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Jeff Hammond looks into pressurized and non-pressurized flow center types on page 14.
Courtesy of WaterFurnance International

William L. Buck Elementary School in Valley Streams, NY, a 63-year-old school, was retrofitted with a geothermal heat pump system and saved the school thousands in heating costs.
Courtesy of William L. Buck Elementary School
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It’s hard to believe we are closing out the first quarter of 2017 already. The year 2016 was a year of changes and challenges at IGSHPA, but those challenges were met head-on by the IGSHPA staff and IGSHPA Board of Directors to ensure we are meeting the needs of you, our members.

As my student workers and I took on this role of redesigning the industry magazine, we have been blessed with industry leaders and partners who have been willing to provide content for the magazine. We could not have pulled off this endeavor without the support of the industry. One of our goals with the redesign was to have articles of relevance for the different industry sectors throughout the year. We will continue striving to meet that goal in 2017.

As excited as I am about the magazine in 2017, I am even more excited about what is to come for IGSHPA in the upcoming year. The staff is energized and looking forward to the 2017 IGSHPA Conference and Expo in Denver. With 45 presentations from all over the world in the research track and 36 general sessions over the course of three days, this conference has a mix of sessions to meet everyone’s needs. We will be rolling out new training courses during the conference and will be offering them over the course of this year and we will be continuing to look at the services we offer our members.

Join us on this journey as we continue to promote the industry in 2017.

Sincerely,
Erin Portman

Writing my last update for Geo Outlook as IGSHPA Board President is rather bittersweet. I will not miss the deadline, but the experience of working alongside some of the best people in our industry these past two years, and getting to highlight their hard work, has been a privilege. These people include my fellow Board members, our committee chairs and their committees, and our staff and Dean Kirtley, just to name a few.

This month our membership will elect two new directors to replace Jack Heinrich and me. We will have new faces on the Board in the GHEX and Dealer/Contractor sectors. As I mentioned in the “Loop” recently, the yearly opportunity for any member to run for open positions on the Board is dictated by our bylaws, and guarantees that the composition of the Board will change with our membership and its needs through time.

The new Board will have a lot of work on its plate when it has its first meeting in Denver. Some of the important issues that need to be tackled this coming year include:

- Supporting GEO, NGWA and other industry groups in working to correct the Federal tax decision that left ground source without the credits that were extended to other renewables in 2015
- Activating members in all 50 states to become part of a coordinated IGSHPA advocacy effort
- Continuing the effort to refurbish our existing training programs and create new courses
- Supporting and nurturing our International chapters
- Continuing to support the development of standards—in particular our ongoing work with the Canadian Standards Association

These are just a few of our challenges, and each will require many volunteer hours to compliment the excellent work of our staff.

I want to close by thanking our membership for continuing to be a part of IGSHPA and encourage you to be involved. It is only through your ongoing financial and volunteer support that IGSHPA can achieve its mission of promoting the widespread adoption of ground source heat pumps. See you all in Denver!

Sincerely,
John Turley
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Speakers from NYSERDA and other state agencies, leading designers and installers, national and international geothermal experts headline this event which in 2016 drew participants from 111 different communities in 25 states, 4 provinces and 5 countries. The first night dinner includes a keynote speaker, and both days allow time to mingle in the Exhibitor Area with leading product manufacturers, distributors and service providers.

Register Now - go online to http://ny-geo.org/pages/2017-registration!

MOU Signed with Virginia Geothermal Heat Pump Association

IGSHPA is pleased to announce the recent signing of a Memorandum of Understanding with the Virginia Geothermal Heat Pump Association, continuing on the path IGSHPA started last year by signing state-by-state MOUs.

IGSHPA and VGHPA recognize the associations serve common interests in promoting the ground source heat pump industry; growing the market share of ground source heat pumps in the HVAC industry; promoting, training and certification of ground source heat pump installers of residential and commercial systems; and creating business opportunities for the different sectors of the ground source heat pump industry.

“The Virginia Geothermal Heat Pump Association is excited to establish a formal working relationship with IGSHPA,” said Richard Lay, Executive Director of VGHPA. “The Commonwealth of Virginia and the country as a whole share similar needs. Energy security, lowering pollution and greenhouse emissions, as well as reducing the demand on the existing power grid now and in the future are of paramount concern. Implementing ground source heat pump technology does more to address these state and national issues than any other single solution can.

“Rapid deployment is the goal, coordination of our efforts is the answer.”

Roshan Revankar, IGSHPA Acting Executive Director says, “By partnering with state associations like Virginia, IGSHPA continues to grow our efforts by tackling local barriers and ensuring statewide adoption of ground source heat pumps, thereby, creating business opportunities for our growing membership.”
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Be Part of the Geothermal Surge!
Our world is moving towards a low-carbon future, driven by a combination of consumer demand and government regulation. For those of us who consider ourselves environmentalists, it may seem too little too late, but there may be positive movement.

Most of the focus has been on efforts to displace the combustion of coal as a primary method to generate our growing demand for electricity, although other trends include calling for more ‘net zero’ buildings. This vision has been driven almost exclusively by the solar photovoltaic industry, which wants to install panels onto a building’s exterior to generate the same amount of electricity as the occupants need over the course of a year.

This strategy usually hinges on matching production and consumption of electricity only, overlooking the energy needed for significant temperature applications in a building: space heating, space cooling and water heating. Most of our demand for temperature energy is supplied from high-carbon sources like natural gas, which emits half the level of greenhouse gas as coal. In the average U.S. home, temperature energy consumes 65% of the buildings total demand while 35% is needed for plug-load of appliances and lighting; in Canada, colder weather means temperature applications account for 85% of energy demand in the average home.

Consumer interest in moving their homes towards a ‘net zero’ level presents a golden opportunity for the heat pump industry to position itself as leaders in a holistic perspective of energy. If occupants can appreciate that temperature is a larger portion of the pie than plug loads, and temperature energy is almost always ‘dirtier’ than plug loads, they will grasp the concept of a heat pump.

This vision was part of my rationale for retrofitting my own home in rural Ottawa over the past decade. I realized that I could not only save money and lighten my environmental footprint, but also prove that buildings anywhere can become more sustainable.

I have worked in the renewable energy sector since 1986, serving national associations for solar, wind and earth energy as well as promoting climate change action for the UK and training under Al Gore’s Climate Reality initiative. When we found a 3,500 ft² house in the rural part of Canada’s capital city, my wife swooned over the interior features such as deep window sills, while I salivated over the double-wall construction that faced due south along the rapids of the Jock River.

Eggertson installed the 3,500 square foot home’s horizontal loops in early winter.

Courtesy of Bill Eggertson
The house was constructed 30 years prior to our move-in but the builder-owner had died before the structure was completely finished, leaving his widow unaware that the poorly-insulated attic was responsible for her high costs for propane heating and electric air conditioning.

My first task was easy: seal the envelope as tightly as possible, add a lot of insulation, incorporate a heat recovery ventilator, and install triple-pane windows filled with Krypton gas. We planted numerous trees, installed low-flow toilets, water aerators and FSC-certified teak flooring, complied with LEED guidelines (we could not register because the home renovation standard did not exist in Canada yet), and applied to be the first microFIT solar array in eastern Ontario to take advantage of the province’s buy-back rate. (We also installed an Energy Star metal roof to increase the output efficiency of the panels.)

I was an early adopter of LED, and much of my house now relies on 12 volt lighting strips which not only consume as little as 3 watts, but allow me to power the strips off a battery storage system that is the emergency backup for my sump pump and critical load. As a survivor of the ice storm of 1998 and the grid blackout of 2003, my overall goal was to increase resiliency and lower my vulnerability to future natural or anthropogenic disasters.

This investment of time and money rated my home as one of the top 20 houses across Canada for energy efficiency under the National EnerGuide for Houses program. Although my EGH score of 90 is reasonably easy to achieve in new home construction, part of my goal was to show that older buildings can also decrease energy consumption and their related carbon emissions. Our utility has time-of-use electricity rates, and my thermostat is programmed to turn off the heat pump at 7 a.m. on cold winter mornings and remain off until 7 p.m., which means that only 5% of electricity I consume is in the peak rate period.

My obsession with tinkering to raise the bar on my own house, combined with my involvement in solar electricity, was one of the factors which led to my development of the ‘Net Zero Plus’ concept that was approved last year by the directors of IGSHPA Canada.

