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Storm Water Technology Fact Sheet

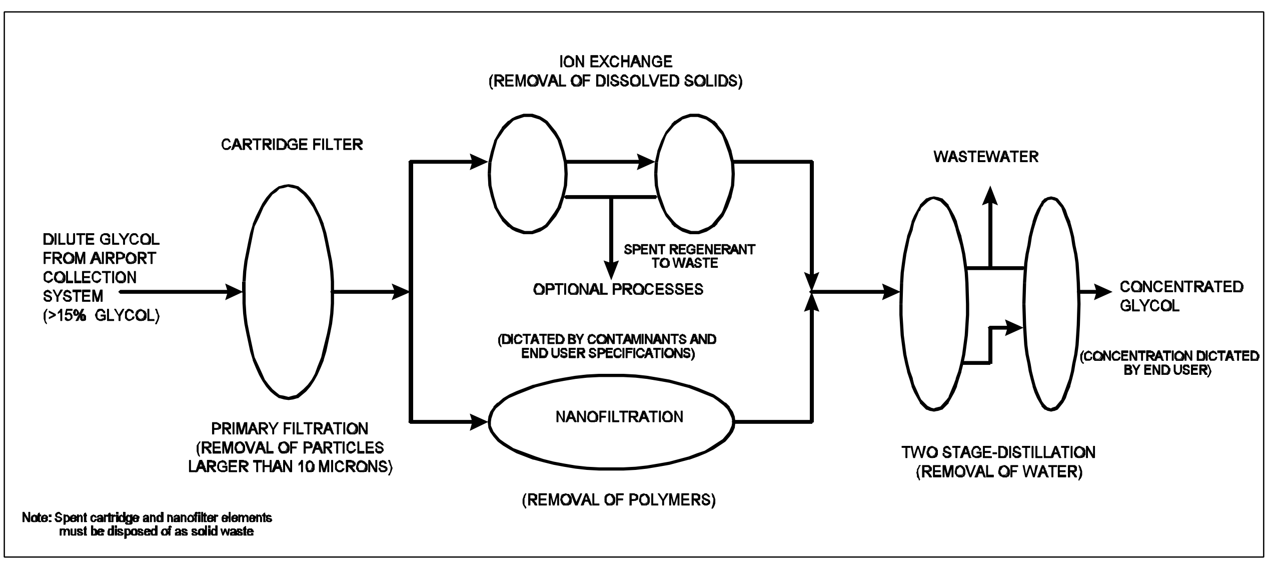
Airplane Deicing Fluid Recovery Systems

DESCRIPTION

Under the guidance of Section 402 of the Clean Water Act, the Federal Aviation Administration has approved the use of ethylene glycol and propylene glycol as chemical deicers. The recovery of spent ethylene glycol or propylene glycol from industrial processes is accomplished by a three-stage process typically consisting of primary filtration, contaminant removal via ion exchange or nanofiltration, and distillation, as shown in Figure 1. The process technologies involved in glycol recovery have been proven in other industries and are now being applied to spent airplane deicing fluid (ADF.)

Primary filtration, which is defined as the removal of solids greater than 10 microns in size, is intended to remove entrained suspended solids from the used ADF. The suspended solids must be removed to avoid plugging of downstream equipment and heat exchangers. Primary filters employed by ADF systems are either polypropylene cartridges or bag filters.

Contaminant removal can occur through ion exchange or nanofiltration. Ion exchange removes dissolved solids such as chlorides and sulfates from an aqueous solution by passing the wastewater through a solid material (called ion exchange resin). This exchange process removes specific ions, and returns an equivalent number of desirable ions from the resin. Another approach to contaminant removal is nanofiltration. Nanofiltration systems are pressure-driven membrane operations that use porous membranes to remove colloidal material and polymeric additives with molecular weights in excess of 500 from the spent ADF. The need to remove polymer additives is dictated by the specifications of the end user of the recovered ADF



Source: ENSR Consulting and Engineering, 1993.

FIGURE 1 TYPICAL AIRPLANE DEICING FLUID RECOVERY SYSTEM

product.

The key process step in the overall ADF recycling system is distillation. Distillation is defined as the separation of more volatile materials (in this case, water) from less volatile materials (glycol) through a process of vaporization and condensation. Distillation is capable of recovering volatiles with little degradation of the recovered product. This is very advantageous in situations where the recovered product can be sold or recycled. Product purity of any desired level can theoretically be obtained by distillation; however, in some cases the processing costs may be prohibitive. In most ADF applications, the separation of water from either a water-ethylene glycol or a water-propylene glycol mixture of ADF employs a two stage distillation process. This will typically remove enough water to produce a recovered ADF with a minimum 50 percent glycol content. The requirement glycol concentration is dictated by the specifications of the end user of the recovered ADF product.

