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ABSTRACT

The heat collecting capacity of the earth and or the earth's ground waters and surface waters exist as potential energy sources for home heating and cooling. Techniques and devices associated with use of the earth's thermal energy capabilities are presented and evaluated in this four-chapter report. Included in these chapters are: (1) descriptions of available types of earth and water-coupled systems; (2) advantages and drawbacks of earth thermal systems (with evaluative decision-making procedures); (3) descriptions of individual projects on earth and water-coupled systems and heat pumps; and (4) lists of resources, literature, and organizations affiliated with earth and water sources and heat pump technology. Explanatory diagrams are also provided for study and analysis. (ML)

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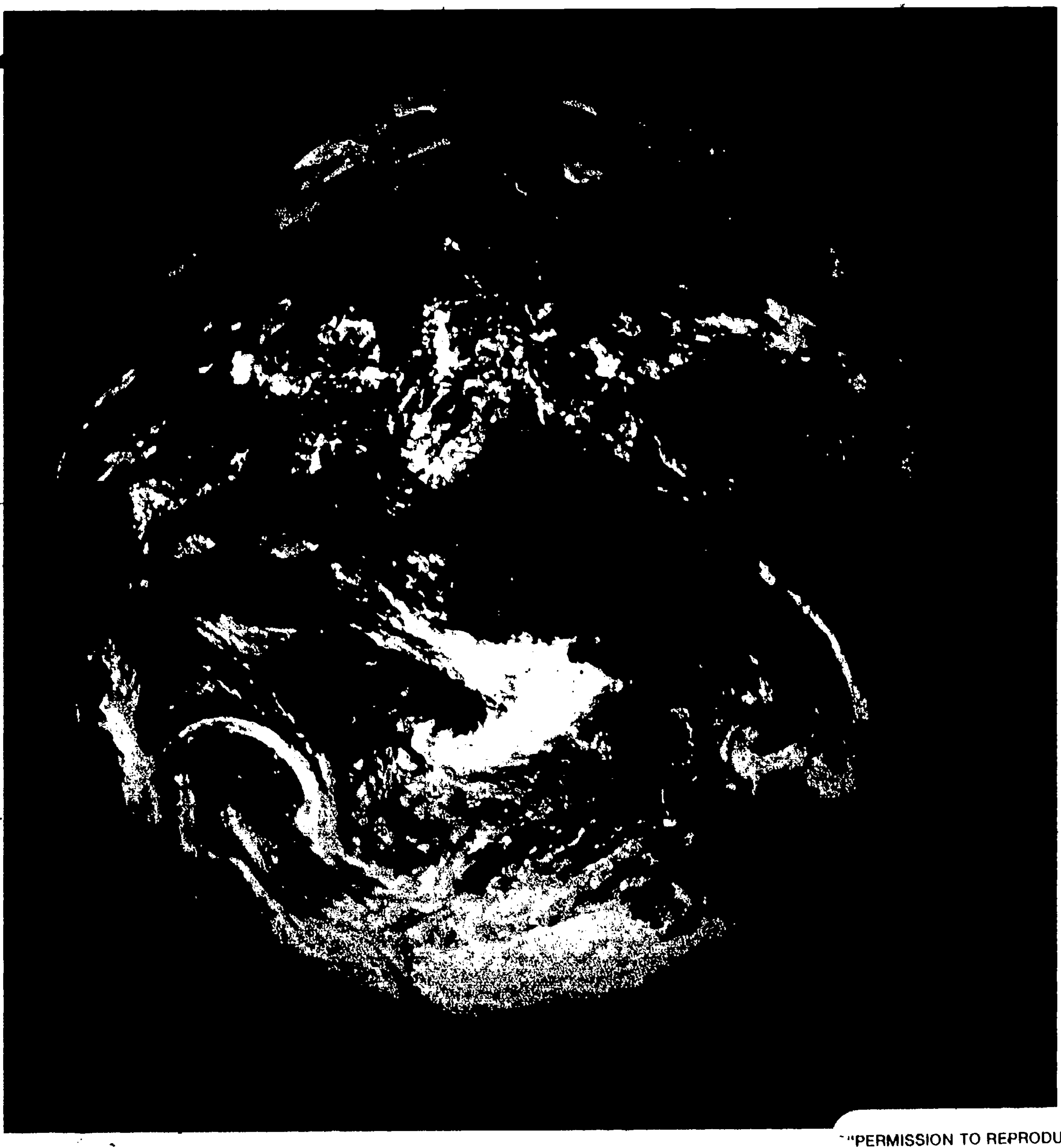
USING THE EARTH
TO HEAT AND COOL HOMES



Prepared for

U.S. Department of Energy
Assistant Secretary, Conservation and
Renewable Energy
Small Scale Technology Branch
Appropriate Technology Program
Under Contract No. DE-AC01-82CE15095

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Preface

From 1978 to 1981, the U.S. Department of Energy (DOE) awarded more than 2,000 small grants to individuals, organizations and small businesses across the nation to research and demonstrate appropriate technologies. Grants were given in the general areas of conservation, solar, biomass, wind, geothermal and hydro power. In 1982, the National Center for Appropriate Technology (NCAT) was placed under contract to review final reports from each DOE grantee to extract new ideas and other proven concepts that could be of value in applying appropriate technologies to energy problems.

This booklet is one in a series of publications that focuses on appropriate technologies and their application in the home and the work place. These publications combine a qualitative assessment of the DOE grant projects by NCAT with the results of current research. In Chapter Three of this publication, there is a list of selected projects reviewed in preparation of this document.

Prepared by:

Ncat the National Center for Appropriate Technology

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While it is impossible to mention every individual who has helped in the development of this document, the following individuals and the staff at the National Center for Appropriate Technology are recognized for their special contributions Stephen G Thomas, author Diane Smith editor George Everett editorial assistant, Evelyn Tracy, production assistant, Stephen P Anderson, technical reviewer, Hans Haumberger, technical illustrator and Tom Cook, graphic designer In addition, the cooperation and assistance of the following people who reviewed drafts of this publication are greatly appreciated Ronald J Fiskum, Program Manager, Technology and Consumer Products Branch U S Department of Energy, Lawrence R. Geni, mechanical engineer, Evanston, IL, John T Krigger, Helena, MT, Bruce F Marsh, Alaska Electric Light and Power Co , Juneau, AK, Harry T Mei Mechanical Engineering Department, Lamar University Beaumont TX, and Mark Sweeney electrical engineer Townsend, DE

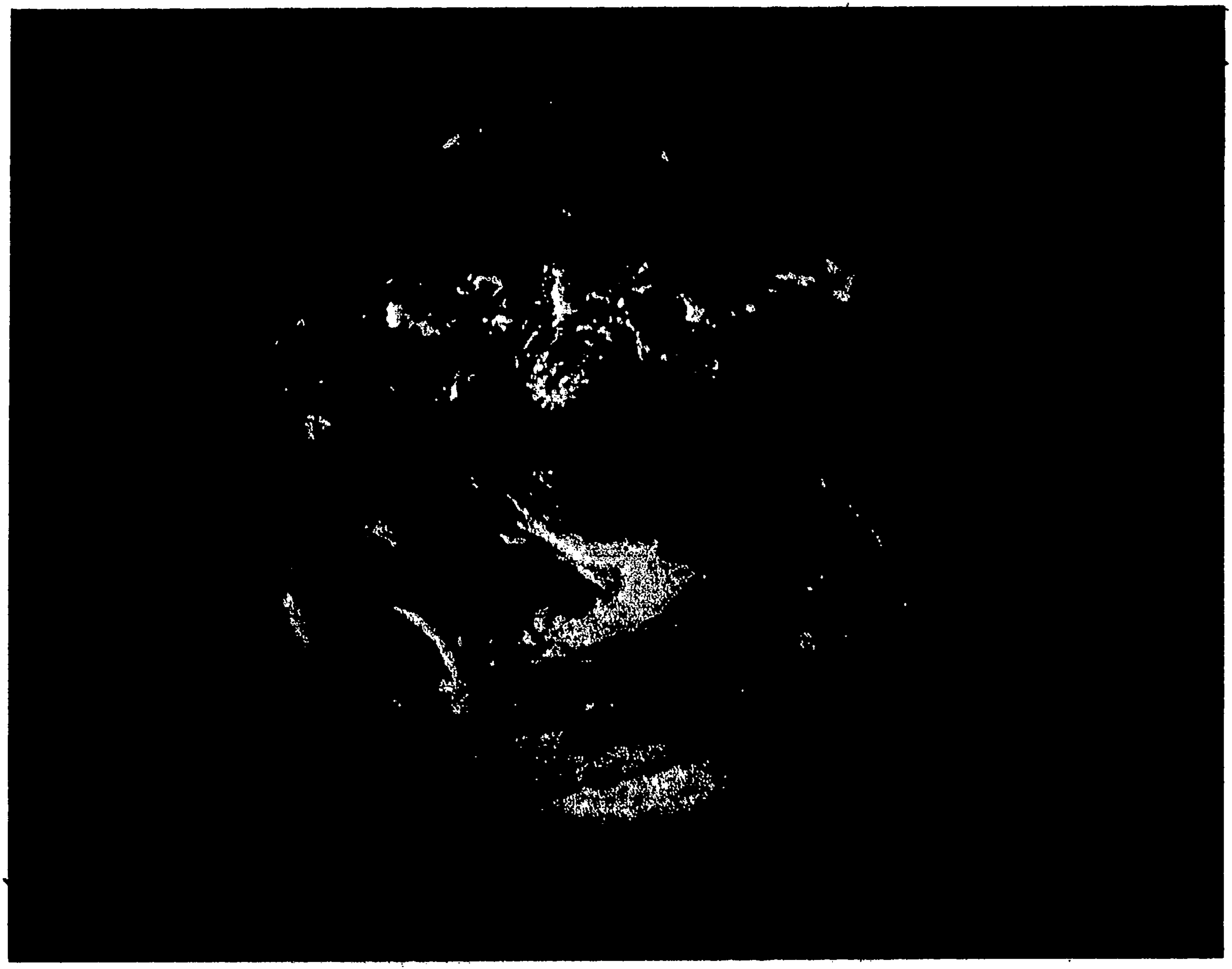
Introduction

Air temperatures in the 48 contiguous states can range from 120°F to −50°F. Even in parts of the country with so-called "moderate" climates, the seasonal range of air temperatures can be extreme. St. Louis, Missouri, for example, has had a record high temperature of 115°F and a record low of −23°F.

Compared with the temperature of the air, which can fluctuate dramatically throughout the year, the temperature of the earth, the earth's ground waters, and even surface waters remains relatively consistent. This moderate condition is a natural resource that is being used by many homeowners to heat—and cool—their homes.

Using the Earth to Heat and Cool Homes introduces techniques and devices put to use by DOE grantees to tap this source of energy. It is not intended to answer every question about the design and operation of every heating and cooling system that uses the earth's thermal energy, but it will help the homeowner ask the right questions. In addition, the publication provides a general method for evaluating the suitability of these systems.

Chapter One generally describes the types of earth- and water-coupled systems available. Chapter Two provides more information on the advantages and drawbacks of these systems. It also includes a five-step, decision-making process that helps the consumer decide which system, if any, is most appropriate for his or her situation. Chapter Three describes the systems used by several grantees from the U.S. Department of Energy's Appropriate Technology Small Grants Program and highlights some of the lessons they learned about this technology. Chapter Four provides a resource list that includes current literature on the technology, organizations that can provide more information, and what to look for when shopping for system equipment.



Chapter One

HOW CAN EARTH AND WATER BE USED TO HEAT AND COOL HOMES?

The earth is a massive collector that absorbs and stores heat from the sun. At depths from 20 to 30 feet, depending on the 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 warmer than air temperatures during the winter and cooler than the air during the summer.

Water has even more potential for absorbing and storing heat. Sufficiently large surface water bodies, such as lakes or large ponds that do not freeze solid in the winter, can be used for both heating and cooling. Ground water can also be used. In fact, ground water has several advantages over surface water; the primary advantage is that the temperature of ground water is more stable.

EARTH-COUPLED AND WATER-COUPLED SYSTEMS

The thermal energy of the earth and the earth's ground and surface water can be used to heat and/or cool homes in several ways. Some use ancient techniques such as earth-sheltered housing or earth tubes *(see sidebars, p. 9)* and others use more "modern" methods of transferring the heat through coils filled with heat-absorbing fluids.

Three systems must work together to get the most benefit from heating and cooling with thermal energy in the ground and water: the earth-coupled or water-coupled system, the heat transfer system, and the heating and cooling distribution system *(Figure 1.1)*. The rest of this chapter introduces these systems and shows how they work together.

Earth Coils

One effective way to tap the energy in the ground is by using earth coils. Earth coils are pipes made of metal or plastic which are buried in the ground. The pipes usually are filled with water or brine which is warmed or cooled by the earth. The liquid is pumped through the pipes and into the house.

There are basically two configurations for earth coil systems: horizontal earth coil systems *(Figure 1.2)* and vertical earth coil systems. Vertical earth coils use either a deep, closed casing *(Figure 1.3)* or a closed-loop pipe to carry the liquid *(Figure 1.4)*.

It is also possible to use several vertical coils in parallel *(Figure 1.5)*. This configuration uses relatively small pipe and can provide adequate heat or cooling without the great depths or high volumes of vertical systems, and without the large area of land required by horizontal systems.

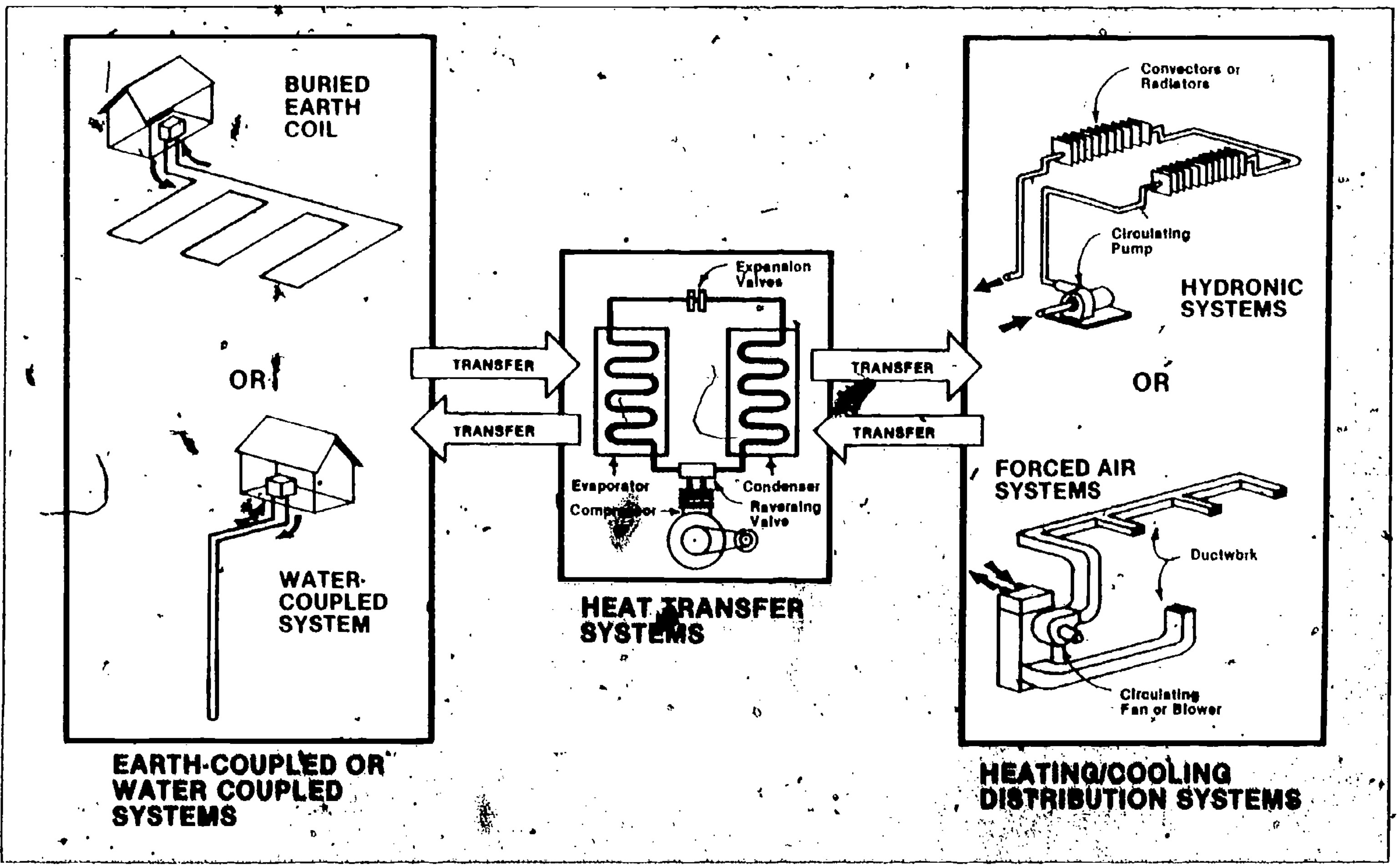


Figure 1.1 **How earth-coupled and water-coupled systems can be used to heat and cool homes.**