Across Canada, the average household (reflecting all occupied dwellings from suburban mansion to tiny high-rise loft) consumes about 30,500 kWh of energy each year\(^2\), of which 4,900 kWh is for plug load and 25,600 kWh is for temperature applications. Since a Net Zero Heat Pump (NZHP) will produce the 25,600 units of renewable energy from the ground (but increase plug load by 7,800 kWh to operate the NZHP), it is easy for the solar industry to see they can install panels to generate 30,500 kWh for the year, or 12,700 kWh for the year if the house has a NZHP.

By including any technology or application which reduces temperature or plug load (as I demonstrated by more insulation and superior windows, to LED lighting and motion sensors), the house reduces unnecessary consumption and replaces the remaining balance with ‘clean’ energy which benefits the grid and the environment as well as the homeowner.

The same concept is applied to the commercial or institutional sector, where energy storage and internal load balancing can boost the efficiency and lower the cost of any structure.

The NZHP industry has long promoted its value as a technology to reduce consumption of energy, both in residential and in commercial/industrial buildings, and to decrease op-
erating/maintenance/lifecycle costs. We brag that our system displaces the need for new generating capacity from dams, nuclear reactors and gas plants, so less high-voltage transmission lines are needed across the landscape. Some people recognize that our installations have a greater positive impact on local employment and our invisible systems eliminate any “not in my back yard” opposition, while we reduce the risk of pollution and explosion, increase occupant comfort, and flatten the demand curve for utilities. The decentralized nature of our technology and its reduced impact means we help to avoid confrontation on Indigenous land issues.

But the NZHP industry has failed to stress that our systems also produce renewable energy, in a form that is more dispatchable than solar or wind. Our ability to dispatch renewable energy on demand is a key element for municipalities that want to become a Smart City or adopt ‘100% renewable’ targets. NZHP technology is critical if politicians are serious about electrifying the economy to reduce GHG emissions, and especially if the goal is to convert all cars into electric vehicles. Ask any owner of a Tesla or a Chevrolet Volt about the quantity of ‘fuel’ their car consumes, and see what they say.

The ground source/earth energy/GeoExchange™/geothermal heat pump industry has suffered from confusion in the marketplace over our technology and our terminology. Now that consumers and politicians care about energy and the environment, and they concede that terms such as green, renewable, sustainable, environmental, low-carbon and net zero are laudable adjectives, the NZHP industry needs to demand credit for the renewable energy we produce and the myriad of downstream benefits we provide.

End Notes:
2 - Occupational Health and Safety Tribunal Canada http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ca&rn=2&page=0

Bill Eggertson has been involved in renewable energies since 1985, promoting solar, wind and earth energy with national associations and international publications. He is also a leading official in the climate change debate, and was selected as a torchbearer in the 2010 Olympics for his contribution to environmental sustainability.
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The residential geothermal heat pump industry has divided into two camps over the last couple of decades for residential flow center preference: pressurized and non-pressurized. By definition, a flow center is a device that pumps fluid between the ground heat exchanger and the heat pump, and provides connections for a flush or purge cart to remove air from the loop piping system.¹ The terms “pressurized” and “non-pressurized” when referring to a geothermal ground loop system, indicate whether there is static pressure on the ground loop and heat pump system. Static pressure is the pressure measured when the pump(s) is not operating.

The circulator pumps used in flow centers require a pressure at the inlet (suction side) that exceeds a minimum level established by the pump manufacturer. In technical terms, the net positive suction head available (NPSHa) of the system must be greater than the net positive suction head required (NPSHr) by the pump. This positive pressure for pressurized systems is induced and captured in the system during start-up/installation by an external pressure source (usually a high-head pump on a flush cart). A positive static pressure is not applied to the ground loop system in a non-pressurized system. Instead, a standing column of water is used to meet the minimum suction pressure requirement of the pump.

So, why two choices? Both types provide positive suction pressure to the pump(s). Some history of early flow centers may be in order to help explain how the industry has evolved, and why there are two types of flow centers.

**THE HISTORY²**

In the late 1970s and early 1980s, most contractors in the industry installed standard hydronic components as part of a pressurized system, similar to the flow center pictured in Figure 1. While these components worked as designed, the condensation that formed during heating mode operation in colder climates caused the steel expansion tank to rust, and prematurely fail. In addition, the many threaded connections tended to leak over time with the wide swing in ground loop temperatures from winter to summer. In the late 1980s, the industry moved from polybutylene pipe to high density polyethylene (HDPE) pipe. Due to the high rate of thermal expansion of the HDPE pipe, many industry practitioners concluded that an expansion tank was no longer needed, especially for residential and light
commercial applications. During this time, the “hydronic specialties” (expansion tank, etc.) were removed from most flow centers, as shown with the mid-1980s flow center in Figure 2.

Since HPDE pipe expands and contracts, it behaves like an expansion tank. However, since the pipe expands more quickly than the fluid as temperature increases, the system pressure drops in the summer. In addition, HDPE pipe is viscoelastic, which means it will stretch but not return to its original shape. Unfortunately, these characteristics create a situation where the loop pressure can drop too low, potentially leading to a “flat loop” (i.e. zero pressure). A flat loop can cause the heat pump to shut down due to low or no water flow, and can lead to premature pump failure. The biggest issue with decreasing loop pressure is air bubbles that remain in the system after system startup (i.e. flushing/purging), or introduced when performing system maintenance (such as replacing a pump), expand to much larger air bubbles as the system pressure decreases. Large air bubbles circulating in the system have the potential to cause noise in the building, could air lock a loop circuit, and could air lock the circulating pump, which could lead to both system shut down and pump failure.

As contractors became frustrated by call-backs due to flat loops, some started building reservoirs or tanks to help reduce service calls, and to provide some volume for loop expansion and contraction over the seasons. Geothermal heat pump and flow center manufacturers started building non-pressurized flow centers as another option for geothermal systems in the 1990s. Figure 3 shows a typical modern-day non-pressurized flow center, along with an illustration of components inside the cabinet. A non-pressurized flow center uses the weight of the water to provide the necessary NPSHr for the pump. Almost all pumps used in flow centers are wet rotor circulators, which require very little suction pressure, typically around 1 psi [69 mbar] or less. Therefore, a tank with about 2.3 feet [70 cm] of fluid above the pump inlet provides the required NPSHr. Plus, the air space at the top of the tank allows expansion and contraction (i.e. the pipe contracts and water level rises, compressing the air; the pipe expands and water level falls, decreasing pressure in the air space), essentially operating as an expansion tank. The volume of fluid in the tank negates the effects of HDPE pipe expansion, providing additional fluid when needed, and avoids the “flat loop” service call, provided that air has been purged from the system, and there is adequate fluid in the tank.

**TODAY’S CHOICES**

Over the past ten years, more industry veterans have started to revisit expansion tanks for residential pressurized systems. Larger commercial applications have typically been designed with an expansion tank, and in most cases, an air separator, automatic air vent, and other hydronic system devices. Figure 4 is a picture of an HDPE bladder-type expansion tank for residential applications. The addition of a bladder-type expansion tank helps minimize flat loops by
providing some reserve fluid in the summer when the pipe expands. With today’s choices available for pressurized and non-pressurized flow centers, the contractor can choose the system that works best for the application. Most non-pressurized systems are closed systems (i.e. the tank is not open to the atmosphere), providing a viable alternative to pressurized flow centers for residential installations. Figure 5 provides examples of typical pressurized and non-pressurized flow centers.

ADVANTAGES AND DISADVANTAGES

Contractors today use both pressurized and non-pressurized flow centers. In some cases, the choice is determined by application constraints; in other cases, it’s based upon customer preference or other factors that provide an advantage for one system over the other. Below are the main advantages and disadvantages of both technologies.

