GROUND SOURCE HEAT PUMPS

SYNOPSIS

This TechData Bulletin covers ground source heat pumps (GSHP); their various configurations and cost advantages/disadvantages.

INTRODUCTION

Where the difference between air temperature and ground temperature is significant, 20°F for long periods of time (in excess of 60 days), the potential exists to tap this thermal reserve. Air temperatures at Air Force installations can range from 120°F to -50°F. Even in moderate climates the air temperature range can be extreme. For example, Scott AFB near St. Louis, Missouri, has recorded a high of 115°F and a low of -23°F. Compared with these dramatic fluctuations in air temperatures, the temperature of the earth and its waters is very stable. One effective way of tapping this stable energy source is through the use of heat pumps having their external coils effectively buried in the earth or submerged in a body of water, otherwise known as adding an earth coil.

SYSTEM DESCRIPTIONS

An earth-coil is a length of piping buried in the ground or submerged in a body of water. The term used is GSHP. Earth-coil systems use polyethylene piping buried/submerged either horizontally or vertically. The pipes carry a water based alcohol/antifreeze solution which is heated or cooled by its passage through the earth. These systems require three additional components which are not part of a standard heat pump (HP); an earth coil, a pump, and a heat exchanger. The pump circulates the water solution through the earth coil while the heat exchanger transfers heat either to or from the HP refrigerant to the water solution. Some systems, called direct expansion (DX) GSHP, have the actual HP refrigerant run through the earth coil which acts like a large condenser, eliminating the need for the water solution, the extra pump, and the heat exchanger. These DX systems use ground coils made of copper tubing and tend to be more efficient since there is no heat exchanger.

With a vertical earth-coil system it is possible to use a number of vertical coils in parallel. This configuration uses smaller diameter pipe and is not placed as deeply as a single vertical system, or take up as much land area as a horizontal system. At depths of 20-30 ft, depending on location and surface characteristics, the temperature of the ground is generally within 5°F of the average annual air temperature. This temperature fluctuates very little throughout the year. In most climates, the ground temperature is more than 20°F warmer than air temperatures during the winter and cooler than the air during the summer. A modification of the buried earth-coil heat pump is a system having its external coil located within either ground water or surface water. Water has even more potential for heat storage than earth. Figures 1-4 illustrate the various types of GSHP systems and their ability to heat and cool buildings.