The details of the distillation processes employed by specific vendors are proprietary. Design variables include temperature, distillation column design (number of stages, type of packing, size) and reflux ratio. Batch distillation systems are generally employed due to the variation in the composition of the influent and the irregular supply of the feed. Secondary filtration and ion-exchange stages vary with the quality of the influent feed and the specifications of the end-user. The temperature of distillation also varies between ethylene glycol and propylene glycol recovery applications.

APPLICABILITY

Ethylene glycol or propylene glycol recovery systems are generally applicable at any airport that collects ADF with a minimum concentration of approximately 15 percent glycol. Spent ADF mixtures with lower glycol content are generally impractical to recover via distillation, without expensive preconcentration steps such as reverse osmosis. Dilute streams are typically discharged to municipal wastewater treatment plants (if permitted), treated by oxidation to destroy the organics prior to direct discharge, or hauled away by a chemical waste contractor. A number of other BMPs, such as water quality inlets and oil\water separators, are being tested to demonstrate their ability and reliability to concentrate dilute streams of spent ADF.

While the basic technologies used to recycle ethylene glycol and propylene glycol are well established, actual operating experience in recycling airplane deicing fluids is limited. To date, there is only one on-site application of ADF recovery operating in the United States. This is a pilot-scale operation conducted for Continental Airlines at the Denver International Airport. Another pilot-scale ADF operation is currently being conducted in Canada at the L.B. Pearson Airport in Toronto. A recovery system is also being proposed for the St. Louis, Missouri, Airport, but this system is currently not in operation. There are also three ADF recovery systems in operation at the airports in Europe: Lulea, Sweden; Oslo, Norway; and Munich, Germany.

Currently three vendors are actively designing, testing or marketing ADF recovery systems for on-site use at airports in North America: DeIcing Systems (DIS), Glycol Specialists, Inc. (GSI), and Canadian Chemical Reclaiming (CCR). In addition, there are a number of chemical waste service companies that will provide off-site processing for spent glycol for other industries. The technology and process applications of ADF are evolving rapidly. The equipment manufacturers and the airport operators should be contacted for current state-of-the-art information.

ADVANTAGES AND DISADVANTAGES

In order for the ADF to be recovered or regenerated, it must first be collected at the airport. The implementation of ADF collection must be coordinated to meet the unique requirements of each airport. The feasibility of glycol recovery is dependent on the ability of the collection system to recover a relatively concentrated waste stream without significant contamination by other storm water components. Since distillation is an energy-intensive process, it is generally not cost effective to distill and recycle waste glycol solutions at low concentrations (< 15 percent). However, individual airports may have to collect and recover lower concentrations of waste glycol solutions to satisfy requirements of their storm water NPDES permits. One method for collecting a more concentrated used glycol stream is to conduct deicing at a remote or centralized location. However, centralized deicing systems may be impractical for all but the largest airport operations due to their cost and physical size. For established airports, a switch to centralized deicing systems would present a number of operational and logistical problems. In lieu of a centralized facility, used glycol can be collected via vacuum trucks and fluid collection containers that siphon glycol from runway aprons. Roller sponge devices have been employed at the Toronto Airport with mixed results due to the irregularity of runway surfaces.

Mixtures of ethylene and propylene glycols cannot be recovered effectively in a single batch process because the technology currently available does not cost effectively separate the two glycols. While there is a market for either recovered ethylene glycol or propylene glycol, there is little demand for a recovered blend of both glycols by end users. In order to recover either ethylene glycol or propylene glycol from spent ADF, an airport must use one or the other, or isolate application and runoff areas. Treated separately, each type of water-glycol mixture can then be recovered effectively via the distillation process.

While the potential for volatile-organic emissions from the recovery process to the air is considered small, the air emissions from the distillation process through losses from condenser vents, accumulator tank vents, and storage tank vents must be considered. Ion-exchange flush and spent wastewater that are generated by recovery processes may generally be discharged to a sanitary sewer. These spent byproducts may require neutralization through the addition of acids or bases before discharge. Discharges to the sanitary sewer system may require permitting under local pretreatment programs. Spent filter cartridges may be generated in some systems, although in most cases these can be disposed in the local landfill.

