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REVIEW OF THE AQUIFER SEASONAL
THERMAL ENERGY STORAGE BUILDING HVAC
SYSTEM AT THE MELVILLE, NEW YORK,
MID-ISLAND MAIL FACILITY

T. J. Marseille
D. A. Wilke

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Pacific Northwest Laboratory
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ABSTRACT

The successful widespread commercialization of aquifer thermal energy storage (ATES) in the United States will depend on the effectiveness with which the experiences gained from early full-scale systems are used as guides in the design, installation and operation of future projects. One such early system from which both anecdotal and quantitative information is available is the Mid-Island Postal Facility in Melville, New York. At this facility, built in the mid-1980s, an ATES system has been integrated with the building's central heating and cooling plant. "Cold" wells are charged with water that is cooled during the winter by heat pump and closed circuit cooler operation. Water from these cold wells is then used to meet the facility's cooling load during the summer, before being pumped back into the ground at "Warm" wells. Dehumidification during summer operation is accomplished by a liquid desiccant system that uses propane boilers to provide a heat source for desiccant regeneration. This system will also add water to the air during periods of low humidity. This paper provides an overview of the project, and describes the analysis being performed to assess energy and economic merits of this innovative system.

INTRODUCTION

The U.S. Postal Service's (USPS) Mid-Island Mail Processing Facility (MPF) is located in Melville New York. The facility (23875 m²) services a population of 2.5 million with sophisticated, computerized mail sorting equipment. Approximately 1200 employees work over the course of a 24-hour day, 7 days a week. The peak period is between 6 p.m. and 3 a.m. Monday through Friday. Various types of mail processing equipment at the facility processes approximately 5 million pieces of mail each day.

The facility was designed and built with systems to use minimum off-site energy, and a building envelope designed to achieve maximum energy savings. The facility incorporates state-of-the-art features that are

designed to be energy efficient, aesthetically pleasing, and economically feasible. Lighting for the workroom area is provided by variable high pressure sodium fixtures, each controlled by a central computer generated radio signal. The luminaire wattage is governed by USPS work program needs, and is reduced as allowable by the natural light level achieved through skylighting, which encompasses 4% of the roof. The building envelope includes white hypalon membrane roofing, mechanically fastened over R-30 insulation, and exterior walls made of insulated precast concrete.

Heating, ventilation, and air conditioning (HVAC) of the building (Figure 1) is provided by a unique combination of ground water heating/cooling with a liquid-desiccant system for humidity control. A seasonal aquifer thermal energy storage (ATES) system was designed to provide "cold" water to handle the cooling load during summer and "warm" water as a heat source for a heat pump in winter. Backup cooling is provided by the heat pump; backup heating is accomplished through modular boilers. Triethylene glycol is used as the liquid-desiccant for moisture removal from workroom supply air. The desiccant system can also add water to the air during periods of low humidity.

Conceptually, the HVAC system at the Melville MPF offers significant operational advantages over more conventional systems. Mechanical refrigeration for cooling was downsized from peak cooling load levels, and its operation schedule can be reduced. Thus, a sizable reduction in summer electric peak loading is expected relative to conventional systems, along with a decrease in total summer electrical usage. Downsizing of the HVAC equipment because of desiccant dehumidification also reduces the amount of ozone-depleting compounds such as CFCs that are required. Because the desiccant system provides dehumidification, a higher temperature (and thus higher efficiency) well cooling system can be used than in other ATES designs. Finally, the glycol liquid-desiccant system provides a much more precise control of building humidity than conventional commercial HVAC systems. Such glycol systems also are purportedly (Amsterdam 1988) highly effective at eliminating bacteri-

ological pollutants, and can help in the removal of airborne particulates.

Because of these perceived advantages and the unique opportunity for study this innovative existing application affords, the U.S. Department of Energy's (DOE) Pacific Northwest Laboratory (PNL) has entered into agreements with the USPS, the U.S. Geological Survey (USGS), and the New York State Energy Research and Development Authority (NYS ERDA) to evaluate the project. PNL is operated for the U.S. DOE by Battelle Memorial Institute.

A technical assessment of the ATES/desiccant HVAC system at Mid-Island Mail Facility has been initiated, with emphasis on predicting the operating performance and cost-effectiveness of the thermal system. This paper first describes the ATES/desiccant HVAC system installed at the USPS MPF at Melville, and then discusses the approach to be taken for the technical assessment.

