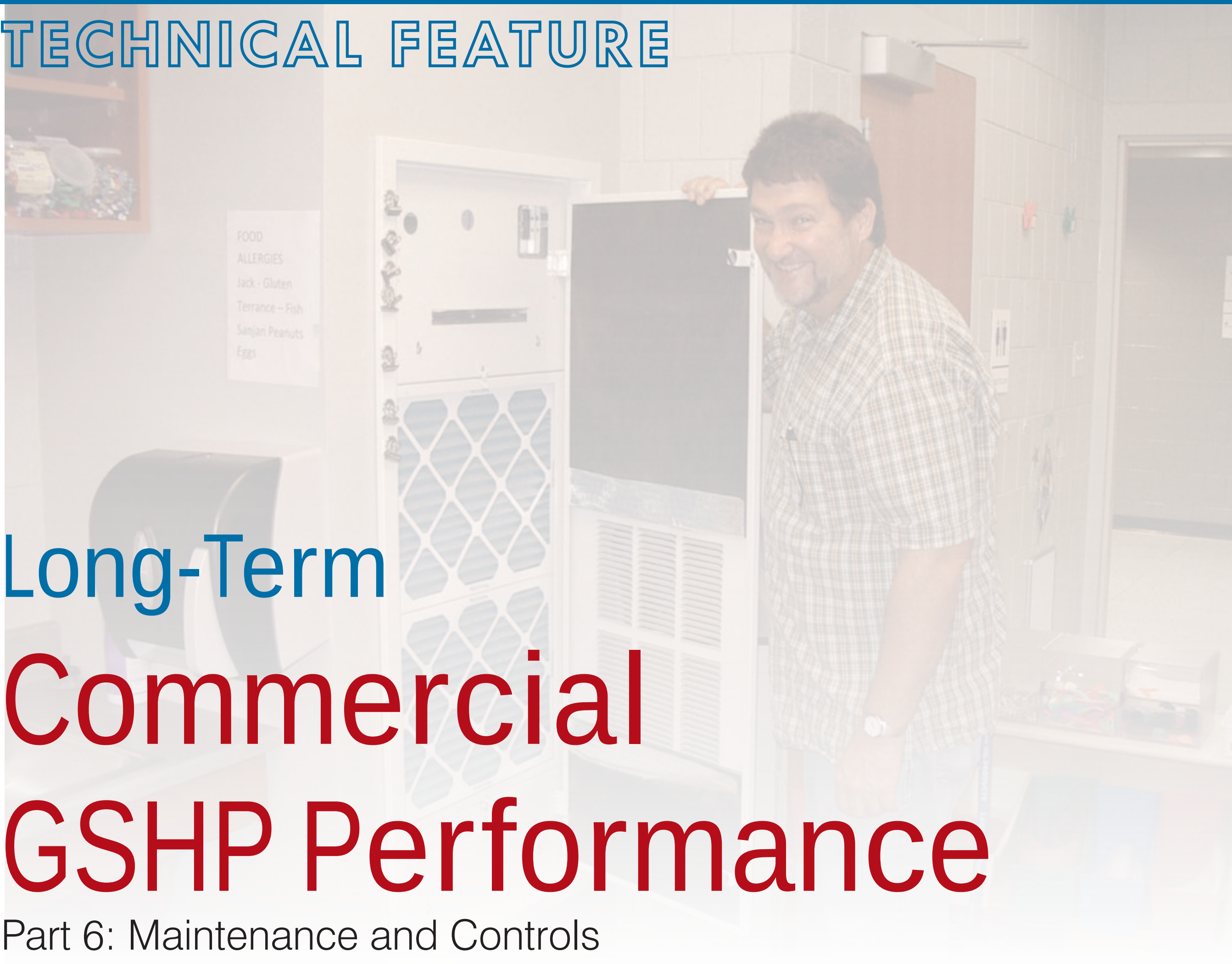
TECHNICAL FEATURE



Long-Term Commercial GSHP Performance

Part 6: Maintenance and Controls

By **Steve Kavanaugh, Ph.D.,** Fellow ASHRAE; and **David Dinse,** Member ASHRAE

This article is the sixth in a series summarizing a data collection and analysis project to identify common characteristics of successful ground source heat pump (GSHP) systems.[1] This article presents results from maintenance personnel assessments of GSHP including controls. Occupant perception of maintenance responsiveness and controls also are provided.