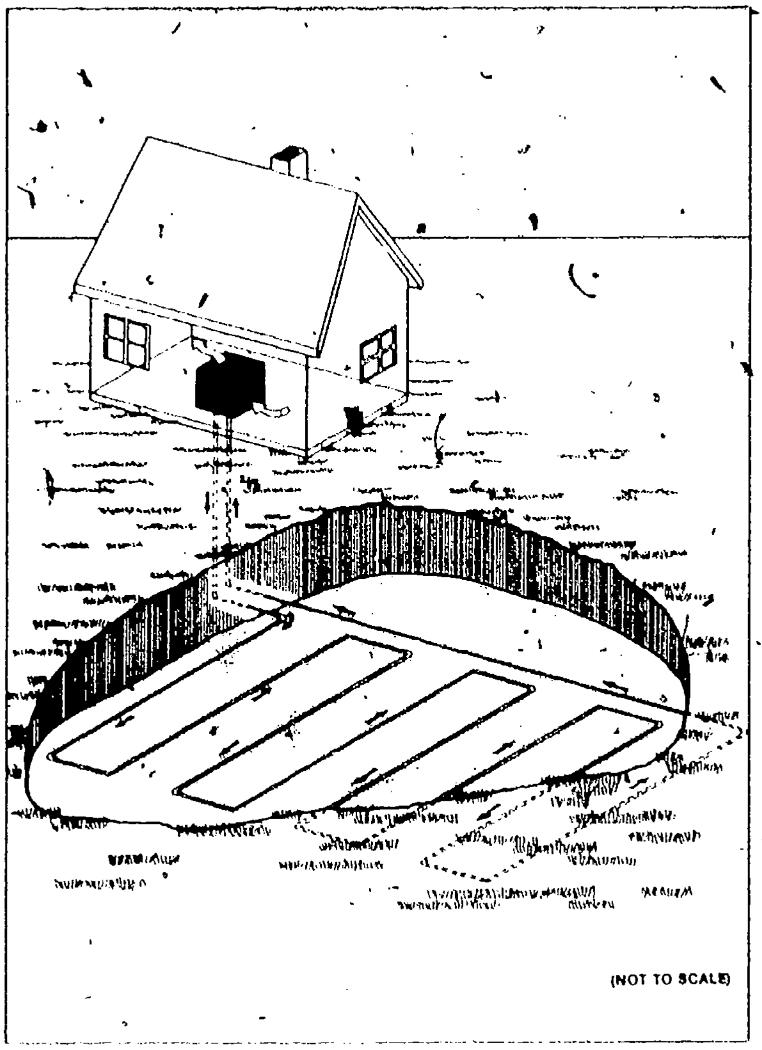


Figure 1.2 **Horizontal earth coil.**

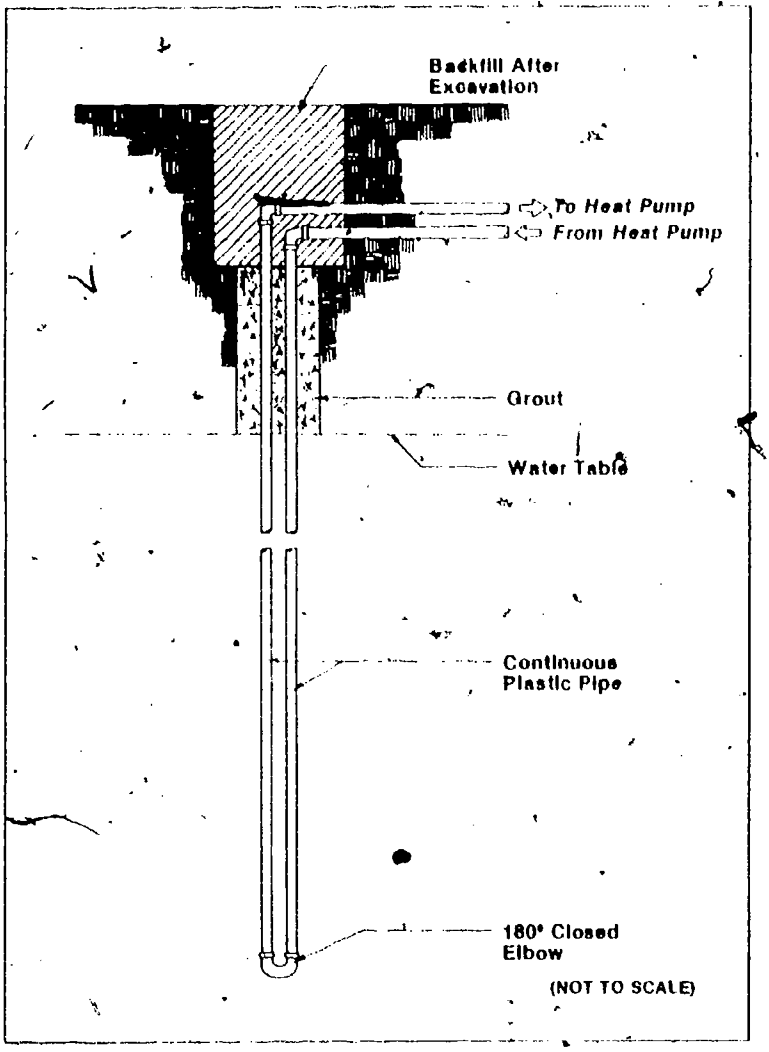


Figure 1.4 **Closed-loop, vertical earth coil.**

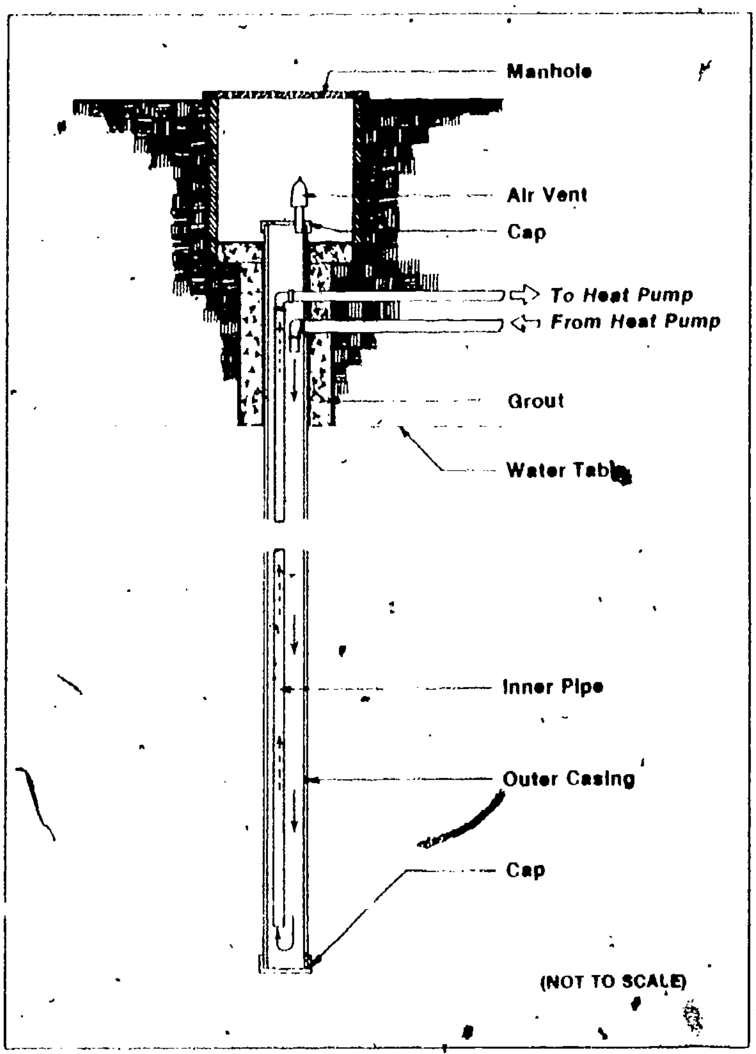


Figure 1.3 **Closed-casing, vertical earth coil.**

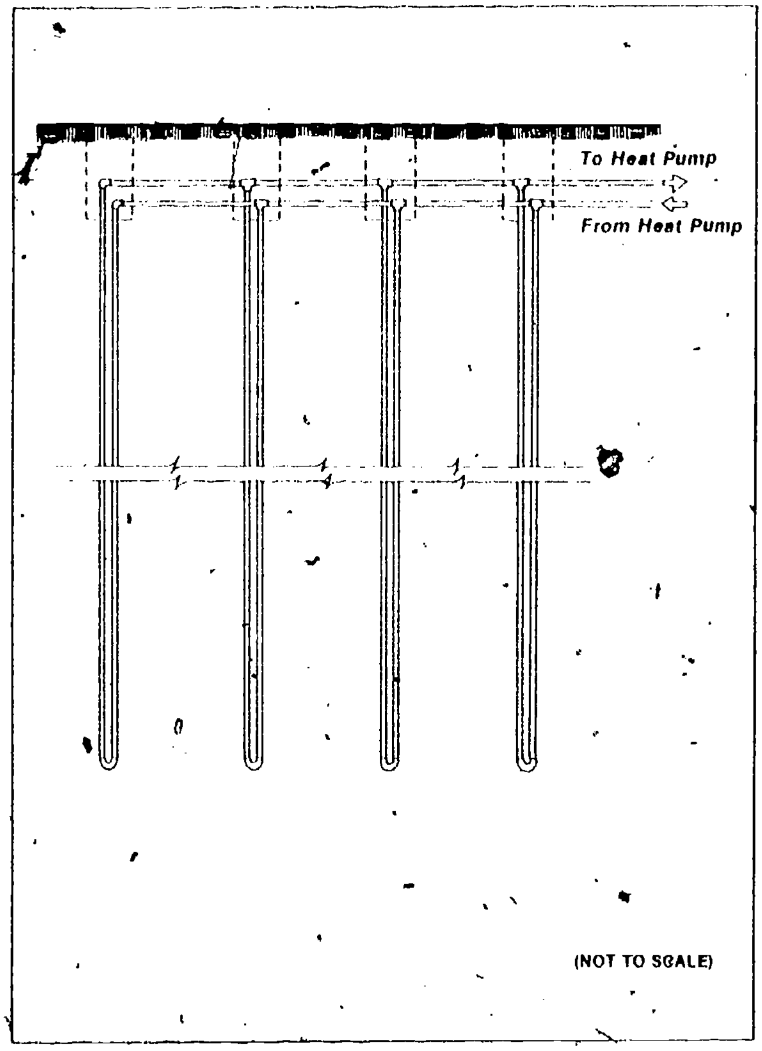


Figure 1.5 **Parallel, closed-loop, vertical earth coil.**

Water-Coupled Systems

Transferring the heat from ground and surface water bodies can be accomplished in two basic ways: with closed-loop or open-loop systems. Like earth coils, closed-loop, water-coupled systems place pipes filled with water, brine, or antifreeze into a water body with a moderate temperature (*Figure 1.6*). During the heating season, the thermal energy of the water warms the liquid in the pipe, and this warm liquid is pumped to the house where it is used by the heating system. In the cooling season, heat from the house is transferred to the liquid in the pipe, and pumped through the pipe back to the water body where it loses heat.

Open-loop systems actually pump the water directly from the ground or surface water body to the house (*Figure 1.7*). After the water is used to transfer heat within the house, the water is usually returned to the surface water or well that it came from, or it is returned to a second well.

HEAT TRANSFER AND DISTRIBUTION SYSTEMS

There are two basic ways to distribute the energy extracted from earth and water. The simplest way is to circulate the fluid through a system of radiators and use fans to blow air through the coils to cool the house. This kind of system is not suitable for heating, however, unless the earth or water source is unusually warm (say 110°F).

The most common way to use the heating and cooling potential of earth and water is to couple the earth coils or water-coupled systems with heat pumps. Heat pumps increase the benefits of using earth and water sources of energy, can be used in many different situations, and can provide both heating and cooling.

What Is A Heat Pump?

Anyone who has a refrigerator is familiar with heat pumps, even if they aren't familiar with the term. Heat pumps were developed to "pump heat" away from a space or "source" where it wasn't wanted (for example, inside a refrigerator), and to transfer the heat outside of that space. Air conditioners, which are heat pumps used for cooling, work on the same principle, extracting heat from a hot space (the source) and dumping it outside (the sink). Some heat pumps are used just for heating, but many heat pumps have a reversing valve so they can be switched to cooling.

When heat pumps are coupled with earth coils or water-coupled systems,

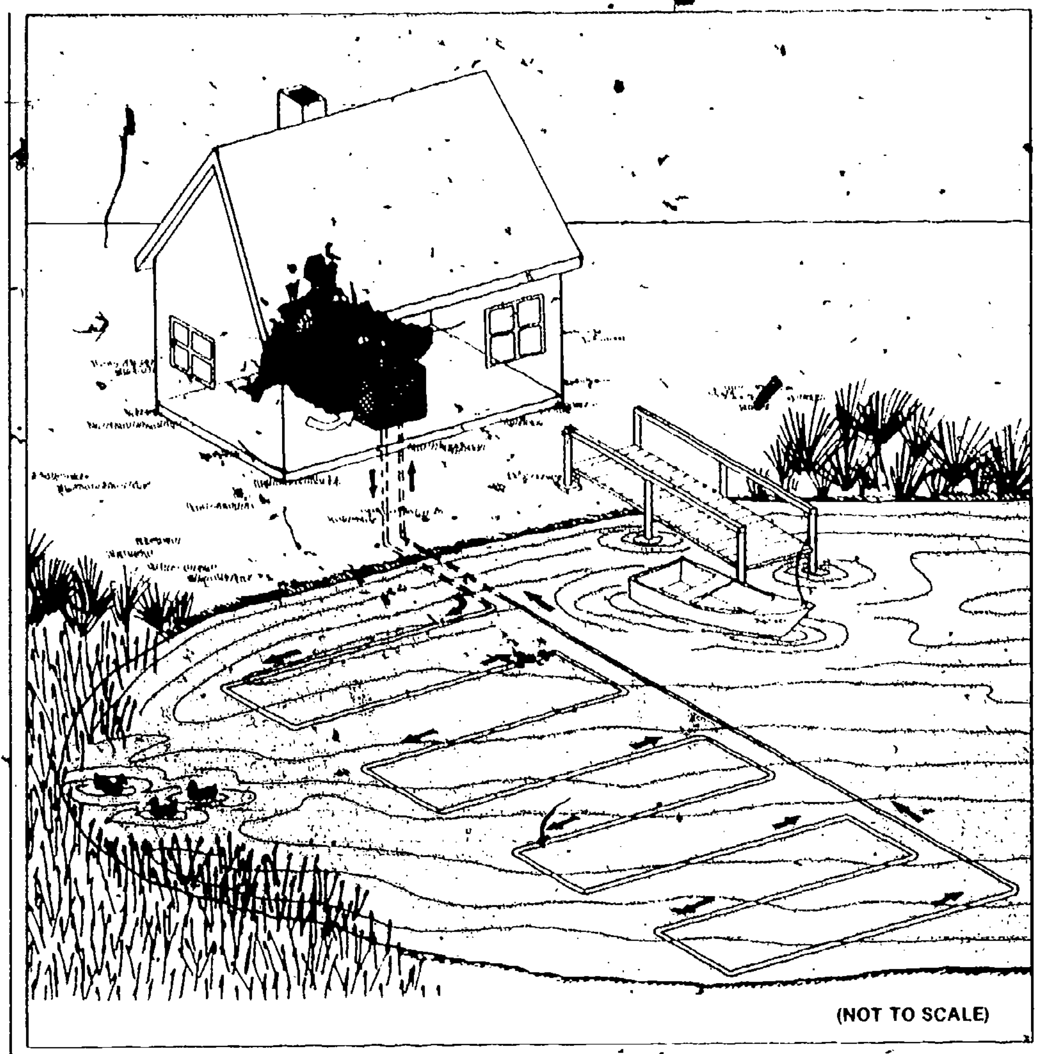


Figure 1.6 .Closed-loop, water-coupled system.