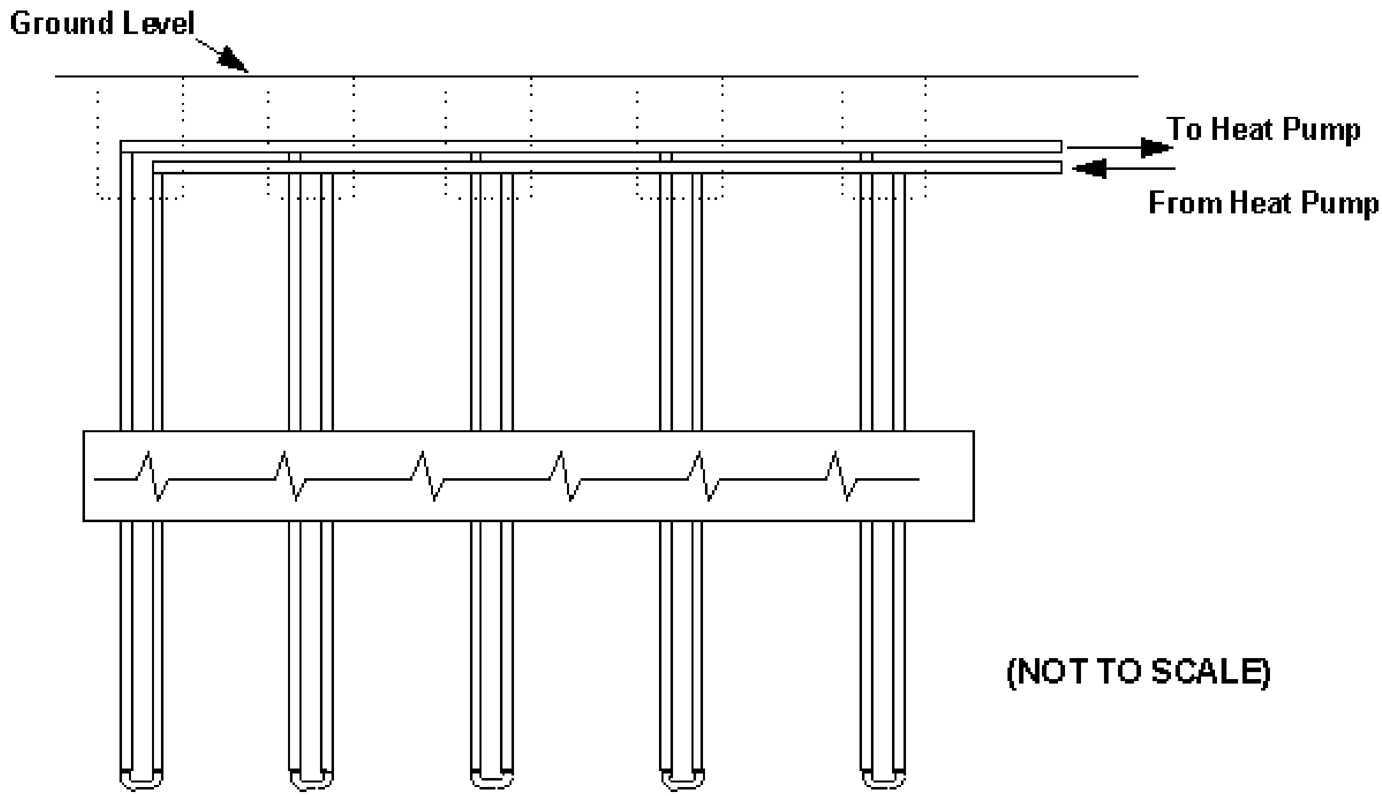

Figure 1: Parallel, Closed-Loop, Vertical Earth-Coil

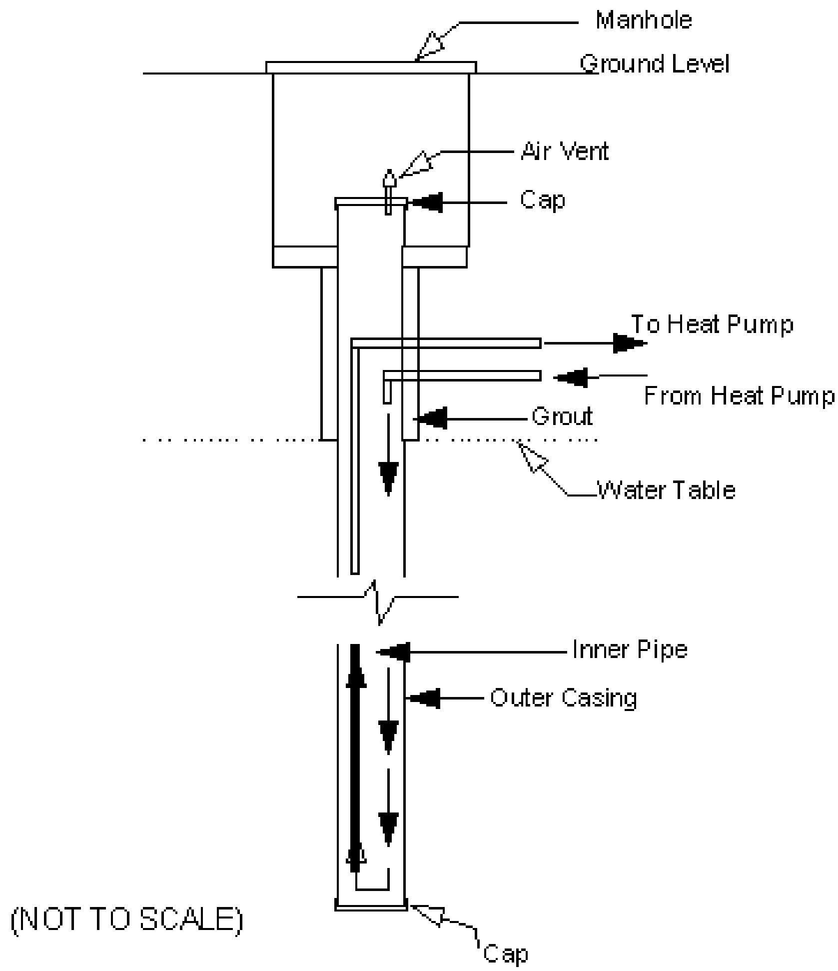

Figure 2: Closed-Casing, Vertical Earth-Coil

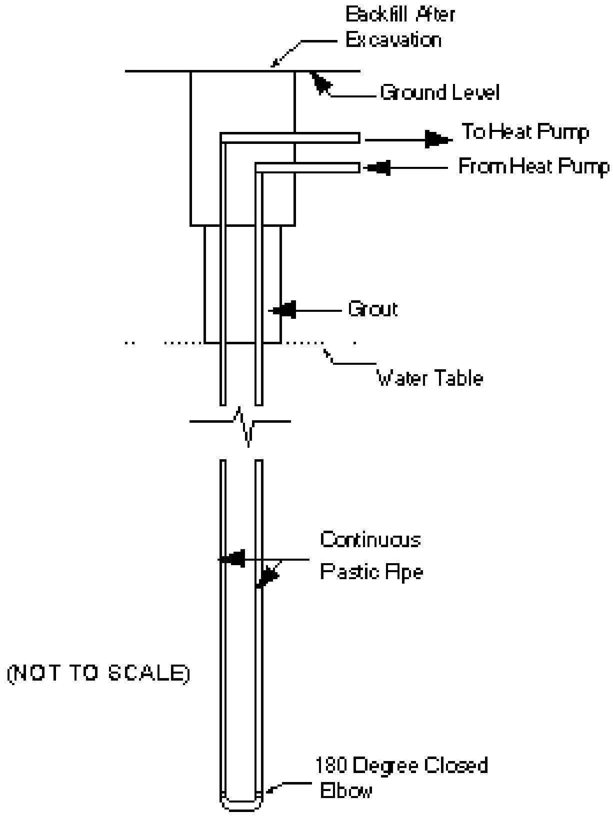

Figure 3: Closed-Loop, Vertical Earth Coil

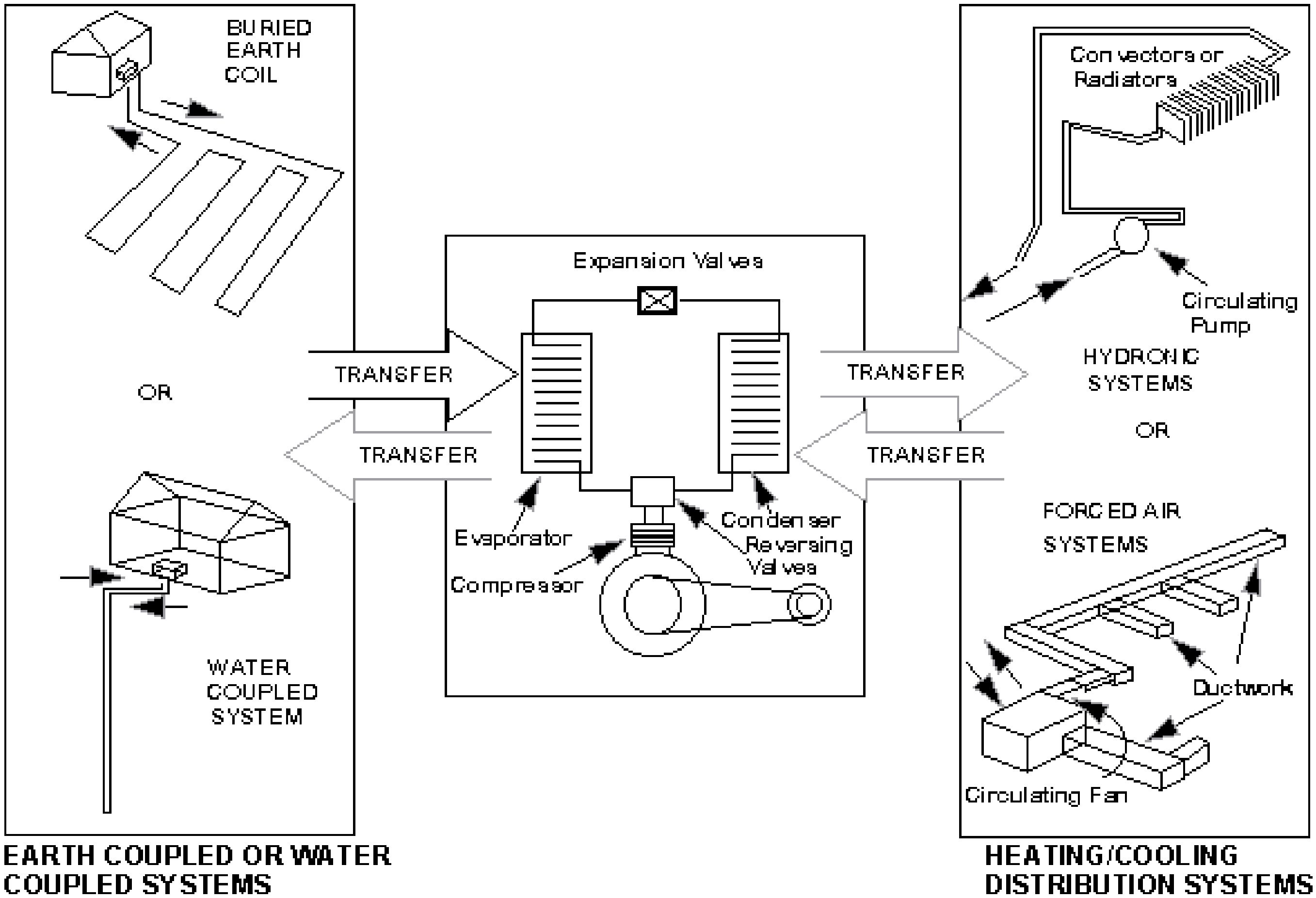

Figure 4: How Earth-Coil Systems Can Be Used To Heat and Cool Facilities

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It is this earth or ground/surface water temperature which stabilizes the difference in temperature ([delta]T) that makes GSHPs more efficient than air to air systems. Additionally, this stable temperature makes design much simpler and energy efficient since it is no longer necessary to consider the large fluctuations in outside air temperature. In the heating situation, the [delta]T between the desired inside temperature and heat source temperature equates to the additional energy which must be added to achieve the desired inside temperature.

- Air to Air heat pump
    - Desired inside temp 68°F
      Outside air temp 35°F
      [delta] T 33°F

  Earth-Coil heat pump

    - Desired inside temp 68°F
      Stable ground temp 55°F
      [delta] T 13°F

In this example, the [delta]T is 20°F greater for the air to air systems. However, at many Air Force bases, the outside air temperature often falls well below 35°F for longer than 60 days. As the air temperature falls or rises, the efficiency of the heating system decreases or increases. With a stable ground temperature, the energy efficiency remains fairly constant over the full heating season.

OPERATION

Instead of simply moving a fluid at a given temperature from place to place, a heat pump uses a mechanical process to increase the temperature of the fluid. This is done by using refrigerants, which boil at low temperatures and produce a gas that can be compressed. As the gas is compressed, the temperature of the gas rises. Heat is released when the gas condenses and returns it to liquid form.