Pressurized flow center advantages:

• Does not require or encourage monitoring or maintenance by the homeowner after initial system start-up.
• Pressurized flow centers are generally much smaller in size, thereby requiring less space for installation.
• Ensures a closed system, which prevents air and/or debris from entering the system after installation.
• Includes 3-way isolation/flush (purge) valves.
• Pressurized flow centers have fewer limitations on installation locations and orientations than non-pressurized. For example, pressurized flow centers have no practical limitation on unit placement below the heat pump or loop field. Also, they can be installed in relatively confined spaces such as a crawlspace, closet, or very small mechanical room. They can be installed vertically or horizontally (12-, 3-, 6-, and 9-o’clock positions), providing installation flexibility exists.
• Flow centers can be plumbed in series or parallel.
• Provides single point isolation location between the ground loop and heat pump (via the 3-way valves).
• Plumbers as well as hydronic technicians are very familiar with pressurized systems since most hydronic (i.e. hot water heating, radiant floor heating, solar, hot water, etc.) systems are pressurized.

Pressurized flow center disadvantages:

• No built-in provision for air elimination. Therefore, if the installation technician does a poor job of flushing air from the ground loop, it will remain in the system. This could lead to issues with noise and/or air-lock of the pump under certain circumstances. Some contractors choose to install air eliminators to pressurized systems to alleviate concern.
• Thermal expansion (during cooling season, i.e. summer) and contraction (during heating season, i.e. winter) of the ground loop piping causes pressure fluctuations in the system. The loop pipe will slightly stretch and relax over time which causes a decrease in system pressure. If the initial system start-up pressure is not high enough to overcome this relaxation of the pipe, the system pressure can drop below the required suction pressure of the pump (NPSHr), causing pump cavitation, which could lead to pump failure. Some installers choose to install an expansion tank in pressurized systems to alleviate this concern.
• Poor installation practices (e.g. small leaks in the ground loop or inside plumbing) result in decreases in system pressure over time, which can lead to low pressure, and potential air lock/pump failure.
• Generally, do not allow homeowner maintenance or interaction with the system. Fluid/pressure can be added to the system via the pressure/temperature ports, but this is typically only performed by a qualified service technician.

Non-pressurized flow center advantages:

• Standing column of water provides necessary suction head for pump, so that the static pressure on the ground loop is not a concern.
• Column of water on suction side of pump prevents air from being drawn into pump (as long as the fluid level remains at an appropriate level), eliminating the chance of air-locking the pump.
• Provides air elimination function.
• Provides expansion tank function.
• Allows homeowner to add make-up fluid to tank if the level gets low.
• Poor installation practices (incomplete flushing, small leaks in piping, etc.) can be tolerated due to the ability for the homeowner to add make-up fluid.
• Pump replacement is much easier, since the system does not need to be re-flushed.

Non-pressurized flow center disadvantages:
• Can be used as a “bandage” to cover up poor installation practices (incomplete flushing, small leaks in piping, etc.). May require continuous fluid level monitoring from the homeowner.
• Allows homeowners to access ground loop fluid. This could cause issues with the antifreeze being diluted or the wrong antifreeze being added to the system.
• Significant water level decrease in the flow center tank (standing column) reduces the positive suction head pressure on the pump increasing the chance of pump cavitation and pump failure.
• Larger size requires more space for installation.
• Flush/purge valves may not be incorporated (in some manufacturers’ systems). So, they must be field fabricated and/or installed.
• Limited installation locations (piping is typically limited to about 30 feet [9.1 meters] above the tank) and orientation (flow center tank must remain vertical).
• May require additional ball valves to be field installed to isolate the heat pump from the ground loop (on some manufacturers’ systems). In general, cannot be installed in series or parallel.

So, Which Flow Center Is Better?
The fact is even the very best system will perform poorly if it is not applied and installed properly. This is true of both pressurized and non-pressurized flow centers. Conversely, both types will perform well when installed according to manufacturer and IGSHPA guidelines. Ultimately, the installation contractor or building owner will decide which system is best for them.

End Notes:
1. ANSI/CSA C448.0-16, Design and installation of ground source heat pump systems for commercial and residential buildings.
2. Based upon the author’s experience in the industry since 1986.
3. 1 psi = 2.31 foot of head [1 bar = 10.2 meters head]

Jeff Hammond is currently the Director of Business Development and Marketing at Geo-Flo Products Corporation, a manufacturer of flow centers and accessories for the geothermal heat pump and hydronics industries. He started with the company in 2012 and has been in the geothermal heat pump industry for over 30 years. Previous to Geo-Flo, he was at Enertech Global for five years, ClimateMaster for nine years and WaterFurnace International for 12 years. Hammond’s experience in the industry consists of positions in R & D, engineering, product management, training, sales, and marketing. His education includes a bachelor of business administration from the University of St. Francis and an associate of applied science in electrical engineering technology from Purdue University. He has been a member of ASHRAE (American Society of Heating, and Air Conditioning Engineers) since 1990 and has served on CSA (Canadian Standards Association), AHRI (Air Conditioning, Heating, and Refrigeration Institute), and IGSHPA (International Ground Source Heat Pump Association) marketing, technical and advisory committees.
Canada

Direct government grants for the installation of Net Zero Heat Pumps are not necessary and could be harmful to the industry, says the Canadian Chapter of the International Ground Source Heat Pump Association (IGSHPA Canada).

The 120,000 ground-coupled systems installed across Canada already produce 3 million kWh-e (kilowatt-hours equivalent) of renewable energy each year. Net Zero Heat Pumps can reduce greenhouse gas emissions to zero, and their low baseline demand for electricity avoid the need for new generating facilities and more high-voltage transmission lines across the country.

“Net Zero Heat Pumps are a totally dispatchable source of renewable energy and, like other sources of renewable energy, they should receive compensation for the energy they produce, not for physical installations,” says Bill Eggertson, Executive Director of IGSHPA Canada. “Regulatory policy should mandate lower tariffs to system owners in recognition of the numerous benefits from installing this technology in the ground.”

The average household in Canada consumes 30,500 kWh of energy each year, according to federal data, of which 4,900 kWh is for appliances and lights while 25,600 kWh is for temperature applications of space heating and cooling, plus domestic water, which are the applications met by a Net Zero Heat Pump.

“Systems can be programmed to run in off-peak periods of electricity pricing, so owners should receive an additional discount for off-peak use which is a major benefit to electric utilities,” adds Eggertson.

In areas where the electricity is carbon free, a building can be classified as ‘zero emission’ and can qualify for carbon credits, as well as avoid any carbon tax. IGSHPA Canada is leading a campaign to develop a ‘greentherms standard’ (similar to the EU-27 directive that requires a percentage of temperature energy to come from renewable heating) and to explain the Green Heat concept that 83% of energy consumed in Canada’s homes are for temperature applications.

“A Net Zero Heat Pump is the core of any green building or Smart City, and key to any city aiming for ‘100% renewable,’” adds Eggertson. “By working with other stakeholders in the energy and environment industries, Canada can finally transition to a Net Zero Plus nation.”

Sweden

The IGSHPA Sweden team has for some time been planning a common trip to the IGSHPA Conference in Denver. Many people are planning to attend, both from the academy and the industry.

We will attend the conference and the workshop Understanding Grouting Applications and Innovations during our trip. It will be interesting to know how grouting is done in the US. We are exited to come and visit and also happy to be able to exchange experience with drillers, manufacturers, engineers and academics during this trip. We will also be happy to tell you about Sweden, our large experience with GSHPs, and the activities we have done in our chapter. Read more at www.igshpasweden.com
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- Geothermal
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- Heating appliances and equipment
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OSHA’s New Silica Rule
Understanding the rule and having a plan can keep workers safe

By: Jerome E. Spears, CSP
Reprinted from Water Well Journal’s December 2016 issue with permission of the National Ground Water Association. Copyright 2016

Silica dust is hazardous when small particles are inhaled. These dust particles can penetrate deep into the lungs and cause disabling—sometimes fatal—lung diseases, including silicosis and lung cancer as well as kidney disease.

Silicosis was listed as the underlying or a contributing cause of death on more than 1,100 death certificates from 2005 through 2014 in the United States (Centers for Disease Control and Prevention, 2016).

Most deaths from silicosis, however, go undiagnosed and unreported. Likewise, the number of silicosis deaths do not include additional deaths from other silica-related diseases such as COPD (chronic obstructive pulmonary disease), lung cancer, and kidney disease.

While the number of silicosis cases has declined over the past several decades, more workers died from silicosis in 2014 than in fires or being caught in or crushed by collapsing materials like trench and structure collapses (Bureau of Labor Statistics, 2014).