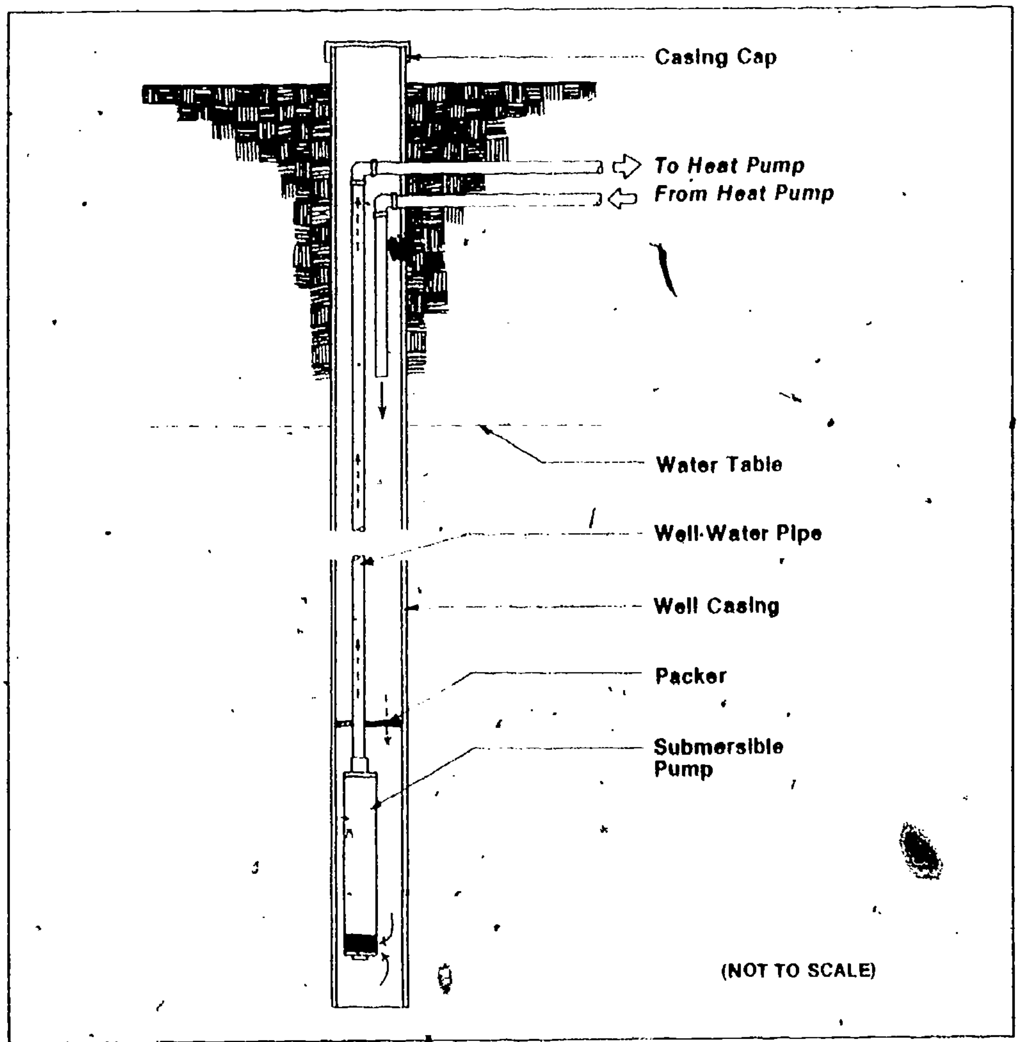


Figure 1.7 Open-loop, ground water well.

they are used to extract heat from the water (or brine or antifreeze) that is circulated through these systems. These heat pumps are called *water-source heat pumps* because they draw heat from the water (or other liquid) circulating through the coils or pipes. The heat pumps are still referred to as water-source heat pumps whether they are attached to an earth coil system or a water-coupled system.

If water-source heat pumps distribute the heat with water passing through radiators (a hydronic system), they are referred to as *water-to-water heat pumps*. If, on the other hand, the heat pumps use a forced-air system to heat the home, they are called *water-to-air heat pumps*. Water-to-air heat pumps are the most common type of residential, water-source heat pumps.

How Do Heat Pumps Work?

Instead of simply moving a fluid at a given temperature from place to place, heat pumps use a mechanical process to increase the temperature of the fluid. This can happen because heat pumps use refrigerants, which boil at low temperatures. The gas produced by boiling a refrigerant can be compressed, and the compression increases the temperature of the gas. This heat is released when the gas condenses.

When heat pumps are used for heating, water from an earth coil or water-coupled system flows alongside the refrigerant tube in the evaporator (*Figure 1.8*). Here, the liquid refrigerant absorbs heat from the water, boils, and changes into a gas. This gas is squeezed by the compressor, and the temperature is raised as a result. This high-temperature, high-pressure gas is then pumped to the condenser where it gives up heat when a fan blows air across the condenser coils. As it loses heat, the gas changes back into a hot liquid. Then it passes through an expansion valve that further reduces temperature and pressure. The low-temperature, low-pressure liquid is pumped back to the evaporator, and the process begins again.

If a heat pump is equipped with a reversing valve, the process can be switched to operate in reverse for cooling. The condenser functions as an evaporator, and the evaporator becomes a condenser. Heat from the living space is pulled across the condenser coils, and the liquid refrigerant evaporates. The compressor pumps the heated gas to the evaporator, heat flows from the refrigerant to the cooler water, and the refrigerant condenses. Then the warmed water is pumped from the heat pump and through the earth coil or

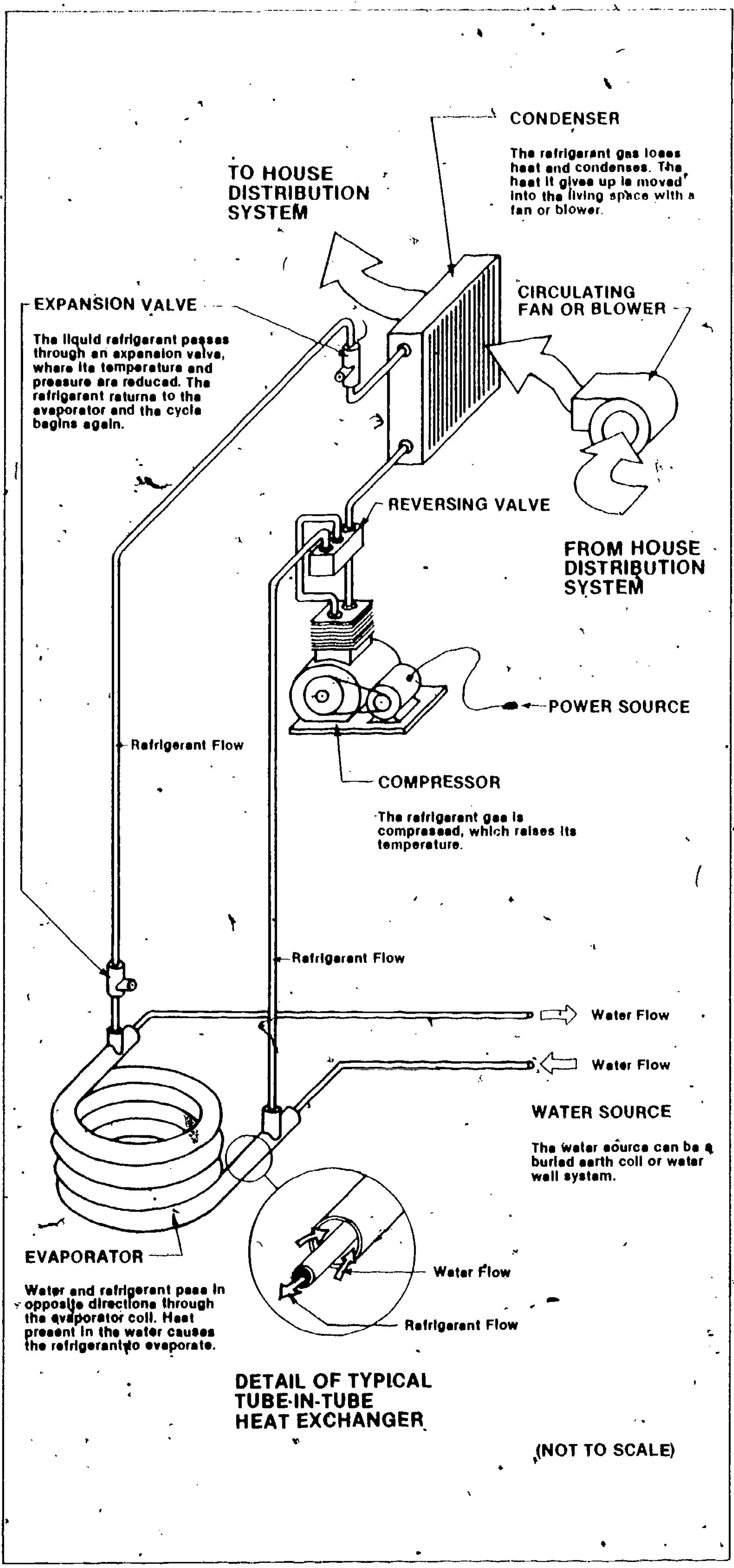


Figure 1.8 **Typical water-source heat pump in the heating mode.**

water-coupled system where the water gives up its heat.

How Efficient Are Heat Pumps?

Heating systems are evaluated by comparing the amount of energy delivered (i.e., heat) with the amount of energy consumed to deliver that energy. This is known as the *Coefficient of Performance* or COP. Electric resistance heaters have a COP of 1; that means it takes 1 watt of electricity to deliver the heat equivalent of 1 watt. Air-source heat pumps generally have COP's of 2; they deliver two times more energy than they consume. Water-source heat pumps normally have a COP of at least 3. Cooling efficiency normally is measured in terms of the Energy Efficiency Ratio (EER). The EER is similar to COP, but it is calculated using different units of measure. With EER's, higher ratings are better, and EER's of 8 or 9 are desirable.

In actual use, the COP's of heat pumps vary depending on the temperature of the source. For example, the efficiency of an air-source heat pump in the heating mode declines as the outside temperature drops because there is less heat in the air. Since the temperatures of the earth and ground and surface waters are more stable than air temperatures, COP's do not vary as much with water-source heat pumps (*Figure 1.9*).

The efficiency of a heat pump is also a function of its performance during all seasons under different operating conditions. When heat pump efficiency is calculated over a period of time, it is called the Seasonal Performance Factor (SPF). An SPF of 2 means that a heat pump will be twice as efficient as electric resistance heating.

How Much Do Heat Pumps Cost?

One of the current disadvantages of heat pumps is the relatively high initial cost. The retail cost of a residential water-source heat pump can be as much as $3,000, or even higher in places like Alaska. Wells or earth coils also add to the cost, often as much as the cost of the heat pump itself. If a heat pump replaces a heating system that uses forced air in an existing house, duct systems also may need to be changed, adding more to the cost of the system.

Operating costs for heat pumps are frequently, but not always, lower than for other systems. Long-term operating costs are affected by a number of factors such as relative fuel costs, geographic location, efficiency of the heat pump and heat delivery system, conservation strategies, and building size.

Most heat pumps available now are well made and reliable, but because they are more complex and have more moving parts than furnaces, conscientious maintenance is important to keep them operating at their peak. Also, compressors typically have to be replaced every 12 to 15 years. In 1982, it cost from $600 to $800 to replace a compressor. Consequently, maintenance usually costs more for heat pumps than it does for furnaces.

The combination of a high initial cost and varying operating costs, requires a full and careful analysis of long-term economics before purchasing a heat pump system. Chapter Two provides more information and a way to evaluate the economic and other factors that must be assessed. Some other advantages and disadvantages of these systems (*Table 1.1*) must also be considered before a heating and cooling system is selected.

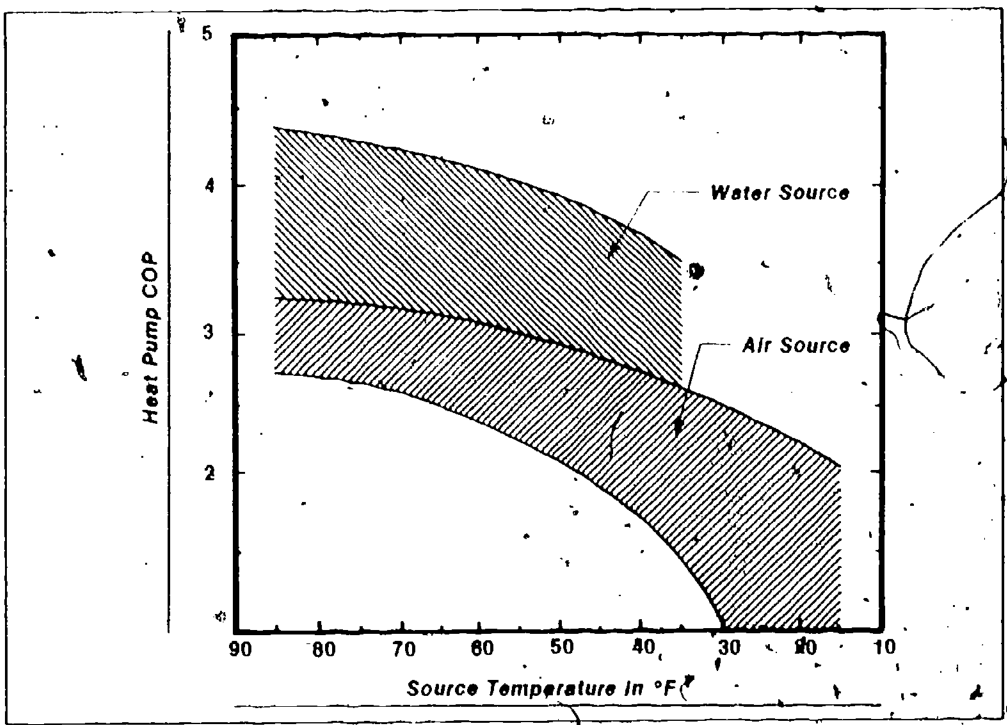
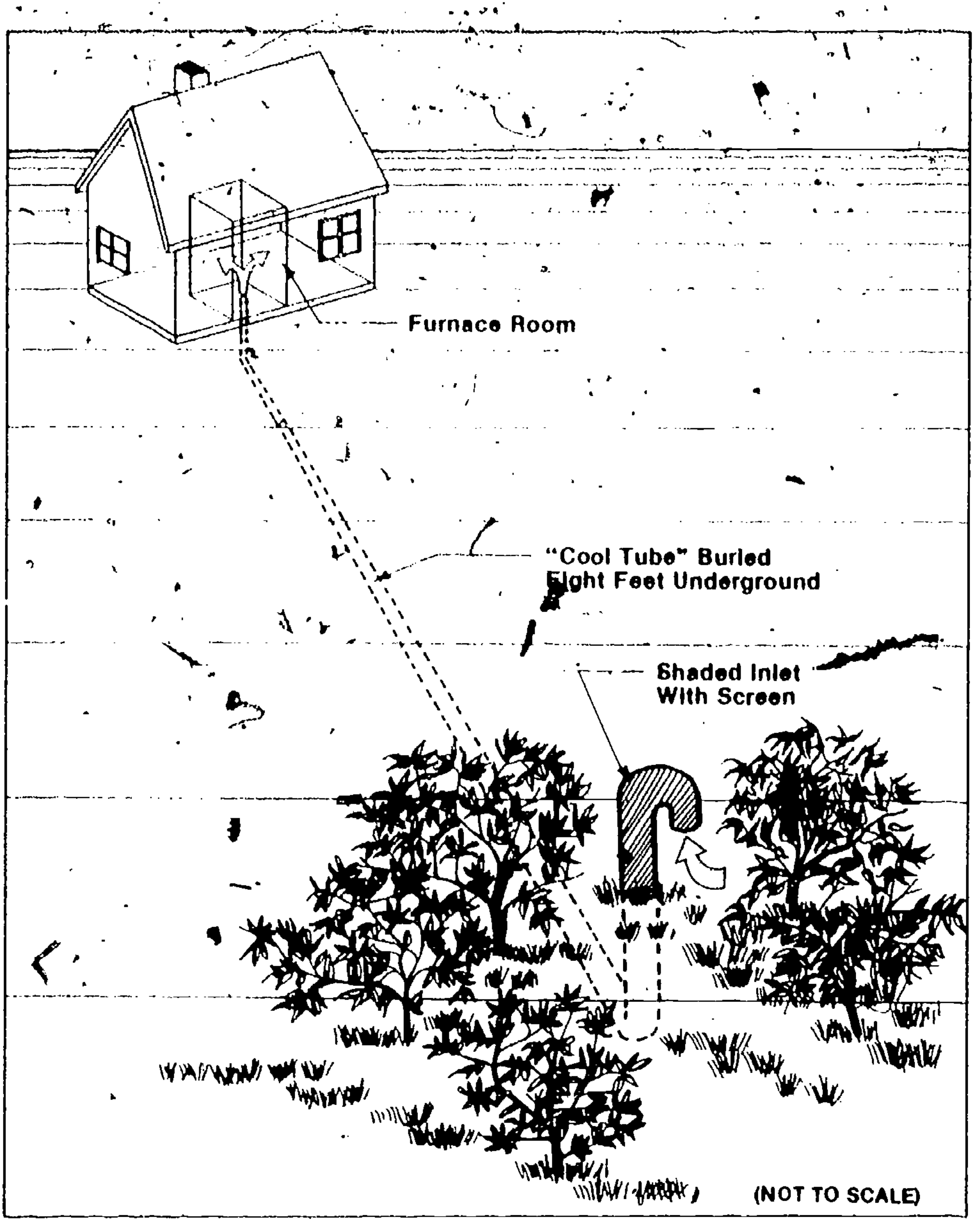


