COVER PAGE

Title of Design: Using a High Vacuum Evaporator to Treat Anti-icing and Deicing Byproducts
Design Challenge Addressed: Airport Environmental Interactions
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Using a High Vacuum Evaporator to Treat Anti-icing and Deicing Byproducts

Airport Environmental Interactions

Improved Containment and Cleanup of Anti-icing and Deicing Products

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Executive Summary

Aircraft deicing is both necessary and costly. Safety demands effective methods for the removal and prevention of frozen contaminants from critical surfaces and components of aircraft. Economics stipulate that it be cheap. Algae blooms, fish kills and hypoxic waters remind us of the environmental consequences of unregulated effluence. Each factor: safety, economics and water quality circumscribes the problem of finding an effective and tenable ground deicing program. A wealth of information and case studies are available describing successful ground deicing solutions which address the three components of aviation's deicing problem; however, these success models are for large scale deicing operations and do not address the particular needs of small to medium sized airports which comprise the bulk of U.S. flight operations.

The environmental, safety and economic benefits to be realized through the adoption of on-site recovery and recycling of glycol for large airports is fairly well-understood but its benefit to small to medium sized airports has yet to be demonstrated. With new effluent limitation guidelines due later this year, viable economic models for on-site glycol reclamation and recycling for small to medium sized airports could ease the financial burden of compliance and improve the economic outlook for the airlines operating through these airports. Engineering affordable, smaller scale glycol reclamation and recycling systems which maximize energy-efficiency has yet to become a reality. Innovations in renewable energy systems promise to reduce the costs of the energy intensive distillation and evaporation systems required for glycol recycling. This document investigates possible solutions for smaller scale glycol reclamation and recycling systems which require less energy consumption. The design presented here utilizes a high vacuum evaporator system to reclaim propylene glycol from spent aircraft deicing fluid. Achieving an affordable and environmental friendly ground deicing program which caters to smaller aviation venues will create broad economic incentive to realize FAA environmental stewardship goals.

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Problem Statement and Background

Keeping aircraft free from frozen contaminants remains a primary safety concern as the presence of even small amounts of frost, snow or ice on critical areas of the aircraft can cause degradation or failure of aerodynamic, mechanical, and system functioning. According to the Federal Aviation Administration (FAA), aircraft are prohibited from takeoff when “frost, ice, or snow is adhering to the wings, control surfaces, propellers, engine inlets or other critical surfaces of the aircraft” (AC 20-73A, 2006; 14 CFR Parts 91, 121, 135). As shown in Figure 1, the use of chemical deicing/anti-icing fluids remains the most common and cost effective method for the removal of frozen contaminants on aircraft surfaces but brings with it environmental safety concerns (EPA, 2000, Section 4.2).

Figure 1: Deicing aircraft in heavy snow.

The majority of U.S. flight operations come from small to medium sized regional carriers. Small regional carriers primarily operate planes that have less than 30 seats. Regional airlines represent approximately 40% of all flight operations in the U.S (EPA, 2000, Section 4.1.3; EPA, 2000, Section 14.1.1.2). Since ground deicing/anti-icing operations are conducted on a per aircraft basis, airports that are situated in cold climates and host a high number of annual flight operations (10,000+) have the greatest potential for significant deicing/anti-icing operations (EPA, 2000, Section 1.0; EPA, 2000, Section 4.1.1; EPA, Section 4.3.1.1). In its Preliminary Data Summary of 2000, the EPA identified 212 hub airports (large, medium, small and non-hub) situated in cold weather climates, which had potential for significant ground deicing operations (EPA, 2000, Section 14.1.1.2, Table 14-4).

The majority of U.S. regional airlines use chemical deicing fluid, specifically ethylene or propylene glycol based Aircraft Deicing Fluid (ADF), as their primary aircraft ground deicing method (EPA, 2000, Section 4.1.3; EPA, 2000, Section 4.2). Chemical ADFs, while providing a reliable and effective means of removing frozen contaminants, often enter into the environment in the form of storm water or runoff and can significantly affect surface water quality. Although propylene glycol is less toxic to human and aquatic life than ethylene glycol, both chemicals pose environmental issues during the biodegradation process. The biodegradation of propylene and ethylene glycol can result in a significant reduction in dissolved oxygen (DO) levels, rendering waters hypoxic and potentially leading to fish kills. The health impacts to humans and aquatic life caused by the presence of these chemicals in local surface waters have raised growing concern. New effluent limitation guidelines due out later this year have prompted the air transportation industry to pursue alternative deicing/anti-icing methods or to find more effective storm water collection and recovery methods (EPA, 2000, Section 1.0).

The ADFs used in ground deicing operations are divided into four classes (Types I, II, III, IV), of which only Type I and Type IV are currently used (EPA, 2000, Section 4.2.1.1). Each ADF type specifies different deicing and holdover capabilities. Holdover is the ability of the deicing fluid to retain its protective effects against ice buildup (EPA, 2000, Section 4.2.1.2). The less expensive Type I fluid, which has an approximate holdover time of 6-15 minutes in light snow, is used for deicing, while Type IV, which has an approximate holdover time of 70 minutes in certain conditions, is used for anti-icing (EPA, 2000, Section 4.2.1.2). A common method for applying ADF to aircraft surfaces is through the use of specialized deicing trucks that are equipped with a moveable boom, cherry picker, and special nozzle for high-pressure spraying. Type I ADF is heated 60^{o} – 82^{o} C and applied to critical surfaces until the aircraft is completely free of ice (EPA, 2000, Section 4.2.1.3). Quantities of deicing fluids required to clean aircraft surfaces vary according to aircraft size and weather conditions. Based on EPA findings, for a single commercial jet, dry-weather conditions require between 20-50 gallons of ADF. Under wet-weather conditions, that number increases to 150-1,000 gallons. In severe weather conditions, as much as 4,000 gallons of ADF can be used (EPA, 2000, Section 4.2.1).

Once aircraft have been deiced, the ADF infused wastewater must be removed from the deicing area to prevent discharge into the environment. In order to contain the wastewater, many airports maintain designated deicing areas or pads, which are equipped to channel and/or remove deicing wastewater to a drainage collection system and ultimately to a wastewater storage unit. Once stored, airports can transport the glycol contaminated wastewater offsite to a reclamation or treatment facility or perform on-site processing. If during the deicing process, large amounts of ice, snow or precipitation is present, the collected wastewater will contain substantial amounts of water, diluting the glycol content. Lower concentrations of glycol in wastewater translate to higher transportation costs per recovered-glycol since the majority of limited tank storage space contains water. Collection tanks must be emptied and their contents transported to treatment facilities regardless of the glycol concentration. Higher concentration of glycol is therefore more desirable as it requires less transport and less processing to achieve glycol concentrations acceptable to glycol secondary markets (EPA, 2000, Section 6.3; EPA, 2000, Section 6.2.3). Therefore, reducing the water to glycol ratio of wastewater will accomplish two things: reduction of transportation cost relative to the amount of glycol runoff and offsetting glycol containment, collection and treatment costs through recycling/recovery and resale in secondary use markets (EPA, 2000, Section 6.2.3; EPA, 2000, Section 6.4.2; EPA, 2000, Section 6.4.3).

There are two problems posed by spraying ADF to aircraft surfaces. The first is to find an effective and environmentally friendly means to both collect and treat/recover the glycol. And the second is to find a solution that will enable the high number of small to medium sized U.S. regional airports to implement and sustain an ADF collection and treatment/recovery program with limited budgets.

To help fully understand this design challenge, a study was performed at the Greater Binghamton Airport (BGM) located in Johnson City, New York, eight miles north of Binghamton. BGM is classified as a Commercial Service Primary Non-hub regional airport and averages 67 flight operations per day (Airport IQ 5010 /BGM, 2009). The Greater Binghamton Airport's deicing/anti-icing program relies primarily on the use of propylene glycol based Type I (heated 60^{o} – 82^{o}C) and, on some occasions, Type IV (unheated) ADF.

Figure 2: BGM deicing truck

Figure 3: BGM deicing pad.

At BGM, a two person deicing crew uses a deicing truck (Figure 2) to administer ADF to aircraft - a process which averages 15 minutes and has a approximate holdover time of 60 additional minutes, depending on weather conditions. Approximately 60-1,200 gallons of deicing agent may be used to deice an aircraft depending on aircraft size and extent of ice accumulation (EPA, Section 4.2.1). A separate deicing area, the North Ramp at BGM (Figure 3), can service two large aircraft simultaneously. The deicing area

Figure 4: BGM deicing pad drainage inlets.

provides a graded paved surface that channels glycol-mixed wastewater to valve-controlled grated drainage inlets. These drainage inlets (Figure 4) funnel the wastewater to a 15,000 gallon underground storage tank. The wastewater, typically containing 15% glycol concentration, is trucked to a local wastewater treatment facility for treatment and discharge. The cost of this contracted treatment service(an average $37,000/year) constitutes 4% of The Greater Binghamton Airport's expenses related to ground deicing. According to President Terry Watson of Pozzi-Tech Inc., an industrial byproducts handling company, trucking costs are approximately $1,000 per day. At BGM, deicing operations typically extend through a five-month period during the cold winter months. On average, wastewater is removed from the collection storage tank 1.5 times a week. This amounts to an average of $30,000 in transportation costs per deicing season. The majority of ground deicing operations costs comes from the purchase of ADF. At BGM, airlines spend approximately $900,000 per year on the purchase of ADF. That amounts to 94% of the total annual deicing operations budget at BGM.

For many small to mid-size airports, alternatives to chemical deicers for deicing operations, such as infrared and forced-air methods, may not be economically viable. For smaller airports, efforts to increase the effectiveness of storm water collection, containment and recovery provide the best option. With this in mind, the objective of this case study is to find a cost-effective solution to reduce environmental impact of current ground (chemical-based) deicing and anti-icing practices at small to mid-sized airports while maintaining FAA safety regulations and recommended guidelines.

Objective components are as follows:

1. Reduce current environmental impact of deicing effluent through enhanced on-site wastewater collection, containment and recovery methods.

2. Maintain 100% compliance with FAA safety regulations and recommended guidelines (AC 20-73A, 2006; 14 CFR Parts 91, 121, 135).

3. Maintain 100% compliance with Environmental Protection Agency (EPA) Clean Water Act (CWA) regulations (Federal Water Pollution Control Act 33 U.S.C, Section 1251).

4. Reduce current ground deicing/anti-icing wastewater transport and treatment cost.

Summary of Literature Review

Current Technologies

In 2000, the EPA published its Preliminary Data Summary: Airport Deicing Operations to provide background and guidance to environmental groups, policy-makers and the aviation industry in preparation for new effluent limitation guidelines (EPA, 2000). In the report, the EPA identified alternatives to chemical based aircraft deicing practices, such as infrared and forced-air, as well as efforts by airports to implement greater pollution prevention practices within existing ADF-based deicing operations.

Alternatives to ADF-based Ground Deicing Operations

Alternative methods such as infrared, forced-air and installation of heating elements to aircraft surfaces, while used with varying degrees of success, are not viable options for small to midsize airports. Infrared technology has been employed by larger airports such as JFK International in New York City, but the large capital costs, energy consumption and lack of anti-icing properties does not recommend itself to smaller airports. At JFK, aircraft is taxied into a large hanger fitted with infrared emitters. The infrared emitters cause ice molecules to rapidly vibrate, warm up, and melt. Once the ice and frozen contaminants are removed, Type IV glycol is applied to the aircraft for anti-icing. Since glycol is not required for the deicing process, glycol usage is reduced by as much as 90% (McCormick, 2008). Unfortunately this solution is not economically feasible for small to midsized airports due to the high costs associated with hanger construction and equipment.