According to the Occupational Safety and Health Administration, about 2.3 million people in the United States are exposed to silica at work. To address occupational exposure to respirable crystalline silica that can be inhaled or breathed in, OSHA has promulgated new silica standards that significantly reduce the amount of silica dust workers can be exposed to on the job.

Understanding the major provisions of OSHA’s new Silica Rule is the first step towards compliance and protecting the health of workers.

WHAT IS SILICA?
Silica is a compound composed of silicon and oxygen (SiO2) and exists in crystalline and amorphous (having no distinct form or shape) states, both in the natural environment and as produced during manufacturing or other processes.

Quartz is the most common form of crystalline silica and accounts for almost 12% by volume of the earth’s crust. Quartz accounts for the overwhelming majority of naturally found silica and is present in varying amounts in almost every type of mineral. Thus, quartz is the most prevalent form of crystalline silica found in the workplace.

Cristobalite is a relatively rare form of crystalline silica—associated with volcanic activity. Cristobalite can be created during some processes conducted in the workplace. Quartz converts to cristobalite at a temperature around 2,700°F. Around 3,100°F, cristobalite loses its crystalline structure and becomes an amorphous fused silica.

Note that OSHA’s new silica standard applies to exposure to respirable crystalline silica, not amorphous silica.

INDUSTRY USES
There are more than 30 major industries and operations where exposures to crystalline silica can occur. They include diverse workplaces such as foundries, dental laboratories, concrete products, and paint and coating manufacturing. Crystalline silica ex-
posure also applies to construction activities including drilling, grinding, and using heavy equipment during demolition activities involving materials containing silica.

Exposures to crystalline silica dust occur in common workplace operations involving the following types of operations:

- Earth drilling (operations involving disturbance of the Earth’s crust.)
- Cutting, sawing, drilling, and crushing concrete, brick, rock, and stone (construction tasks)
- Operations using sand products (hydraulic fracturing, glass manufacturing, sandblasting.

Sand and gravel are used in road building and concrete construction. Sand with greater than 98% silica is used in the manufacture of glass and ceramics. Silica sand is used to form molds for metal castings in foundries and abrasive blasting operations. Silica is also used as a filler in plastics, rubber, and paint, and as an abrasive in soaps and scouring cleansers.

In hydraulic fracturing for oil and gas recovery, silica sand is used to filter impurities from municipal water and sewage treatment plants. It is also used to manufacture artificial stone products used as bathroom and kitchen countertops—where the silica content in those products can exceed 85%.

**MAJOR PROVISIONS OF OSHA’S NEW SILICA RULE**

OSHA promulgated two separate standards that address occupational exposure to respirable crystalline silica. The one applies to exposures in general industry (29 CFR 1910.1053). The other applies to exposures in the construction industry (29 CFR 1926.1153).

The two standards are similar with some differences to account for the different work activities, anticipated exposures, and other conditions. The major provisions of OSHA’s Silica Rule and the differences between the two standards can be summarised by the following:

**Scope and Application**

The new Silica Rule applies to all occupational exposures to respirable crystalline silica in construction work, except where employee exposure will remain below 25 micrograms per cubic meter (25 µg/m³) of air.

**Permissible Exposure Limit**

50 µg/m³

**Action level**

25 µg/m³

**Exposure Assessment**

Any combination of exposure monitoring data or objective data may be used to accurately characterize exposures to crystalline silica.

A reassessment of exposures is required whenever there has been a change in the production process, control equipment, personnel, or work practices that may reasonably be expected to result in new or additional exposures to respirable crystalline silica at or above the action level (25 µg/m³).

At construction work sites, the employer is not required to assess the exposures of employees engaged in the tasks or take additional measures to ensure exposures do not exceed the permissible exposure limit (50 µg/m³) where the employer has fully and properly implemented the engineering controls, work practices, and respiratory protection prescribed in the standard for specified tasks.

**Silicosis was listed as the underlying or a contributing cause of death on more than 1,100 death certificates from 2005 through 2014 - Centers for Disease Control and Prevention, 2016**
Exposure Monitoring

If the scheduled exposure monitoring option is used to assess exposure, monitoring must be performed:

- Initially
- Every three months if greater than or equal to the permissible exposure limit.
- Every six months if greater than or equal to the action level.

Discontinue if less than the action level, and subsequent exposure monitoring taken at least seven days later confirms exposure is less than the action level.

Employee Notification

Results of the exposure assessment must be posted, or each affected employee must be notified in writing, within:

- Fifteen working days after completing an exposure assessment (general industry).
- Five working days after completing an exposure assessment (construction).

The employee notification must describe the corrective action being taken to reduce employee exposure to or below the permissible exposure limit.

Written Exposure Control Plan

Is required and must contain at least the following elements:

- Description of the tasks involving exposure to respirable silica.
- Description of the engineering controls, work practices, and respiratory protection used to limit employee exposure to respirable crystalline silica for each task.
- Description of the housekeeping measures used to limit employee exposure to respirable crystalline silica.
- For construction work sites, a description of procedures used to restrict access to work areas, when necessary, must also be included to minimize the number of employees exposed to respirable crystalline silica and their level of exposure, including exposures generated by other employees.

Competent Person

Someone designated for construction work sites who has the responsibility to implement the written exposure control plan. A competent person as defined by OSHA is:

"An individual who is capable of identifying existing and foreseeable respirable crystalline silica hazards in the workplace and who has authorization to take prompt corrective measures to eliminate or minimize them."

Regulated Areas

Must be demarcated when reasonably expected to be in excess of the permissible exposure limit. Signs marked “DANGER” must be posted at all entrances to regulated areas.

This provision applies to general industry work sites, but does not apply to construction work sites. However, the silica standard for construction requires the exposure control plan include procedures to restrict access to work areas to minimize the number of employees exposed to respirable crystalline silica.

Methods of Compliance

Feasible engineering controls must be implemented to reduce exposures to or below the permissible exposure limit. When it is not feasible to do so, the employer must reduce exposures to the lowest achievable levels and supplement such engineering and work practice controls with respiratory protection.
Specified Exposure Control Methods

The construction standard specifies 18 tasks and prescribes the engineering controls, work practices, and respiratory protection for each task.

The employer is not required to perform an exposure assessment or limit exposures when engaged in these specified tasks—provided the employer has fully and properly implemented the engineering controls, work practices, and respiratory protection as specified for these tasks in the construction standard.

OSHA permits employers of general industry to follow the construction standard rather than the general industry standard when the tasks specified in the construction standard are indistinguishable from the tasks performed at the general Industry work site. This option is permitted by general industry employers only when the tasks are not performed regularly in the same environment and conditions—for example, maintenance and repair tasks.

Housekeeping

Dry sweeping or dry brushing is not allowed unless wet sweeping, HEPA-filtered vacuuming, or other methods minimizing the likelihood of exposure are not feasible. Compressed air shall not be used to clean clothing or surfaces where such activity could contribute to exposure to respirable crystalline silica unless effective local exhaust ventilation is used or there is no feasible alternative method.

Medical Surveillance

For general industry work sites, medical surveillance examinations shall be made available to employees who will be occupationally exposed to respirable crystalline silica at or above the action level for 30 or more days per year.

For construction work sites, medical surveillance examinations shall be made available to employees who are required to use a respirator for 30 or more days a year.

Hazard Communication

Employees must have access to labels on containers of crystalline silica and safety data sheets. Workers must receive training in the following silica hazards: cancer, lung effects, immune system effects, and kidney effects.

Recordkeeping

The following record documents must be maintained:

- Exposure monitoring data
- Objective data
- Medical surveillance records

COMPLIANCE DATES

OSHA’s new Silica Rule became effective June 23, 2016, but employers have been given time to comply with the new standards. Employer obligations for construction were given one year to comply with the standard, establishing an effective compliance date of June 23, 2017, except for the laboratory analysis provisions of the standard, which has a compliance date of June 23, 2018.

The compliance date for general industry is June 23, 2018. Some additional delays for the compliance dates are provided for complying with the medical surveillance requirements and implementing feasible engineering controls for hydraulic fracturing operations in the oil and gas industry.

The effective date for complying with the medical surveillance provisions of the standard for general industry is June 23, 2018, if exposed at or above the permissible exposure limit for 30 or more days per year.
The compliance date is June 23, 2020, if exposed at or above the action level for 30 or more days per year. The effective date for complying with the provisions for implementing feasible engineering controls for hydraulic fracturing operations is June 23, 2021.