Maintenance Personnel and Occupant Survey Results

Near the end of this project it became apparent that many of the operation and maintenance (O&M) personnel servicing GSHPs had useful insights into the long-term performance of these systems. A survey was distributed to 15 personnel who had been assigned to serve as guides during the site visits. Maintenance and energy managers from four school districts responded. The survey consisted of providing the information in *Table 1* and spaces for responses to the following queries:

1. List the operation and maintenance advantages of GSHPs;
2. List the operation and maintenance disadvantages (or problems) of GSHPs; and
3. Provide recommendations for future GSHPs to improve O&M.

An unexpected result from the survey, shown in *Table 1,* is that a single HVAC service technician is responsible for three to eight buildings.

Occupant satisfaction with the responsiveness to maintenance issues and ability to control has previously been presented in relation to ENERGY STAR rating.[2] *Figure 1* displays the occupant satisfaction with maintenance responsiveness results by date of system installation and distinguishes results by control type. Systems with room thermostat controls had average ratings of "satisfied" and levels remain relatively constant with system age. GSHPs with building automation system (BAS) controls had slightly lower maintenance response satisfaction ratings but there is a notable decline for newer systems.

Figure 2 plots occupant satisfaction with ability to control by date of system

About the Authors

Steve Kavanaugh, Ph.D., is a professor emeritus of mechanical engineering at the University of Alabama, Tuscaloosa, Ala. **David Dinse** is a senior project manager in Technology Innovation at the Tennessee Valley Authority, Chattanooga, Tenn.

installation. Systems with thermostat controls had average ratings approaching "satisfied," but levels decline somewhat with newer installations. GSHPs with building automation system (BAS) controls had average satisfaction ratings below "acceptable" and ratings also decline for newer systems.

Location	Total Buildings	GSHP Buildings	Years of GSHP Use	HVAC Techs	Buildings Per HVAC Tech
Tennessee	29	12	16	5	5.8
Tennessee	8	2	12	1	8
Illinois	31	11	5	9	3.4
Georgia	17	10	6	3	5.7

Table 1: Number of buildings per HVAC service technicians in GSHP school districts.

Maintenance and Operation Personnel Comments

When Jeff Monahan, maintenance and construction coordinator for McLean County (IL) Unit No. 5, learned that several older schools would be converted to GSHPs, he was sure he would have to hire additional maintenance staff to deal with all the compressors. "Nothing could be further from the truth. We rarely make service calls at the older schools with the geothermal heat pumps."

The survey responses from the McLean County district, which incorporate the one-pipe building loop design, were the most positive of the four received. The advantage listed in the survey was "very low maintenance" while the main disadvantage was "our newer schools with more complex controls have been more problematic." The primary recommendation was "keep the control systems simple as they perform better."

Energy manager Bruce Boswell realizes that the ENERGY STAR ratings at the three newer schools are lower (91, 75, 75) than the ratings for the five 1950s vintage schools with thermostats (98, 98, 97, 95, 95), but he expects things to improve as he and the operators become more familiar with the controls. Monahan is less optimistic, "…with decreasing school budgets and a reduced supply of experienced technicians, why would you put something complicated in our buildings that uses more energy? The engineers are shoving these controls down our throats."

Figure 3 demonstrates equipment designs that are simple and relatively easy to service because of accessibility. Technicians Carl Foeller and Bill Thomas, who according to Monahan are "…great technicians and very smart," view the core refrigeration package (compressor, water coil, air coil and pump) of a vertical unit that can be easily removed from the cabinet. If major service is required the package is replaced and the problem unit can be serviced at the maintenance shop. *Figure 3* also illustrates the interior arrangement of a vertical classroom unit with ample access room for primary components. *Figure 4* shows the complex proprietary controls for a dual capacity water-to-air heat pump that would likely incite Monahan's ire. *Figure 4* also demonstrates the difficulty of servicing units located in ceiling spaces.

Keith Simmons, HVAC&R service technician for the Unicoi County (TN) Schools, is satisfied with the ease and frequency of maintenance with 12-year-old GSHP system at the high school. He rates the quality of system design and system installation as "acceptable." He sees the indoor location of the equipment as an advantage with fewer weather-rated failures and ease of service during extreme outdoor conditions. The more constant refrigerant pressures/temperatures and the elimination of defrost cycles are important benefits. He also feels GSHPs provide more consistent room comfort.