Forced-air methods of deicing have not gained widespread usage in United States airports because it requires the use of glycol to effectively remove ice. A forced-air solution requires the use of trucks, similar to those used in a glycol solution, which are fitted with high-pressure nozzles that blow air onto the aircraft at high velocity. In the case of a hybrid solution, a dual nozzle is used to combine forced-air with a glycol solution. Airports are cautious in adopting a forced-air solution because of high start up costs, as well as the concern that the high velocity forced air might damage aircraft wings (EPA, 2000, Section 6.2.3).

A more aircraft-centric method of deicing/anti-icing is the fitting/retrofitting of heating elements directly into the structure of the aircraft. These elements can be built directly in the aircraft or used as an auxiliary device that can be attached or removed from an aircraft as needed. One example of this is the *thermal blanket* being used on MD-80 and DC-9 aircrafts. In these cases, heating elements are bonded physically to the wings of an aircraft. The elements then heat the aircraft wings in order to melt ice build-up (EPA, 2000, Section 6.2.13). Glycol based solutions may still be required to remove heavy ice, or to remove ice faster when the plane is waiting for take-off. Although this technique has shown success with the MD-80 and DC-9, there has not been widespread adoption of this technique yet because each aircraft model requires unique elements. Airports would also still require the use of alternative anti-icing/deicing methods for planes not fitted with these anti-icing/deicing techniques.

A similar emerging technology uses electro-static forces to remove ice from aircraft. Through the creation of static electric fields, the bond which permits ice to cling to aircraft is destroyed, and the ice simply falls away from the aircraft (EPA, 2000, Section 6.2.18). This is a very new technology, and is not readily available. It would also need to be built into the aircraft, or legacy aircrafts would have to be retrofitted at great cost. Airports would still require ―traditional” anti-icing/deicing techniques to handle aircraft not fitted with such a device.

ADF Containment, Recovery and Reuse

Interesting developments in containment, recovery and reuse of aircraft deicing chemicals show promise in significantly offsetting some of the financial and environmental costs of deicing operations. The widespread adoption of designated deicing areas at airports has dramatically improved containment and collection of deicing runoff. According to Philip Grayson, Pretreatment Administrator at the Endicott Waste Water Treatment Plant, when BGM installed its deicing pad and collection system, the treatment facility saw a significant increase in chemical oxygen demand (COD) levels due to higher glycol collection capability.

Containment and collection is only one part of the equation. The collected wastewater must be disposed of. In an ideal scenario, the glycol could be recovered and reused. Glycol recycling success stories abound in ground deicing literature; however, these stories reflect recycling efforts at large commercial airports. From the EPA <u>Preliminary Data Summary</u>, the majority of flight operations occur at small to medium sized airports which have the greatest demand for aircraft deicing (EPA, 2000, Section 4.1.3; EPA, 2000, Section 4.2). Finding a financially viable recycling model for smaller airports has proved difficult.

The major processes used in recovering and re-concentrating glycol are distillation, evaporation and reverse osmosis (EPA, 2000, Section 6.4). Distillation processes are the most expensive, requiring high energy consumption, but also yield the some of the highest distillate concentrations (EPA, 2000, section 6.4). Two major businesses dealing in glycol recycling equipment, Canada's Inland Technologies, Inc. and the American The Environmental Quality Company, offer systems based on mechanical vapor recompression (MVR). The MVR units typically use an electrical motor which drives a mechanical compressor. The compressor sustains evaporation through re-use of the energy contained within the compressed vapor. Through this re-use, the system minimizes its energy consumption (The Environmental Quality Co: MVR, 2009;

Inland Technologies Inc: Glycol Concentrator, 2007). The MVR unit manufactured by C.E. Rogers Company, outputs glycol concentrations from 25–80% (The Environmental Quality Co: MVR, 2009). Inland's Glycol Concentrator outputs glycol concentrations of 50-60% (Inland Technologies Inc: Glycol Concentrator, 2007).

Membrane filtration systems such as those produced by Dynatech Systems, Inc. and New Logic Research, Inc. use a combination of ultrafiltration and reverse osmosis to remove contaminants and water from the glycol concentrate. Glycol concentrations resulting from membrane filtration remain low at 10-20% (The Environmental Quality Co: Dynatech, 2009; New Logic, 2009).

NATCO's gas dehydration systems employ a glycol re-concentrator to remove water from glycol feeds. When the glycol solution becomes 23-50% saturated with water, it goes in a re-concentrator which filters the solution of impurities and heats it to 204^{o} C. The water is released as steam, while the 99% pure glycol is reused in the gas dehydration system. With a duty of 6,000,000 Btu /day, a re-concentrator can purify 2,160 gallons of glycol solution from 50% to 99% concentration. With a duty of 13,200,000 Btu/day, it can process 5,040 gallons of the same concentrations. These re-concentrator systems could be built and used by airports on-site to purify and reuse glycol, with the potential of saving costs (NATCO, 2007).

Viable Economic Solutions

Although many deicing technologies are available, for many smaller regional airports, finding cost effective solutions to meet stricter effluent guidelines may be difficult to achieve. The key will be in finding ways to minimize the energy consumption associated with current glycol reclamation and recycling systems.

Problem Solving Approach

Overview

Finding an environmentally responsible and cost effective model for improved containment and cleanup of deicing/anti-icing runoff proved a challenging task. In order to better understand the issues surrounding ground deicing, the team researched current and developing aircraft deicing and anti-icing practices, environmental effects of chemical-based deicers (especially propylene glycol) and FAA regulations and guidelines related to safety and deicing.

Figure 5: Team at BGM

Figure 6: Brainstorming with the experts

Figure 7: Deicing Area Drain

The Greater Binghamton Airport (BGM) provided a departure point from which to further examine the problem (Figure 5). At BGM, experts Chad Nixon, the Aviation Director of McFarland-Johnson, Inc. and Carl Beardsley, the Broome County Commissioner of Aviation explained deicing/anti-icing procedures at BGM. Together, they led a brainstorming session (Figure 6) to solicit ideas for improved pollution prevention in deicing operations. A tour of BGM's deicing pad and equipment (Figure 7) provided the team a reference point from which to consider possible solutions.

Suggested Solutions

Based on initial research and discussions with our industry partners, the team put together a list of the most promising solutions based on environmental benefit, safety, cost and ease of implementation (Figure 8).

Solution Options			
Solution	Description	Advantages	Disadvantages
Glycol on-site reclamation & recycling via high vacuum evaporation. (Wastech, 2009)	Depressurize and heat deicing by-product to remove water from glycol.	Glycol resale offset costs. Eliminate wastewater trucking costs. Low temperature distillation. Energy-efficient system. Zero discharge possible.	High startup costs.
Biological decomposition. (Liner & Hallahan, 2009)	Eliminate glycol in wastewater through biological break down. Engineered wetlands.	Ability to handle fluctuations in flow.	Environmental variables for successful biological breakdown unknown. Space requirements.
Thermal & mechanical ice protection systems. (NASA, Deicing and Anti-Icing Unite, 2002)	Ice protection system combining electro-thermal anti-icing with mechanical deicing technologies.	Planes deice themselves. Low energy costs. Performed in flight and on ground.	Requires alteration to the actual aircraft. Elimination of ice not guaranteed. Possible damage to engines from freed ice.
Infrared technology (McCormick, 2008)	Uses radiant heat to deice aircraft surface from within a hangar.	Eliminate glycol use. Consistent results.	High energy and implementation costs. No anti-icing capability. On average not as fast to deice as ADF.
Glycol on-site reclamation via membrane filtration. (Dynatech, 2009)	Multi-stage membrane filtration process takes 1-4% glycol influent and returns 20% glycol concentrations.	4 to 6 horsepower energy consumption per 1,000 gallons of influent.	Does not meet goal of 60% glycol concentrations after processing.
Rooftop concept.	Construct hangar over deicing areas to prevent further dilution of glycol/water mix in collection tanks.	Prevents further dilution of glycol.	High implementation costs.

Figure 8: Table of Possible Solutions

After a review of possible options, the team determined that the best solution would be one that could build upon existing airport infrastructures and deicing practices in order to minimize costs and disruption to airport operations, and take advantage of practices known to be effective. Additionally, the team looked for a model of pollution prevention that would engender an economic incentive to eliminate glycol from entering the environment. The key to a successful pollution prevention model is to make the recovery of glycol financially beneficial. The way to do this is through recycling. However, developing a viable glycol recycling system would depend largely on the system's energy-efficiency in removing water and impurities from the deicing runoff. With this in mind, the team decided to develop a system using a high vacuum evaporator.

FAA Requirements

Processed glycol produced by the high vacuum evaporator can be resold to recyclers or re-used at the airport upon receiving FAA certification. The evaporation and storage apparatus must be under the maximum height requirements of the airports (Part 77--Objects Affecting Navigable Airspace). In addition, the design must follow all EPA regulations. For example, it must prevent glycol from contaminating drinking water (Managing Aircraft and Airfield Deicing Operations to Prevent Contamination of Drinking Water).

Lessons Learned

The team learned that all options, no matter how far-reaching from existing designs, should be considered as possible solutions. Innovative and developing technologies as well as technologies not yet in existence must be included in the problem solving approach for both completeness and future viability. Another important factor is the solution's practicality. Any proposed solution must be worth the investment of implementing it. Reuse of existing infrastructures must be considered at all levels to reduce execution effort. In addition, the lifetime of the solution must justify the costs of its installation. The team learned of the significant impact that deicing/anti-icing has on the airline industry, including cost and time.

Problem Solving Approach - Summary and Conclusions

The team's problem solving approach favored practical solutions which could build from existing and well-tested current practices. Ideas judged as a poor return on investment or too disruptive to current operations were rejected. A central issue was the energy requirements for the reclamation system.

Safety and Risk Assessment

The “FAA Safety Management System Manual” (“SMS Manual,” 2008) and the “Introduction to Safety Management Systems (SMS) for Airport Operators” (“SMS for Airport Operators,” 2007) were important documents which helped the team analyze and assess the risks and hazards associated with the implementation of our solution. By following the five phases of Safety Risk Management (SRM) as described in these documents, we were able to identify the hazards, determine the risks, and propose safety measures as needed. Applying the five phases of SRM to each aspect of our solution enabled us to create a comprehensive safety and risk assessment.

The safety management concerns of using glycol are the effects it has on the environment and the health aspects pertaining to contact or ingestion. Glycol is an odorless, colorless liquid and is an excellent substance for deicing because it absorbs water (“ToxFAQs for Ethylene Glycol,” 2007). Health concerns regarding ingestion or contact to skin of glycol are not severe in low amounts; however, some side effects include headaches, nausea, weakness, rapid breathing, dizziness, and rapid heart rate (“Ethylene Glycol,” 2008). Ingestion of glycol in large amounts will cause major health risks such as damage to the nervous system, lungs, heart, and kidneys (“ToxFAQs for Ethylene Glycol,” 2007). Glycol may enter the environment by air or runoff/leaks but exposure is minimized for aircraft passengers and staff due to their containment. Staff members spraying the glycol solution on the aircraft are advised to take preventative measures to not inhale the solution and to seek medical care if side effects are experienced. In the air, glycol solution will break down in up to 10 days and low amounts are not a medical concern (“ToxFAQs for Ethylene Glycol,” 2007). Accidental damage or improper maintenance of storage tanks may cause glycol to leak or runoff. In water, glycol will break down in at most 7 days (“ToxFAQs for Ethylene Glycol,” 2007). Considerable measures should be taken to prevent glycol from entering the environment in large quantities. Regular inspections and maintenance of the storage tanks should be made to prevent events such as leaks, damage, or improper use of the tanks. Should one of these events occur it should be reported and addressed immediately. In the case of a large quantity of glycol entering the environment, the Agency for Toxic Substances and Disease Registry should be contacted at 1(800)222-1222 immediately (―Ethylene Glycol," 2008).