OSHA estimates the new silica standards will save the lives of more than 600 workers and prevent more than 900 cases of silicosis each year, once the full effects of the rule are realized.

Jerome E. Spear, CSP, CIH, is president of J.E. Spear Consulting and has more than 22 years of experience helping organizations prevent injuries and illnesses, control losses, and achieve regulatory compliance. He held the positions of technical services manager with XL Specialty Risk Consulting and corporate industrial hygiene manager for Chicago Bridge and Iron Co., a worldwide steel fabricator and construction company.
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BACKGROUND

Bosch Thermotechnology Corp. (Loudon, New Hampshire) and American Water Company (Voorhees, New Jersey) have provided a novel approach to commercial building environment control.

The companies combined their knowledge, products, and talents to introduce a sustainable, energy efficient technology for environmentally sound, large-scale heating and cooling systems in cooperation with the City and State of New York and Nassau County. Although Bosch has equipped many schools with traditional geothermal and water source heat pump systems, this school’s installation is unique. An innovative heat exchanger in this particular application eliminates the need to drill multiple geothermal ground loops.

In this proof-of-concept installation, Bosch FHP water source heat pumps are supplied with the utility’s water as the transfer medium to heat and cool the building. It is a natural extension of proven geothermal heat pump technology. In a departure from traditional geothermal, which requires drilling multiple bore holes up to hundreds of feet into the ground to install a geothermal loop, this geothermal pilot project uses water from the water utility’s main distribution system to heat and cool the 1950s-era William L. Buck Elementary School in Valley Stream, New York.

The project began in September 2013 with a meeting among representatives from the New York Public Utilities Commission, American Water, along with Jack DiEnna, executive director of the Geothermal National and International Initiative (Geo-NII). The concept of installing ground source heat pumps using utility water supply, without the cost of drilling bore holes, was unique. To get the project going, DiEnna invited the regional North American president of Bosch Thermotechnology at the time to join the team. With Bosch and American Water support, lead geothermal design engineer, Don Penn, of Image Engineering Group, was brought in to direct the project team.

According to DiEnna, “Combining the talent of this team, American Water’s commitment, along with the full support of the school administration, principal, and head of maintenance, allowed this project to bring a 1950s-era school building into the comfort levels of 2016.”

INSTALLATION SUMMARY

Construction of the geothermal system began in September 2014 with crews working at night with minimal disruption to student learning. By February 2015, ductwork was complete, the heating and cooling geothermal console units had been installed in each classroom, and the system was put into service.

In heating mode, the utility’s water main feeds ground-temperature water into a food-grade heat exchanger located in a 13x17 ft. pump house on the school’s grounds, where heat from the water is extracted and transferred to the water/glycol solution piped into the 63-year old school building and delivered to its rooms. Each room has its own Bosch CA model water source console unit with individual Hi-Lo fan-speed control. Bosch FHP model EC Large Capacity water-to-air geothermal units located above the ceiling and in utility space circulate heated

Educators know physical comfort affects the learning environment, so not only does the system save money and reduce a school’s carbon footprint, it also helps improve education - a triple win! - William Varley, former president of NY American Water
Innovative Geothermal Heat Pump System Uses Utility’s Water Instead of Wells to Save Cost

or cooled air through ductwork, providing conditioned air to open areas in the building such as cafeteria and gymnasium. All 40 heat pump units are supplied with water/glycol closed-loop system via the school’s pump room incorporating a flat-plate heat exchanger.

Many U.S. schools don’t have year-round space-conditioning, but the use of computer technology has dramatically increased the building’s internal heat gain, creating an uncomfortable environment in the classrooms. Geothermal technology delivers comfort year-round. The advantage of a ground source heat pump is that it can work in reverse, where the water/glycol solution extracts heat from the rooms and transfers it to the utility’s water through the heat exchanger. With the geothermal heating system in place, there is no extra cost to have a cooling system.

According to William Varley, at the time president of NY American Water, and senior vice president of American Water’s northeast division, “the transfer of heat between the utility’s water and the geothermal loop occurs within the heat exchanger unit (which is small - about 4 x 4 feet). The heat exchanger is a food grade, double wall containment unit, which ensures there is absolutely no contact between the water and the geothermal loop. Educators know physical comfort affects the learning environment, so not only does the system save money and reduce a school’s carbon footprint, it also helps to improve education - a triple win!”

In the pilot phase, the water passing through the heat exchanger is constantly being sampled with an analyzer to determine any change in quality and is then diverted into a diffusion well. Once the pilot is complete and receives regulatory and health department approval, the water will be recirculated into the utility’s distribution system, so there is essentially zero water waste.

DiEnna said geothermal systems are used in more than 1,000 schools in the U.S., but none like William L. Buck’s. The system at Buck costs far less to install because there is no need to dig boreholes for the ground loop.

“With the support of New York City and State for innovative energy efficiency standards, it is going to become a reproducible model,” DiEnna said. “This pilot program proves it can be used in schools, military bases, commercial, and public facilities across the country.”

DiEnna added that the system maintains the school at a steady temperature, regardless of the weather outdoors. “The kids aren’t too hot or too cold,” he said. “It gives them an environment for more effective learning.”

CONCLUSION

The entire system saved approximately $600,000 by eliminating the cost and disruption required to drill over 100 geothermal bore holes. Preliminary data shows the geothermal system has saved the school district more than $40,000 per year in heating costs, while increasing comfort in the summer by providing cooling. Two oil-fired boilers remain unused in the building, but are available for emergency use if ever...
Bosch technical engineer Edgton Wright examines water supply system inside the pump building. A flat plate heat exchanger transfers heat from utility’s water system to a water/glycol loop through the building. (Courtesy of Bosh Thermotechnology Corp.)

Bosch FHP water-to-air geothermal heat pumps installed in building crawlspace provide conditioned air via ductwork and are fed by water/glycol piping. Bosch console units provided custom comfort in classrooms. (Courtesy of Bosh Thermotechnology Corp.)

The utility’s water feeds ground source heat pumps at 200 gpm flow rate with temperature rise <2°F. The HVAC system is monitored and controlled remotely by the facilities manager using computer software application. (Courtesy of American Water.)

required. The facilities manager monitors and controls the entire HVAC system via a computer application.

Among the many benefits of geothermal heating and cooling in this application:

• It is clean and efficient.
• It is quiet and equipment is protected from wind and damaging weather.
• It is safer for the environment.
• It is practical and reproducible in schools and commercial buildings throughout the United States.
• It is comfortable for building occupants and improves security by keeping windows and doors closed.

The preliminary results of yearlong water testing indicate there is no change in the quality of the water and no significant temperature change in either summer nor winter. Those results are being verified by Oak Ridge National Laboratory.

“What this proves is that we can now offer geothermal heating and cooling to inner city or landlocked facilities using water provided by the water utility, and that opens an entire spectrum of projects throughout the U.S.,” adds DiEnna.

In conclusion, this first-of-its-kind installation proves it can save significant cost and add value to older facilities in populated areas not suitable for traditional geothermal installations.

LIST OF RESOURCES

Geothermal Systems – Bosch Thermotechnology Corp.
Water Utility – American Water Company
Engineer – Don Penn, Image Engineering Group, Ltd
Geothermal Consultant – Jack DiEnna, Geo-NII
Mechanical Contractor – Bancker Construction

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ABOUT BOSCH THERMOTECHNOLOGY CORP.

Bosch Thermotechnology Corp. is a leading source of high quality heating, cooling and hot water systems. The Company offers Bosch tankless, point-of-use and electric water heaters, Bosch and Buderus floor-standing and wall-hung boilers, Bosch and FHP water-source, geothermal and air-source heat pump systems, as well as controls and accessories for every product line.

Bosch Thermotechnology is committed to reinventing energy efficiency by offering smart products that work together as integrated systems that enhance quality of life in an ultra-efficient and environmentally friendly manner.

Bosch strives to bring the most energy-efficient and environmentally responsible products to global consumers. In delivering the best products at affordable prices to our markets, Bosch has established multiple collaborations and joint ventures on a global scale to bring the latest technologies to North America. All global manufacturing facilities must adhere to stringent quality standards in order to provide the trusted Bosch brand.

Visit www.boschheatingandcooling.com to learn more about this and other Bosch Thermotechnology Corp. projects.