When heat pumps are used for heating, water from the earth-coil flows alongside the tube of refrigerant in an evaporator where the liquid refrigerant absorbs heat, boils, and changes into gas. The gas is compressed mechanically, raising the temperature. The high temperature, high pressure gas is then pumped to a condenser where the heat is released to the air blown across the coils. As it loses heat, the gas returns to a liquid state, passing through an expansion valve that reduces both temperature and pressure. The low temperature, low pressure liquid is returned to the evaporator where the process begins again.

If a heat pump contains a reversing valve, the reverse of the process can be used for cooling, with the heat source becoming a heat sink.

SAMPLE PROBLEM AND CALCULATIONS

In order to properly size and determine the savings to evaluate a GSHP, many involved calculations are necessary. To simplify this process and speed up time required to perform the analysis, several software packages were developed. These programs need a certain amount of user defined information to size and cost the GSHP. Some of these packages can actually design the shape, size, and length of the earth coil.

The user defined data most always consist of the following: cooling/heating load, geographic information (earth or ground water temperatures), soil type, water content of soil, regional weather data, etc. Some programs tend to be more involved than others, but the concept is the same for all of them.

Included in the Appendices of this techdata bulletin is a sample print out of the input data and output information from GSHP design/sizing/cost package written by Waterfurnace Inc. These printouts are in Appendices A through F. Appendix A represents the results of the load calculations program for the building (house). Appendix B displays the input building load and other miscellaneous data. Appendix C through F obtain nearly all the information they require from Appendix B. Appendix C, given which type (model) of GSHP was chosen, calculates the correct size of the GSHP and the system performance, including electric usage and peak demand. Appendix D sizes an air source heat pump for the same application so that cost and usage comparison can be made. These values could be replaced if an existing heat pump and its energy usage is known. Appendix E sizes a fossil furnace system for the heating application for comparison purposes. Appendix F provides the results of the economic analysis which includes the capital and operating costs for the GSHP and the air source HP, and an annual cost savings analysis based on a thirty year loan. Sample data has been entered in the input sections of the program, the results of which were run through a Life Cycle Cost program with a discount rate of 4%, and using a DOE region #5 (US average), the following results were obtained:

INVESTMENT	$3,000.00

COST SAVINGS (PER YEAR)	$ 452.00
Savings to Investment Ratio (SIR)	2.82
Simple PayBack (SPB)	6.64
Discounted PayBack (DPB)	7.75
Return On Investment (ROI)	11.3%

POSSIBLE APPLICATIONS

The Air Force has a large number of bases in the northern half of the U.S. which are subject to long periods of low temperatures. These bases are candidate locations for technical and economic analysis to determine applicability and life-cycle cost for such systems. AFM 88-29 is the guide in determining if any base worldwide is a prime candidate for GSHP evaluation. Bases which have more than 5,000 heating degree days should be considered prime candidates with those above 4,000 degree days potential candidates depending on fuel costs and geographic considerations.