The first step in our proposed process is to pump the glycol solution from the underground runoff storage tank into a high vacuum evaporator where the deicing byproducts will be depressurized and heated. There are several hazards and risks associated with the implementation of this first step of the process. The glycol solution being pumped may contain sediment from storm water runoff, which could cause corrosion of the pipes connecting the underground runoff storage tank to the above-ground evaporator. Over a long enough time corrosion could result in a leak in the pipes and the release of the glycol solution into the environment. Secondly, the sediment may buildup inside of the pipes, resulting in a blockage within any of the joints of the pipes. Blockage could cause a pressurized buildup while pumping the glycol solution and result in burst pipes, again leading to the release of the glycol solution. To address these safety concerns the use of pipes which are resistant to corrosion from the sediment and the use of wide enough joints and smooth enough pipes to avoid internal sedimentary buildup are recommended.

The sediment will need to be filtered out of the glycol solution before it reaches the above-ground evaporator because too much sediment in the solution can compromise the integrity of the high power evaporator. The risk of using these filters is normal wear and tear, so they will need to be periodically inspected and replaced when necessary. Removed filters will contain sediment saturated with the glycol solution, thus the filters should be disposed of in an appropriate, environmentally friendly, manner.

Once the glycol solution reaches the above-ground high vacuum evaporator, it will then need to undergo a process involving depressurization. The hazards associated with this step of the process depend on the level of depressurization. If the pressure is too low, relative to the heat applied to the tank, then some of the glycol may be boiled and released into the atmosphere. If the pressure is too high, relative to the heat applied to the tank, then not enough water will be boiled and the resulting glycol solution will be overly diluted with water and will not contain the target ratio of water to glycol. To protect the surrounding environment and all those within it, the level of depressurization must be closely monitored to ensure that no glycol will be boiled and released into the atmosphere and to verify that the quality of the resulting glycol solution contains the target ratio of water to glycol. To address these issues, pressurization monitoring equipment should be installed and tanks should be periodically checked for leaks.

The above-ground high vacuum evaporator requires a heat source in order to boil water out of the glycol solution. There are several hazards associated with this step in the process. The equipment must be able to withstand the amount of heat that will be applied to it. A temperature control system should be installed to monitor the amount of heat being applied in order to ensure the equipment is not heated beyond its heat tolerance level. Normal wear and tear of the evaporator is to be expected. Therefore regular maintenance and inspection of the evaporator is required.

The type of heating system is also an important concern. If a gas heating system is used, the system must be monitored and inspected for gas leaks. A gas leak could result in a catastrophic accident if the above ground tanks are heated inside of an enclosed structure. Regular inspection and maintenance of gas tanks and lines are a requirement.

To ensure the safety of airport staff, only authorized personnel with proper training should be allowed near the above-ground evaporator. The tanks should be kept within an enclosed structure or area with appropriate signs indicating the presence of toxic chemicals and heated equipment. Maintenance staff should be provided with masks to avoid breathing in any toxins from the boiled glycol solution. If side effects of glycol are felt, staff should be instructed to seek immediate medical care.

The actual boiling of the glycol solution creates several hazards. Similar to the problems relating to depressurization, if the glycol solution is not heated appropriately, relative to the level of depressurization, then one of two outcomes will occur. If the temperature is too high, relative to the depressurization level, then some of the glycol may be boiled and released into the atmosphere. If the temperature is too low, relative to the depressurization level, then not enough water will be boiled and the resulting glycol solution will be overly diluted with water and will not contain the target ratio of water to glycol. To deal with these hazards temperature monitoring equipment should be installed.

When the water is boiled from the glycol solution, the water vapor will be released into the atmosphere. There are several hazards associated with this final step of the process. Firstly, to ensure that no one inhales the water vapor, which may also contain additives from the original glycol solution, it should be released a safe distance away from airport staff and patrons. Secondly, it should be released a safe distance from the airport runways because the water vapor could settle onto the runways and freeze in cold temperatures, thus creating additional runway hazards. After the glycol solution is boiled into its new concentration, it will need to be cooled to appropriate levels. To ensure the solution is cooled to a level where it can be transported out of the tanks, appropriate temperature monitoring equipment should be installed.

After the glycol solution has been cooled, it will need to be recertified by the FAA before reuse, or it can be resold to industrial companies without recertification. If the glycol solution is moved offsite, appropriate trucks should be used for transportation. The trucks should be marked with signs indicating hazardous materials are onboard.

Technical Aspects Addressed

Description of Overall Process

Glycol containment and collection is the first component of this proposal's pollution prevention objectives. Most aircraft deicing/anti-icing operations occur in a dedicated area, referred as a deicing pad. This keeps the propylene glycol and associated runoff contained (Figure 9). The deicing pad consists of a smooth surface with slight grading to channel runoff into grates along the perimeter of the area. BGM possesses a deicing pad lined with grates which direct runoff flow to a 15,000 gallon underground wastewater storage tank (BGM Glycol Collection Details, 1994).

The second component of this proposal's pollution prevention plan is glycol reclamation and recycling. By making the collection of recovered glycol a value-added process, airports and airlines can potentially benefit by their efforts to comply with new effluent limitation guidelines. The glycol reclamation system proposed for BGM consists of a motor driven reciprocating pump, filtration system, an industrial high vacuum evaporator and two additional storage tanks (Figure 9).

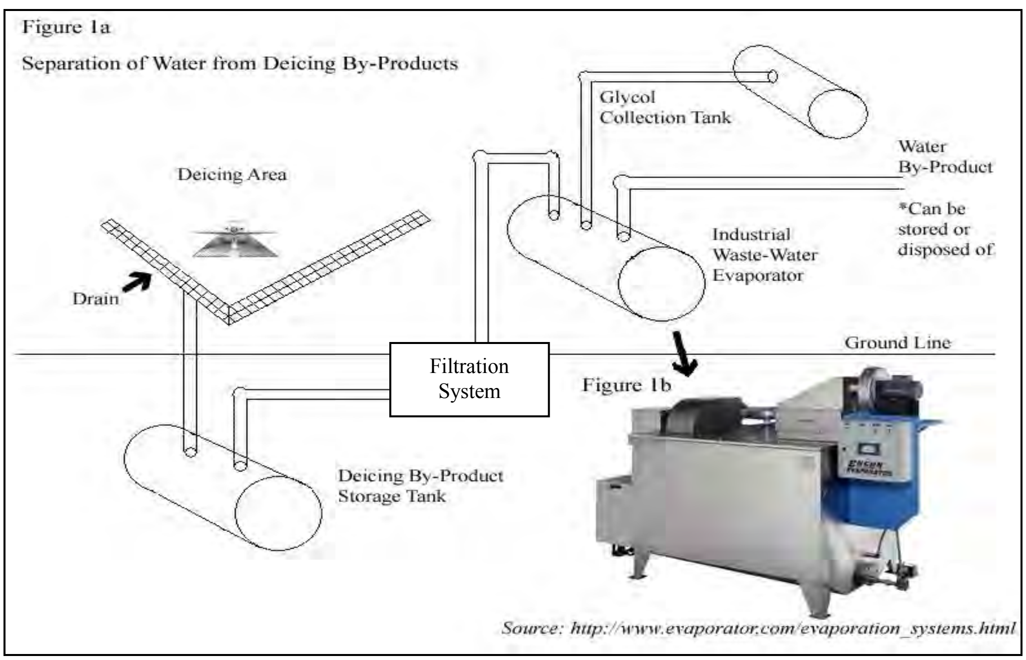

Fig. 9: Glycol reclamation system.

The wastewater from the underground storage tank is pumped into a filtration system which removes dissolved solids and other impurities from the system. Once filtered, the feed enters the high vacuum evaporator chamber which has a capacity of up to 400 gallons. The wastewater feed of 85% water and 15% glycol is a ratio optimal for processing by an industrial evaporator. The high vacuum evaporator heats the feed at temperatures greater than the boiling point for water but less than that to boil propylene glycol. The high vacuum chamber enables the system to vaporize water at temperatures lower than that at atmospheric pressure. Lower temperatures translate to reduced energy utilization and increased efficiency. The final propylene glycol/water solution will contain at approximately 60% propylene glycol. Excess water may be stored in a separate storage tank for later use or may be released as steam. The propylene glycol/water solution remaining in the tank is then released into a separate glycol collection tank for storage. The output from the high vacuum evaporator may be reprocessed to boil off any additional impurities and further increase the concentration of propylene glycol.

Description of Propylene Glycol Compound

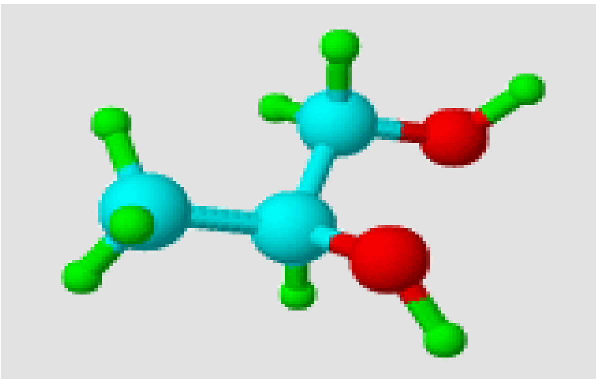

Fig. 10: Structural Image of Propylene Glycol
http://chemindustry.ru/1,2- Propanediol.php

Propylene glycol, commonly known as *1,2-propanediol*, is a colorless, odorless liquid at room temperature (Figure 10). It is a highly hygroscopic liquid and is fully miscible with water. The boiling point of Propylene glycol is approximately 188ºC and the vapor pressure at 25ºC is less than 0.1mm Hg (Merck Index, 11th Edition, 1989).

Operation of a Reciprocating Pump

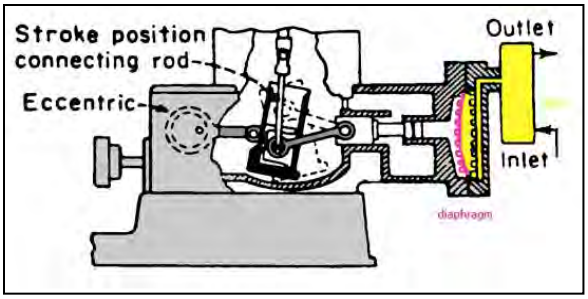

Fig. 11 Diaphragm-Type Reciprocating Pump
Source: http://www.rpi.edu/dept/chem-eng/Biotech-Environ/PUMPS/reciprocating.html

A spinning piston powers the reciprocating pump (Figure 11). The piston pumps an arm, with a diaphragm at the end, in and out of a liquid collection chamber. There are two tubes connected to the liquid collection chamber, an inlet tube and an outlet tube. As the pump arm recedes, the diaphragm recedes. The inlet tube remains open and the outlet tube is sealed shut. This allows liquid to fill up the liquid collection chamber. As the pump spins around, the arm begins to push the diaphragm into the liquid collection chamber causing a buildup of pressure. The outlet tube then opens and the inlet tube closes. As the diaphragm continues to close on the collection chamber, it pushes the liquid in the chamber through the outlet tube.