DESIGN SUMMARY

- Ground Water System: Three wells supply cold water to the building during the summer, and are recharged in the winter through heat pump and closed-circuit cooler operation. Three other wells supply warm water during the winter as a heat source for the heat pumps, and are recharged in the summer by the water that has been circulated through the building (and thus warmed).
- Heat Pump: Two 352 kW chillers are operated in series to reduce supply cold water temperature from the wells as required to meet the summer cooling load. Condenser water is used for winter heating. During the winter heating season, the heat pumps also produce cold water to recharge the cold water wells.
- Closed-Circuit Cooler: A roof-top closed-circuit cooler is used to reduce warmer well water temperatures in the winter (in conjunction with the heat pumps, or alone) prior to injection into cold wells.
- Radiant Gas Heaters: Perimeter mail platforms are heated during cold periods with overhead propane gas radiant heaters.
- Modular Boilers: Back-up heating and regeneration of liquid-desiccant is accomplished through the use of modular propane boilers.
- Liquid Desiccant System: Air conditioning of workspace supply air is accomplished using "conditioners" supplied by the desiccant system manufacturer (Figure 2). Heating and cooling coils are located in each conditioner to control supply air dry bulb temperature. For dehumidification, triethylene glycol is sprayed over unit cooling coils in summer, absorbing water from the supply air stream. Water absorbed by the glycol is removed at a central liquid desiccant concentrator serviced by the modular boilers. In winter the cycle is reversed, and the liquid-desic-

cant system is used to add water to the supply air stream as necessary to increase relative humidity.

WELL DESCRIPTION

The ATES system consists of six wells, each 55 m in depth, and made up of a 0.305-m diameter (I.D.) steel casing fitted with a 15.2 m long screen, of 0.2 m diameter. The screen is surrounded by an 0.46 m diameter fine gravel envelope that extends 6.1 m above the screen for a total height of 21.3 m. The casing above the gravel pack is enclosed in cement grout. The well pump is located within the casing above the screen and within the water table at a sufficient distance to allow for draw-down. Clearance of 25 mm around the pump on all sides allows for recharge. The pump drive motor is located above the well. The subsurface in which the wells are located is comprised of glacial outwash sand and gravel sediments known as manetto gravel. The ground water table is 12.2 m below surface grade. At the level of the well screen the aquifer is classified as the upper glacial aquifer.

Wells 1A, 2A, and 3A are located on the eastern boundary of the USPS property (Figure 3). The temperature of water from these wells prior to ATES system operation has been recorded at 17.5 °C. This relatively high temperature is considered to be a result of warm water discharge into the ground from off-site wells located to the north that service air conditioners of large office complexes. Through regional flow of ground water, this discharge impacts the aquifer below the USPS/MPF. As a consequence, the warmest wells of the ATES system, (the east wells) are used as the winter supply for the heat pumps. Therefore, in summer, warm water return from the USPS/MPF is injected into the ground at these wells.

Wells 4, 5, and 6 are located on the western side of the USPS property (Figure 3). The temperature of water from these wells prior to ATES system operation was recorded at 13.3 °C. These wells are not in line with the regional flow of discharge water from the off-site wells to the north. These wells are for summer supply of cool water to the heat pumps and are reinjected with cool water during winter.

WELL SYSTEM OPERATING CONCEPT

The well system is designed to supply the USPS/MPF with cool water to meet the building cooling load during summer and warm water for heating during winter. The basic concept employed is that of seasonally storing masses of warm and cool water in separate locations in the aquifer. As it is warmed in summer, the water is injected into east (warm) wells 1A, 2A, and 3A; as it is cooled in winter, the water is injected into west (cold) wells 4, 5, and 6.

Because the building envelope is well insulated and internal heat gains caused by equipment is high, design calculations indicated that more cooling energy is required on a seasonal basis than heating. To meet the

additional cool water requirements beyond what can be produced during winter heat pump operation, water drawn from the east wells may also be passed through the roof-top closed-circuit cooler and redeposited into the west wells. The roof-top closed-circuit cooler is designed to reduce water temperatures in the winter prior to injection into cold water wells. This additional cooling capacity is required to help offset the heat loading generated by the mail processing operation to balance annual heating and cooling ground water thermal storage. Following seasonal changeover, a cool water mass should be available from the west wells for summer cooling, and a warm water mass should be available from the east wells for winter heating. The heat losses caused by (horizontal) regional water flow and vertical conduction, along with other geologic factors, limit the amount of stored heat or chill that can be recovered from the wells. As a result of the regional flow, the southernmost west (cool) and east (heat) wells have the coolest and warmest water, respectively.

The summer cooling process was designed to use 9.4 °C water during periods of highest temperature. When cool water well recovery temperatures are above 9.4 °C, the heat pumps are designed to operate as water chillers to further chill the water as required. The design goal is to be able to obtain direct cooling with well water without electric chillers at all, but this will be dependent on whether the amount of cold water stored in the previous season (less recovery losses) is adequate to meet the annual cooling load and whether recovery flow rates can be maintained at design levels. The wells were designed to supply water at 26 L/s. Maximum design system operation is for two wells (a total of 52 L/s) to be operated simultaneously. Reinjection is assumed to be to two wells when a single 26 L/s supply well is being employed by the system, and three wells for a 52 L/s two well supply to system. The design assumes wells will be pumped only as required to meet the heating or cooling needs of the building on a daily basis. Single-well operation occurs during moderate cooling and heating periods. Two-well supply operation occurs during periods of high cooling needs.