Figure 1.9 **Relationship of source temperatures to COP's of 3-ton heat pumps in the heating mode.**

System	***Advantages***	***Disadvantages***
Earth tubes	No energy or low energy consumption	Limited areas where they can be used effectively Moisture, vermin, or radon in tubes may be problems
Earth coil with heat pump	Relatively low energy consumption Moderate operating costs Better performance than air-to-air heat pumps	Dry earth is not as good as water as a source/sink High initial cost Leaks difficult to find and repair Pumping cost
Water-coupled system with heat exchanger	Lower initial cost than for heat pump Lower operating cost than for heat pump	Limited areas where they can be used effectively Requires thorough understanding of design factors
Surface water-coupled system with heat pump	Heat source/sink temperatures are relatively constant compared with air Good energy efficiency Moderate operating cost Does not require defrost cycle like air-source heat pump May not require supplemental heat	Suitable water bodies are limited, System clogging, fouling, scaling, or corrosion Current or wave action can damage equipment High initial cost Pumping cost
Ground water-coupled system with heat pump	Heat source/sink temperatures are relatively constant Good energy efficiency Does not require defrost cycle like air-source heat pump Moderate operating cost May not require supplemental heat	High initial cost Scaling or corrosion can be problems Pumping cost

Table 1.1 **Advantages and disadvantages of earth-coupled and water-coupled systems.**



EARTH TUBES

Earth tubes can be used to warm the air entering a building, but they are most often used for cooling and are called "cool tubes." Cool tubes were used centuries ago in Iran and have recently been rediscovered. Cool tube systems use a large pipe, or "tube," which is buried approximately 8 feet underground. The tubes are made of plastic, masonry, or metal, are usually 8 to 20 inches in diameter, and can be anywhere from 100- to 400-feet long. Air is drawn into the tube through a shaded, screened, above-ground opening. As the air passes through the tube it is cooled by the ground and then it is drawn into the house where it is distributed through ductwork or vents. The cool air can be drawn through the tubes by natural convection or with forced convection.

Cool tubes are not likely to be very effective in hot, damp climates because they don't dehumidify the air well. Also, if new materials are used and the necessary excavating is done exclusively for the cool tubes, they are unlikely to be cost-effective, even though they use little or no energy to operate. However, if materials can be obtained for little or no cost, if the excavation work is done at the same time as other tasks, and if the cool tubes are used with other passive cooling methods, they can provide a home with a useful source of cool air. (Chapter Four has references that provide additional information on cool tubes.)

CASE STUDY:
Measuring cool tube performance
Paul Grant
Davis, California
DOE Grant No.
DE-FG03-79R910567
ATMIS ID:
CA-79-012

The Davis Alternative Technology Associates in Davis, California constructed a cool tube system with 75 feet of 12-inch corrugated pipe buried 8 feet deep to measure and analyze its cooling capability. Air was pushed through the pipe with a variable-speed fan. Air was cooled by as much as 8.6°F. Using new materials and trenching just for the test, the system cost about $1,000, about twice as much as an air conditioner of similar capacity.

EARTH-SHELTERED STRUCTURES

From the days of the cave dwellers to the present, people have used the earth to protect them from the elements and to moderate the temperatures of their homes. Today, an earth-sheltered house is not necessarily hollowed out of rock or dirt. Integrating modern architectural methods, the walls of a dwelling may be banked with earth, or part of the building can be in the ground and part of it above ground, or the entire structure can be below ground level. Builders can now fully waterproof earth-sheltered houses and provide them, in some cases, with as much window space as above ground structures. All, in one way or another, use the earth's inherent ability to insulate the building and moderate temperatures. (A reference in Chapter Four provides more information on earth-sheltered housing.)

CASE STUDY:
An earth-sheltered passive solar residence
Richard Yarnel
Carson City, Nevada
DOE Grant No.
DE-FG03-80R950014
ATMIS ID:
NV-80-001

One grantee built an earth-sheltered, passive solar home in Carson City, Nevada. The east, west, and north walls are built into the earth, up to the roof line. These walls are constructed of 8-inch, reinforced concrete and covered on the outside with rigid foam insulation and a plastic film vapor barrier. The front section of the house is an attached solar greenhouse, and much of the rest of the south-facing area has glass that lets in the sunshine. Temperatures in the house are moderated in the winter by the earth surrounding it and the mass of the floor and walls inside. Heat comes from the sun and a wood-burning stove. In the summer, various shading techniques are used to limit heat gained from the sun, and the earth around the house helps to keep it cool. A cool tube, built in along the north side of the house, provides cooling and ventilation in the summer. One added bonus that the residents have realized is that an earth-sheltered house is very quiet.

Chapter Two

WHEN ARE EARTH- AND WATER-COUPLED SYSTEMS APPROPRIATE?

Using the earth or water to heat and cool homes is not common. Consequently, the decision to install one of these systems has to be based on a more comprehensive analysis than when choosing more conventional heating systems.

The decision sequence in this chapter does not consider every style of residence, geological or hydrological variation, or heat pump and plumbing configuration. It does raise the basic questions that have to be asked and suggests some of the ways these questions can be answered, based on the experiences of grantees from the Appropriate Technology Small Grants Program and others who have used and refined earth- and water-coupled technologies.

Earth- and water-coupled systems are relatively simple, but homeowners who plan to design, build, and maintain them should have the benefit of expert advice and service. Each step in this decision sequence suggests the most likely sources of assistance, and Chapter Four provides more detailed information.

There are some cases where earth- and water-coupled systems will not be suitable, and there are others where they are especially attractive. Earth- or water-coupled heat pump systems should definitely be considered when:

- an existing heating system needs to be replaced;
- both heating and cooling are desirable;
- an on-site well or surface water is available;
- natural gas is not available.

Step 1: *Evaluate conservation alternatives.*

Conservation and weatherization can save energy and money. In fact, they can be so effective they may eliminate the need for a conventional central heating system or make it possible to use a relatively small heating system in a very energy-efficient way.

So, before even considering a heat pump system, look into conservation techniques to weatherize your home. Conservation and weatherization materials could be much less expensive than a heat pump system and offer a faster payback in energy and dollars. To get the most from any heating and cooling system, conservation and weatherization are a must.

Who can help:
Utilities
State and local energy offices
Libraries
Heating, ventilating, and air-conditioning engineers

Step 2:
Determine what regulations apply.

When considering an earth- or water-coupled heat pump, it's best to know right from the start if such a system will be permitted. Most regulations that can affect these systems relate to water use, but the regulations were not written specifically for water-coupled heat pumps. As a result, the regulations may be subject to interpretation and applied inconsistently.

Begin by inquiring about regulations at the local level. In urban areas, it is common for private wells to be prohibited in areas served by municipal water systems. This prohibition is waived sometimes if the well is used only for heating and cooling, and if it can be demonstrated that the well will not adversely affect the municipal water system. Municipalities may also have: domestic well permit requirements, waste water disposal prohibitions, and requirements that water taken from a ground water body (aquifer) be returned to the source it is taken from. County health departments often regulate the specifications for, and spacing of, wells. Building codes and zoning ordinances are also likely to apply.

Local officials may also be a good source of information about state regulations. States are most likely to regulate water use, water quality, and waste water disposal. Many of these regulations do not address water-source heat pumps specifically, and some states have looked at virtually identical regulations and come to opposite conclusions about how they apply to water-coupled heat pumps.

In most cases, a state office will also administer the two Federal programs that pertain: the National Pollutant Discharge Elimination System (NPDES) and the Underground Injection Control (UIC) program. NPDES is concerned with the pollution of surface waters and defines heat as a pollutant. The UIC was created to safeguard the underground drinking water supply, and it regulates injection wells. Heat pump return wells are specifically included in a UIC injection well category, but this category as a whole is not considered a significant threat to water quality. If a state does not administer NPDES or UIC, the U.S. Environmental Protection Agency does.

Never assume that a water-coupled heat pump will be permitted without checking all of the possible regulatory agencies. Regulators are required to protect the interests of all of their constituents. Many regulators are not familiar with water-coupled heat pump systems, and they may hesitate to approve something they do not fully understand.

Who can help:
Local and state regulatory agencies
State or local citizen advocates

Step 3:
Size and select a heating and cooling system.

No matter what kind of heating and/or cooling system is eventually chosen, it is important that the system be properly sized so that it is energy-efficient and provides comfort. If heating is the primary concern, a *rough assessment* of the size can be determined by selecting the appropriate weather zone on Figure 2.1 and then multiplying the square footage of the house by the capacity figures from Table 2.1. This will give the approximate amount of heat in British thermal units

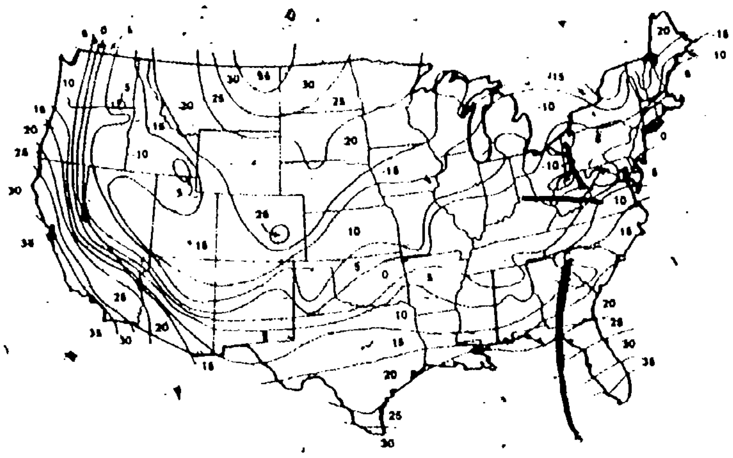


Figure 2.1 **Winter design temperatures in °F.**

(Note: A thorough heat transfer analysis *must* be conducted to determine the proper heating equipment size. Heating systems should *not* be selected based on this table.)

1. Find the winter design temperature on the map, Figure 2.1. Use the design temperature to select the heat load capacity from this table.
2. Multiply the appropriate heat load capacity by the heated area of the house to get an estimate of the heat pump size.
3. Multiply the result by 1.5 if the house is poorly insulated. Multiply the result by 0.5 if the house is well insulated.

Winter Design Temperature	***Heat Load Capacity (Btu/ft²)***
−35	42.1
−30	40.0
−25	37.9
−20	35.8
−15	33.7
−10	31.7
− 5	29.6
0	27.5
5	25.4
10	23.3
15	21.2
20	19.2
25	17.1
30	15.0
35	12.9
40 & above	10.8

Table 2.1 **How to get a rough estimate of heating equipment size.**

per hour (Btuh) that are needed to keep the house warm and, in effect, the size of the heating system.

For example, if your winter design temperature is 5°F and the area to heat in your house is 1,200 square feet (ft²), your heat pump should be able to provide about 30,480 Btuh to keep the house at 70°F. (1,200 ft² x 25.4 Btuh/ft² = 30,480 Btuh.)

A more accurate (and ultimately necessary) way to calculate the proper size of the heating equipment is to do a heat transfer analysis that considers how much heat the house loses through cracks, doors, and windows, and how much it gains from things like occupants and appliances. Heating and cooling contractors can do this calculation, and some of them will do the analysis at no charge. (Refer to Chapter Four to find resources that you can use to do heat transfer calculations.)

With heat pumps, sizing is critical because the heat generated by the system is never as "hot" as traditional forced-air furnaces. For example, while a furnace can blast 150°F air into a room, the air from a water-to-air heat pump is rarely over 100°F, and can be as low as 80-85°F. Pumping this lower temperature air through a home can make it seem drafty. However, when properly sized and designed, a heat pump system can make a home feel very comfortable because the heat is more even than heat from a furnace with forced air. When used for cooling, heat pumps also help dehumidify the air.

With a heat pump system, back-up heat is also a consideration. Even though back-up heat may not be necessary, sometimes it saves energy and money when some kind of supplemental heat is used in combination with a heat pump. Back-up heat can be provided by electrical resistance heat strips built into the heat pump, or by any fuel-fired system, such as a gas furnace, an oil furnace or heater, or a wood stove. Fuel-fired systems can be separate, or they can be combined with the heat pump and share such things as the air distribution and control systems.

The advantage of a fuel-fired back-up source is its availability if electricity is lost. (Remember, though, that most fuel-burning systems use electricity for fans and controls.) The main disadvantage of adding a separate fuel-fired source is that it costs more money. However, if an old oil furnace still works and is safe, or an efficient wood stove is already installed, they can be used. The capacities of these heat sources and the amount of time they will be used must be determined when calculating the part of the load to be carried by the heat pump.

Many water-coupled heat pumps do not use supplemental heat sources. In such cases, accurate heat load analyses, heat pump sizing, and air delivery system design are mandatory. Also, heating and cooling loads are rarely equal, and depending on the circumstances, the heat pump will have too much heating or cooling capacity.

If a contractor calculates the heating load, be sure to mention any preferences for particular temperatures in particular rooms. Older heating systems often leave some rooms too hot and others too cold. Installing a new heating system is the time to remedy those conditions.

When all of the heating and cooling load factors have been considered, the heat pump size can be determined. When the size is known, the flow and pressure requirements of the water supply can be determined from manufacturers' specifications.