Operation of a High Vacuum Industrial Evaporator

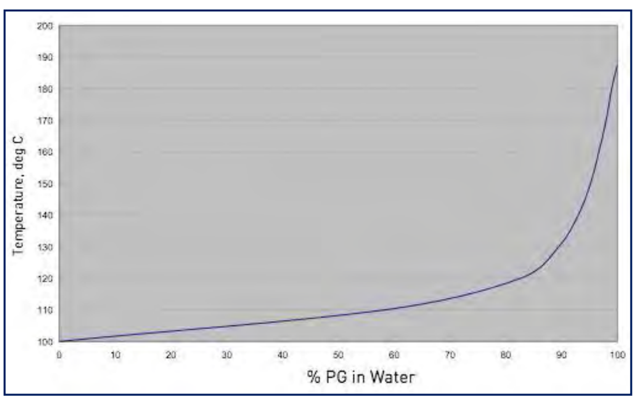

Fig. 12: Boiling Point of Aqueous Propylene Glycol Solutions
Source:*http://www.lyondellbasell.com/Products/ByCategory/basicchemicals/IntermediateChemicalsAndGlycols/PropyleneGlycolIndustrialGrade/TechnicalInformation/*

The process of boiling is defined as a liquid undergoing a change of phase into a gas. The boiling point is when the liquid's vapor pressure is equal to the pressure surrounding the liquid. In the case of pure water, this is 100ºC. With an addition of 15% propylene glycol, the boiling point of a propylene glycol/water solution increases to approximately 105ºC (Figure 12) (Curme and Johnston, 1952). The gaseous pressure within a volume of space can be substantially lower than the atmospheric pressure surrounding the space. As the pressure decreases so does temperature, lowering the boiling point of the propylene glycol/water solution. The lowered boiling point of the propylene glycol/water solution reduces the amount of heat energy required to separate the propylene glycol from the water. The approximate boiling point of the propylene glycol/water solution can be determined using the Clausius-Clapeyron equation (Clapeyron and Clausius-Clapeyron Equations, 2001). The atmospheric pressure is 101.325 kPa and the obtained boiling point of a propylene glycol/water solution containing 15% propylene glycol at atmospheric pressure is approximately 105ºC. The heat of vaporization of water is 41 kJ/ml and the heat of vaporization of propylene glycol is about 60 kJ/ml. The propylene glycol/water solution is predominantly water so by using a ratio the heat of vaporization is found to be 44 kJ/ml. After solving this equation using a reduced pressure of 50 kPa within the industrial evaporator, the approximate boiling point of the propylene glycol/water solution is 87ºC. Far less energy is needed to heat the propylene glycol/water solution to this new temperature. The evaporated water vapor from the propylene glycol/water solution will escape as steam through the release valve. As the ratio of propylene glycol to water increases, an exponential increase in temperature is required to continue evaporation. The boiling point of the propylene glycol/water solution containing 60% propylene glycol is calculated to be 91ºC by slightly raising the heat of vaporization and plugging it in to the Clausius-Clapeyron equation. A 60% propylene glycol concentration meets industry standards for resale in secondary markets.

Description of Interactions with Airport Operators and Industry Experts

The project team worked with several airport operators and industry experts. Most interactions were with the Greater Binghamton Airport (BGM) and McFarland Johnson Incorporated. The consultants from these companies were Carl Beardsley, Commissioner of Aviation at BGM, and Chad Nixon, Aviation Director at McFarland Johnson Inc. In conjunction with our primary consultants, the project team contacted several outside resources throughout North America.

On February 6, 2009 the project team participated in a brainstorming session at the Greater Binghamton Airport. Carl Beardsley and Chad Nixon discussed the environmental design challenge and provided an overview of BGM's ground deicing operations (Figure 13). We reviewed the characteristics and uses of both Type I and Type IV glycol. The project team toured BGM's deicing facilities, noting the drainage system and “Mount Glycol,” a 1000 ft. x 25 ft. pile of snow containing concentrations of spent ADF (Figure 14). The team then discussed possible solutions to the design challenge. The session concluded with identifying the best candidate for a solution: a glycol reclamation/recycling system using evaporation technology. To conserve energy, a depressurizing chamber in which to boil the propylene glycol/water solution at significantly lower temperatures was suggested. After processing, the re-concentrated glycol could be resold or reused (pending FAA certification).

Figure 13: Students meet with aviation industry professionals at Greater Binghamton Airport.

On February 16, 2009 the project team contacted Terry Watson, President of Pozzi-Tech Inc, an industrial byproducts consulting firm regarding trucking costs to transfer deicing byproducts from the Greater Binghamton Airport to the Endicott Waste Water Treatment facility. Watson estimated the trucking costs to be $1000 per day.

Figure 14: Mount Glycol

Individuals from the project team also contacted Philip Grayson from Endicott Waste Water Treatment Plant on March 5, 2009 and April 9, 2009, to discuss the plant's treatment of wastewater containing propylene glycol. According to Grayson, the treatment plant places the propylene glycol into an anaerobic digester to break it down. The byproducts of glycol after being broken down are methane gas and water. The Endicott Waste Water Treatment Plant recycles the propylene glycol byproducts of methane gas and water and uses the methane gas, in part, to fuel to digester.

Members of the project team contacted Chad Nixon and Carl Beardsley via telephone conference on March 5, 2009. Nixon and Beardsley fielded questions relating to the types of propylene glycol typically used in the aviation industry, and provided specifications on the 15,000-gallon underground deicing byproduct storage tank. BGM uses a diluted Type I glycol solution, which is 55% propylene glycol and 45 % water, to deice the planes and a Type IV glycol solution, which is 100% propylene glycol, to prevent ice from forming on aircraft. When full, the underground wastewater storage tank has a ratio of approximately 15% propylene glycol to 85% water. The underground wastewater storage tank is made out of steel, surrounded by a one foot stonewall.

On March 6, 2009, Carl Beardsley and Chad Nixon met at Binghamton University with the project team to review the design solution (Figure 15). Nixon outlined the major components of the system including: 15,000 wastewater collection tank, pump, filtration system, depressurized evaporation chamber and tanks to store process outputs. In addition, the ability to recycle the propylene glycol/water solution was discussed during this meeting. Industry standards identified during the meeting gave a target percentage of the propylene glycol/water solution of least 60% propylene glycol. A solution of this target percentage can be sold to a third-party recycler. The buyer could potentially reuse the propylene glycol and the airport would not only save money, but also reduce the impact footprint on the environment through reuse of materials.

Figure 15: Project Team meets with Aviation Industry Professionals at Binghamton University

Members of the project team contacted Don Larabie of Inland Technologies Inc., on March 7, 2009 to discuss the feasibility of an approach based on evaporation. Inland Technologies offers filtration and chemical recovery systems that filter and separate chemicals from water. Larabie indicated the proposed approach would require boiling the propylene glycol/water solution at high temperatures since propylene glycol absorbs heat. He estimated that a propylene glycol/water solution containing 20% propylene glycol would need to be boiled at 113°C to remove the water from it. Furthermore, he said that boiling a 5,000 gallon tank would require a lot of heat and time due to the tank’s size. In conclusion, he said that implementing an evaporation system using heat only would be too costly to the airport and that the cost of trucking off the propylene glycol would be about one-third the cost. From this discussion, the importance of an energy-efficient system emerged. Depressurization would reduce the heat required for evaporation, and would reduce the energy consumption of the system.

Individuals from the project team spoke with Roger Heckman of LyondellBasell Industries on March 10, 2009. LyondellBasell is a major provider of a formulated deicing product to many major airports throughout the United States. Roger Heckman described the boiling point graph listed on their website (Figure 12). The graph correlates the percentage of propylene glycol in water to the boiling point of the substance. Roger Heckman also informed the team that the product supplied to airports is a mixture of propylene glycol, water and a small amount of additives.

On March 24, 2009 members of the project team went to McFarland Johnson Incorporated to further discuss technical aspects of the project and met with Chad Nixon and Don Harris, Senior Project Manager, Electrical Engineer.

On April 13, 2009 the project team contacted Jason Rouba to discuss costs of operating and maintaining an industrial water evaporator. He recommended performing a quality control of the system weekly for a few hours. He also said that using the industrial water evaporator would require an energy amount of 1.74 million British Thermal Units (BTU) per hour.

Members of the team participated in individual discussions with the above named airport operators and industry professionals on a regular basis throughout the development of the FAA proposal.

Contact With Airport Operators and Industry Professionals		
Name	**Company**	**Title**
Carl Beardsley	Greater Binghamton Airport	Commissioner of Aviation
Chad Nixon	McFarland Johnson Inc.	Aviation Director
Don Harris	McFarland Johnson Inc.	Senior Project Manager

Don Larabie	Inland Technologies Inc.	Manager of Ottawa and Trenton Facilities
Philip Grayson	Endicott Waste Water Treatment Plant	Pretreatment Administrator
Roger Heckman	LyondellBasell Industries	Manager, Chemical Technical Services, Americas
Terry Watson	Pozzi-Tech Inc	President
Jason Rouba	ENCON Evaporators	Sales Engineer

Projected Impacts

The design proposed in this document addresses the FAA Design Competition 2008 Airport Environmental Interactions goal of greater environmental stewardship through improved containment and clean-up of aircraft anti-icing and deicing products. The design solution presented here, targets the approximately 200 small-to-medium U.S. commercial airports which have significant ground deicing operations and whose deicing practices center on the use of glycol based Aircraft Deicing Fluid (EPA, 2000, Section 14.1.1.2, Table 14-4). The principles underlying this solution place a priority on economic viability, ease of implementation and maintenance, and maintaining airport and passenger safety. With the introduction of new EPA effluent limitation guidelines (ELGs) at the end of 2009, pressure on airports to comply with new environmental regulations seeking to minimize discharge of deicing runoff into the environment will prompt many to seek affordable and effective means to meet these new requirements (Luther, 2007). Newer technologies (infrared, forced-air) which seek to eliminate chemical-based ground deicing of aircraft were not considered since these solutions proved more disruptive to current operations, required greater capital to implement, and overall could not achieve the effectiveness (under equivalent time and cost constraints) that a more incremental approach using existing chemical deicers/anti-icers would provide (EPA, 2000; Section 4.2.1.6). The proposed system builds upon current best practices for storm water containment and collection (pollution prevention); seeks to minimize and offset costs through energy-efficient on-site processing of wastewater to recover glycol for use in secondary markets (recycling). The key advantages of the widespread adoption of an affordable and improved containment, collection, treatment and recovery of glycol are:

1. Reduction in total glycol effluent discharged to environment.
2. Maintains current airport and passenger safety levels using well-established ground deicing/anti-icing practices.
3. Costs are shifted away from non-value-added services (wastewater transport, off-site treatment fees) and applied to value-added processes (glycol recovery/recycling).
4. Cost benefit to airports and airlines through minimizing capital expenditures, operational and maintenance costs.
5. Cost benefit to airports and airlines through resale of recovered/recycled glycol.
6. Reduced disruption to current ground deicing operations and flight schedules through development within existing infrastructures and practices.
7. Decreases load burden to local POWTs.

Financial Analysis

The environmental, safety and economic benefits to be realized through the adoption of airport on-site recovery and recycling of glycol for large airports is fairly well-understood but its benefits for small to medium sized airports has yet to be demonstrated. According to Broome County Commissioner of Aviation, Carl Beardsley, aircraft ground deicing costs at the Greater Binghamton Airport during 2008 was estimated at $962,000. Of this total cost, 97% came from purchase of ADF (94%), wastewater transport (3%) and wastewater treatment (< 1%). For the proposed glycol reclamation system to be successful at BGM, the cost benefit gained through the reclamation of glycol must reduce costs associated with current deicing operations and recover, over time, the expenses related to the reclamation systems design and implementation. After examining BGM's current collection capabilities, a scenario for the best possible economic outcome was developed.

For the 2008 deicing season, BGM purchased and used roughly 75,000 gallons of concentrate ADF at approximately $12/gallon. Their 15,000 gallon storage tank, containing approximately 15% glycol concentrations was emptied 30 times during 2008. This means that 67,500 gallons of glycol was collected and transported to the Endicott Waste Water Treatment Plant. This collected glycol represents a 90% collection success rate (see Figure 16).