Based in Bosch Thermotechnology’s North American headquarters in Londonderry, New Hampshire, Heather Anderson serves as the Business Development Manager and Chief of Staff to the North American President. Anderson is responsible for developing and executing business strategy. Previously, she served as Business Integration Manager where she directed the post merger activities of Bosch Thermotechnology in North America. She joined Bosch in January of 2010 as Sales Operations Manager. Prior to Bosch, she worked in various local government and non-profit leadership roles. Anderson earned a Master’s degree in Business Administration at Southern New Hampshire University and holds a Bachelor’s of Arts degree in Political Science from Tufts University.
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An Updated Assessment of the Technical Potential of Geothermal Heat Pump Applications in the U.S.

By: Xiaobing Liu, Patrick Hughes, Jeffery Spitler, and Arlene Anderson

INTRODUCTION

Geothermal heat pumps (GHPs), also referred to as ground source heat pumps (GSHPs), have been proved capable of producing large reductions in energy use and CO₂ emissions in buildings while satisfying the demands for space heating (SH), space cooling (SC), and domestic water heating (DWH). This paper provides a brief review of the current status of GHP applications in the United States and presents an assessment of the technical potential of GHP applications in both residential and commercial buildings.

CURRENT STATUS

GHPs have been used in all 50 states and the District of Columbia in the United States (EIA 2010). Current GHP applications are more concentrated in areas with a cold climate and high population density. A recent Navigant Research report (2013) indicates that the United States represented 29% of global GHP installations by capacity, with 13,564 MWt (3.9 million tons, or 1.1 million GHP units given the typical GHP unit size is about 12 kWt) installed by 2012. These GHP systems provide space conditioning to roughly 199 million m² (2.14 billion ft²) of residential and commercial buildings in the United States. The current market share of GHPs in the U.S. heating, ventilation, and air-conditioning (HVAC) market is approximately 1% (EIA 2016a).

The installed cost of GHPs varies widely, depending on geological conditions, building loads, system designs, and heat pump equipment. A few surveys have been conducted to collect cost information for GHPs. According to those surveys, the average cost of a commercial GHP system was $20.75/ft² in 2012 (Kavanaugh et al. 2012). The typical price of a GHP system installed in a new home was in the range of $3,000–5,000 per cooling ton (Ellis 2008).

The high initial cost and the lack of public awareness and strong governmental support are believed to be the major barriers preventing rapid adoption of GHPs in the United States. Recent low prices of oil and natural gas (NG) reduce the monetary value of the energy savings, which makes consumers less willing to invest in GHPs. Unfortunately, tax credits for GHP installations expired at the end of 2016 despite the many efforts of the GHP industry to persuade Congress to extend the tax credits. It is believed that the high initial cost barrier for GHP deployment could be overcome by breakthroughs in the following areas:

- Lower-cost ground heat exchangers and customized drilling techniques/equipment for GHP
- Better design of GHPs as a result of more information on the ground formation
- Volume manufacturing of GHP equipment
- Financial incentives or third party financing
- Integration of GHPs as a part of utility infrastructure in new developments

METHODOLOGY

The GHP technical potential is assessed based on (1) energy consumption data obtained from the latest survey of energy consumption in residential and commercial buildings; and (2) energy savings data for GHPs compared with existing conventional
HVAC systems. The procedure for assessing the technical potential of GHPs is depicted in Figure 1.

This study uses a database of county-level site energy consumption data in residential and commercial buildings, which was developed by the National Renewable Energy Laboratory (NREL) (McCabe et al. 2016). The county-level data were derived by disaggregating regional-level (states, aggregates of states) site energy consumption data for SH, SC, and DWH—reported in the most recent residential and commercial building energy consumption survey (EIA 2013 and EIA 2016b)—using several other databases, including the count of housing units and the total square footage of each type of commercial building in each county.

Computer simulations using eQUEST (Hirsch et al. 2016) for a group of reference buildings were carried out to calculate the energy savings resulting from GHP retrofits. These computer simulations account for many factors affecting energy savings, including thermal loads, performance of the existing HVAC systems, local geological conditions (i.e., undisturbed ground temperature and ground thermal conductivity), and the performance of GHPs. Totally, 13 locations (cities) were selected to represent the major climate zones in the Continental United States.

A reference building—a 1,644 ft$^2$ (153 m$^2$) one-story, slab-on-grade, wood-frame house—is used to represent typical U.S. homes with SH (DOE 2009). Commercial buildings are categorized into five groups based on the similarity of the building activities, and each group of commercial buildings is represented in this study by one of DOE’s Commercial Reference Buildings (CRB; DOE 2012) as listed in Table 1. It was found that the size of a particular type of building does not affect energy saving percentages significantly so the impact of building size on the energy saving percentage is not accounted for in this study.

Each CRB model includes an HVAC system that is commonly used in the represented commercial building (Table 1). However, there are many other existing HVAC systems serving each type of commercial buildings. The existing HVAC systems can be categorized based on the energy source for SH and SC. Table 2 lists different energy sources and their shares in the national site energy consumption for SH and SC of each group of buildings.

As can be seen in Table 2, electricity is the exclusively predominant (with a more than 98% share) energy source for SC in both residential and commercial buildings. NG, heating oil, and propane are the predominant (with more than 80% combined

### Table 1. Commercial Reference Buildings

<table>
<thead>
<tr>
<th>Categories</th>
<th>Description of Reference Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>3 stories, 53,620 ft$^2$ - direct expansion (DX) cooling and gas-fired furnace with electric heat</td>
</tr>
<tr>
<td>Lodging</td>
<td>4 stories, 40,095 ft$^2$ - DX cooling and gas furnace for common area; DX cooling and electric resistance heating for guest rooms</td>
</tr>
<tr>
<td>Education</td>
<td>2 stories, 210,095 ft$^2$ - chilled water and hot water (from gas-fired boiler)</td>
</tr>
<tr>
<td>Store</td>
<td>1 story, 22,500 ft$^2$ - DX cooling and gas furnace</td>
</tr>
<tr>
<td>Inpatient</td>
<td>5 stories with basement, 241,500 ft$^2$ - chilled water and hot water (from gas-fired boiler)</td>
</tr>
</tbody>
</table>
TABLE 2. ENERGY SOURCES OF EXISTING HVAC SYSTEMS

<table>
<thead>
<tr>
<th>REFERENCE BUILDING</th>
<th>ENERGY SOURCE FOR SH</th>
<th>CONTRIBUTION</th>
<th>ENERGY SOURCE FOR SC</th>
<th>CONTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Electricity</td>
<td>9.5%</td>
<td>Electricity</td>
<td>99.4%</td>
</tr>
<tr>
<td></td>
<td>NG/oil/propane</td>
<td>90.5%</td>
<td>Other</td>
<td>0.6%</td>
</tr>
<tr>
<td>Lodging</td>
<td>Electricity</td>
<td>17.8%</td>
<td>Electricity</td>
<td>99.2%</td>
</tr>
<tr>
<td></td>
<td>NG/oil/propane</td>
<td>82.6%</td>
<td>Other</td>
<td>0.8%</td>
</tr>
<tr>
<td>Education</td>
<td>Electricity</td>
<td>3.8%</td>
<td>Electricity</td>
<td>98.6%</td>
</tr>
<tr>
<td></td>
<td>NG/oil/propane</td>
<td>96.1%</td>
<td>Other</td>
<td>1.4%</td>
</tr>
<tr>
<td>Store</td>
<td>Electricity</td>
<td>9.5%</td>
<td>Electricity</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>NG/oil/propane</td>
<td>90.1%</td>
<td>Other</td>
<td>0.0%</td>
</tr>
<tr>
<td>Inpatient</td>
<td>Electricity</td>
<td>0.5%</td>
<td>Electricity</td>
<td>99.6%</td>
</tr>
<tr>
<td></td>
<td>NG/oil/propane</td>
<td>99.4%</td>
<td>Other</td>
<td>0.4%</td>
</tr>
<tr>
<td>Single Family Home</td>
<td>Electricity (resistance)</td>
<td>9.4%</td>
<td>Electricity</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>NG/oil/propane</td>
<td>99.4%</td>
<td>Electricity</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Electricity (air-source heat pump)</td>
<td>18.7%</td>
<td>Electricity</td>
<td>100%</td>
</tr>
</tbody>
</table>

FIGURE 2

Figure 2: Annual source energy saving percentages by building principal activities and climate zones.
share) energy sources for SH in commercial buildings. For single-family homes, the combined share of NG, heating oil, and propane is relatively lower (66.5%), and electricity contributes 28.1% to the total site energy consumption for SH, of which two-thirds is from heat pumps (mostly air-source heat pumps) and the rest from electric resistance heaters. The minimum code-compliant efficiencies specified in ASHRAE 90.1-2004 (ASHRAE 2004) were used in the representative CRB model to predict the existing SC equipment’s energy consumptions. Since the minimum code-compliant efficiencies of boilers or furnaces that use NG, oil, or propane are very similar (around 80% Annual Fuel Utilization Efficiency according to ASHRAE 90.1-2004), the non-electric heating equipment is modeled with the same heating efficiency.

