 Day 24/7 Operation
1,000	220,000
3,000	660,000
5,000	1,100,000
10,000	2,200,000

The advantages and features of the ThermoEnergy ADF Recovery technology are:

- Lowest capital cost of any treatment system
- Applicability across many process chemistries
- Recovery of process chemistry for reuse or recycle
- Handles high-strength wastewaters
- High uptime
- Lowest maintenance and operational costs
- Large heat transfer surface
- Low cost materials of construction
- External pumps and valves for ease of operation
- A small footprint that allows it to be effectively installed in the existing wastewater pump house building or adjacent to it
- High quality water with less than 1% glycol concentration that allows discharge to the sanitary sewer on site
- High quality glycol recovery that obtains the highest price

ThermoEnergy's ADF Recovery System is also the only process that can:

- Meet EPA's Final Rule on Aircraft Deicing Fluid (April 25, 2012 Volume 74, Number)
- Meet ASTM 1177-09 specification for recycled propylene glycol
- Provide a RCRA permit exemption with significant savings in permit fees and engineering support

5.0 Option Economic Analysis

This section analyses the capital and operating costs of collecting, storing and treating the spent ADF and stormwater. The costs presented are gathered from airports and the EPA. The operating assumptions and cost factors and are a representation of the costs of managing ADF.

5.1 Assumptions and Cost Factors used in the Analysis

Based on the expected performance of a representative airport's deicing program as described in previous sections the following conditions listed in Table 3 can be assumed and used in comparing the five treatment options in Section 4.0.

Table 3: Operational Assumptions

Variable	Value
Normalized Annual ADF Use (Concentrated ADF)	150,000 gallons
Collection Efficiency	40%
ADF/Water Mix Ratio	45/55
Concentration of ADF in Stormwater	23%
Spent ADF collected	60,000 gallons
Treatment Volumes (at 60,000 gallon collection goal/23% concentration)	260,870 gallons/season
Glycol Recovery (88% of spent ADF collected)	52,800 gallons
COD per season (1.53 lbs of COD per pound of propylene glycol)	701,205 pounds

Table 4 provides the cost factors used in the economic analysis for the five treatment options. In the Table, the unit cost, source of the data and periodicity and estimated total cost for each factor is provided.

Table 4: Cost Factors, Duration and Estimated Total Costs for Storage and Treatment

Cost Factor	Unit Cost	Source	Duration	Total Cost
Disposal Costs	\$0.86 per gallon treated	Clean Harbors	Season	\$224,348
ThermoEnergy CAST ADF Treatment Equipment	\$650,000	ThermoEnergy	Long-term	\$650,000
Thermo Energy CAST ADF Operating costs (260,870 gallons)	\$0.20 per gallon	ThermoEnergy	Season	\$50,941 per season
Labor costs	\$25/hour without benefits	Deicing Contractor	4380 hours per season	\$109,500 per season
Revenue from sale of 50/50 Recovered Glycol	\$2.50 per gallon	ThermoEnergy	Season	\$132,000 per season credit
Revenue from sale of 100% Recovered Glycol	\$7.00 per gallon	ThermoEnergy	Season	\$343,200 per season credit
Biological Treatment Capital Cost	\$1,659 per pound of COD per day	EPA	Long-Term	\$3.187 million
Biological Treatment Operating Cost	\$77.72 per lb of COD per day	EPA	Season	\$149,300
Discharge of COD to sewer	\$0.10 per pound of COD greater than 500 mg/l (Assume 52,800 to 68,640 of glycol collected at 8.68 lbs/gallon times 1.53 COD per pound of glycol)	Municipality	Daily	\$70,120
MVR Capital Cost	\$4.08 per gallon treated	EPA	Long-Term	\$1,064,350
MVR Operating Cost	\$0.10 per gallon treated	EPA	Season	\$26,087

5.2 Collection and Storage Costs Analysis of Treatment Options

5.2.1 Collection

Common to all treatment options are the collection and storage of the spent ADF/stormwater. An Airport has two choices for collection: improvements to the drain system or the use of Ground Recovery Vehicles. The capital costs for both options are provided in Table 5 below. These costs were based on a specific airport. The capital costs for the drainage improvements were made by ThermoEnergy.

Table 5: Collection Capital Costs

Collection Option	Description	Capital Costs
Improvements to stormwater drainage	Isolate Drains for \$400,000 4000' Concrete drainage system for \$492,500 Concrete Collection Basin for \$190,000 Engineering \$100,000 General Contracting Markup \$180,352	1,362,852
Ground Recovery Vehicles	Two Global 2,000 gallon trucks	\$440,000

Because of the high cost of capital improvements to the drainage system the use of Ground Recovery Vehicles to collect the spent ADF/stormwater would have a lower capital cost. Depending on which deicing area is used during a storm event the GRVs can be moved from around the deicing pad giving the Airport added flexibility in its deicing management.