Estimated Glycol Use and Collection at BGM for 2008 (All numbers are estimates)		
Glycol Use/Collection	**Gallons**	**Calculations**
ADF Concentrate Purchased & Used (Glycol)	75,000	$900,000 ADF purchased for 2008 at $12 per gallon $900,000/$12 = 75,000 gallons
Glycol Collected	67,500	Wastewater collected in tank contains 15% glycol Glycol removed from storage tank at removal time 15,000 x 0.15 = 2,250 gallons Glycol transported to treatment facility during 2008 30 x 2,250 = 67,500 gallons

Fig. 16: Estimated Glycol Use and Collection at BGM for 2008

Cost/Benefit Analysis

The greatest benefit to on-site glycol reclamation would be to achieve maximum economic incentive to collect and recycle glycol ADF. If on-site glycol recycling systems could produce FAA certified ADF within current operating budgets, there would be greater incentive to capture deicing runoff, thus preventing pollution, and the cost to deice would dramatically decrease. At present, the primary obstacles to realizing such a plan seem to lie in the high capital costs and in the energy-efficiency of such systems. An alternate solution might entail an on-site reclamation system producing an intermediate grade of glycol solution which in turn could be sold to a recycling facility for further processing. The scenarios below examine possible cost/benefit outcomes were BGM to implement an on-site recycling system.

If BGM sold its 67,500 gallons of recovered glycol to a recycler for $2/gallon, this could offset annual deicing operations costs by $135,000 or by 15%. In a best case scenario, if a recycler could use the glycol output produced by the BGM's reclamation system to produce a glycol based ADF meeting FAA certification, a deeply discounted FAA certified recycled ADF could then be sold back to the airlines providing a substantial cost savings. For instance, in an ideal situation, if the recycled ADF were sold back to airlines at $7/gallon then annual costs for ADF concentrate would drop from $900,000 to $375,000 representing a 58% savings in total deicing operations at BGM. In both scenarios, capital costs for the new reclamation system and annual operational/maintenance costs would need to be less than or equal to the cost savings realized through resale of the reclaimed glycol (Meeting with Industry Advisors, 2009).

Suppose the capital costs for the design and installation of the glycol reclamation system consisting of a pump, filtration system, high vacuum evaporator and two additional tanks to store recovered glycol concentrate and process distillate is $2,000,000. Amortized over a 20 year period would result in a $100,000 deduction from revenues gained through the resale of recovered glycol or from the savings gained through the purchase of discounted ADF. In our first scenario, whereby BGM's recovered glycol is sold to a recycler for $2/gallon, this would mean $35,000 would need to cover annual operational/maintenance costs. In our second scenario, this amount increases dramatically to $275,000 (Meeting with Industry Advisors, 2009).

The primary financial risks engendered by any system to reclaim glycol are in the yearly operational/maintenance costs. If we assume the reclamation system is robust requiring minimal monitoring and maintenance, the energy consumption rates and costs become the biggest risk factor. If gasoline prices soar, costs to transport the airport's reclaimed glycol to the recycler could easily outweigh any economic gains. Both risks rate high in terms of likelihood and impact. For this reason, steps to minimize these impacts should be closely examined to ensure the financial success of the on-site glycol reclamation system.

Funding

Funding for large capital projects presents one of the biggest challenges for small to medium sized airports. Possible sources for funding are FAA grants, the airlines, and the revenue produced from the sale of the recycled anti-icing and deicing products. Airlines, as key stakeholders, may be willing to provide some financial support to if it leads to lower prices for the anti-icing and deicing products in the future (Meeting with Industry Advisors, 2009).

Summary and Conclusion

The environmental, safety and economic benefits to be realized through the adoption of airport on-site recovery and recycling of glycol for large airports is fairly well-understood but its benefits for small to medium sized airports has yet to be demonstrated. With new effluent limitation guidelines due later this year, viable economic models for on-site glycol reclamation for small to medium sized airports could ease the financial burden of compliance. Engineering affordable, smaller scale glycol reclamation and recycling systems which maximize energy-efficiency could make glycol pollution a relic of the past.

Appendix A: Contact Information

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Appendix B: Description of the University

Binghamton University was founded in 1946 as the Triple Cities College, intended to serve the needs of local veterans. It was renamed Harpur College, after Robert Harpur, four years later when it was incorporated into the State University of New York. By 1961 the college had moved from Endicott across the Susquehanna River to Vestal, and soon became one of the four doctorate-granting university centers in the State University of New York System, and was officially renamed the State University of New York at Binghamton.

Informally named Binghamton University in 1992, Binghamton is "the premier public university of the northeast" according to The Fiske Guide to Colleges. Its four year graduation rate is second highest in the country among public universities, with 25% of undergraduates going on to receive graduate degrees in Binghamton. Students at Binghamton come from 50 states and 100 countries, and 84% of them were in the top 25% of their graduation class.

Binghamton University is made up of six separate schools. the Decker School of Nursing, the School of Education, The Harpur College of Arts and Sciences has been the backbone of the University since its foundation, and maintains high academic standards and a faculty that includes a Pulitzer Prize winner and recipients of many scholarly recognitions. The Thomas J. Watson School of Engineering and Applied Science was founded in 1983, and is the 7th largest engineering school in New York State, with steadily increasing enrollment and programs in bioengineering, computer engineer, electrical engineering, and computer science. The School of Management is rated 15th best public business school by BusinessWeek, and has a number of MBA and PhD programs. The College of Community and Public affairs offers an undergraduate program in human development and graduate programs in human development, public administration, social work and student affairs. The Decker School of Nursing has offered academic preparation for professional nursing since its establishment in 1969. Lastly, the School of Education offers a number of graduate programs designed to prepare caring, competent and qualified professional educators.

Appendix C: Description of Non-University Partners

Chad Nixon currently serves as the Aviation Director at McFarland Johnson, a multi-disciplined engineering firm that provides financial and aviation planning, environmental, engineering, and construction inspection services to airports throughout the U.S. He also serves as a Technical Lead on statewide and airport specific aviation planning projects. He has a highly diverse aviation background that began with his service in the U.S. Navy as an air traffic controller, then airport operations, airport management and aviation planning. As a fully qualified radar and tower air traffic control supervisor, he served for several years as the Chairman of the Air Traffic Procedures Evaluation Board tasked with coordinating air traffic control functions in the Gulf Coast Region of Florida. He has performed FAA and DOD airspace liaison duties in numerous countries including Malaysia, Thailand and Oman. He has also served as an interim airport manager for a regional commercial service airport. His current responsibilities include aviation forecasting, economic analysis, airport negotiations, aviation planning, airspace analysis, project management and strategic development of MJ's aviation practice.

Chad received his MBA with a specialization in Aviation from Embry-Riddle Aeronautical University. He serves on numerous national and regional aviation committees, as well as serving on the New York Aviation Management Association Board of Directors. In his free time he enjoys riding motorcycles, skiing, hiking, and camping with his family.

McFarland-Johnson, Inc., established in 1946, is a 100% employee-owned, multi-disciplined engineering firm. Since its inception, the headquarters office has remained in Binghamton, NY, the office which will provide the services required under this term agreement. Their permanent staff includes over 120 technical and administrative personnel of all disciplines, 67 of which work from the Binghamton office. The headquarters office is located at 49 Court Street, Metrocenter, Binghamton, NY 13902. McFarland-Johnson also maintains five other offices located throughout the northeastern United States: Saratoga Springs, NY; Hallstead, PA; Concord, NH; South Burlington, VT; and New London, CT. McFarland-Johnson maintains fully-staffed engineering and planning/environmental departments comprised of civil, structural, mechanical and electrical engineers, planners, environmental analysts, hydrologists, technicians and computer/CADD specialists, allowing us to provide any service on a project without having to outsource it. In addition, a staff of on-site resident engineers carefully monitors contractor activities to ensure smooth progression and conformance to the Airport Sponsors' and FAA specifications, without costly delays. McFarland-Johnson engineers also prepare cost estimates, process payment requests, and complete other necessary paperwork to alleviate this burden from the Airport Sponsor.

Since 2005 Carl R. Beardsley, Jr. has been the Commissioner of Aviation at the Greater Binghamton Airport. Since his promotion to this position, Carl has implemented nearly $30 m in capital improvements at the Greater Binghamton Airport including a full-scale primary runway rehabilitation. He has also lead business development activities that lead to securing a major Fortune 500 company to lease a large hangar at the airport. Before becoming Commissioner of Aviation, Carl held the position of Deputy Commissioner of Aviation for nearly eight years.

Since its inception in the early 1950's the Greater Binghamton Airport has grown to become the air transportation center for the region. From the Binghamton Airport, three airlines offer service to three of the largest and most active hubs in the United States. Northwest Airlink, United Express and US Airways combine to offer 30 flight per day to hubs in Detroit, Washington DC and Philadelphia, respectively. In addition to airline service, BGM offers travelers access to charter aircraft, airplane maintenance, United States Customs, a National Weather Service Office and a national fixed base Operation.

Carl’s educational background includes holding a Bachelor’s Degree in Aviation Management and Flight Operations. He is also a licensed Private Pilot. He has a wife named Tracy and two young boys named Nathan and Nicholas.

Appendix E: Evaluation of the Educational Experience

The Student Team

1. Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?

The FAA design competition has provided the team with a rewarding, purposeful, and valuable experience. Most importantly, participants were given the opportunity to interact with and confront industry professionals and experts on solving a modern, real word dilemma. On several occasions, students held group discussions with both Carl Beardsley, the Commissioner of Aviation at the Greater Binghamton Airport, and Chad Nixon, the Aviation Director at McFarland Johnson, Inc, including the experience of first-hand observations at the Greater Binghamton Airport and instruction on the industry deicing and deicing fluid collection procedures in practice today. In addition, team members consulted with professionals at Inland Technologies Inc., the Endicott Waste Water Treatment Plant, and LyondellBasell Industries.

This interaction with industry experts is invaluable professional experience that is sure to benefit the students' careers and professional life. In addition, the application to a present-day, unsolved obstacle has given them exposure to a set of challenging circumstances that will no longer be alien to them in the future. Participants now have a confidence with such interplay, which they will carry with them throughout their professions.

2. What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?

Throughout the project, team members were challenged with various—sometimes unexpected—difficulties and trials, and by persistence or, at times, improvisation were able to overcome them. These challenges ranged from technical dilemmas of the project itself, to team member dependence and communication issues.

Considering the magnitude of the task at hand, perhaps the most obvious and significant challenge the students faced consisted of tackling such a problem when very few—if any—of the team members possessed knowledge or experience in the aviation industry. As a result, students made the necessary adaptations through personal research, interfacing with industry professionals more versed in the areas, and—for some—by applying the knowledge of the sciences they were already familiar with to the problem space.

One of the main technical constraints confronted consisted of finding a solution to the problem while considering the limited resources available to the typical airport. Many established solutions, such as using infrared heat to deice, are simply not feasible for the average sized airport due to costs. With the assistance of local aviation professionals, and after much brainstorming and elimination of infeasible possibilities, an environmentally- and cost-effective solution was devised, with The Greater Binghamton Airport serving as the team design model.

An additional challenge was the lack of centralized and formal communication protocols, which resulted in disorganization and email-overload. As a consequence, students came to realize the value of formalized, communication frameworks, and are now aware that communication issues must be handled in a more serious manner. Moreover, businesses often have serious communication issues as well, so the students will enter the workplace better prepared to understand the effects of poor communication.

In addition, coordination of various group responsibilities, many of which were dependent on other members' progress, sometimes resulted in delays, and at other times there was a failure of communication regarding those dependences. Likewise, key members were occasionally absent in spite of their crucial role in participating in the task at hand. In these situations, members were challenged with the task of improvising in order to compensate for these difficulties, or—when confronted with the former case—communicating their discontent to the offending members.