The residential GHP system simulated in this study consists of a packaged water-to-air heat pump (WAHP) unit with a two-stage scroll compressor and variable-speed electronically commutated fan-motor, a energy-efficient loop fluid circulator, and a properly designed and installed vertical-borehole ground heat exchanger. The nominal cooling efficiency of the two-stage GHP unit is energy efficiency ratio (EER) 18.2 at full capacity and EER 27 at 76% of full capacity. The nominal heating efficiency of the two-stage GHP unit is COP 4 at full capacity and COP 4.5 at 76% of full capacity. The ground heat exchanger is sized to maintain the fluid temperature from the ground loop (the entering fluid temperature to the GHP unit) within the range of 30 to 95°F for given building loads and ground thermal properties. The simulated commercial GHP system consists of multiple WAHPs connected by a common water loop, with each WAHP serving an individual zone in the building. Although a GHP may also provide partial or full DWH (e.g., with a desuperheater or more advanced integrated heat pump), this study does not account for this service.

RESULTS AND DISCUSSIONS

Figure 2 shows the annual source energy saving percentages resulting from retrofitting the most common existing HVAC systems, which are included in the original CRB models, with GHPs at different locations (each representing a climate zone). As shown in Figure 2, the range and magnitude of source energy saving percentages vary widely by building type: 32–59% for a single-family home, 14–50% for offices, 18–41% for lodgings, 17–33% for schools (education), and 12–33% for stores. In general, more energy savings can be achieved at locations in cooler climates. These results indicate that the source energy saving percentages for residential buildings are higher than those for commercial buildings. For buildings in hot climates (e.g., climate zones 2A and 2B), the energy savings in SH are very small; and the moderate energy savings in SC could be offset by the pumping energy of commercial GHPs.

Figure 3 shows the combined source energy savings potential in both residential and commercial buildings in each county of the United States (not including counties in Alaska and Hawaii). The amount of source energy savings in each county (in Billion Btu per square mile) is color-coded as shown in the figure legend. As Figure 3 shows, there are substantial energy savings potentials in many counties in the United States, and the Northeastern region has more counties with high source energy saving potential (>2.7 Billion Btu per square mile) than other regions.

Table 3 lists the annual site energy savings, source energy savings, carbon emission reductions, and energy cost savings in the residential and commercial sectors, respectively, and the sum of the two sectors. As shown in this table, retrofitting the residential sector with GHPs has three times more potential than retrofitting the commercial sector. Combining both residential and com-
Table 3. Technical Potential of GHP Retrofits in the United States

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>3.3</td>
<td>4.3</td>
<td>271.1</td>
<td>38.2</td>
</tr>
<tr>
<td>Commercial</td>
<td>1.2</td>
<td>1.3</td>
<td>85.2</td>
<td>11.6</td>
</tr>
<tr>
<td>Total</td>
<td>4.5</td>
<td>5.7</td>
<td>356.3</td>
<td>49.8</td>
</tr>
</tbody>
</table>

Commercial sectors, GHP retrofits have a potential to save 5.7 quadrillion Btu of source energy, avoid 356.3 million metric tons (Mt) of CO2 emissions, and reduce energy costs by $49.8 billion, each year. The 5.7 quadrillion Btu source energy savings can reduce the national source energy consumption for SH and SC by 45%.

CONCLUSIONS

This paper presents an analysis of the technical potential of GHP applications in both residential and commercial buildings in the United States. The analysis indicates that retrofitting existing conventional HVAC systems in U.S. residential and commercial buildings can result in significant energy savings and carbon emission reductions. The residential sector has three times more energy saving potential than the commercial sector. Combining both residential and commercial sectors, GHP retrofits have a potential to save 5.7 quadrillion Btu of source energy, avoid 356.3 million metric tons (Mt) of CO2 emissions, and reduce energy costs by $49.8 billion, each year. Given this huge energy savings potential, GHP could be a key component of national energy and climate change mitigation strategies.

REFERENCES


Be Aware of Temperature Lift

By: Ed Lohrenz

GSHP systems are widely recognized as the most efficient space conditioning technology available for both residential and commercial applications. The design of the distribution system—the ductwork for a water to air heat pump or the design of a hydronic heating/cooling system—can make a significant difference in system efficiency, how well it will perform over the long term and can even have an impact on the longevity of the heat pumps.

A water to air heat pump warms or cools air that is circulated throughout the building in ductwork. A water to water heat pump warms or cools water that is pumped through radiant floor tubing or fan coil units or air handling units. The air or water temperature required by the distribution system has an impact on the coefficient of performance of the heat pump, how long the compressor will last and the size (and cost) of the ground heat exchanger (GHX).

**THE IMPACT OF TEMPERATURE LIFT**

A heat pump is designed to remove heat from a heat source and reject it to a heat sink. When a GSHP system is extracting heat from 40°F (4°C) fluid delivered from a GHX and produces 90.8°F (32.7°C) air, the temperature lift is 50°F (28°C). Reducing the air flow increases the leaving air temperature to 98.1°F (36.7°C), but this affects the capacity and efficiency of the heat pump. When air flow is increased and the leaving air temperature is reduced, heat pump efficiency increases 12%, power consumption is reduced 9% and 6% more heat is extracted from the earth.

A water to water heat pump is no different. When the temperature lift increases, COP and capacity drop and power draw increases. When the power draw increases, that indicates that the compressor is working harder and the compression ratio increases. Refrigerant pressures are higher, putting more strain on compressors and heat pump components. The life of the compressor is compromised and long-term maintenance costs will increase. Depending on other electrical loads of the building, and the peak demand structure from the utility providing electrical power, this could also trigger peak demand charges.

**IMPACT OF TEMPERATURE LIFT ON THE GHX**

The heating capacity of a heat pump consists of two components—the energy taken from the heat source and the electrical energy used to power the compressor and fans or pumps used to distribute the energy. In heating mode, power used by the compressor contributes to the heat delivered to the building. A less efficient heat pump uses more power and contributes more heat to the building. In cooling mode, heat removed from the building plus power used by the compressor is rejected to the ground. A more efficient heat pump uses less power and rejects less heat to the ground.

![Figure 1](figure1.png)

Figure 1: If the GHX temperature is 40°F (4°C) and the heat pump is producing 110°F (44°C) water, the temperature lift is 70°F (40°C). If the water from the GHX drops to 35°F (2°C) and the building requires 125°F (52°C) the temperature lift increases to 90°F (50°C) and the COP drops from 3.8 to 3.0—a drop of 21%. The compression ratio increases from 4.3 to 5.3.
Figure 2 compares actual building heating and cooling loads to the amount of energy rejected to the ground when cooling and the amount of energy extracted from the ground when heating when more or less efficient heat pumps are connected to the GHX.

The difference in the amount of energy rejected to or extracted from the GHX is taken into consideration, the amount of pipe required for a project can change significantly. Figure 3 graphically illustrates the difference in the amount of energy rejected to the GHX when cooling with different heat pump efficiencies and the amount extracted from the GHX with different heat pumps.

SYSTEM DESIGN CONSIDERATIONS

Since the efficiency of the heat pumps selected for a project can have a significant impact on the size and cost of a GHX, it is important to consider the heat pump(s) selected in designing a system. If a system is being considered for a home in a warm climate, there is a high likelihood that it will be cooling dominant. The ambient ground temperature may be as high as 60-70°F (15-21°C) and the cooling loads are likely to be greater than the heating loads. Selecting the most efficient heat pump available, may actually reduce the cost of the overall system. Figure 4 shows a reduction of approximately 145' in total borehole required to maintain a maximum temperature of 85°F (30°C). If the cost of the additional borehole is $12 / foot, the cost of the borehole is approximately $1,740. This can offset the cost of a more efficient heat pump and offer the homeowner a system with lower operating costs.