Who can help:

Heating and cooling contractors
Utilities
Energy consultants
Local energy offices

TWO EXAMPLES OF HEAT PUMPS INSTALLED BY GRANTEES

Townsend, Delaware
House type:
Two-story, wood-frame farmhouse
Heated area:
1,100 ft²
Insulation level:
Low
Previous heating system:
70,000 Btuh, oil, forced-air furnace
Climate type:
Coastal
Mean winter temperature:
39°F
Mean summer temperature:
74°F
Heating Degree Days:
5,000 HDD
Cooling Degree Days:
1,500 CDD
Winter design temperature:
0°F
Heat pump heating design rating:
45,000 Btuh
Heat pump cooling design rating:
40,000 Btuh

Bloomfield, Iowa
House type:
New, main floor with heated basement
Heated area:
1,800 ft²
Insulation level:
High, R48 insulation in ceiling
R21 insulation in walls
Double- and triple-glazed windows
Climate type:
Humid continental
Mean winter temperature:
20°F
Mean summer temperature:
71°F
Heating Degree Days:
8,149 HDD
Cooling Degree Days:
994 CDD
Winter design temperature:
-10°F
Heat pump heating design rating:
30,000 Btuh
(Cooling with heat exchanger and fan)

TWO EXAMPLES OF EARTH- AND WATER-COUPLED SYSTEMS INSTALLED BY GRANTEES

Townsend, Delaware

Heat pump heating design rating:
45,000 Btuh
Heat pump cooling design rating:
40,000 Btuh
Heat pump water specifications:

Cooling

Temperature In	***Flow***
70°F requires	*3 gpm*
110°F requires	*13 gpm*

Heating

Temperature In	***Flow***
40°F requires	*13 gpm*
75°F requires	*3 gpm*

Well type:
156-ft deep, 4-in. cast-iron case
Average annual water temperature:
About 60°F
Pump type:
Jet, 0.5 hp, 6 gpm flow
Expansion tank:
64 gal
Return well:
28-ft deep, 3-ft diameter, hand-dug, brick-lined

Bloomfield, Iowa

Heat pump heating capacity:
30,000 Btuh
Cooling:
Fan and heat exchanger
Heat pump water requirements (heating):

Temperature In	***Flow***
42°F requires	*11 gpm*
54°F requires	*8 gpm*

Earth coil:
2,200-ft long, 1.5-in. PVC, 10-ft deep
Annual temperature range for water from coil:
42°F to 52°F
Pump:
0.5-hp boiler pump
Storage reservoir:
15-gal fiberglass tank

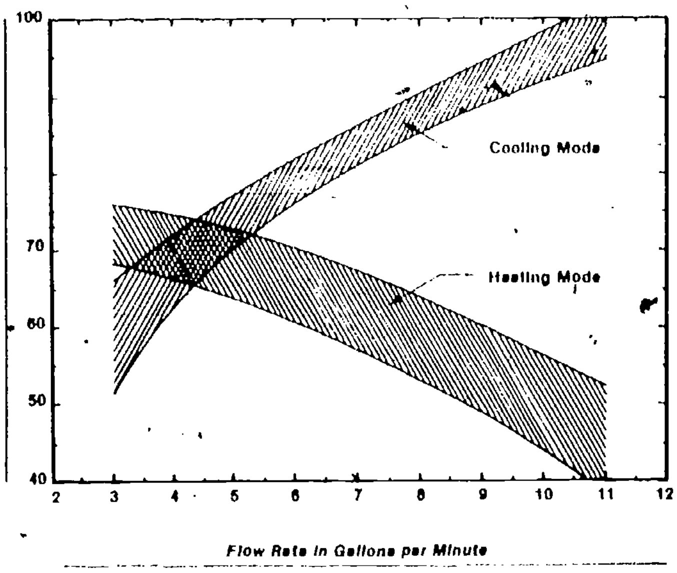


Figure 2.2 **Relationship of temperature to flow rate for typical 3-ton water-source heat pumps.**

Step 4:
Evaluate the earth and water resources.

The next question to consider is: which resource is appropriate, earth or water? In general, water-coupled systems are more efficient because the heat transfer and storage capability of water is higher. The primary advantage of earth coils is that the system is closed and uses a relatively small amount of energy to transfer heat to or from the soil.

Water Resources

Start by evaluating water resources. If there is surface water on or adjacent to the property, determine who has the rights to it. In the eastern part of the country, the landowner generally has the right to use water flowing through her or his property. This is not necessarily true in western states.

Is there enough water? For rivers and streams, base any decisions on low flows, not annual averages. Remember that the actual volume must be based on the flow requirements of the heat pump. Also remember that the volume of any surface water body must be based on dry years and hard freezes. Obviously, a pond that freezes solid will not be a good heat source.

There are certain disadvantages to using surface waters that should be considered. Surface water systems may be affected by clogging, freezing and biological fouling, and warm water from a heat pump may stimulate unwanted aquatic plant growth. Salt water can be used, but special precautions and equipment are necessary to handle it. Systems can also be damaged by waves and currents.

Ground water sources must be evaluated for flow, quality, and temperature. Flow rates are the most critical, since heat pumps can use up to 14,000 gallons per day during heavy use. Most residential water-coupled systems use between 3 and 12 gallons per minute. Besides volume, the important thing is to get sustained flow. Wells must be pumped continuously for at least 12 hours (a drawdown test) to prove that they are adequate.

As more ground water-coupled heat pumps are being used, observed, and improved, there is less concern about water quality. However, water quality remains a potential problem, because various chemicals in the water (especially calcium and sulfur compounds) may cause scaling or corrosion in heat exchangers and valves. If heat exchange tubes in the heat pump become coated with mineral deposits, heat exchange efficiency is diminished significantly. If deposits build up too much, the flow may be reduced so much that both the water pump and heat pump may be damaged. Severe corrosion can eat through the heat exchanger walls or other heat pump components.

Recent experience indicates that scaling is more of a problem in valves than in heat exchange coils. To determine if water quality will be a problem, have the water tested, and then consult with the heat pump dealer to determine if any special precautions need to be taken.

Water conditioners are available that can treat very bad water, but conditioners will add to the cost of the whole system. However, if the water is used for domestic consumption, a water conditioner may be necessary anyway.

Water temperature is also less critical than it once was. Earlier water-coupled heat pumps operated best at a relatively narrow range of temperatures, about 50°F to 70°F. Some heat pumps were built to handle lower or higher temperatures, but they were essentially custom-made and more expensive. Now with an expanding market, several manufacturers make "standard" heat pumps designed to provide excellent heating performance with water source temperatures at 40°F or lower. To get the best performance from a system, the heat pump has to be selected to match the normal range of temperatures from the well. The temperature can be readily determined while the flow tests are being conducted. Remember too, that low temperatures require higher flow rates in the winter (*Figure* 2.2).

Once water flow, quality, and temperature are known, the type of well system can be determined. A bountiful aquifer with a lot of water movement may support a single-well system where water is withdrawn from and returned to the same well. Generally, two wells will be necessary. Because of the potential for clogging, a return well should actually be larger than the supply well. Also, the return well can be as simple as an uncased hole filled with rock. Some older, rural homes may have unused dug wells that can be used for return water. These should be tested to determine their capacity to accommodate return volumes.

Ground water characteristics are very site specific, but in most cases it is advisable to separate the return well from the supply well by at least 50 feet to prevent a significant change in the supply well temperature.

City residents sometimes are allowed to use storm sewers for water disposal. Although storm sewers can actually benefit from this "flushing," storm sewer disposal is not recommended because it wastes water. Sanitary sewers (or combined sewers) should never be used for water disposal because it makes sewage treatment less efficient and more costly.

Pump sizing on the supply well is really a job for the well driller and heat pump supplier. Water pumps must supply the maximum flow rate required by the heat pump and provide enough pressure to overcome friction losses in the pipe and heat pump. Pumps must be big enough, but an oversized pump may exhaust the well and will reduce the overall energy efficiency of the system. Pumping requirements are a part of the total energy cost, and the pump payback period should be considered. The pump should be purchased based on a life-cycle cost analysis; the cheapest pump to buy will not necessarily be the cheapest pump to operate.

Earth Resources

If there is not enough water for a water-coupled system, look at earth coil options. (There are some other ways to get the most out of limited water supplies that are discussed in Chapter Three.)

Water transfers heat better than dry soil, and two types of earth coil systems take advantage of moisture in the soil. One is the vertical system, which can use either a sealed casing to contain the heat exchange liquid or an open casing (or uncased hole) with a long loop of pipe (*Figures 1.3 and 1.4*). The other is the hybrid system where several vertical loops are run off of a horizontal header (*Figure 1.5*).

With earth coils, it is necessary to determine what kind of space is available. For vertical systems, limitations on drilling must be assessed. Geological profiles are available for many parts of the country that will indicate what might be expected below the surface. Even the depth of horizontal systems may be limited by obstructions underground. Horizontal systems also must be located below the frost line (*Figure 2.3*).

The depth of a horizontal system often involves a tradeoff of performance and practicality. In most areas, ground temperatures are most stable below 20 feet. But, even a 10-foot trench is difficult to work in, and the coil performance may not be that much better at 10 feet than at 6 feet. Sometimes it is more effective to place one coil above another closer to the surface than it is to place one coil deeper in the ground (*Figure 2.4*). Horizontal systems generally require about 350 to 400 linear feet of exchanger for one ton of cooling.

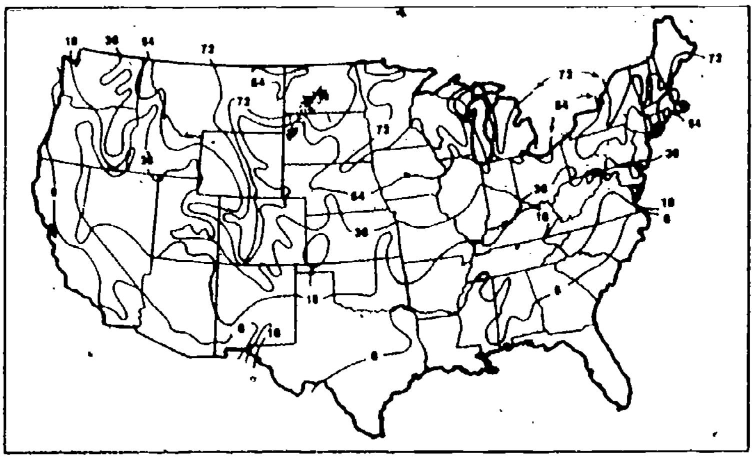


***Figure 2.3* Maximum depth of frost penetration in inches.**

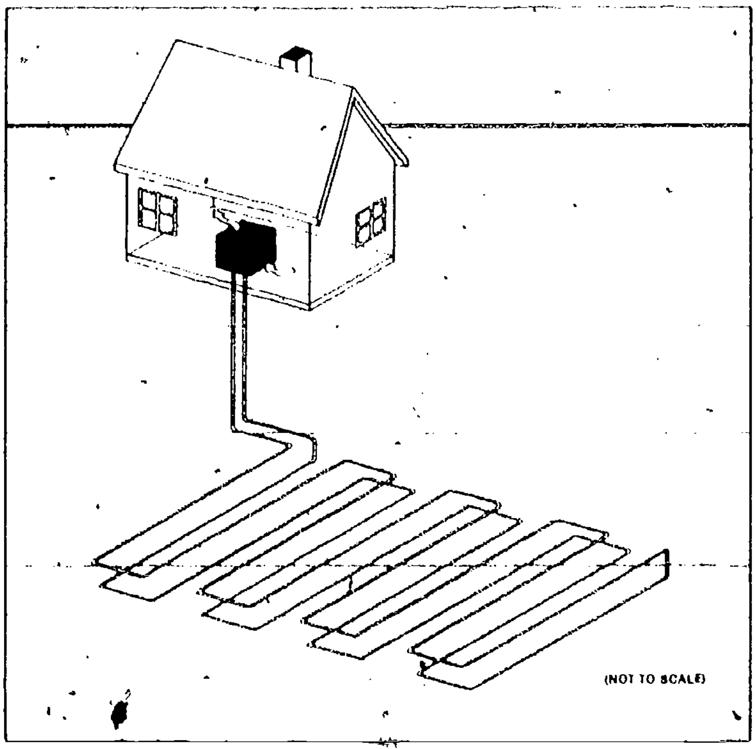


***Figure 2.4* Multiple-layered horizontal earth coil.**

When an earth coil configuration has been selected, the heating and cooling contractor can help decide what pumping capacity is required to move the heat exchange fluid in the loop.

Who can help:

Well drillers
State geologists
Soil Conservation Service
Water conditioner dealers
Heating and cooling equipment dealers and contractors
Heating, ventilating and air-conditioning engineers

Step 5:
Conduct a cost analysis.

If the four previous steps indicate that an earth- or water-coupled system is feasible, it is time to analyze the costs. To do this effectively it is important to compare costs with other types of systems. For example, how do the costs of an earth coil heat pump installation compare with the costs of an efficient gas furnace and central air-conditioning system?

The best way to evaluate the cost-effectiveness of a heating and cooling system is with a *life-cycle cost analysis*. This method of analysis uses three main cost factors: the initial cost of buying and installing the equipment, the cost of energy over the lifetime of the equipment, and the cost of maintaining the equipment. A thorough life-cycle cost analysis should also consider three economic factors that can have a dramatic effect on life-cycle costs: the interest rate, the fuel cost escalation rate, and the general inflation rate. For example, more expensive equipment may have to be paid for with borrowed money, and higher interest rates mean that the equipment will cost more because money is more expensive. On the other hand, the higher the escalation rate for fuel costs, the more money an efficient system like a heat pump will save.

Unfortunately, interest rates, inflation, and fuel costs over 20 or 30 year periods are difficult to predict, and the formulas for considering these variables are somewhat complex. The cost analysis method that follows is a relatively simple way to find out how the costs of different heating and cooling systems compare using the three basic cost elements: equipment costs, energy costs, and maintenance costs. It does not consider the economic variables, and the numbers used in the examples cited are very generalized. Despite the limitations, the cost information presented provides a basic yet useful way to compare costs of different heating and cooling systems. (There are references in Chapter Four which explain and demonstrate complete life-cycle cost analyses.)

A. Determine the cost per unit of energy.

A long-term energy price rise may be inevitable, but the rise may not be as dramatic as in the past. It also is difficult to say how the price of one energy source will compare with another. Consequently, current energy costs and trends may be used to give some indication (and only that) of the relative costs of different energy sources in the future.

Energy prices also vary by location. Utility companies (or your utility bill) can provide the current prices for energy sources in your area. For the sake of convenience, the calculations that follow are based on the *national average residential prices* for energy in the United States in 1982.

Natural gas
$5.53 per thousand standard cubic feet (mscf)
Fuel oil
$1.19 per gallon (gal)
Electricity
$0.07 per kilowatt-hour (kWh)

B. Determine the cost per million Btu's.

To compare the cost-effectiveness of various heating and cooling systems, it is necessary to convert the costs of different energy sources to a common base. The cost per million British thermal units (MBtu's) is commonly used.

To find the cost per MBtu's, multiply the unit costs by the multipliers used in this example.

Natural Gas
$5.53 per mscf x *0.97* = *$ 5.36 per MBtu's*
Fuel Oil
$1.19 per gal x *6.94* = *$ 8.26 per MBtu's*
Electricity
$0.07 per kWh x *293.00* = *$20.51 per MBtu's*

C. Determine the energy efficiency of the heating and cooling systems.

One of the reasons for the increasing interest in earth- and water-coupled heat pumps is that they use energy efficiently. To find out how this translates into cost savings, and how those savings compare with other systems, the efficiencies of other systems have to be known.

New furnaces have energy efficiency ratings determined by the manufacturers. Some new natural gas furnaces have very high heating efficiencies, ranging from 80 percent to 95 percent. (These efficiency ratings can be thought of as COP's of 0.80 to 0.95.) However, most of the installed oil and gas furnaces in the country have efficiencies of 65 percent or less depending on their design and level of maintenance.

Electric resistance baseboard heating has a COP of 1; but electric furnaces have COP's slightly below that, because of the energy used to run the fan. Efficiency ratings certified by the American Refrigeration Institute are available for most heat pumps and air-conditioning units. Most central air-conditioning units should have cooling COP's of 2.25. If electric central air conditioning will be used in combination with a fuel-burning furnace, the efficiencies of both units have to be taken into account.