3. **Describe the process you or your team used for developing your hypothesis.**

The team's development of a hypothesis took a very direct approach. Initially, each member of the team was assigned to conduct research on such topics as: the environmental effects of glycol, airplane deicing and anti-icing procedures, as well as the different forms of chemicals in use for deicing and their differences. With this research, all members were able to come prepared with a wealth of knowledge—and perhaps personally formulated, potential solutions—for a meeting with Chad Nixon, Aviation Director of McFarland Johnson, Inc, and Carl Beardsley, Commissioner of Aviation at the Greater Binghamton Airport.

The meeting, which took place on site at the Greater Binghamton Airport consisted of a tour of the deicing area of the airport, a demonstration of the deicing equipment, and a brainstorming session where a compilation of potential solutions were collected from the discussion. Some of the proposed solutions consisted of radiant infrared heating, using an in-development NASA technique where exterior parts of the aircraft are electrified, utilizing the excess glycol-water waste as plant food for certain types of organisms, treating the glycol on site, and investigating the boiling point of the glycol-water mixture that is collected from de-iced aircraft, with the intention of separating the mixture and subsequently reusing and remarketing the glycol. Ultimately, the last solution—of boiling the glycol—was chosen due to a consensus of the students and an elimination of the infeasible ideas given certain limitations. Further research was then conducted on the behalf of the students with the corresponding responsibilities, and a secondary meeting with our competition partners allowed refinement of the hypothesis.

4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?

Participation by the industry professionals was crucial to the success of the project, and team members were often in close contact with a variety of professionals of differing areas. As mentioned before, Carl Beardsley, Commissioner of Aviation at the Greater Binghamton Airport, and Chad Nixon, Aviation Director of McFarland Johnson, Incorporated were very enthusiastic about assisting the team, and personally met with the team on numerous occasions for discussion and collaboration. They deserve a special commendation for their extensive participation in the FAA Design Competition, since their advising and contribution to the project—as a source of information, direction and enthusiasm—were invaluable.

Other industry professionals contacted by students include: Don Larabie of Inland Technologies, a firm dedicated to the development of environmentally responsible solvents, who provided assistance in determining the soundness of our solution; Philip Grayson of the Endicott Waste Water Treatment Plant, who aided the team in resolving any hazards our solution may incur on the environment; and Roger Heckman of LyondellBasell Industries, who presented the team with information on the boiling point of a glycol-water solution at different consistencies.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

The skills and knowledge the team acquired over the duration of the project encompass technical, professional, and experience-based skills. Perhaps most importantly, the professional communication skills procured should afford the class of aspiring engineers and scientists an upper hand in such an industry where communication skills are often lacking. Team members frequently interfaced with industry experts through various mediums of communication—both formal and informal, including: direct, face-to-face meetings; telephone conversations; and e-mail correspondence. Coupled with the necessary teamwork and inter-group coordination compulsory to the project, teammates have greatly enhanced their communication and cooperative skills. Similarly, the research experience, the compilation of formal oral-presentations and papers, and the learned professional communication and ethics pragmatisms grasped from in class discussions and assigned readings provided both an academic skill set in the area of professional communication, and an invaluable know-how with respect to the expression of ideas in a scientific or engineering profession..

In addition, the team has familiarized itself with the modern dilemma of environmentally sound methods to aircraft deicing and anti-icing. Students are now well versed in the justification, the modern procedures, the environmental effects, and the containment or avoidance methods of deicing and anti-icing processes. Students also gained experience performing cost analyses, challenging themselves with the general engineering impositions and investigations, and resolving the environmental considerations—feats sure to benefit problem solving skills and future endeavors.

The Faculty

1. **Describe the value of the educational experience for your student(s) participating in this Competition submission.**

Real world experience can never be gained by sitting in a classroom. Most of my students participating in this competition have never even been on a plane; most have never consulted with experienced professionals, nor ever had to solve an engineering problem that did not come out of a textbook. They have never had to perform real research on a topic they began knowing nothing about, they have rarely worked in teams, and they have never had to collaborate with so many individuals. When they can learn and experience all of those lifelong skills in one semester, then they truly have had an educational experience that is simply immeasurable in value.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

The competition was undertaken as a class project in a required senior level undergraduate course titled Professional Communication and Ethics. The course is intended to bridge academe and professional practice within the themes of communication and ethical decision making. The learning experience presented by the FAA competition is exactly what is expected in this course.

3. What challenges did the students face and overcome?

There were two primary challenges. First, the students are all undergraduate Computer Science seniors with no experience relating to air travel, airports, aviation, etc. However, they are experienced at problem solving, research, and communication, which are the foundations of the competition. Their lack of experience relating to the aviation industry took them far from their comfort zone and that was quite a challenge for them. However, the biggest challenge was that of communication. The student team consisted of 24 students, far too many for such a project. However, as the students learned, sometimes you have to seize the moment when opportunity arises, and the FAA competition was such a moment. As I tried to explain to the students, you do not always get to work on the ideal team, the perfect team size, or the perfect project; the idea is to learn and adapt as you go. They will realize later that the technical and communication challenges they faced on the FAA project prepared them well for the future.

4. Would you use this Competition as an educational vehicle in the future? Why or why not?

I am already making plans to enter my students in the competition next year. This has been a fabulous experience for not only the students, but also our aviation partners who assisted us in the competition, and of course for me. I have reviewed and analyzed every action and decision throughout the competition with the goal of making the experience for my students even better the next time around.

5. Are there changes to the Competition that you would suggest for future years?

The FAA competition is by far the best-organized competition I have seen in my 30 years in higher education. Because my students are computer scientists, this competition was quite a stretch for them. However, the educational value and experiences presented by participating in the competition is simply unmatched anywhere else, so I am willing to go the extra effort to bring my students up to speed, just to be able to participate.

My only concern is that it seems that most of the suggested topics had been covered in previous years, so it was difficult to come up with a twist on a topic because we did not want it to appear that we were copying ideas that had already been presented at some earlier time.

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Appendix G: Photo Gallery of Participation in FAA Competition

Greater Binghamton Airport
2/7/2009

Greater Binghamton Airport
2/7/2009

Deicing station, planes will pull into this section of runway to be sprayed down with Glycol before take off.
The platform is at a slight gradiant so the excess Glycol runs off and collects in underground tanks.
2/7/2009

Students learn about Greater Binghamton Airport's
Deicing methods and facilities
2/7/2009

Carl Beardsley, Chad Nixon and Students discuss potential
solutions to improve their deicing operations
2/7/2009

Class photo in front of "Mt. Glycol" a hill of frozen water
and glycol mixture piled ontop of the underground tanks.
2/7/2009

Front drains for Glycol run-off
2/7/2009

Students tour the airports deicing facilities
2/7/2009

Deicing facilities tour
2/7/2009

Students examine deicing platform
2/7/2009

Drains for Glycol run-off
2/7/2009

Deicing Equipment at Binghamton Airport
2/7/2009

Deicing truck at Binghamton Airport
2/7/2009

Map of Greater Binghamton Airport
3/5/2009

Carl Beardsley, Chad Nixon and Professor Ziegler
3/5/2009

Deicing truck at Binghamton Airport
2/7/2009

Spray gun applicator for Glycol deicing
2/7/2009

Carl, Chad, Professor Ziegler and Students discuss solution
3/5/2009

Carl and Chad hear ideas from Students
3/5/2009

US Airways propeller plane and side of Mt. Glycol
2/7/2009

Side drains
2/7/2009

Group outlines objectives for the meeting
3/5/2009

Group discusses the proposed boiling solution
3/5/2009

Appendix H: Ethical Considerations

Ethics are the principles of conduct that this group bounded themselves to when we embarked on this endeavor. Throughout the process we have faced repeated decisions, many of which involved ethical concerns we were required to address. Many times the issues were straight forward and the choice between being ethical or not was easy. The harder decisions are naturally so because we found situations where the issues were foggy and the lines blurred. Consider a proposal that is too expensive for a small airport. Do we let the glycol run off into the local watershed and harm the environment or do we skimp on an alternative that may put passengers' lives at risk. Decisions like this one have no clear answers. In the end, we have a completed project with our beliefs, assumptions, and values embedded deeply throughout.

In attempting to deal with the used glycol that airports produce, the environment and passenger safety comes to mind first. Yet, at the same time, we must take care that we obey the laws and regulations that govern our activities. All the while, it is our own due-diligence in reporting our findings accurately and honestly. Even so, some choices never get considered. Our personal morals may lead us to never consider certain paths or the decisions are obscured by many secondary interconnections.

In presenting the idea to dehydrate the glycol, our primary focus has been to limit or erase the negative impacts of glycol and to protect the local environment. We have sought to present our findings accurately and in totality. All the while, we have maintained adherence to all laws and regulations that are applicable to our solution. In general, the glycol is captured and dealt with. This is where many secondary ethical concerns enter the picture. The alternative methods of disposal possess various implications. Trucking the glycol away contributes to CO_2 emissions, increases demand on foreign oil, and carries several other tertiary implications. Although we must focus on increased affordability and utility, we must make sure this does not come at a cost to the environment. We must ensure that our method of boiling the glycol is friendly not only to the environment but cost-beneficial as well.

The issues of deicing are even more relevant in light of the recent plane crashes that have reportedly resulted from difficult icing problems. The safety of the passengers is now of the most concern. We must ensure that our method of glycol treatment not only maintains passenger safety, but also is safe to those involved in the boiling process. If our implementation were to involve extremely hazardous working conditions for those treating the glycol, an alternative solution is necessary. The final approach must ensure that all information sources are both justifiable and unbiased toward the goal. Also the approach must be sensible, logical, thought-out step-by-step, exploring all avenues of possibility, even those not necessarily considered to be the greatest solutions. All solutions must be safe in all manners possible and must be in the best interests of the goal of the project, and not in the self-interest of any of the project members. By no means should the efficiency of the solution be reduced to lower implementation expenses.

Ethical issues become abundant when making a proposal for the acceptance of an idea. Foremost is the honesty and accuracy of the report. There are countless examples throughout history of individuals misrepresenting the facts in order to gain a favorable decision. This unfortunate chain of events is generally initiated because the proposer has an economical benefit from the acceptance of the proposal. It is completely unethical to mislead decision makers who have only the best of intentions.

At all times, this group has adhered to a higher standard. It is after all a class in professionalism and ethics. The motivation has been to offer a new solution to an existing problem. As an educational experience, there is no financial benefit and ethics has remained at the forefront of every decision. Research was conducted and cited every step of the way and plagiarism has been avoided at all times. This has proved tedious as the explosion of information freely available on the internet pervades our generation. In this era, we must make extra effort to verify the credibility of the sources.

Ethical issues also arise when there exists a misrepresentation of conditions, measures, or degree of understanding which results in a decision for action that would otherwise be rejected in the presence of factual and balanced information. Regardless of whether this misrepresentation is deliberate or through a lack of due diligence, the consequences are real and therefore require vigilance on the part of both parties: the party representing the case for action and the party who ultimately decides upon a course of action. It is for this reason, that information that is reviewed by peers, experts, and key stakeholders has a stronger likelihood to be reality-based and lead to better decision making and ultimately better outcomes.

From minimal understanding of deicing and airport operations, comes the necessity to utilize the abilities and knowledge of experts in the field. Concern for the choices of these experts must be acknowledged. Great care was taken to transform their expertise into a viable means of handling glycol. Like the other inclusions of facts, we must ensure that what is learned is represented accurately. This task is more difficult than a written source. A misunderstanding in transcription is more difficult to catch than the verification of information that comes from a written source. It is a more personal and the misrepresentation can reflect back on the expert's integrity. Therefore, this group took extra precautions to ensure the accuracy and validity of all outside contacts. Several individuals took notes of each contact. These notes were then compared and discussed in order to solidify content. In the end, it was the expert's knowledge and our increased understanding that allowed us to create a unique solution to glycol disposal.