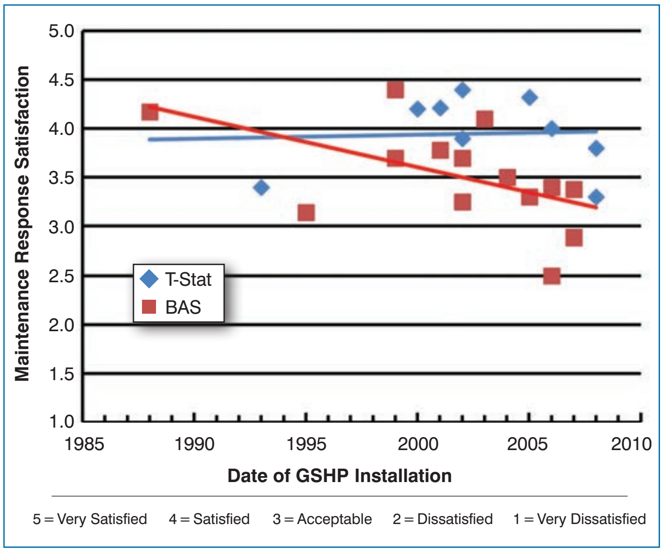


Figure 1: Occupant satisfaction with maintenance response vs. GSHP system age.

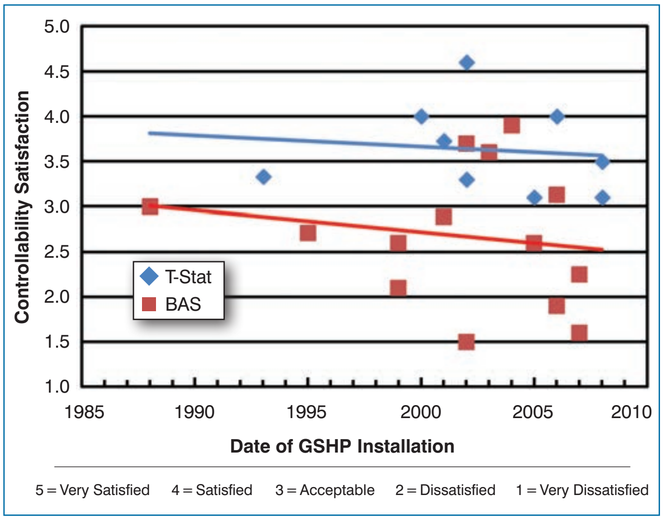


Figure 2: Satisfaction with ability to control for thermostat and building automation systems.

Simmons sees water treatment and corrosion issues as a primary disadvantage. He expressed the common complaint that units are often located in restricted spaces where servicing is difficult with equipment that has many components inside small cabinets. His suggestions include:

- Service technicians should be consulted when specifying equipment brands based on their experience.
- Adequate valves are needed for isolating wings of buildings and individual units in the event of water leaks.
- More space should be provided in equipment cabinets and rooms so that units can be serviced without removal of unaffected components.
- Standard filters should always be used since custom sizes are much more expensive.

Although, the ground loop at the high school performed well the ENERGY STAR rating was only 59. Simmons' insight provides clues to this result.

"The VS drive on the loop pump has never operated below 95%. The control of the fresh air system has always been a source of problems. The system stays in alarm more often than not. The factory service technician worked on the system in the second year of operation, but it didn't help much. Also, the dressing room area of the gym is poorly heated, and there is no cooling other than the fresh air system. It is a glycol loop, which has never provided the design heat transfer. Backup is provided by an electric resistance duct heater. This was on ongoing issue between the engineer and others involved. Twelve years later it is still not correct."

Figure 3: Service-friendly heat pump package (left). Classroom unit with room for service (right).

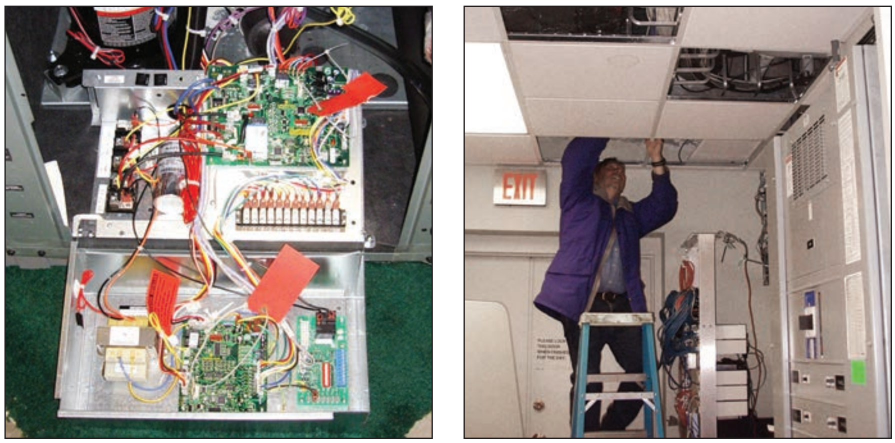


Figure 4: Control circuits for "advanced" heat pump. Unit in difficult-to-service location.