D. Determine the cost per MBtu of heat delivered.

Now that the cost of energy and the efficiencies of the heating and cooling systems are known, the cost per MBtu's can be calculated. Divide the cost per MBtu's of energy that goes into the heating system by the efficiency rating for the system to get the cost per MBtu's of heat delivered.

FOR EXAMPLE;
Natural gas
$\frac{\$5.36 \text{ per MBtu's input}}{0.85 \text{ COP}} = \$\ 6.31$ *per MBtu's delivered*
Fuel oil
$\frac{\$8.26 \text{ per MBtu's input}}{0.70 \text{ COP}}$ *$11.80 per MBtu's delivered*
Electric baseboard
$\frac{\$20.51 \text{ per MBtu's input}}{1.0 \text{ COP}} = \$20.51$ *per MBtu's delivered*
Air-source heat pump
$\frac{\$20.51 \text{ per MBtu's input}}{2.0 \text{ COP}} = \$10.26$ *per MBtu's delivered*
Water-source heat pump
$\frac{\$20.51 \text{ per MBtu's input}}{3.0 \text{ COP}} = \$\ 6.84$ *per MBtu's delivered*

E. Determine the annual energy consumption in Btu's.

As pointed out earlier in this chapter, an analysis of conservation and weatherization opportunities is the necessary first step in deciding on the size and characteristics of the heating and cooling equipment that will be needed. This step in the cost analysis assumes that existing homes have been audited and will be suitably weatherized, and that new homes have been planned with conservation in mind.

For new construction, a thermal load analysis should be an integral part of planning for the heating and cooling system. For an existing weatherized home, a careful energy audit and thermal load analysis (see Step 3 of this chapter) will provide information on the amount of heating that will be required. Utility records for existing homes normally do not differentiate between heating and cooling energy demand and other energy uses, such as lighting and appliances. For the average residence in the United States in 1970, about 60 percent of the total energy consumption was for heating and cooling. The energy consumption for heating and cooling in well-insulated, tight houses can be less than half of that. Because energy consumption patterns can vary so much, annual heating and cooling demand should be based on a thermal load analysis, rather than simply summing up a year's utility bills and eliminating 40 percent for uses other than heating and cooling.

F. Determine the annual heating and cooling cost.

To find the projected annual heating and cooling cost, simply multiply the cost per MBtu by the annual heating and cooling energy requirement. In the following examples, it is assumed that 80 MBtu's would be required to heat the house for a year and 10 MBtu's would be needed for cooling. The heat pumps would be used for both heating and cooling, requiring 90 MBtu's per year.

FOR EXAMPLE:
Natural gas
$6.31 per MBtu x *80 MBtu's per year* = *$ 505 per year*
Fuel oil
$11.80 per MBtu x *80 MBtu's per year* = *$ 944 per year*
Electric baseboard
$20.51 per MBtu x *80 MBtu's per year* = *$1,641 per year*
Electric central air conditioning
$10.26 per MBtu x *10 MBtu's per year* = *$ 103 per year*
Air-source heat pump
$10.26 per MBtu x *90 MBtu's per year* = *$ 923 per year*

Water-source heat pump
$6.84 per MBtu x *90 MBtu's per year* = *$ 616 per year*

G. Determine the lifetime energy costs.

Most heating and cooling units should have useful lives of 20 to 30 years. Consequently, their costs and potential savings should be figured over that period. This lifetime energy cost, which in this case does not consider fuel cost escalation, is calculated by multiplying the annual cost of energy by the chosen lifetime.

FOR EXAMPLE:
Natural gas
$505 per year x *30 years* = *$15,150*
Fuel oil
$944 per year x *30 years* = *$28,320*
Electric baseboard
$1,641 per year x *30 years* = *$49,230*
Air-source heat pump
$923 per year x *30 years* = *$27,690*
Water-source heat pump
$616 per year x *30 years* = *$18,480*

H. Determine the cost of equipment.

Now that the energy costs are known, it's time to consider the heating and cooling equipment costs. The easiest way to determine new equipment costs is to get estimates from dealers. Some of the variables associated with heating and cooling equipment costs are hard to estimate without knowing the details of the installation.

One of these variables is ductwork. For new construction, any forced air system will require a new duct system, and the costs will be about equal for furnaces or heat pumps. For heat pumps installed in existing homes, duct modification costs can range from nothing to nearly $1,000.

Prices vary widely in different parts of the country, but here are some rough estimates of retail equipment costs (not including installation) to indicate the relationship between systems of comparable size (approximately 30,000 Btuh to 40,000 Btuh).

Natural gas furnace with flue damper, electronic ignition, and setback thermostat (COP 0.75)	$ 750
High efficiency (COP 0.9) natural gas pulse furnace	$1,500
High efficiency (COP 0.75 to 0.8) oil furnace	$1,700
Electric baseboard resistance heat	$ 200
Electric central air conditioning	$1,350
Air-source heat pump	$1,850
Water-source heat pump	$2,500
(Add $2,500 for new earth coil or well)	

I. Determine cost of maintenance.

Emergency maintenance costs are nearly impossible to predict, but dealers may be willing to give estimates of general, annual maintenance costs. However, even these estimates are likely to vary.

Heat pumps and air conditioners have one maintenance item that sets them apart from other systems. While actual performance varies considerably with specific circumstances, the compressors on heating and cooling heat pumps may have to be replaced after 12 or 15 years. (The U.S. Department of Energy Technology and Consumer Products Branch indicates that the average compressor life is 5 to 7 years.) Compressor reliability is increasing all the time, and there is less stress on water-source heat pump compressors than for air-source heat pumps, but as of today, two compressor replacements would be expected for a 30-year lifespan. Here are some maintenance cost estimates for the sake of comparison.

Natural gas furnace
$50 per year, $1,500 for 30 years
Oil furnace
$50 per year, $1,500 for 30 years
Electric baseboard heat
$0
Central air conditioning
$50 per year, $1,500 for 30 years
+ *$1,400 for two compressors*
$2,900 for 30 years
Heat pumps
$75 per year, $2,250 for 30 years
+ *$1,400 for two compressors*
$3,650 for 30 years

J. Determine the lifetime cost.

A basic lifetime cost of a heating and cooling system can be determined by adding up the lifetime energy costs, the initial cost of equipment, and the cost of maintenance. Remember, this does not consider changes in fuel costs, inflation, and interest rates over the next 30 years.

FOR EXAMPLE:

Natural gas furnace with electric central air conditioning		**Water-source heat pump**	
$ 1,500	*gas furnace*	$ 2,500	*heat pump*
1,350	*air-conditioning*	2,500	*coil or well*
1,000	*duct work*	1,000	*duct work*
$ 3,850	*equipment subtotal*	$ 6,000	*equipment subtotal*
$15,150	*cost of gas*		
3,090	*cost of electricity*		
$18,240	*energy subtotal*	$18,480	*electricity*
$ 3,000	*maintenance cost*	$ 2,250	*maintenance*
$ 1,400	*2 compressors*	$ 1,400	*2 compressors*
$ 4,400	*parts and maintenance*	$ 3,850	*parts and maintenance*
$26,490	*Total cost for 30 years*	$28,330	*Total cost for 30 years*

COST COMMENT

In the final example, an earth- or water-coupled heat pump would cost $1,840 more to own for 30 years than an efficient gas furnace and electric central air-conditioning, because of the relatively low cost of natural gas. A quick review of the cost analysis step also reveals that electric baseboard heat would be the least expensive to buy initially and is virtually maintenance free, but the electricity costs for 30 years are $49,200, more than $20,000 above the total lifetime cost of the heat pump.

The real lesson of this analysis should be that every situation is unique and must be carefully analyzed. Any one of the factors considered in this analysis, and the economic variables that aren't, may change the outcome. For example, look at the results if natural gas prices were increased to $8.00 per mscf and electric rates were $0.10 per kWh. Or, consider the advantage to be gained with a water- or earth-coupled heat pump if the annual cooling load is twice the annual heating load. Even when a cost analysis is done as completely as possible, there will be room for considerable speculation about what the effects of general economic trends will be. But remember, any cost analysis will be more meaningful when it is based on the most specific information available at the time.

Chapter Three

LESSONS LEARNED THROUGH THE APPROPRIATE TECHNOLOGY GRANTS PROJECTS

The concept of using the earth and water as sources of heating and cooling has been around for centuries, but more information is needed about how these systems really work in different applications. There is no substitute for experience, and several grantees funded by the U.S. Department of Energy's Appropriate Technology Small Grants Program have found ways to use earth- and water-coupled systems more effectively. A summary of some selected projects, based on the final reports, is presented on the following pages. Copies of final reports for these projects are available from the National Center for Appropriate Technology.

Some of the grantees' practical suggestions to improve the use of these systems are detailed later in this chapter.

SELECTED PROJECTS FROM THE DOE APPROPRIATE TECHNOLOGY SMALL GRANTS PROGRAM

Earth coil heat pump system
Dean E. Amstutz
Bloomfield, Iowa
DOE Region VII
DOE Grant No. DE-FG47-80R701100
ATMIS ID: IA-80-001
A 3-ton, water-to-air heat pump was installed in a well-insulated, new house with 1,800 ft^2 of heated area. The heat pump was sized to meet a calculated heat load of 30,000 Btuh. An earth coil of 2,200 ft of 1.5-in. PVC pipe was buried at a depth of 10 ft. The coil contained 215 gal of water circulated at 8 to 11 gpm. A 0.5 hp pump circulated the water continuously, and water was drawn from a tank by the heat pump as needed. The system was modified for summer cooling so that water circulated through an automobile radiator in the cold air return. The furnace fan distributed the cool air. The earth coil heat pump provided all heat during the winter of 1980-81. Water temperatures from the coil went from 54°F in December 1980 to 46°F in March 1981. The radiator and fan cooled the house effectively, but condensation dripping from the radiator was somewhat of a problem.

Vertical earth coil heat pump system
Dr. Harry J. Braud
Gonzalez, Louisiana
DOE Region VI
DOE Grant No. DE-FG46-81R612014
ATMIS ID: LA-81-002
A natural gas furnace, a gas hot water heater, and a 4-ton central air conditioner in a house built in 1970 were replaced with three water-source heat pumps, one serving a day zone, one serving a night zone, and one for hot water. The house had 2,100 ft^2 of living area. One heating and cooling heat pump had a cooling EER 11.5 with water at 85°F, and a heat COP of 3.8 at 65°F. The other heat pump had a rated EER 10.4 with 85°F water and a COP 3.9 with 70°F water. The water heater was rated to use 70°F water and deliver hot water at 120°F with a COP of 5. Two vertical earth coils were used. One was a side-by-side (U-bend), 1.25-in. polyethylene pipe exchanger, 400-ft deep. The other was a pipe-in-pipe installation with a 1.25-in. PVC pipe within a 2.5-in. PVC pipe. Water was circulated through the heat exchangers with a 0.25 hp pump. During the heating season, water temperatures from the coils typically rose from 70°F to 90°F and returned to 70°F over a 24-hr period. Total energy consumption was reduced, on a monthly basis, from 11 percent to 41 percent.

Wind powered ground water heat pump system
Roger H. Cross, Jr.
Rush, New York
DOE Region II
DOE Grant No. DE-FG42-80R205161
ATMIS ID: NY-80-013
A water-coupled heat pump that used a customized, belt-driven compressor powered by a windmill was used to heat a residence. Ground water was at about 51°F, and water was returned to a pond. A 4,000-gal storage tank coupled with solar panels was also added to the system. A desuperheater and circulating pump moved excess hot water to supplement a conventional gas water heater. An AC electric compressor was installed in parallel to provide back up to the wind-powered system.

Earth coil heat pump system
East Tennessee State University
Johnson City, Tennessee
DOE Region IV
DOE Grant No. DE-FG44-80R410162
ATMIS ID: TN-79-006
An experiment tested heat transfer and storage capacities of soils. Three earth coil configurations were installed and one tested with a simulated heat pump load. Test coils were buried at 6 ft. Water temperatures from the coil ranged from 55.2°F to 66.1°F during the heating season. However, the air temperature was often higher than ground temperatures during the winter, and the researchers suggested that a hybrid ground and air-source system might be effective for their location.

Ground water fan cooling system
Dr. E.F. Jones
Mobile, Alabama
DOE Region IV
DOE Grant No. DE-FG44-81R410445
ATMIS ID: GA-81-001
Well water at 61°F was passed through two auto radiators at 2 gph for cooling. Using a fan powered by photovoltaic cells, air was pulled over the radiators, reducing the air temperature from 83°F to 71°F at optimum conditions. Condensation dripping from the radiators was sometimes a problem. Because of the system location and cloud cover, the photovoltaic power source (without storage) performed inconsistently. The materials cost of the prototype was nearly $800, but $600 of that was for the photovoltaics.

Artesian municipal water heat pump system
James H. Kanable
Mound City, South Dakota
DOE Region VIII
DOE Grant No. DE-FG48-79R800455
ATMIS ID: SD-79-003
About half of a 1,250 ft^2 house was heated with a water-to-air heat pump. Water came from the municipal system with a 2,200-ft deep artesian well source. Water at the well was at 70°F, but water delivered to the house ranged from 53°F to 60°F. Water at 5 or 6 gpm went to the heat pump before it went to other household uses. Water was disposed into the sewer system. The cost of operating the heat pump during the first heating season was 76 percent less than the average cost of oil for each of the four previous years. The heat pump also used less electricity than the oil furnace fan and electric resistance heat had used the previous year.

Earth coil and ground water heat pump comparisons
Lamar University
Beaumont, Texas
DOE Region VI
DOE Grant No. DE-FG46-80R612057
ATMIS ID: TX-80-008
Two earth- and two water-coupled systems were installed to test their suitability for heating and cooling a house with a cooling

load of 42,220 Btuh. A water-source heat pump was selected with a 40,000 Btuh cooling capacity (EER 8.8) and a heating capacity of 62,000 Btuh (COP 3.2). Two variations of horizontal earth coils were studied: a 1,000-ft, 1.5-in., polyethylene coil and a 600-ft, 0.75-in. copper coil. Both were buried at 4 ft, where the normal temperature range was 52°F in mid-February to 82°F in mid-September. The other earth coil studied was a vertical exchanger that used a closed, 5-in. casing, about 360-ft deep. Earth temperatures below 50-ft were a constant 69°F. The EER of the heat pump (excluding water pump) was measured as 11.3 with supply water at 69°F. Two ground water wells were studied, one at 25 ft and one at 100 ft. Flows and temperatures were fairly consistent for both wells: 12 gpm and 69°F for the 25-ft well and 12 gpm and 72°F for the 100-ft well. The ground water wells were found to be the most effective, followed by the vertical exchanger, and then the horizontal earth coils.

Single well ground water heat pump system
Marcum Contracting Co., Inc.
Jarrettsville, Maryland
DOE Region III
DOE Grant No. DE-FG43-81R308076
ATMIS ID: MD-81-017
A single, 500-ft well was tested at various depths to determine how well it would work as a heat source and sink. With a 6-in case, 65 ft of well provided 12,000 Btuh, which was the amount required for each ton of capacity. A heat loss evaluation indicated that 43,000 Btuh were necessary at 0°F winter design temperature, and a 42,000 Btuh heat pump was selected. Water quality in the well was monitored, and no changes in quality occurred. The house had duct work for a central air-conditioning system in place, but it was inadequate for the heat pump system and had to be completely redesigned. The measured performance of the heat pump indicated a seasonal heating COP of 2.57 and a seasonal cooling EER 9.22. The cost of operating the heat pump during the first winter was 60 percent less than the cost of oil the previous year.

Ground water, swimming pool heat pump system
Dr. Howard S. Minn
Lake Charles, Louisiana
DOE Region VI
DOE Grant No. DE-FG46-80R612010
ATMIS ID: LA-80-006
A water source heat pump with a heating capacity of 42,500 Btuh (rated COP 3.5) and a cooling capacity of 35,600 Btuh (rated EER 10.6) used a ground water well and a swimming pool as heat source/sinks. A duct heater was added to the system that increased the delivered air temperature by 4°F. During the cooling season, heat from the house was used to heat the swimming pool, but by mid-summer the pool was above 95°F. Hot water from the heat pump was trickled over a water curtain at the pool to cool the water. The heat pump reduced electrical consumption for cooling by 59 percent and heating consumption by 80 percent.