In light of the recent global financial crisis, ethics takes on a new perspective when considering the financial implications of our proposal. It has been our intention to find a financially viable solution for the sustainability of airplane safety. The ―Green" movement has a tendency to raise costs of doing business in order to protect our planet. As with any endeavor of this type, our proposal has associated start-up costs. It is likely advantageous to pursue federal incentive funding to cover the installation costs and then let the airports and airlines benefit from the long-term savings from reduced disposal costs. In these economically difficult times, this agenda may have a dual benefit. First, airports may be able to cover the initial costs with governmental incentive funding and provide construction jobs and cash flow in a floundering economy. Second, airports have a perpetual expense reduction that lowers the cost of doing business. Third, the design is environmentally advantageous. By looking at the problem and the proposed solution it seems almost unethical not to pursue further.

An additional ethical consideration is; which airports should receive grant funding for a dehydration system? Obviously, this system cannot be immediately installed at every airport. There just is not enough money to go around. Nor does every airport need the system. This choice of candidate airports carries ethical considerations. Large airports may have the financial capability to install the system and then recoup the costs. Small airports may not see any benefit and it may cost those airports more to use the equipment than the savings can cover. The medium sized airports then remain. These are the locations where there is not enough money for installation, but the savings would make the airport more economically sound. In our financial analysis, we have been honest and have attempted to give as accurate an analysis on our design as possible. We must try to cut costs as much as possible, but we also have to maintain the integrity of our design. We cannot cut any corners in our design implementation; even it would result in more money saved.

Throughout the learning experience of this project, this group has encountered a plethora of ethical issues. The beliefs and values we abide by are deeply embedded throughout the paper. The solution we have presented reflects our concern for the people involved, the environment, and the choices we have made. We believe in our solution's viability.

Appendix I: Biographies

Faculty Biography

William Ziegler

William Ziegler is an Associate Professor of Computer Science in the T.J. Watson School of Engineering and Applied Science, and the Faculty Master of Newing College at Binghamton University. He is a graduate of Syracuse University, the State University of New York at Binghamton, and Broome Community College. His professional interests are in computer systems analysis and design, engineering management, engineering education, and effective communication in engineering and science.

Professor Ziegler has been a consultant to and/or supervised student projects at well over 100 organizations including IBM, Lockheed Martin, Borg-Warner, Corning Inc, and New York State Electric and Gas. He has authored numerous papers that have been published by organizations such as the IEEE, ACM, ASEE, and others.

Non-university Partners

Chad Nixon

Chad Nixon currently serves as the Aviation Director at McFarland Johnson, a multi-disciplined engineering firm that provides financial and aviation planning, environmental, engineering, and construction inspection services to airports throughout the U.S. He also serves as a Technical Lead on statewide and airport specific aviation planning projects. He has a highly diverse aviation background that began with his service in the U.S. Navy as an air traffic controller, then airport operations, airport management and aviation planning. As a fully qualified radar and tower air traffic control supervisor, he served for several years as the Chairman of the Air Traffic Procedures Evaluation Board tasked with coordinating air traffic control functions in the Gulf Coast Region of Florida. He has performed FAA and DOD airspace liaison duties in numerous countries including Malaysia, Thailand and Oman. He has also served as an interim airport manager for a regional commercial service airport. His current responsibilities include aviation forecasting, economic analysis, airport negotiations, aviation planning, airspace analysis, project management and strategic development of MJ's aviation practice. Chad received his MBA with a specialization in Aviation from Embry-Riddle Aeronautical University. He serves on numerous national and regional aviation committees, as well as serving on the New York Aviation Management Association Board of Directors. In his free time he enjoys riding motorcycles, skiing, hiking, and camping with his family.

Carl R. Beardsley, Jr.

Since 2005 Carl R. Beardsley, Jr. has been the Commissioner of Aviation at the Greater Binghamton Airport. Since his promotion to this position, Carl has implemented nearly $30 m in capital improvements at the Greater Binghamton Airport including a full-scale primary runway rehabilitation. He has also lead business development activities that lead to securing a major Fortune 500 company to lease a large hangar at the airport. Before becoming Commissioner of Aviation, Carl held the position of Deputy Commissioner of Aviation for nearly eight years.

Carl's educational background includes holding a Bachelor's Degree in Aviation Management and Flight Operations. He is also a licensed Private Pilot. He has a wife named Tracy and two young boys named Nathan and Nicholas.

Student Biographies

Francis Heaney

Francis Heaney is a Computer Science major studying at Binghamton University. Francis—in cooperation with Matt Svoboda—was responsible for the Safety and Risk Assessment. His interests include Internet Security and Application Development.

Jeongvin Kim

Jeongvin Kim is from a small city of South Korea, and came to the United States to learn English and finish his college degree. For the duration of the project, Kim—along with his partner, Joshua Casner—was in charge of Appendices A, B, and C, which encompassed compiling contact information and descriptions of both the university and non-university partners involved. While he has not had employment experience, Jeongvin is very enthusiastic about game development—particularly in online gaming—and hopes to be part of a game development company in the future.

Joshua Casner

Joshua Casner is a Computer Science student graduating in May 2009. Hailing from New York, he's responsible for several of the appendices of the report, including collecting all the contact information from the project participants, and the description of the university. He looks forward to having a long and fulfilling career in software engineering and related fields.

Joshua Schell

Joshua Schell is from the Binghamton area and graduated from the Central Baptist Christian Academy. He is finishing his degree in Computer Science at Binghamton University, and plans to continue his studies at Binghamton with graduate school. For the span of the project, Joshua and his partner Stephen Peek were responsible for the Literature Review.

Li Li

Li Li was born in Foshan, a medium-sized city in the Guangdong Province of Southern China, where he completed high school before coming to the United States. He is now a senior in the Computer Science curriculum at Binghamton University. Li professes himself as one who has always been deeply interested in computer science, having owned and programmed for his first computer—the APPLE II—at the early age of ten. In addition to programming, his personal interests encompass jogging, cooking, dating, and gaming. Li hopes to find work in a small area similar to Binghamton, but is still open to traveling as far as Silicon Valley.

Matthew Giliotti

Matthew Giliotti is a junior computer science major at Binghamton University. Born in Charlotte, NC, he has moved five times in his life and currently resides in Bentonville, AR. Matthew's responsibilities encompassed that of the technical aspects of the FAA design project, and he also acted as an airport liaison. Matthew will spend the summer of 2009 interning at Bloomberg L.P. and is uncertain of his post undergrad plans.

Matt Svoboda

Matt Svoboda is currently a senior studying Computer Science at Binghamton University with a cumulative GPA of 3.5. He was responsible for the Safety and Risk assessment of the project. Matt's professional experience includes several years of work as a software engineer on various avionics and embedded applications.

Michael Pitcher

Michael Pitcher is a senior at Binghamton University majoring in Computer Science. He has been working part time at Lockheed Martin System Integration-Owego since 2007, and will assume a full-time position there as an Embedded Software Engineer after graduation. He also plans to pursue graduate degrees in Computer Science and Systems Engineering.

Nathan Bower

Nathan Bower is a Computer Science student at Binghamton University in his senior year. He currently lives in East Meredith, NY, a rural area in Upstate New York. Some of Nathan's academic and personal interests comprise computer programming, physics, mathematics, and computer graphics. He also enjoys calisthenics and reading. During the FAA Project Competition, Nathan worked alongside William Li to compile and manage the Evaluation of the Educational Experience, the Bibliography, and the Student and Faculty Biographies.

Nick Drohan

Nick Drohan grew up in Westchester, New York, and was always fascinated by computers. He is a Computer Science major with a minor in math and plans on continuing on with a Masters in Mathematics at Wesleyan University. He is also the captain of the club water polo team and use to swim on the varsity swim team. In this FAA contest, he is the primary editor and is in charge of the Executive Summary and the Evaluation Review.

Nicole Hofmann

Nicole Hofmann currently resides in Binghamton, NY, where she is a Computer Science major at Binghamton University. Nicole contributed to the problem statement of this document and overall editing. Nicole has work experience at Lockheed Martin Systems Integration and The Procter & Gamble Company. At The Procter & Gamble Company, she provided intranet development and support for their Global Beauty Care business; at Lockheed Martin Systems Integration she worked with the A-10 Software Validation and Software Development teams. Her personal interests include knowledge management systems, computational mathematics, and embedded systems.

Pavel Etkin

Pavel was born in Kharkov, Ukraine in 1987. He grew up in Brooklyn, NY but graduated from high school in Fair Lawn, NJ. He studies various aspects of computer science and psychology. For this project, he and Richard Reilly were responsible for the Problem Solving Approach.

Richard Reilly

Richard was born in 1987 in Brooklyn, NY. He is a computer science student at Binghamton University and project manager for this FAA airplane deicing project. He has experience with management due to his position as General Manager of Binghamton Sound, Staging & Lighting (BSSL). Along with Pavel Etkin, he is responsible for the Problem Solving Approach.

Ryan Nash

Ryan Nash is a local student who has lived around the Binghamton area for several years. He is a computer science major and takes an active interest in interactive entertainment development, web design, technology and digital art. His other hobbies include wine tasting, snowboarding, games, and music production. He is currently working for a local company as a developer and team lead for their IT department. After graduation he will be moving to New Jersey to work on counter-terror analysis software.

Scott Stolz

Scott Stolz is from Liverpool, New York—just outside of Syracuse. Scott contributed to the Executive Summary and the Quality Control Summary. Scott is a senior majoring in Computer Science at the State University of Binghamton. He enjoys video gaming and the martial arts, having earned a Black Belt in karate at Steve Lavalley's East Coast Karate and Kick Boxing.

Eric Entin

Eric Entin was born and raised in New York City. After attending the prestigious Bronx High School of Science, Eric moved on to a Computer Science major at Binghamton University. He is currently a junior, planning to graduate in 2010. He enjoys programming, writing, and computer graphics, and currently performs independent research in the field of grid computing. He was responsible for reviewing ethical concerns during the project along with his partner Tony Worm.

Sean Ngai

Sean Ngai is a junior at Binghamton University, majoring in Computer Science. His responsibilities in the FAA Project included the Projected Impacts and Summary/Conclusion. Sean is from Long Island, NY, and—with a father and two uncles having careers in the programming field—comes from a family well versed in his area of interest. His father is a programmer for JPMorgan Chase, and Sean hopes to follow in his footsteps one day. Ultimately, he would like to work in the banking or financial industries in New York City. He is interested not only in the programming aspects of computer science, but also the business aspects. Sean has been accepted to the Watson Fast-Track MBA Program at Binghamton University and is planning on earning an MBA by May 2011.

Stephen Peek

Stephen Peek is a computer science major from Utica, NY scheduled to graduate in spring 2010. For the past two summers, Stephen has worked at the Air Force Research Laboratory in Rome, NY, programming for parallel computing. His goals in life are to become an entrepreneur in web and software programming. His contributions towards this project include working on the Literature Review.

Tony Worm

Born and raised in Binghamton, New York—and returning many years later to complete degrees in Computer Science and Math, Tony finds the city and school bursting with opportunity. He is currently involved in forming a start-up company in conjunction with a Computer Science professor, a business professor, and the technology transfer program at the university. Tony also enjoys programming, understanding complex systems, and the great outdoors. In the summer of 2009, Tony plans on moving to New York City—a stark contrast from his rural upbringings.

Travis Farrell

Travis Farrell worked on the Projected Impacts as well as the Summary and Conclusion. He comes from Long Island, New York, and is pursuing a Bachelor of Science in Computer Science. Some of Travis' interests within Computer Science include cryptography and performance optimization.