5.2.2 Storage

Once the spent ADF/stormwater is collected it will have to be stored for future treatment and disposal. An airport can erect a permanent 250,000 Gallon storage tank or use temporary storage tanks to hold the spent ADF/stormwater. The temporary tanks will cost \$1,100 per month for six months. Each tank will hold 21,000 gallons. It is estimated that 7 tanks holding 147,000 gallons will be needed to handle the average spent ADF/stormwater flow of 260,870 gallons if GRVs are used assuming that some stormwater will be treated during those six months.

Table 6: Storage Costs

Storage Option	Description	Capital Cost
Permanent 250,000 Gallon Concrete Tank	250,000 gallons at \$1.90/gallon	\$475,000
Temporary Tanks	7 tanks for 6 months at \$1,100 per month	\$46,200 (Operating Cost)

5.2.3 Total Annual Collection and Storage Costs

The total costs for collection and storage is presented in Table 7. It is assumed that for the Ground Recovery Vehicles the amortization is 7 years. The total costs are presented as cost per gallon of spent ADF and stormwater treated, the cost per gallon of glycol recovered and the cost per aircraft takeoff assuming 250,000 departures per year.

Table 7: Total Annual Collection and Storage Cost by Gallon Treated, Gallon Recovered and Aircraft Departures

	\$ per gallon of Spent ADF/Stormwater treated	\$ per Gallon of Glycol Recovered	\$ per Aircraft Departure
Collection	\$0.34	\$1.68	\$0.36
Storage	\$0.16	\$0.88	\$0.18
Total	\$0.50	\$2.56	\$0.54

5.3 Treatment Capital Costs

Table 8 provides the estimated total capital for the five options described in Section 4.0 Options Disposal, Discharge, Biological Treatment, Dewatering and Recovery. Note the EPA ADF regulations are not final and the costs below may change once the regulations become final.

Table 8: Capital Costs for Collection Storage and Treatment Options

Option	Capital Cost Components	Total Capital Costs
Option 1: Do Nothing		\$0
Option 2: Disposal		\$0
Option 3: Discharge	1000' Connection Pipe from tank to sewer for \$123,000 Duplex Pump and Feeder for \$100,000 Discharge Piping for \$100,000 Engineering and Permitting \$100,000 General Contractor Markup for \$100,000	\$523,000
Option 4: Biological	General Construction	\$3,187,000
Option 5A: Dewatering	MVR	\$1,064,350
Option 5B: Recovery	ThermoEnergy Equipment	\$650,000

5.4 Operating Cost Analysis

Operating costs are based on the collection of 191,111 gallons per season of spent ADF /stormwater. All treatment options use two GRVs and 7 temporary tanks for storage. It is expected that the 260,870 gallons treated will have 552,800 gallons of propylene glycol. Option two, Disposal, includes a cost for transportation of the spent ADF and stormwater to an off-site disposal facility and cost per gallon for treatment. Option Three: Discharge, has sewer charges for a connection to the sewer, a charge for flow and a fee for high COD wastewater. Propylene Glycol has high Chemical Oxygen demand of 1,000,000 mg/l which is greater than the allowable COD concentration of 500 mg/l. Table 9 shows sewer rates as of July 1, 2011 for an airport's spent ADF/stormwater.

Table 9: Annual Discharge Costs for High COD Wastewater

Sewer Cost	Rate	Annual Cost
Fixed Billing Rate	\$2.40 per month	\$28.80
Fixed Sewer Availability Charge (1" line)	\$10.75 per month	\$129.00
Sewer Usage Charges	\$4.14 per 748.05 gallons	\$1,444
Chemical Oxygen Demand	\$0.10 per pound greater than 500 mg/l	\$70,120
Total		\$71,721.80

Option Four: Biological Treatment has an annual operating cost of \$388,600. Option 5A: MVR includes a credit of \$132,440 based on a sale of 37,840 gallons of glycol at \$3.50 per gallon. Option 5B, Recovery, also includes a credit for the sale of recovered glycol from the spent ADF. It is assumed that 37,840 gallons of recovered glycol are sold or reused each year \$7.00 per gallon or \$264,880. Table 10 summarizes the operating costs for all three options.

Table 10: Operating Cost (Credit) for Three Treatment Options

Option	Operating Costs Component	Total Annual Operating Cost
Option 1: Do Nothing		\$0
Option 2: Disposal	Transportation and Disposal \$0.86/Gallon for 191,111 gallons	\$224,348
Option 3: Discharge	Sewer Fees	\$71,722
Option 4: Biological	\$77.72 per lb of COD per day times 1,921 lbs per day	\$149,300
Option 5A: Dewatering	\$0.10 per gallon treated and 260,870 gallons treated per season plus \$132,000 credit at \$2.50 per gallon recovered plus labor of \$109,500	\$3,587
Option 5B: Recovery	\$52,174 /yr for 260,870 gals treated Recovery \$6.50/Gallon @352,800 gal or \$343,200 Credit per year plus labor costs of \$109,500	(\$181,526) Net Credit

5.5 Total Annual Costs for Each Option

Of all five Options analyzed, Option 5A: Dewatering and 5B: Recovery are the only Options that would reduce an Airport's deicing costs. Option 2: Disposal and Option 3: Discharge would increase costs to the airline by \$0.67 and \$0.87 respectively. Including capital costs and assuming a 20 year life for Biological treatment the annual cost per aircraft departure would be \$3.21. Assuming a 7 year life for the MVR and the ThermoEnergy ADF Recovery system the annual costs would be for Option 5A: Dewatering a reduction of \$0.01 per aircraft departure and for Option 5B: Recovery the reduction per aircraft departure would be \$0.48.

