Issue 18
July 2013
Division of Technical Resources
Office of Research Facilities
National Institutes of Health
Technical News BULLETIN

Ground Source Heat Pumps Part I of III: Overview

Introduction

Energy intensities for laboratory buildings are often 5 times higher than those in non-laboratory buildings.[2] The U.S. Environmental Protection Agency (EPA) encourages the use of renewable energy sources. Solar and wind power are the most common renewable energy sources in the United States, but on-site harvesting of geothermal energy (GTE) is becoming more popular. Approximately 70% of the energy used in a ground source heat pump system (GSHPs) is renewable energy from the ground and GSHP products are often rated as Energy Star® by the EPA because of their overall efficiency. On the NIH Bethesda campus, the Porter Neuroscience Center II is the first building to incorporate a closed-circuit loop GSHPs as a supplementary cooling system to remove heat loads from its labs and reduce the building's carbon footprint.

GSHPs are electrically powered systems that rely on the relatively stable heat of the Earth to provide heating, air conditioning, and hot water. Low-temperature geothermal energy is the heat energy contained beneath the surface of the earth. Shallow earth temperatures fluctuate with seasonal outside air temperature and become more stable with increasing depth.[2] Beginning at 4–6 ft. (1.22–1.82 m) below the earth's surface, the ground remains at a relatively constant temperature of between 45°–75°F (7.22°–23.88°C). At depths below 16 ft. (4.88 m), temperatures remain nearly constant.[2]

Methods

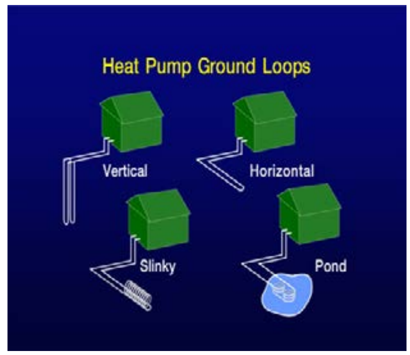
In winter, a GSHP collects the earth's natural heat through a series of pipes, called a loop, installed below the surface of the ground or submersed in a pond or lake. Water or an environmentally safe antifreeze solution circulates through the closed loop typically made of high-density polyethylene and carries the heat to the building. The heat absorbed from the ground / water changes refrigerant from a liquid to a gas (in the evaporator). The refrigerant is compressed, using an electrically driven compressor, raising its temperature. A heat exchanger (condenser) then extracts the heat from the refrigerant and transfers it into water. The refrigerant passes through an expansion valve, reducing its pressure and turning it back into a liquid. Ductwork distributes the heat to interior spaces. The process is reversed in summer. The underground loop draws excess heat from the building and allows it to be absorbed by the ground. GSHPs are appropriate for new construction as well as retrofits of older buildings. In new construction, GSHPs can be integrated into the design to optimize system efficiency and costs. In retrofit construction, GSHPs can be used to replace unit ventilators or fan coil units, and for historical preservation projects.[2]

Considerations

GSHPs are more costly to install initially than regular heat pumps, but save money in operating costs and maintenance costs (Part II). There are four basic types of ground loop systems: horizontal, vertical, pond, and slinky. Horizontal, vertical, and pond/lake systems are closed-loop systems, which exchange only heat with the ground. In an open-loop system, groundwater is pumped from a well, exchanges heat and water with the ground, and returns the water to the ground from the building, transferring its heat to the building in the process. The choice of system depends on the climate, soil conditions, available land, and installation costs at the site.[3]

• Horizontal ground closed loops are the most cost effective to dig, but take up a large footprint. The trenches are 3–6 ft. (.91–1.82 m) below the ground. A series of parallel plastic pipes are laid and covered with soil.

• Vertical ground closed loops (VGCLs) are used where there is limited horizontal space. Vertical holes 150–450 ft. (45.72–137.16 m) deep are bored in the ground. A single loop of pipe with a U-bend at the bottom is inserted before the hole is backfilled. Each vertical pipe is then connected to a horizontal underground pipe that carries fluid in a closed system to and from the indoor exchange unit. Vertical loops are generally more expensive to install, but require less piping than horizontal loops because the earth's temperature is more stable farther below the surface.



• Pond loop systems may be the most economical when the building is near a body of water. Fluid circulates underwater through polyethylene piping in a closed system. The pipes may be coiled in a slinky shape to fit more pipes into a given amount of space. Because it is a closed system, it has no adverse impact on the aquatic system.

• Hybrid systems use several different geothermal resources, or a combination of geothermal resources with outdoor air (i.e., a cooling tower).

• Another system is the standing column well system, which can be up to 1,500 feet (457.2 m) deep and can furnish potable water.[3]

The earth's constant temperature makes geothermal heat pumps one of the most efficient, comfortable, and quiet heating and cooling technologies available today. This series will concentrate mostly on the VGCL and hybrid systems.

Part II of this series will address costs and design considerations for GSHPs.

References

1. Bell, G.C., Mills, E., Sartor, D., Avery, D., Siminovitch, M., Piette, M.A. A Design Guide for Energy-Efficient Research Laboratories (LBNL-PUB-777). Berkeley, CA: Lawrence Berkeley National Laboratory, 2003. http://ateam.lbl.gov/Design-Guide/DGHtm/abstract.energy.efficientresearchlaboratories.htm

2. Klaassen, C.J. Geothermal Heat Pump Systems. Ames, IA: Iowa Energy Center Energy Resource Station. http://www.iowaenergycenter.org/learning-institute/homeowners/geothermal-energy/

3. California Energy Commission. Available at: http://www.consumerenergycenter.org/home/heating_cooling/geothermal.html