Mitchell Gravitt, energy coordinator for the Catoosa County (GA) Schools sees the overall lower energy use in GSHP schools as the primary advantage. He cautions that these savings "…can be reduced with the cost of water chemical control, pump repair/replacement, VFD operational issues, and piping leaks. One of our systems includes a cooling tower and this is a maintenance cost."

The energy use and maintenance requirements of the GSHP systems in the district have varied from good to poor. So Gravitt recommends, "Quality check the engineering calculations that determine the system thermal load to ensure the ground loop is sufficient. Cooling towers are an option but maintenance cost should be considered up front. Continued improvement in piping installation and material is needed to reduce the chance of leaks."

Gary Basinger is one of five HVAC technicians serving 29 buildings for the Washington County (TN) Board of Education. Twelve buildings have GSHPs and the oldest installation served as a site for multiple "lessons learned" that helped improve newer systems. This first GSHP system at a large high school has had higher than expected energy use, multiple service issues, and control problems since its installation in 1995. The GSHP system replaced an R-11 chiller and electric heat. In the first full year of operation, the building total electrical usage was 2,298 MWh as opposed to an average of 3,481 MWh per year for the two years prior to the retrofit. This amounted to a 34% annual savings.[3] Encouraged by these results, water-to-air heat pumps replaced air-to-air units during a recent renovation and expansion but the ground loop was not enlarged. The school system now has twelve GSHP systems that incorporated lessons learned from the first installation.

Figure 5 demonstrates one of the necessary solutions to problems that result when maintenance is not a primary design consideration. A heat pump was installed in a confined space above a lighting fixture and sprinkler pipe. This prevented access to the side panel when the fan motor failed. Motor replacement necessitated removal of the entire unit. When the motor failed again a few years later, Basinger cut out the drywall blocking the panel access. "They could hang a picture over the hole if it bothers someone, but they were happy the unit was repaired quickly."

Basinger likes the fewer components in the self-contained units and the absence of outdoor condenser units and fan motors. He feels no auxiliary heat is necessary when units are properly functioning. There are instances in which auxiliary

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Figure 5: A solution for lack of service access to problematic fan motor.

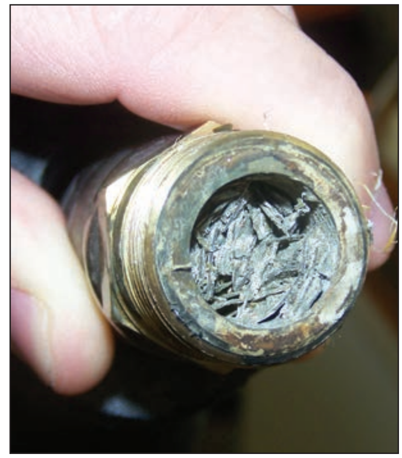

Figure 6: Results of failure to maintain water chemistry in two steel pipe building loops.

heat would be useful during emergency situations due to lack of personnel to repair multiple units in a large complex. He echoes many of Simmons' sentiments including:

• Minimum clearance specifications accommodate proper unit servicing is essential;

• Water treatment is necessary to minimize blockage of heat exchangers and water lines;

• Isolation valves are needed to clean strainers without draining the system; and

• Custom air filters for some equipment is an unnecessary expense.

He adds that the heat pumps have slow recovery time because the high school system does not preheat the outdoor air. "The high and low water temperatures in extreme hot or cold weather causes lost efficiency or failure of equipment."

Basinger realizes the extreme loop temperatures in the high school system are a result of a relatively small ground heat exchanger (113 ft/ton [10 m/kW]) and vertical bore spacing (15 ft [4.5 m]). He also recommends that the size and spacing "of the vertical piping be sufficient to allow proper dissipation of heat/cool into surrounding areas." He encourages the use of high density polyethylene (HDPE) inside the building to minimize the problems with blocked strainers and mineral buildup. His final recommendation is to conduct "very close inspection of installation as it progresses."

Basinger's perspective on BAS is upbeat. "In the ever-changing world of technology, controls are becoming necessary. We have recently entered into a contract with an energy management company that requires the building to be shut down or placed at an energy demand temperature. Each time we receive a call from the contractor we have 20 to 40 minutes to prepare for this event. This is accomplished online with the assistance of our control companies without the need to visit every school. Understanding and being able to utilize control systems is becoming vital to increase energy savings as we continue to change with the times."