After a distillation condensate with a glycol concentration of 7-10 percent is generated, it is commonly reused or disposed depending on the nature of the runoff and the economics involved. Recently the EPA officially changed the reportable quantity for ethylene glycol from 1 pound to 5000 pounds. If more than 5000 pounds of the glycol, as concentrate, is released into the environment, then the release needs to be reported under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Emergency Planning and Community Right to Know Act (EPCRA). A spill prevention control and countermeasure (SPCC) plan should also be developed for all ADF systems to address the handling, storage and accidental release of chemicals, regenerated products and waste byproducts.

DESIGN CRITERIA

There are a number of important criteria that must be determined in order to properly design an ADF system. Table 1 lists some of the key criteria. The storage and handling of process chemicals, energy requirements, and the disposal of spent chemicals and residuals generated in the recovery process must also be carefully considered. Other factors, such as site drainage, weather patterns, water quality requirements, state and local restrictions, marketability of the recovered product, etc., will also influence the final design of the system.

Sodium hydroxide (NaOH) and hydrochloric acid (HCl) are required for regeneration of the ion exchange process unit. As a part of the recertification process, wetting agents and a corrosion inhibitor must be added to the recovered product prior to its reuse as airplane deicing fluid. While recertification and reuse of recovered airplane deicing fluids is practiced in Europe, the FAA currently has no recertification guideline for reuse of recovered ADF in the United States.

For the most part, energy requirements for the recovery process are dependent on the waste stream glycol concentration of the fluid to be recycled and the purity required by the end user. Recovery by distillation is energy-intensive, with nominal energy requirements being about 250 to 1200 BTUs per pound of feed. As the technology is refined and as operating experience grows, these costs should decrease. Flush and spent wastewater are generated

TABLE 1 KEY CRITERIA FOR DESIGNING AN AIRPLANE DEICING FLUID RECOVERY SYSTEM

Deicing Fluid Data
-Type
-Concentration
-Total Consumption per Season
-Total Consumption per Peak-day
-Average Consumption per Aircraft

Airport Operations Data
-Flights per Day
-Peak Traffic Periods

Length of Deicing Season
-Number of Deicing Days per Season
-Future Traffic Extension Plans

Spent Fluid Data
-Volume Generated
-Glycol Concentration

Reuse Specifications
-Glycol Concentration
-Acceptable Impurities

Source: Kaldeway and Legaretta, 1993.

by recovery processes which employ ion-exchange systems. After neutralization through the addition of acids or bases to the sanitary sewer, the fluids can be disposed. Spent filter cartridges may be generated in some systems and may be sent to a landfill for disposal. Distillation condensate, with less than 1.5 percent glycol according to local landfill operator requirements, is also generated and may be reused or disposed. Currently discharges to the sanitary sewer system may require permitting under local pretreatment programs.

PERFORMANCE

Three ADF recovery systems were evaluated using data provided by three vendors. In each ADF recovery system investigated, the quality of the fluid recovered was dictated by the specification objective. The data provided for the ethylene glycol recovery system at the Toronto Airport shows that the process reliably produced an effluent with a glycol content over 80 percent. The data from the ADF recovery system in Denver also showed that high purity (98.5 percent glycol) can be reliably produced. The process at the Munich Airport reliably produced an effluent with a glycol content over 50 percent, which meets the lower end-user requirements in Europe.

COSTS

Since there are no full-scale ADF systems currently operating in the U.S., it is difficult to determine the actual construction costs for these systems. However, based on the pilot study at the Denver Stapleton Airport, the total capital cost for the complete project, including deicing and anti-icing application equipment, collection piping, storage facilities, and a glycol recovery system, has been estimated to be between $6 and $7 million dollars. The construction costs for the ADF collection system, storage and handling facilities, piping, and recovery system has been estimated at approximately $600,000 (GSI, 1993).

The total capital cost for the new system at the Denver International Airport, including deicing and anti-icing application pads and equipment, drainage and collection piping, storage and handling facilities, and complete glycol recovery system is currently estimated at between $20 and $25 million dollars. These costs are based on a complete package, and include planning, engineering design, equipment, construction and installation, start-up services, and other contingencies. The construction costs for the ADF collection system, storage and handling facilities, piping, controls and instrumentation, and a complete recovery system, is currently estimated at approximately $5 million dollars.

The major operating expense for all ADF systems is the cost of energy used in the distillation process. Maintenance costs include flushing of filters and ion-exchange units, disposal of spent filter cartridges, purchasing process and neutralization chemicals, lubricating pumping equipment, and inspecting and repairing distillation equipment and heat exchangers. The collection system and storage facilities will also require periodic cleaning and maintenance. Based on very limited operating data from the pilot study at the Stapleton Airport, the cost for processing ADF with a 28 percent glycol concentration is approximately 35 cents per gallon treated. However, this cost will vary depending on the volume treated and the concentration of glycol in the waste stream. As the technology is refined and as operating experience grows, these costs should decrease.