Table 11: Total Annual Recovery Costs by Option and by Gallon Treated, Gallon Recovered and Aircraft Departures

	Annual Cost (w/ capital)	\$ per gallon of Spent ADF/Stormwater treated	\$ per Gallon of Glycol Recovered	\$ per Aircraft Departure
Option 1: Do Nothing	\$0	\$0	\$0	\$0
Option 2: Disposal	\$224,348	\$0.86	\$4.25	\$0.90
Option 3: Discharge	\$71,722	\$0.27	\$1.36	\$0.29
Option 4: Biological	\$149,300	\$0.57	\$2.83	\$0.60
Option 5A: Dewatering	\$3,587	\$0.01	\$0.07	\$0.01
Option 5B: Recovery	(\$181,526) Net Credit	\$0.70	\$3.46	\$0.73

5.6 Selection of Option based on Lifecycle Economic Value

Based on the information provided in Tables 8,9,10 and 11, Option 5B: Recovery has the greatest reduction in deicing costs and is the preferred option. While the estimated operating costs for Option 5A: Dewatering is more than half of Option 5B, Option 5B Recovery generates \$119,174 in additional revenue from the sale of the recovered glycol from the spent ADF.

5.7 Simple Payback Analysis for the Selected Option Recovery

Table 12 summarizes the payback for Option 5B: Recovery. The payback of 2.9 years on the equipment is very rapid.

Table 12: Payback Analysis for Option 5B: Recovery

Estimated Cost	Amount
Capital	\$650,000
Operating Credit	\$181,526
Simple Payback on Recovery Equipment Only (years)	3.56 years

5.8 Sensitivity Analysis

The simple payback for the project is dependent on several factors including:

- Concentration of spent ADF in stormwater
- Amount of glycol recovered
- Market price of recovered glycol
- Capital Deployed
- Energy Costs

Table 13 provides a sensitivity analysis of payback to these factors. From this analysis, the simple payback for the project Base Case is 2.9 years. Note that the recovery of more glycol and a higher concentration of ADF in the collected stormwater, have the most significant impact on payback. The capacity of the proposed ThermoEnergy System is 660,000 gallons per year and at 23% ADF concentration in the collected stormwater the facility has the capacity to recover 130,000 gallons of glycol per year without additional capital.

Table 13: Sensitivity Analysis

Factor	Change	Simple Payback (years)
Base Case	Treatment of 260,870 gallons of spent ADF/stormwater 23% concentration of ADF in stormwater collected 60,000 gallons of ADF collected Recovery of 42,800 gallons of glycol Glycol value \$6.50 per gallon \$0.42 operating costs per gallon treated	3.56
Higher Concentration of Spent ADF	35% instead of 23%	3.36
Lower Concentration of Spent	10% instead of 23%	5.85

ADF		
Market price of recovered glycol	\$6.00 per gallon instead of \$6.50	4.16
Market price of recovered glycol	\$7.00 per gallon instead of \$6.50	3.11
Capital Deployed	\$800,000 instead of \$650,000	3.82
50% increase in Operating Costs	\$0.63 per gallon treated	8.69

6.0 Other Factors

Additional factors that the Airport may consider in its selection of a treatment option may include sustainability and environmental impact, ease of operation, maintenance, alternative public-private financing and a potential service to other airports in the area that need to dispose of spent ADF. Table 14 provides a summary of these factors for each option.

Table 14: Additional Evaluation Factors

Option	Advantages	Disadvantages
Dispose	<ul style="list-style-type: none"> Easiest to manage Lowest capital cost Low maintenance costs 	<ul style="list-style-type: none"> Need to ship out of state Highest operating costs
Discharge	<ul style="list-style-type: none"> Passive management of system Low operating costs Low maintenance costs 	<ul style="list-style-type: none"> Additional construction around cargo area Runway 5-23 does not have a drainage system Highest capital cost
Biological		<ul style="list-style-type: none"> Large footprint Active management of facility Poor performance during Winter
Dewatering and Recovery	<ul style="list-style-type: none"> Sustainable and Green Produces revenue and payback on equipment Can provide a service to other airports Public/private partnership 	<ul style="list-style-type: none"> Requires active management of facility Marketing of recovered glycol

7.0 Conclusion

The recovery of spent ADF from stormwater is the best economic choice for an Airport to comply with the proposed EPA regulations. Because the recovered glycol has value, recovery is the only option that has a payback on the Airport investment in collection, storage and treatment equipment and operations. In addition, the recovery of spent ADF has additional benefits:

- Sustainable solution that lessens the impact on the surrounding environment
- Reuse of an existing, abandoned building and equipment saving capital costs
- Ability to provide a service to surrounding airports with ADF