Commercial building, ground water heat pump system
Telesis Laboratory
Chillicothe, Ohio
DOE Region V
DOE Grant No. DE-FG02-79R510149
ATMIS ID: OH-79-009
The laboratory was in a well insulated building with an area of 13,000 ft². It was served by a 180,000 Btuh water-to-air heat pump. Water was drawn from an 80-ft well at about 55°F. The well could provide 50 gpm on a continual basis, and the heat pump used a flow of 30 gpm. The measured efficiency of the 2 hp water pump and the heat pump combined was COP 2.7. Water is drawn from a surface pond (about 1/2 million gal volume) during spring and fall for cooling, and well water from the heating and cooling system is returned to the pond during the rest of the year. The entire system is controlled with a custom-designed microprocessor system.

Two well, ground water heat pump system
Mark Sweeney and Vance Kerschner
Townsend, Delaware
DOE Region III
DOE Grant No. DE-FG43-79R306049
ATMIS ID: DE-79-004
A water-coupled heat pump with a 45,000 Btuh heating capacity and 40,000 Btuh cooling capacity was selected to replace a 70,000 Btuh oil furnace in a two-story, wood-frame farmhouse with 1,100 ft² of heated area. Water at about 60°F was drawn from a 156-ft well with a cast iron case. The water went to a 64 gal expansion tank that also provided potable water. The water was disposed of in a hand-dug, brick-lined well 28-ft deep and 3-ft in diameter. Water from the well was hard, but did not significantly affect the performance of the heat pump. The heating efficiency of the system was measured at COP 3 and the cooling COP was 3.1. Comparing the cost of the heat pump system with the cost of oil saved, the heat pump had a payback of 10.5 years. Compared with the cost of operating an air-to-air heat pump, the payback on the water source heat pump would have been 7.5 years.

Earth tank heat pump system
Gemma Veloso
Tampa, Florida
DOE Region IV
DOE Grant No. DE-FG44-80R410298
ATMIS ID: FL-80-001
A water-source heat pump, coupled with a tank of water buried 8-ft underground, was added to the existing equipment in a 1,300-ft² house. Most of the tank was in contact with the ground water which had a fairly constant 70°F temperature. The heat pump had a rated COP 4 for 23,000 B[illegible] of heating and an EER 15 for 19,000 Btuh of cooling. The materials cost of the system was about $1,160. Cost savings on electricity of more than 50 percent were reported.

Commercial building ground water fan cooling system
Wormser Scientific Corporation
Stamford, Connecticut
DOE Region I
DOE Grant No. DE-FG41-79R110067
ATMIS ID: CT-79-010
Ground water at about 52°F was used as a cooling source for a well-insulated, wood-frame commercial building. The ground water passed through two shell-and-tube heat exchangers. The exchangers were connected with a closed loop that circulates cool water (about 53°F) through the building. Smaller, water-to-air heat exchangers were located throughout the building, and fans blew across the exchangers to cool the air. At maximum cooling load, the system operated about 50 percent of the time. Temperatures were maintained at about 78°F with 50 percent relative humidity, even at maximum load. Water was returned to a well about 100 ft from the supply well at about 75°F, and no change in the aquifer temperature was apparent.

Common Questions About Earth-Coupled Systems

How reliable is plastic pipe when used for earth coils?

Plastic pipe is commonly used for earth coils because it is generally easier to work with and less expensive than metal pipe. When properly installed, plastic pipes can last 30 years. However, if these materials are not properly installed and maintained, the earth coil may leak when it is first pressure-tested, or it may fail soon after installation.

Two types of thermoplastic pressure pipe work best: polyethylene and polybutylene. The integrity of polyethylene pipe depends on the grade used. The integrity of polybutylene pipe depends on the wall thickness. Plastic pipe dealers should be able to help you select the most suitable materials. Connectors must also be of high quality and properly installed.

Both polyethylene and polybutylene pipe are adversely affected by high pressures and water hammer. Therefore, the earth coil system should be designed and operated to avoid unnecessarily high pressures or drastic changes in pressure or flow. Plastic pipe is also weakened by high temperatures. If the system is expected to operate for long periods at temperatures above 120°F, plastic pipe may not be suitable. If the system will operate occasionally at these temperatures, it may be better to use metal pipe for the parts of the coil nearest the heat pump, or to use a holding tank to buffer temperatures.

It is essential to properly bed and backfill plastic pipe. Consult with the pipe dealer for proper backfill techniques. (In general, clods, rocks, and other hard objects larger than one-half inch should not be within 6 inches of the pipe.)

Plastic pipe can also fail when exposed to some organic compounds, notably ethylenes and acetones. Consequently, if any cleaning or antifreeze solution must be used, it should be selected and used with caution.

How close can earth coils be placed to each other?

The analysis of an experimental earth coil system in Tennessee revealed several things. Most of the heat transfer and storage capacity of soils takes place fairly near the coil, and the coil will probably operate effectively with the pipes separated either vertically or horizontally by only 2 feet. This close spacing may help if space is at a premium.

What kinds of soils work best?

The best soils for earth coil systems appear to be sandy loams, sandy clay loams, loams, and some sandy clays. Heavy clay soils can be a problem because of the way they shrink and swell. At its worst, shrinking and swelling could pull the joints apart. On a less serious level, shrinking may pull the clay away from the coil pipe. This leaves an air gap around the pipe which functions as an insulator, reducing heat transfer between the pipe and the soil, significantly lessening the thermal efficiency of the coil.

Do earth coils work in sand?

Earth coils do work well in sandy soils, but trenching in unstable sandy soils can be very dangerous, because the walls of the trench could collapse. If earth coils are installed in sand, never work alone, and do not work in deep trenches if at all possible. Try to select an earth coil design that does not require joints to be assembled in the ground. If work must be done in the trench, make sure that the sides are stabilized.

Is it necessary to compact the soil after installing earth coils?

Proper backfilling of earth coil trenches, usually by mechanical compaction or soaking with water, serves two purposes: it prevents the surface of the soil from dropping as it settles, and it improves the heat transfer rate of the soil by removing some of the insulating air that is left in loose soil. Local offices of the Soil Conservation Service should be able to provide guidelines for the best way to compact the backfill in specific soils.

Is there any advantage to keeping the soil around the coils wet?

Horizontal earth coils work much better if the soil is wet. Some systems use "trickler" or "weep" pipes above the earth coil to keep the soil moist (*Figure 3.1*). Earth coils should not be located under septic systems, because a rise in temperature from the earth coil may increase biological growth that can clog the septic system. And, any repairs that are required for the earth coil will come at the expense of tearing up the septic system.

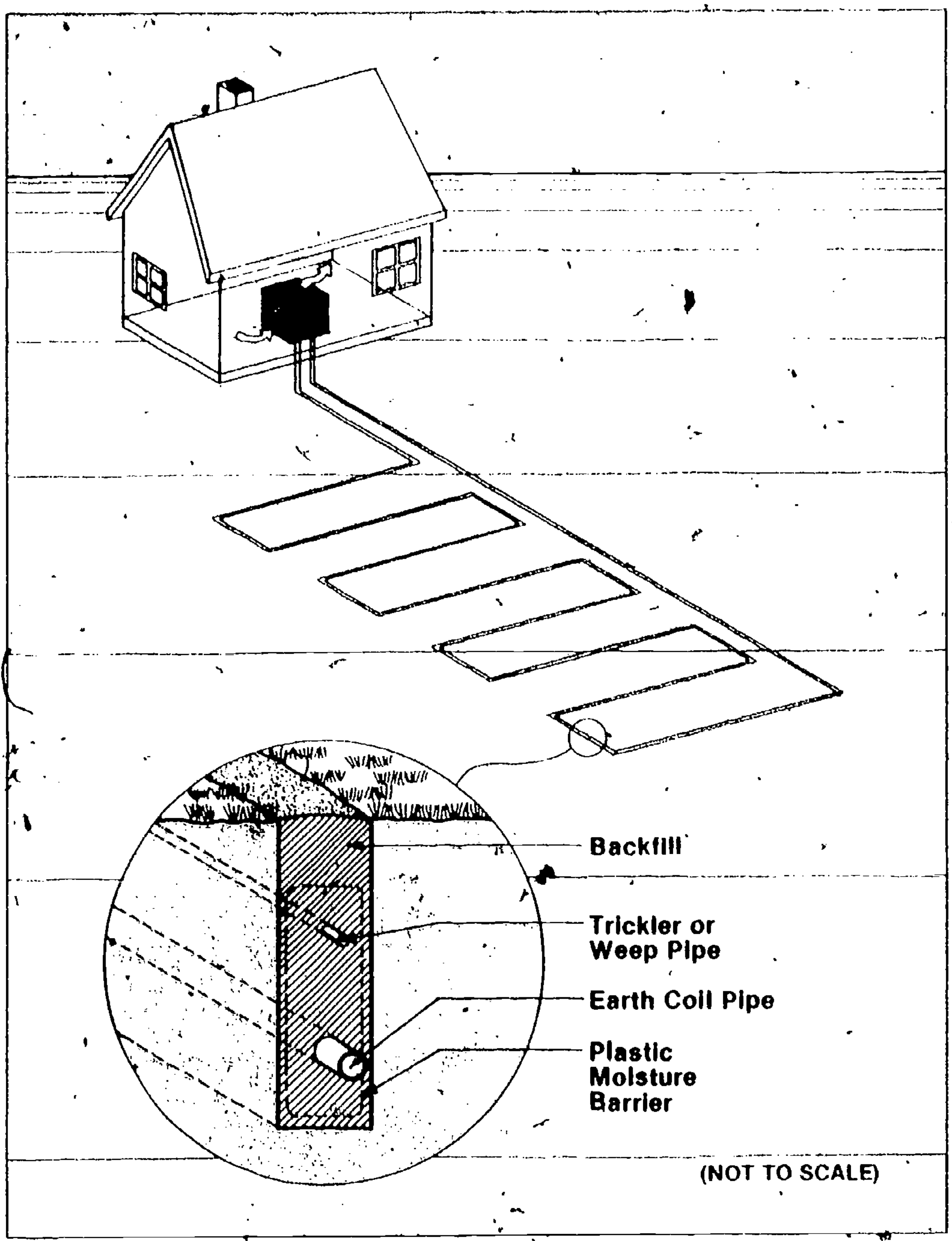


Figure 3.1 **Typical trickler or weep pipe installation.**

Common Questions About Water-Coupled Systems

Should intake systems be located near the top or the bottom of a surface water body?

Intake structures for surface water sources normally are located off the bottom to reduce the solids taken into the system. Some ocean intakes, however, are installed under the sand so that the sand can function as a preliminary filter.

What kind of valves work best with water-coupled systems?

Gate valves should be used throughout the water delivery system to minimize pressure loss. Mechanical valves may lead to fluctuations in pressure when the heat pump starts up. This causes the pressure switches to kick out the compressor. In most cases, the use of solenoid valves will eliminate this problem. The size of solenoid valves should be selected to minimize pressure drop through the valves.

What is the purpose of holding tanks?

Holding tanks can be used to get the most from the water supply if low water flow rates are a problem. Tanks also help to minimize pressure fluctuations and can help to moderate water temperatures.

What kind of water pump is recommended?

There is a tradeoff involved with the choice of a water pump. Submersible pumps deliver greater flows with less energy than jet pumps, but submersible pumps generally require more maintenance.

How can mineral deposits in heat pumps be reduced?

The heat exchange coils in many water-source heat pumps are now made of a cupro-nickel alloy that expands and contracts as the surface temperature changes. Any scale that forms in the tubes tends to pop off as the surface changes. Some other heat pumps use polyethylene or polybutylene pipe in the heat exchanger. Plastic resists some of the scaling that may occur with metals (iron bacteria, for example), and it also expands and contracts.

Fine particulates in the water also can cause valves to deteriorate. A water line filter may be necessary. In Texas, where the water had high iron levels, a 12-in. tube filter with 20 micron retention worked effectively, but at the end of six weeks, the water flow rate dropped from 11 gpm to 8.5 gpm, because the filter had filled with particulates. A larger filter would not have to be replaced so often. However, any filter will necessarily result in some decrease in flow.

Can water-coupled systems freeze in the winter?

In some installations, the outdoor water lines were not buried below the frost line and during the winter, the lines froze. It is advisable, especially on long runs from the water source to the house, to insulate the pipes with closed-cell foam to minimize heat loss to the ground and to reduce the danger of freezing.

Common Questions About Heat Pump Systems

Are heat pumps reliable?

Heat pumps are increasingly reliable, but it is necessary to maintain them routinely. It is important to change both air and water filters regularly, to keep heat exchanger coils clean, and to monitor refrigerant levels at least twice a year at the beginning of the cooling and heating seasons. Maintenance is much easier if the heat pump is located in an area that provides easy access to it.

Can heat pumps be operated with setback thermostats?

Conventional night setback thermostats do not work well with heat pumps in the heating mode. This is because the relatively low temperature of the delivered air cannot make up for the heat lost during the night quickly enough. Either the heat pump unit will have to operate for relatively long periods of time or supplemental heat will be required to heat the house in the morning. There are some microprocessor control systems available now (with more being developed) that do allow for a thermostat setback. Most of these units operate by sensing outside temperatures during the night and turn on the heat pump so that the temperature in the house does not drop too low by morning. Without such a control system, most owners find it most comfortable to set the thermostat at one level and leave it.

Can existing duct work be used with heat pumps?

Remember that the flame in furnaces exceeds 1,000°F and the refrigerant in a heat pump is rarely over 200°F. Heat pumps need larger ducts to deliver larger volumes of this warm air. When heat pumps replace other types of heating systems in existing houses, the ductwork is rarely adequate. Ducts should be analyzed and improved if necessary to allow the system to provide the desired comfort levels.

Are heat pumps noisy?

Noise is an occasional complaint with heat pumps, primarily because a large volume of air is moved through undersized ducts at relatively high speeds. However, this can be avoided if the air delivery system is sized to provide high volumes of air at low velocities. Noise is also reduced if ductboard is used to construct new ducts. Ductboard also delivers heat better than metal ducts, because it is insulated. However, if ductboard is not properly manufactured and installed, fiberglass particles can be blown into the house. These small particles can be a hazardous irritant for people with sensitive respiratory systems. Existing metal ducts in unheated spaces should also be insulated to retain as much heat as possible. Running the heat pump fan on the low setting all the time also helps control noise and makes the house more comfortable by circulating the air.

Will room fans help make heat pumps more efficient?

If heat pump systems are properly sized and installed, additional fans shouldn't be necessary. However, in Louisiana, three ceiling fans were installed for use during the cooling season. This low-energy installation allowed the cooling thermostat to be set up from 78°F to 81°F and provided the same degree of comfort.

What is the difference between COP and EER?

EER stands for Energy Efficiency Ratio. The efficiency of most cooling devices, such as air conditioners, is usually measured with EER's, instead of the COP's used for heating devices. The EER is a ratio similar to COP, but it compares *Btuh* of heat rejected with *watts* of energy consumed. An EER can be converted to COP by dividing the EER by 3.413, the number of Btu's in one kilowatt-hour.

Chapter Four

WHAT SOURCES OF HELP ARE AVAILABLE?

Three main sources can provide information to help evaluate and implement earth- or water-coupled heating and cooling systems: publications, organizations, and heating and cooling equipment dealers.

Publications

The following publications are organized by topic areas, and the topics are generally in the order they appear in the text. Summary evaluations are provided for each publication.

General

McGuigan, Dermot, *Heat Pumps*, Charlotte, VT: Garden Way Publishing, 1981.

This is a good overall introduction to heat pumps and includes information and case studies on earth- and water-coupled systems.

Available at many libraries and through bookstores.