ASSESSMENT

The goal of the assessment is to develop models to predict the annual energy costs and performance of the existing HVAC system if it is operated "per design", and compare the system's economics to a "baseline" HVAC system model. Because the HVAC system at the USPS/MPF has a central chilled water loop, a conventional central system will be used for the base line model. This base line model will include a water chiller, a boiler, a cooling tower, and standard air handling units with heating coils (for supply air heating) and cooling coils (to provide both cooling and dehumidification of supply air).

For mathematical modelling, mechanical system schematics, equipment specifications, and shop drawings will be referred to, and necessary data needed to define the building envelope, equipment operating

schedules, occupancy schedules, and control modes of HVAC system will be obtained from the USPS. A limited amount of monitored electrical data, fuel cost records, and anecdotal information is also available. To the extent possible, this data will be used to support model development and validation. In addition, algorithms will be developed to model the performance of the glycol liquid-desiccant system using information provided by the manufacturer.

In the analysis of ATES systems, the coupling of the aquifer's performance with the dynamic "load" it is serving is often overly simplistic. Total annual heating and cooling load estimates typically have been used to estimate the "average" recovery flow rates from the aquifer for the entire heating/cooling season and the total "charge" of water that must be recovered over the season. Following a survey of the site, a hydrogeologic model is then developed to predict how well a seasonal ATES system can meet these requirements. The aquifer models numerically solve for the thermal response of the subsurface environment (Vail 1989), accounting for horizontal transport and vertical conduction within the aquifer. However, even if the aquifer model is highly accurate, this simplified approach to coupling the aquifer with the building can result in significant errors in predicting of system performance because it does not capture the dynamic impact of changing building loads (i.e., hourly, daily, monthly). Also, if average flow rates are used, the analysis might falsely predict that an ATES system is adequate when actually it might fail to produce sufficient flows at cold enough temperatures late in the summer, the time when peak cooling loads generally occur. An equally unsophisticated approach, and one that is often used to estimate chiller annual energy consumption for buildings with conventional HVAC systems, is the "equivalent full load hours" (EFLH) method. Results of EFLH analyses are overly conservative if cooling loads vary much from the peak. Using peak recovery flow rates to estimate ATES seasonal performance might lead to overly conservative well designs.

On the other end of the spectrum, the most sophisticated method for modeling the USPS/MPF would link an ATES computational model created to predict aquifer performance (i.e., flow rates, and heat/chill recovery efficiency) directly with a sophisticated transient simulation model of the actual building, so that the HVAC dynamic effects can be captured. Such an approach is beyond the scope of the assessment described here. Instead, PNL will precalculate hourly building loads using a building thermal model, and convert these loads to required aquifer recovery flow rates. The loads will be averaged over larger time increments (e.g., days) if desired, to match the computational time step of PNL's aquifer analysis program (Vail 1985). Leaving water temperatures from the building will be calculated by an energy balance based on predicted recovery flow rate. Using this approach, the aquifer capability at the USPS/MPF can be compared with actual required cooling and heating water flow rates. Whenever the aquifer is inadequate to meet cooling or heating needs, the balance will

be assumed to come either from increased reliance on mechanical refrigeration (cooling) or the back-up modular boiler (heating).

The building cooling and heating load information can also be used to determine operation requirements for the closed-circuit cooler. Finally, predicted latent heat loads will also provide a prediction of the annual desiccant system operation. From this, an estimate of annual energy usage for the desiccant system will then be obtained, including the propane used by modular boilers for regeneration of desiccant in the concentrator.

The economic assessment will be conducted using an analysis methodology developed by PNL for thermal storage evaluations (Brown 1987). Levelized energy costs of the ATES/desiccant HVAC system at the USPS/MPF will be compared to those for the base-line system. Operating and maintenance costs for the existing system and economic parameters used in the analysis will be provided by the USPS. Standard estimating procedures will be used to develop comparative costs for the base-line system.

An additional, supporting, investigation is being conducted by the USGS to better understand the geotechnical performance of the ATES wells at the MPF. The objectives of this investigation will include defining the local geohydrologic setting, evaluating the potential causes of well clogging, and providing general recommendations for improving overall system operation. This data will help in the development of a more accurate computational model of the aquifer, which will be used for the technical assessment.

Finally, a desiccant system operation assessment will be performed. The primary objective of this evaluation will be to identify any performance anomalies and provide recommendations (where possible) for improving and maintaining the performance of the desiccant system. This task will include on-site monitoring and analysis of existing operational data (both logs and anecdotal data) of the liquid-desiccant system. This work will also help support validation of the desiccant system performance model being created for the technical assessment.

CONCLUDING REMARKS

The ATES/desiccant HVAC system at the USPS/MPF in Melville provides a unique opportunity for an in-depth study of an innovative system that in theory offers both energy and environmental advantages over more conventional systems. The technical/economic assessment described in this paper should provide a means of evaluating the cost effectiveness of this system. Supporting studies, operational logs, and anecdotal data will also provide insights on actual performance. It is hoped that this study and the experience gained from maintaining and operating the system will help guide the evaluation of designs of similar systems in the future, both at USPS facilities and at other locations.

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Figure 1. HVAC System Schematic

Figure 2. Liquid Desiccant System Schematic

Figure 3. Well Site Details

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