Cooling should not be overlooked for southern bases which have long periods of high temperatures and humidity. Cooling should be considered where there are more than 3000 air conditioning hours over 67°F (wet bulb) annually as indicated in AFM 88-29.

- Ask these questions to determine the possible earth-coil application for any base.
  1. Does AFM 88-29 indicate the location is a prime candidate?
  2. Is there sufficient clear area or water area to lay out the earth-coil?
  3. Can a trench or well be dug without difficulty?
  4. Are there any intangible constraints that would make a water source heat pump or other high efficiency system not acceptable?
  5. Do the savings over other high efficiency systems give a reasonable payback (greatest SIR)?

The following illustrates the relative merits of earth coil applications and provides guidance for their evaluation and implementation.

Some Advantages and Disadvantages of Earth-Coil Heat Pump Systems

Systems	**Advantages**	**Disadvantages**
Earth-coil buried heat pump (horizontal)	1. Low energy consumption. 2. Moderate operating cost. 3. Better performance than air to air systems.	1. Dry earth is less of a heat source/sink than water. 2. High initial cost. 3. Leaks difficult to find and repair. 4. Pumping costs. 5. Requires extensive open land area

Earth-coil buried heat pump (vertical)	1. Low energy consumption. 2. Moderate operating cost. 3. Better performance than air to air systems.	1. Dry earth is less of a heat source/sink than water. 2. High initial cost. 3. Leaks difficult to find and repair. 4. Pumping costs. 5. Deep wells more expensive than trenching.
Surface water-submerged heat pump	1. Energy efficient. 2. Moderate operating costs. 3. May not need supplement heat. 4. Better performance than air to air.	1. Suitable water bodies limited. 2. System clogging, scaling. 3. Current or wave action can damage equipment. 4. High initial cost. 5. Pumping cost.

SUMMARY

The Air Force application of GSHP looks promising. For example, in the immediate area of military family housing, there are thousands of possible candidates for GSHP systems. Life cycle cost analyses show that not only do GSHPs reduce energy usage, helping the Air Force reach its usage reduction goal of 30%, but it also saves money and has a DPB of under eight years.

MANUFACTURERS

The following is a list of GSHP manufacturers. There may be other manufacturers not on this list. This list is for information only.

Addison Products Company

- Bob Williamson
  P.O. Box 607715
  Orlando, FL 32860-7715
  (407) 292-4400

Bard Manufacturing Company

- Fred Paepke
  P.O. Box 607
  Bryan, Ohio 43506
  (419) 636-1194

ClimateMaster

- Mike Albertson
  P.O. Box 25788
  Oklahoma City, OK 73125
  (405) 745-6000

Econar Energy Systems

- Delwin Overholser
  1135 West Main St., Suite 201
  Anoka, MN 55303
  (612) 422-4002

Florida Heat Pump

- Division of Harrow Products, Inc.
  Chris Smith
  601 NW 65th Court
  Ft. Lauderdale, Fl 33309
  (305) 776-5471

Trane Corporation

- 3221 Speight Street
  P.O. Box 7916
  Waco, Texas 76714-7916
  (817) 840-3244

USPower Climate Control, Inc.

- Jeffrey Aspacher
  954 Marcon Blvd.
  Allentown, PA 18103
  (215) 266-9500

WaterFurnace International

- Andy Taussig
  9000 Conservation Way
  Fort Wayne, IN 46809
  (219) 478-5667

REFERENCES

1. Adopted partially from USDOE, **Using the Earth to Heat and Cool Homes**. DOE/CE/15095-6. December, 1983.
2. E. F. Lindsley, "Heat Pumps Go Underground." **Popular Science**, Vol. 223, No. 4. October, 1983.

3. James E. Bose. "Design of Closed-Loop Ground-Coupled Heat Pump Systems." Div. Eng. Tech., Oklahoma State University, Stillwater, OK.

ADDITIONAL INFORMATION

International Ground Source Heat Pump Association

- Oklahoma State University
    - Fred Jones
      482 Cordell South
      Stillwater, OK 74078
      (405) 744-5175

Appendix A
Appendix B
Appendix C
Appendix D
Appendix E
Appendix F