U.S. Department of Energy, *Heat Pump Technology, A Survey of Technical Developments, Market Prospects and Research Needs*, June 1978, prepared by Gordian Associates, Inc. for the Assistant Secretary for Conservation and Solar Applications, Division of Buildings and Community Systems, Washington, DC, under contract No. Ex-76-C-01-2121.

This technical report surveys the status of heat pump technology as of 1978. While the information on earth- and water-coupled systems is limited, the report does present information on the wide range of heat pump systems, including some more technically advanced systems.

Available through the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

U.S. Department of Energy, *Ground-water Heat Pumps: an Examination of Hydrogeologic, Environmental, Legal, and Economic Factors Affecting Their Use*, 2 vols., November 12, 1980. Prepared by the National Water Well Association for the Division of Buildings and Community Systems. (Appendix D, "State Hydrogeologic Descriptions and Maps," is a separate volume.)

As the title indicates, this report contains extensive information on the physical, environmental, legal, and economic factors related to ground water heat pumps. Much of this information is related directly to case studies developed for nine test cities throughout the country.

Available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.

Gannon, Robert, "Ground-water heat pumps—home heating and cooling from your well," *Popular Science*, Vol. 212, No. 2, February 1978, pp. 78-82.

A general introduction to ground water heat pumps.

Available in most local libraries.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., *ASHRAE Handbook*, ASHRAE, 345 East 47th Street, New York, NY. Series consists of four volumes: Fundamentals, Systems, Equipment, and Applications. Each volume is revised every fourth year.

This is a technical series designed for heating and cooling professionals. It covers a wide range of topics from the physics of thermal energy to the specifics of duct sizing.

Available from larger public or university libraries, or may be purchased from ASHRAE.

Earth Sources

Lalo, Julie, "Cool Tubes," *Rodale's New Shelter*, Vol. 1, No. 5, July/August 1980, pp. 22-25.

This article presents some general information on cool tubes with some case studies on installations. (There is additional information in this issue on other low-energy cooling options.)

Available in most libraries.

University of Minnesota, Underground Space Center, *Earth Sheltered Housing Design*, 1978, prepared for the Minnesota Energy Agency.

This book introduces design considerations, energy use, and public policy issues that affect earth-sheltered housing. It also details existing houses throughout the United States.

Available in libraries and bookstores.

Braud, Harry J., Henry Klimowski, and James Oliver, *Earth-coupled Heat Pump Research and Applications in Louisiana*, St. Joseph, MI, American Society of Agricultural Engineers, 1983. Paper No. 83-3086, presented to the summer 1983 meeting of the American Society of Agricultural Engineers.

This technical paper reports on a three-year project involving analytical, experimental, and application phases of concentric pipe and U-bend heat exchangers, and reviews the status of several residential and commercial installations in Louisiana.

Available from the American Society of Agricultural Engineers, P.O. Box 410, St. Joseph, MI 49085.

Water Sources

Michigan Department of Public Health, Division of Water Supply, Ground Water Quality Control Section, "Ground Water Heat Pump Installations in Michigan," Lansing, MI, March 1982.

This report provides a good overview of ground water heat pumps in Michigan with considerable information on supply and return well spacing.

Available from the Michigan Department of Public Health, P.O. Box 30035, Lansing, MI 48909.

Dembny, Ken, et al., "Ground Water Heat Pumps," *Ground Water Age*, August, 1982, pp. 25-32.

This article provides good technical information on the ground-water and pumping requirements for water-coupled systems.

Available from university or larger public libraries.

The Water Systems Council, *Water Systems Handbook*, 221 North LaSalle Street, Chicago, IL 60601, 1980, 7th Edition.

This handbook provides complete guidelines for installing and maintaining water systems, including well drilling, system fundamentals, pump selection, electrical components, pressure tanks, and water distribution systems. It is well written and illustrated, and contains useful selections on troubleshooting.

Available for purchase from the Water Systems Council.

Conservation Alternatives

Scientific Staff of the Massachusetts Audubon Society, *The Energy Saver's Handbook for Town and City People*, Rodale Press, Emmaus, PA, 1982.

This handbook provides a good overview for conserving energy, primarily in existing buildings. It includes numerous detailed examples of weatherization materials and techniques for different building types.

Available at many libraries and through bookstores.

McGrath, Ed, *The Superinsulated House: A Working Guide for Owner-Builders, Architects, Carpenters and Contractors*, That New Publishing Company, Fairbanks, AK 1981.

This book covers the general theory and principles of superinsulation, explains the key terms, and shows how to do superinsulation construction.

Available at some libraries and

through bookstores.

Regulations

National Conference of State Legislatures, "Guidebook to Water Source Heat Pumps," October 1981.

This report provides background information on ground water heat pumps and emphasizes regulation and policy concerns.

Available for purchase from the National Conference of State Legislatures, 1125 Seventeenth Street, Suite 1500, Denver, CO 80202.

Thermal Load Calculations

Air Conditioning Contractors of America, *Load Calculations for Residential Winter and Summer Air Conditioning*, Manual J, Washington, DC, 1982, 6th Edition.

A simplified load calculation method is described and a step-by-step example is given. Climate data and insulation values of selected materials are presented.

Available from larger public libraries or university libraries.

ASHRAE, "Cooling and Heating Load Calculation Manual," ASHRAE, New York, NY.

This manual is designed to provide a convenient and consistent way to calculate heating and cooling loads. Calculation forms also are available.

Available for purchase from ASHRAE Publications Sales Dept., 345 E. 47th Street, New York, NY 10017.

Cost Analysis

Ruegg, Rosalie; and Harold Marshall, "Economics of Building Design," *Solar Age*, July 1981.

This article is slanted to solar heating system economics, but it provides a good background for methods to analyze the costs of various energy systems.

Available at larger public libraries and university libraries.

Thomann, Gary C., and Jay A. Fulton, "Economic Analysis: Water Source Heat Pumps," *ASHRAE Journal*, September 1980.

This article documents a lifecycle cost analysis for ground-water heat pumps compared with an air-source heat pump, a gas furnace/central air-conditioning combination, and electric heat with air-conditioning.

Available at larger public libraries and university libraries.

Paepke, Frederick G., "Economic and Energy-use Comparison of Space-conditioning equipment," *Ground Water Energy Newsletter*, Vol. 2, No. 2, May/June 1983.

This article compares energy use and costs of ground water heat pumps with several other heating and cooling options.

Available at some larger public libraries and university libraries.

Improving Heat Pumps

Benton, Ronald, "Heat Pump Setback: Computer Prediction and Field Test Verification of Energy Savings with Improved Controls," *ASHRAE Journal*, Vol. 24, No. 12, December 1982.

This article provides information on the problems with using setback thermostats with heat pumps including a detailed look at a new setback thermostat designed specifically for heat pump use.

Available at larger public libraries and university libraries.

Organizations

Four organizations figure prominently in the field of earth and water sources, and heat pump technology.

The NATIONAL WATER WELL ASSOCIATION is a non-profit research institute, education foundation and publishing company concerned with the heating and cooling uses of ground water. It offers a variety of publications and services, including thermal load calculations.

For more information, write:

The National Water Well Association
500 West Wilson Bridge Road
Worthington, OH 43085

The AIR-CONDITIONING AND REFRIGERATION INSTITUTE (ARI) is an association of manufacturers of heating, cooling, and refrigeration equipment. It develops standards and certifies equipment, and promotes the development of uniform codes. It publishes several items, most notably equipment standards and directories.

For more information, write:

Air-Conditioning and Refrigeration Institute
1501 Wilson Blvd. Suite 600
Arlington, VA 22209

The AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE) is a professional society that conducts research and technical programs in heating and cooling, ventilation, and refrigeration technologies. It has several publications, the monthly journal and the ASHRAE Handbooks are of most interest.

For more information write:

ASHRAE
345 E. 47th Street
New York, NY 10017

The DIVISION OF ENGINEERING TECHNOLOGY at OKLAHOMA STATE UNIVERSITY has had considerable experimental and practical experience with the development, installation, and monitoring of earth-coupled heat pump systems. The results of this research are available in numerous papers.

For more information, write:

Energy Technology Extension
Oklahoma State University
Stillwater, OK 74078

Dealers and Equipment

Selecting a Dealer

In the long run, the heating and cooling equipment dealer is more important than the particular brand of equipment that is selected. A good dealer will provide sound advice during the decision-making period, will coordinate installation of a reliable system, and will service the equipment after it is installed. Here are some things to look for when selecting a dealer.

Experience. Some experience with water-source heat pumps is preferable, but a dealer who has installed air-source heat pumps, and is familiar with their operation in his or her service area, should be able to install a good water-source system.

References. A good dealer will be glad to supply the names of customers who have installed similar systems.

Excavation contractors and well drillers. The equipment dealer will have to work closely with the excavation contractor or well driller who will install the earth coil or well. The equipment dealer should be able to provide advice concerning these other contractors.

Limitations. A good dealer will know what physical limitations (bedrock, water quantity and quality, etc.) and regulations will affect installations.

Load Analysis. Any dealer should be able to do the required thermal load calculations. Dealers may charge for this service or include [illegible] as a part of estimates or contracts.

Conservation. A dealer should not hesitate to consider weatherization or conservation strategies that will help to reduce the heating and cooling load.

Comparisons. The dealer should be able to provide advice on the merits and disadvantages of various heating and cooling options. In many cases, a dealer will handle furnaces or baseboard heat in addition to heat pumps. Even if the dealer handles water-source heat pumps exclusively, he or she should be able to provide enough information on other systems to do an accurate comparison.

Maintenance. The dealer should be able to indicate what kind of maintenance is to be expected. An annual inspection by the dealer is reasonable.

Warranties. Most heat pumps are warranted by the manufacturer for one year, but it is up to the dealer to provide the service. He or she should be able to explain how warranted service is handled, about the extent of the dealer's parts inventory, and about the responsiveness of the manufacturer to warranty claims.

Selecting Equipment

The basic size and source requirements of the heat pump will be selected as a result of a heating and cooling analysis and an evaluation of the earth or water resource. The particular heat pump chosen should have most, if not all, of the following characteristics.

Efficiency. A water-source heat pump should have a COP of 3 or better and an EER of 10 or better, based on ARI ratings.

Refrigerant. The refrigerant system should have a site glass so the refrigerant level can be monitored.

Water-to-refrigerant heat exchanger (heating mode evaporator). This heat exchanger coil should be made of cupronickel alloy or plastic, or both.

Refrigerant-to-air heat exchanger (heating mode condenser). This heat exchanger should have multiple copper tubes (the more the better) with aluminum or copper fins.

Noise. The heat pump itself should be mounted on vibration pads and insulated to limit noise from the compressor.

Refrigerant system. For reliable operation, the refrigerant system should be equipped with an accumulator and suction filter dryer.

System protection. The heat pump should be equipped with sensors for high and low pressures and temperatures to shut off the compressor. The compressor crankcase should be equipped with a heater. This is to help prevent refrigerant from being drawn into the lubricating oil.

Pipe fittings. The heat pump should come equipped with threaded-pipe fittings for the water supply and return lines and a water drain. Pipe fittings should be di-electric to prevent corrosion.

Access. The heat pump cabinet should provide easy access for emergency and routine maintenance, including filter changes.

Pipe insulation. Piping other than the heat exchangers should be insulated.

Fan. A multi-speed fan should be provided to permit selection of the proper level of air distribution.

Condensation. The heat pump should have a condensation trap and non-corrosive pan.

Electrical protection. The heat pump should have an integral circuit breaker.

Refrigerant valves. The refrigerant system should have at least two, built-in refrigerant service valves.

Water pressure valves. The heat pump should have water modulating valves that control water flow in response to refrigerant pressure changes.

Warranty. The heat pump should have a warranty for parts and labor.

There are also some extra features that might be desirable.

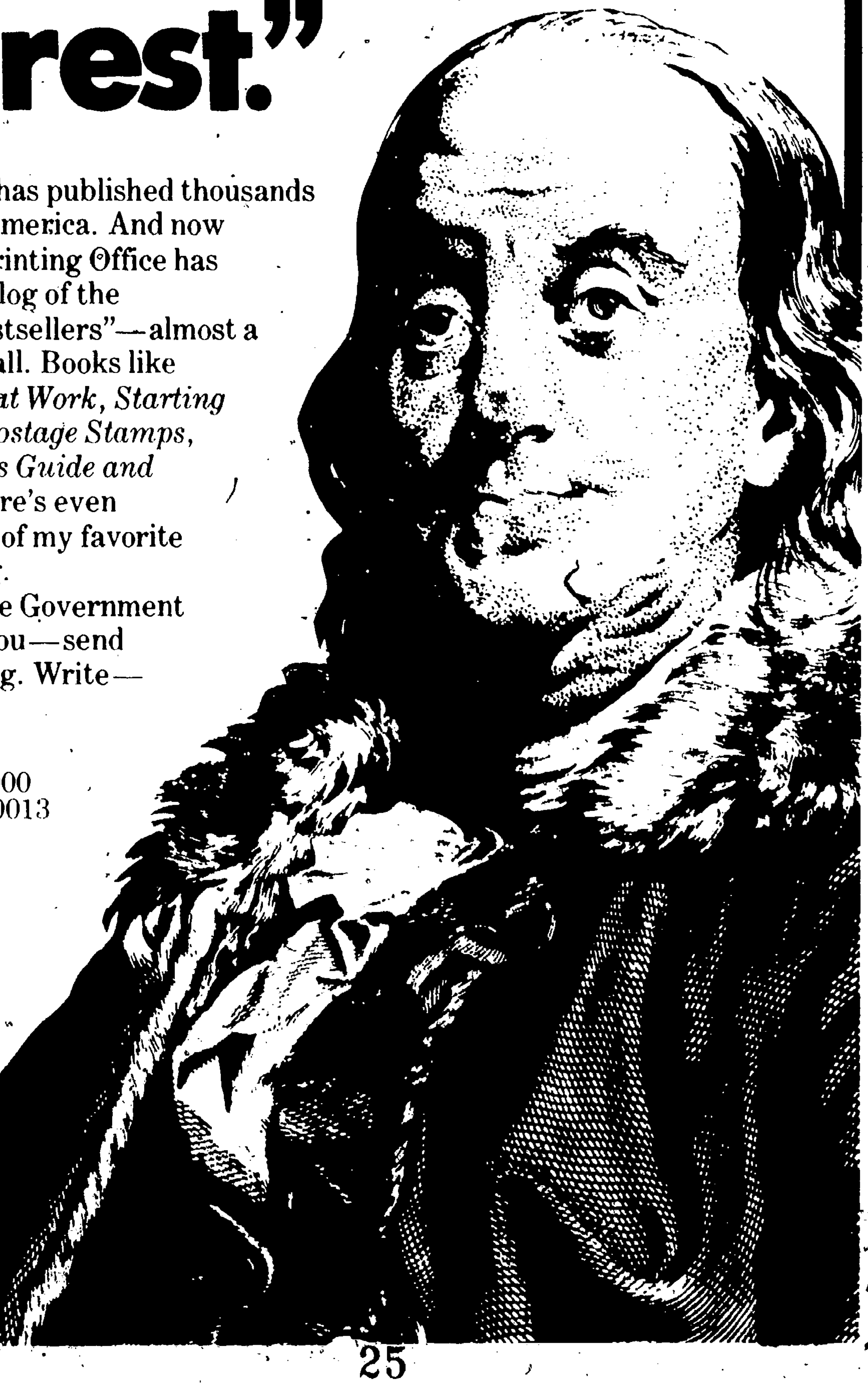
Hot water. Domestic hot water can be supplied if the heat pump has a desuperheater and hot water circulator pump.

Setback controls. A few heat pumps have microprocessor setback control options available, and more are on the way. (Conventional setback thermostats save little, if any, electricity.)

Back-up heat. Supplemental resistance heat is routinely built into air-source heat pumps and can be built into water-source heat pumps.

Multi-stage compressor. A single stage compressor does not work at peak efficiency under all loads. A two-stage compressor's first stage operates during normal loads, and the second stage cuts in during very high demand periods and both stages run together at high efficiencies.

Humidifier. A humidifier may be required to maintain comfortable relative humidity levels during the heating season, especially in dry climates.



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