Results presented in a previous article[4] indicate only one of the 14 variable speed pump drives (VSDs) observed during the project was functioning properly. *Figure 6* includes photos that provide some insight into a possible reason for this result. The photo on the left was taken at a site in which the interior piping was a combination of PVC, steel, and copper. PVC tees regularly cracked at the mechanical copper connection and piping sections in which failure occurred could not be isolated. Maintenance personnel were preoccupied with keeping the system operating and were not able to keep up with the constant need for chemical treatment. The photo on the right demonstrates a plugged 0.5 in. (13 mm) hose connection at an office. The owners were not aware that water chemistry maintenance was required. At both sites it is likely that ports to differential pressure sensors for the VSDs were also plugged.

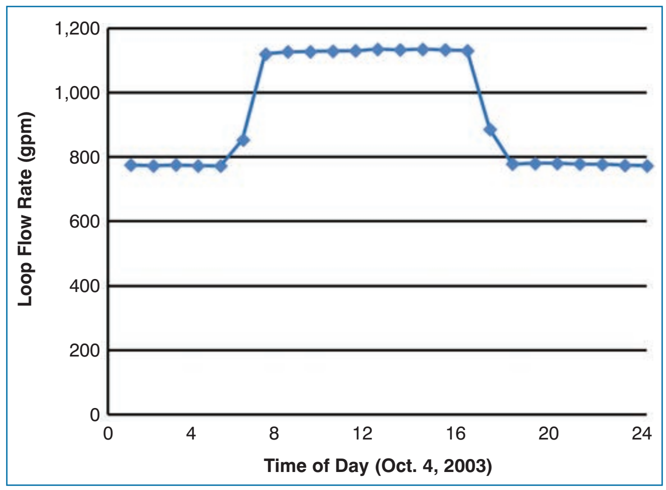

Figure 7: Flow rate with two-way valves interlocked with fans rather than compressors.

Examples of Typical Operation Issues

In one variable speed pump system with two-way valves on the individual heat pumps, very low differential temperatures and warm loops were experienced. Observation with an ultrasonic flow meter indicated continuous operation at full speed while the school was occupied and 70% flow at night as shown in *Figure 7*. It was discovered that the two-way valves opened with the continuously operating supply fans rather than with compres-

sor operation essentially making the system two-speed with the minimum flow being the bypass when the fans shut down. The controls were re-programmed but a later site visit determined the pump continued to provide excessive flow at part load.

In another system that experienced high humidity, the sequence of operation specified that the exhaust fans be operated only when the building was occupied. Investigation revealed that the fans were operating continuously and dedicated dehumidifiers connected to the ground loop were dysfunctional.

A third system with a variable speed drive experienced frequent heat pumps trip outs. Investigation revealed the supply pipe diameter to each heat pump was reduced to accommodate smaller control valves as shown in *Figure 8*. The problem was mitigated when the full line size piping and valves were installed.

Figure 8: Reduced line size control valve caused flow problems.

Summary and Conclusions

• For the four school districts that returned survey forms, each mechanical service technicians is solely responsible for three to eight building HVAC systems.

• Maintenance personnel generally have the opinion that their experience and perspective are not adequately considered when designing GSHP systems.

• Water treatment issues, interior piping corrosion, and plugging of strainers and heat exchangers are significant problems in buildings with steel interior piping.

• A common complaint is the failure to provide adequate space to service heat pump units.

• Occupants are generally satisfied with the response to GSHP system maintenance issues.

• Building automated system (BAS) controls do not appear to be operating as intended since they received multiple complaints from maintenance personnel, use more energy than room thermostat systems,[5] and received occupant satisfaction ratings below "acceptable."

• The long-term performance of outdoor air equipment, control methods, and airflow rates should be thoroughly reviewed since they significantly affect comfort and energy use.

• The system sequence of operations should be clearly written, easily understood, and verified during startup, final inspections, and periodically reviewed.

• Care should be taken in specifying and approving equipment and components to avoid unnecessary flow restrictions in the piping systems.

• The size and experience level of the maintenance personnel staff should be an important design consideration when selecting equipment, piping materials, controls, and determining equipment location.

• Experienced maintenance personnel recommendations are a valuable but often overlooked information source for enhanced GSHP system performance.

The project was made possible with a tailored collaboration through the Electric Power Research Institute (EPRI), with the Southern Company (SoCo) and the Tennessee Valley Authority (TVA) providing the funding. Project direction and collaboration were provided by Ron Domitrovic (EPRI) and Chris Gray (SoCo).

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