REFERENCES

1. American Association of Airport Executives, 1993. *Conference on Aircraft Deicing*. Washington, D.C.

2. Comstock, C., 1990, as cited in R.D. Sills and P.A. Blakeslee, 1992. "The Environmental Impact of Deicers in Airport Storm Water Runoff," in *Chemical Deicers in the Environment*, ed. Frank M. D'Itri. Lewis Publishers, Inc., Chelsea, MI.

3. ENSR Consulting and Engineering, 1993. *Evaluation of the Biotic Communities and Chemistry of the Water and Sediments in Sand Creek near Stapleton International Airport*. Prepared for Stapleton International Airport. Document Number 6321-002.

4. Freeman, H.M, 1989. *Standard Handbook of Hazardous Waste Treatment and Disposal*. McGraw-Hill, New York, N.Y.

5. Federal Aviation Administration, Advisory Circular (150/5320-15), 1991. *Management of Airport Industrial Waste.* U.S. Department of Transportation, Washington, D.C.

6. Federal Register Notice, November 16, 1990. *EPA Administered Permit Programs; the National Pollutant Discharge Elimination System,* Vol. 55, No. 222, page 48062.

7. Federal Register Notice, November 19, 1993. *Fact Sheet for the Multi-Sector Storm Water General Permit (Proposed),* Vol. 58, No. 222, page 491587.

8. Federal Register Notice, June 12, 1995. *Reportable Quantity Adjustments*, Vol. 60, No. 112, page 30925.

9. Hartwell, S.I., D.M. Jordahl, and E.B. May, 1993. *Toxicity of Aircraft Deicer and Anti-icer Solutions to Aquatic Organisms*. Chesapeake Bay Research and Monitoring Division, Annapolis, Maryland. Document Number CBRM-TX-93-1.

10. Health Advisory, 1987. *Ethylene Glycol*. Office of Drinking Water, U.S. Environmental Protection Agency. Document Number PB87-235578.

11. Kaldeway, J., Director of Airport Operations. L.B. Pearson International Airport, Toronto, Canada. 1993. Personal communication with Lauren Fillmore, Parsons Engineering Science, Inc.

12. Legarreta, G., Civil Engineer. Design and Operations Criteria Division, Federal Aviation Administration. 1993. Personal communication with Lauren Fillmore, Parsons Engineering Science, Inc.

13. Lubbers L., 1993. *Laboratory and Field Studies of the Toxicity of Aircraft Deicing Fluids*. Presentation to the SAE Aircraft Ground Deicing Conference, Salt Lake City, Utah, June 15-17, 1993.

14. McGreevey, T., 1990, as cited in R.D. Sills and P.A. Blakeslee, 1992. "The Environmental Impact of Deicers in Airport Storm Water Runoff," in *Chemical Deicers in the Environment*, ed. Frank M. D'Itri. Lewis Publishers, Inc., Chelsea, MI.

15. Morse, C., 1990, as cited in R.D. Sills and P.A. Blakeslee, 1992. "The Environmental Impact of Deicers in Airport Storm Water Runoff," in *Chemical Deicers in the Environment*, ed. Frank M. D'Itri. Lewis Publishers, Inc., Chelsea, MI.

16. NIOSHTIC™ *Search Results - Ethylene Glycol, Propylene Glycol.*

17. Roberts, D., 1990, as cited in R.D. Sills and P.A. Blakeslee, 1992. "The Environmental Impact of Deicers in Airport Storm Water

Runoff", in *Chemical Deicers in the Environment*, ed. Frank M. D'Itri. Lewis Publishers, Inc., Chelsea, MI.

18. SAE International, May 17, 1993. *Unconfirmed Minutes of Meeting No. 37 of AMS Committee*, Rome, Italy.

19. Sills, R.D. and P.A. Blakeslee, 1992. "The Environmental Impact of Deicers in Airport Storm Water Runoff," in *Chemical Deicers in the Environment*, ed. Frank M. D'Itri. Lewis Publishers, Inc., Chelsea, MI.

20. Transport Canada, 1985. *State-of-the-Art Report of Aircraft Deicing/Anti-icing*. Professional and Technical Services, Airports and Construction, Airport Facilities Branch, Facilities and Environment Management. Document Number AK-75-09-129. (Type I Fluid Only).

21. Verschueren, K., 1983. *Handbook of Environmental Data on Organic Chemicals.* 2nd Edition, Van Nostrand Reinhold Co., New York, N.Y.

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