The reduction in the number of boreholes can have a significant impact in commercial projects where the land area available for construction of the GHX may be limited. Reducing heat rejection to the GHX while increasing heat extraction by specifying a more efficient heat pump may help balance energy loads to and from the ground. More balanced loads allow reduced spacing between boreholes with little impact on performance and can reduce the potential risk of long term temperature increase in the GHX.
As seen in Figure 1, the temperature of water or air required for the distribution system has a direct impact on the efficiency of the heat pump, which in turn affects the size of the GHX. Selecting fan coil units with larger air coils that allow the use of 105°F (40°C) water rather than 125°F (52°C) water improves the efficiency of the heat pump(s) by approximately 21%. Designing a radiant floor heating that can heat the building with 85°F (30°C) water will increase the COP from 3.8 to 4.8—an improvement of 60% compared to fan coil units requiring 125°F (52°C) water.

It may not always be possible to reduce water temperature to the distribution system on the design day…but it’s worth remembering that peak loads, by definition, only occur for a very short time in a given period. The rest of the time the temperatures are warmer and the heat loss is lower. That means it may be possible to reduce the supply temperature the rest of the time, allowing the heat pump to operate more efficiently most of the year. Controls that allow adjustment of the temperature delivered to the distribution system based on outdoor temperature (i.e. outdoor reset to lower the aqua stat setpoint on the buffer tank) can help improve system efficiency most of the time to offset higher peak short duration loads.

Paying attention to the manufacturer’s data can also help improve system efficiency. A typical manufacturer’s data sheet, shown in Table 1, shows 12% higher efficiency when the air flow for the selected heat pump is 1,250 cfm (590 l/s) rather than 900 cfm (425 l/s). Sizing the ductwork for the air flow and ensuring the heat pump controls are set at the appropriate air flow will improve overall system efficiency.

### Table 1: Illustrates the impact of changing the air flow through the heat pump from 900 cfm (425 l/s) to 1,250 cfm (590 l/s). Leaving air temperature drops from 98.1°F (36.1°C) to 90.8°F (32.7°C). Heating capacity increases from 27.3 kBTU/hr (8.0 kW) to 28.1 kBTU/hr (8.2 kW). Heat of extraction increases from 20.1 kBTU/hr (5.9 kW) to 21.4 kBTU/hr (6.3 kW). The coefficient of performance increases from 3.73 to 4.17

<table>
<thead>
<tr>
<th>EWT</th>
<th>Airflow (cfm)</th>
<th>Htg (kBTU/hr)</th>
<th>KW Power Requirement</th>
<th>Heat of Extraction</th>
<th>Leaving Air Temperature</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>40°F</td>
<td>900</td>
<td>27.3</td>
<td>2.14</td>
<td>20.1</td>
<td>98.1</td>
<td>3.73</td>
</tr>
<tr>
<td>1,250</td>
<td>28.1</td>
<td>1.96</td>
<td>21.4</td>
<td>90.8</td>
<td>4.17</td>
<td></td>
</tr>
</tbody>
</table>

### PAYING ATTENTION TO THE DETAILS

Most people purchasing a GSHP system are looking for a reasonable rate of return on their investment. Paying attention to details such as the temperature lift when designing a system will maximize the performance of the system and, at the same time, can help reduce capital cost and long term maintenance cost of the system.

Ed is the founder of GEOptimize Inc., a consulting firm focused on improving design and implementation of geothermal heat pump systems. He has worked in most facets of the industry since 1982, including the design and installation of residential systems, manufacturing, equipment distribution and the design and implementation of large scale and district geothermal systems.
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There’s a geo unit that’s right for your home, your location and your lifestyle.

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Separate air handler or furnace fan required

HEV Series Vertical
with digital controls

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This January I began my 40th year in the industry, and since 2003 I have been honored to do the Earth Insights column for Geo Outlook. I shared what I thought and hoped was useful, hands-on information the reader could put to use in their GSHP industry activities. Unfortunately, as I get older, I find I am spending less time in the field and much more time with administrative activities – not very conducive to maintaining a “boots on the ground” perspective on applications and GSHP industry developments/advancements. Since I can no longer provide that first-hand perspective, and in order for Earth Insights to continue to provide the reader with the most current and beneficial information, it is time for me to step aside.

My hope is that IGSPHA continues the Earth Insights column with an author that stays on the leading edge of the geothermal heat pump system technology through their hands-on, “boots on the ground” experience in system design, application, and installation activity. This column should be written by and filled with information from and for individuals who get their hands dirty. While I will remain active, I cannot help but look back at a few of the milestones or issues I was fortunate enough to either participate in, or witness, that many of our readers may take for granted:

- Dr. Jim Partin (Partin Construction Company), Dr. Jim Bose (OSU), and Carl Ledbetter (a local Carrier dealer - now deceased) developed an alternative to air source heat pumps and/or open loop ground water source heat pumps called a closed-loop ground-coupled heat pump in the last half of the 1970s.
- Earl Maroney bought the FIRST closed-loop ground-coupled heat pump system (that was not a research installation) for his new home built northwest of Stillwater, Oklahoma, by Partin Construction. It used a horizontal ground heat exchanger and was put into service in early 1978.
- The first vertical closed loop ground heat exchanger application (I am aware of) was installed near Stillwater. It used a 5” diameter PVC casing, sealed top and bottom with an internal dip tube.
- The first pond closed loop heat exchanger application (I am aware of) was installed near Stillwater. It used copper pipe in the pond water – copper is no longer used because of its effects on some fish species’ reproductive systems.
- The standing column well technology was developed and applied by Carl Orio in the New England area during the 1970s.
- The evolution of ground heat exchanger materials – PVC (BAD!!! and banned), Polybutylene (better, but banned), Polyethylene (Best!!), and PEX (personally do not like it and its mechanical fittings, but opinions are like noses – everybody has one). (Opinions don’t really matter - time will tell whether or not my concerns about PEX and its mechanical fittings are justified.)
- Heat fusion pipe joining technology replaces barbed fittings and clamps.
- Simplification of application/installation via packaged pumping modules instead of site-built water side component assemblies.
- Simplification of start-up/maintenance via test ports – (it’s that “nooses” thing again, but I really hate the reliability and calibration issues of thermometers, flow meters, and pressure gauges over their “useful” life – too many opportunities for bad data.)
- Formation of IGSPHA
- Formation of Geothermal Heat Pump Consortium (now The Geothermal Exchange Organization)
• Creation of IGSHPA installation standards and manuals.
• Creation of IGSHPA/ACE industry designer and IGSHPA installer training and credentialing programs.
• Lake plate prefabricated submerged heat exchangers assemblies for fresh, brackish, or salt water applications.
• Development of thermal conductivity testing technology and materials
• Development of thermally enhanced grout materials
• Development of computerized ground heat exchanger design tools.
• Continuous gains in GSHP unit efficiencies from the early 1980s to present.
• Incorporation of desuperheaters into the GSHP units.
• Development of enhanced ground heat exchanger designs. (There are many options, but do the math – it’s your money. Unless there are special site or ground conditions that dictate otherwise, instead of using multiple U-bends or pipe assembly bundles, keeping it simple – a single U-bend per borehole – is a time-tested, cost effective, less labor intensive, and proven approach.)

There have been many other developments – both minor and significant. The GSHP industry has grown and evolved into a world-wide technology that has been applied in all climates, from inside the Arctic Circle to the Middle East.

In closing, I am still active in the industry through my association with One Earth Geo Mech, and will continue to support the industry and industry participants in any way possible. If I can be of assistance with questions or otherwise, please do not hesitate to contact me at geoman@geusnet.com. It has been a fun ride that will only get better, so get out there and get your hands dirty!

Thank you, Phil!

Starting with our premier issue in 2003, your Earth Insights column has graced Geo Outlook. The information you brought to light has impacted thousands of IGSHPA members and Geo Outlook readers. Your insight into the geothermal industry will not easily be forgotten. IGSHPA wishes you all the best in your future endeavors.