William Li

William Li is a Computer Science major from Brooklyn, NY, scheduled to graduate in the spring of 2009. His contribution towards the project includes working on the Biographies, Bibliographies, and the Evaluation of the Educational Experience with Nathan Bower.

Appendix J: Interview and Meeting Reports

BINGHAMTON UNIVERSITY State University of New York	Binghamton University State University of New York PO Box 6000 Binghamton, NY 13902-6000

Section Meeting Report

Meeting Date and Times: Friday, February 6th, 2009 from 8:30a.m. to 10:00a.m.______

Attendance: CS495 Class and Instructor__ **Location:** Greater Binghamton Airport____

Speakers:

Carl Beardsley, Commissioner of Aviation

Chad Nixon, Aviation Director_________

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Topics:

Currently used methods of deicing aircraft

Alternative methods of deicing_______

Safety, cost and environmental concerns__

Description:

Carl and Chad started the meeting with an introduction on how deicing of airplanes in the Greater Binghamton Airport is done. The deicing agent used is Propylene Glycol. Propylene Glycol comes in two forms, Type IV and Type I. Type I is heated anywhere from 140 to180 degrees and is used to remove frost that has accumulated on the plane. Type IV is not heated and is sprayed on the plane to serve as an anti-icing agent. To reduce costs, a solution of about 55% Type I Glycol and 45% water is sprayed on the aircraft. Removing one inch of ice from a plane requires about 1,200 gallons of the Glycol mixture. Planes are deiced after passengers are on board. For safety reasons, if the plane doesn't take off within 45 minutes of being deiced, it is deiced again.

The Greater Binghamton Airport has a containment area in the North Ramp that the Glycol seeps into. The Glycol sprayed on the aircraft goes onto the ground, then down the North Ramp and into the underground tank. When the tank is about 2/3rd's full, it is emptied into two trucks and taken to Endicott treatment facility, where it is treated and released into a nearby river. The tank typically holds a solution that is 1/10th glycol and 9/10th's water.

After the introduction, the class explored ideas to either reduce Glycol costs or use some completely different deicing method that was cost effective and environmentally friendly. After several ideas were discussed, six were written on the board: boil Glycol to reuse it, use Glycol as plant food, deice planes with shock technology, heat the wings on the plane, construct a dome over the entire deicing area or use alternative chemicals.
Seeking to get a better idea of what goes on in the airport, the entire class took a shuttle to the North Ramp. Chad and Carl reiterated how deicing is done and showed the deicing equipment and the hatches to the sewers that lead to the underground tank. They explained that the hatches were used to keep rainwater from entering the tank, but could only be closed if all of the Glycol on the ground seeped into the tank. They also explained that snow that was plowed from the runway had to remain on the site to melt into the underground tank due to Glycol contamination.

When everyone got back to the meeting room, the ideas on the board were reviewed for their merits and narrowed down. Use of shock technology was discarded because even the geniuses at the National Aeronautics and Space Administration (NASA) were still working that out. Heating the wings is a good idea but very expensive and not as safe as Glycol. Using Glycol as plant food doesn't have much research done on it. Other chemicals for deicing tend to either be more expensive or less safe than Glycol. Constructing a dome would easily be over a million dollars and would only slightly increase the concentration of Glycol in the underground tank. So the group decided that boiling the Glycol to reuse or sell would be the best method. It was also affirmed that research needed to be done on reducing the required boiling temperature by implementing a low-pressure tank, much like what is done to concentrate orange juice.

The class gathers in the Greater Binghamton Airport meeting room to begin the working with Chad Nixon and Carl Beardsley.

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Section Meeting Report

Meeting Date and Times: Thursday, February 19th, 2009 from 8:30a.m. to 9:55a.m.___

Attendance: CS495 Class and Instructor__ **Location:** Science Library, Room 302____

Speakers:

William Ziegler, Associate Professor___

Topics:

Formatting of the final project________

Boiling Glycol in a tank______

Description:

The meeting was mostly on how to deal with the formatting for the final project, but the class also touched on the boiling Glycol idea.

Since some documents may cite the same source and some people may cite their works slightly differently, there must be a single unified way of dealing with citations. It was decided that all references should be e-mailed to cs495.02.spr09.refs@gmail.com in American Psychological Association (APA) format. Since Uniform Resource Locators (URLs) were referenced in previous competitions, they are permitted, but only if they link to reputable sources that are peer reviewed. Only the primary editor should number the pages of the final project, not the individuals working on their parts. Photos would go well in the appendices and must be included somewhere in the project. Everything should have a title and/or a heading, where appropriate.

The cost of having the tank emptied and shipped to Endicott is a factor, but it is not in the books because it is a Broome County budget item. Some important facts that still need to be researched are:

1) How, if at all, the percentage of Glycol in the water changes the boiling point.
2) If the current tank can tolerate being heated and/or depressurized.
3) Based on the requirement for Federal Aviation Administration (FAA) approval, is it better to reuse the glycol on site or sell it to someone else?
4) How evaporators can separate water from other liquids

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Section Meeting Report

Meeting Date and Times: Thursday, February 26th, 2009 from 8:30a.m. to 9:55a.m.___

Attendance: CS495 Class and Instructor__ **Location:** Science Library, Room 302____

Speakers:
William Ziegler, Associate Professor___

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Topics:
Rough drafts are due soon___________

Current status on the rough drafts______

Description:

In this meeting, Prof. Ziegler informed the class of next week's meeting. Then the class talked about some ideas and problems with completing the project and each person reported their current status on the project.

Chad and Carl, the Aviation Advisors for the class, wanted to have another discussion for the following week on Friday. Prof. Ziegler made the date for the next meeting to be Friday, March 6th in the Newing Discovery Center from 9:30am to 10:30am. Prof. Ziegler suggested that everyone should e-mail questions to either Chad or Carl prior to the meeting so they have a chance to come prepared.

The winning contestants from last year sent out questionnaires to several experts in order to get a better idea of how to solve their problem. It was decided that, to give the class the edge, Matt and David should contact Mcfarlen Johnson Inc. (a consulting firm for the Greater Binghamton Airport) and ask them questions on the boiling Glycol idea. They should also contact the Endicott Treatment Facility and ask for details on how glycol is treated.

Prof. Ziegler then asked each individual on his or her current progress and gave him or her an opportunity to ask for any material that they may need to complete their portion of the project. The important items that were asked were a rough draft of the problem statement and the problem solving approach.

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Section Meeting Report

Meeting Date and Times: Friday, March 6th, 2009 from 9:30a.m. to 10:30a.m.________

Attendance: CS495 Class and Instructor__ **Location:** Newing Discovery Center______

Speakers:

Carl Beardsley, Commissioner of Aviation
and
Chad Nixon, Aviation Director, McFarland Johnson, Inc.

Topics:

Existing systems that handle Glycol____

Getting Glycol at a required concentration

General concerns with the project______

Description:
The meeting kicked off with some questions from the class, which lead to a discussion on existing systems and the details of the boiling process for Glycol.

From the inquiries, several important facts were learned:

1) The cost of filters will have to be factored in. Since debris from the ground goes into the underground tank, a filter will be needed so the debris won't end up in the boiled concentrated Glycol solution.
2) The current tank can only go up to 120^{o}F. It holds about 10,000 gallons, but usually only makes it to 2/3rd's its capacity before being emptied.
3) The cost of 100% Propylene Glycol is about $17/gallon. The cost of having a single truck remove liquid from the underground tank is over $1000.
4) It takes about 382^{o}F to boil a water and Glycol solution to 100% Glycol, but it takes only 220^{o}F to boil it to about 60% Glycol.
5) It's easy to test the concentration of Glycol. All that is needed is a refractometer, which costs about $1.

The Environmental Protection Agency (EPA) conducted a study on recycling Glycol in Swedish airports. They treat the solution on site and reprocess it for reuse. They are quite successful with Type I Glycol, but not Type IV. However, Type IV is rarely used in the Greater Binghamton Airport so this isn't much of an issue.

Re-concentrating the Glycol to 100% would be very expensive because such would require a tank that can either be heated to 400^{o}F, or depressurized and heated to some equilibrium to get the Glycol to 100% purity. However, such is not a requirement because the Glycol used to deice aircraft is 55% anyway. So if the Glycol were concentrated at least that much and then approved by the FAA, the Glycol could be reused. Additionally, if the Glycol were to be concentrated to at least 80%, there are prospective buyers who would pay for that.

There are some aspects of the project that need further research and study before the rough drafts are completed:

1) What temperature and pressure requirements are there to get the Glycol solution to 60% and 80% concentration?
2) What are the technical aspects of having a depressurized tank to boil the solution?
3) How will the costs be different, since this project is on a smaller scale from existing systems, like the one in Denver Airport that handles a thousand times more Glycol than Greater Binghamton Airport?
4) How much time would it take to boil the Glycol solution?

The idea, currently, is to have one or two 5,000-gallon, aboveground tanks that boil the Glycol, depending on how long it takes for the boiling process to complete. From there the Glycol can either be sold or reused, depending on if the Federal Aviation Administration (FAA) approves it or not.

Nicole and Chad discuss the EPA study on the recycling of Glycol in Swedish airports.

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Section Meeting Report

Meeting Date and Times: Thursday, March 12th, 2009 from 8:30a.m. to 9:55a.m._____

Attendance: CS495 Class and Instructor__ **Location:** Science Library, Room 302____

Speakers:

William Ziegler, Associate Professor___

Topics:

Educational experiences____________

How to include photos______________

Description:
The meeting was mainly focused on a discussion of the educational experiences of each individual. The class learned about:

1) Deicing airplanes, obviously
2) Problem solving within a group
3) Dealing with people of different disciplines
4) Academic approaches to business problems
5) How important good communication is (and how e-mail can be torture)
6) Being good designers

Before the meeting was over, the class touched on the best way to deal with the inclusion of photos. Everyone agreed that a grid layout would look the most professional, with six photos on a page. Everyone also agreed that some sections would do well with photos, but the specifics should be discussed next week.

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Section Meeting Report

Meeting Date and Times: Thursday, March 19th, 2009 from 8:30a.m. to 9:55a.m._____

Attendance: CS495 Class and Instructor__ **Location:** Science Library, Room 302____

Speakers:
William Ziegler, Associate Professor___

Topics:
Corrections to rough drafts__________

Description:
Prof. Ziegler handed back everyone's rough drafts with corrections and comments that he made. He then constructed a chart of what needed to be done with each part before the final project deadline. The chart was as follows:

	Photos	References	Other	Diagram
Executive Summary	X	X	Review executive summary format	X
Table of Contents	X	X	X	X
Problem Statement	GBA deice area	√	Move financial review to technical aspects section	X
Literature Review	X	At least one per paragraph	X	X
Problem Solving Approach	One of Chad & Carl with the airport	Needs more FAA references	X	Timeline
Technical Aspects	X	√	X	All of the design
Safety and Risk	X	Need FAA references	X	X
Interactions	The airport and the classroom	X	X	X
Projected Impacts	X	FAA flight plan goals and EPA	Cost benefit analysis	Financing options
Overall Summary	X	X		Schedule

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Section Meeting Report

Meeting Date and Times: Tuesday, March 24th, 2009 from 10:30a.m. to 11:30a.m.___

Attendance: David and Matt___________ **Location:** McFarland Johnson__________

Speakers:

Chad Nixon, Aviation Director_______
and
Don Harris, Senior Project Manager_____

Topics:

Corrections to rough drafts_________

Description:
Matt and David, the duo in charge of the technical aspects section for the project, went to McFarland Johnson Incorporated to meet with Chad and Don. There, they reviewed the technical aspects section together. Besides just correcting errors, they expanded the paper by coming up with more details pertaining to the process of boiling Glycol. They also included a financial review, and explained important details on the possible sale of Glycol in the paper.