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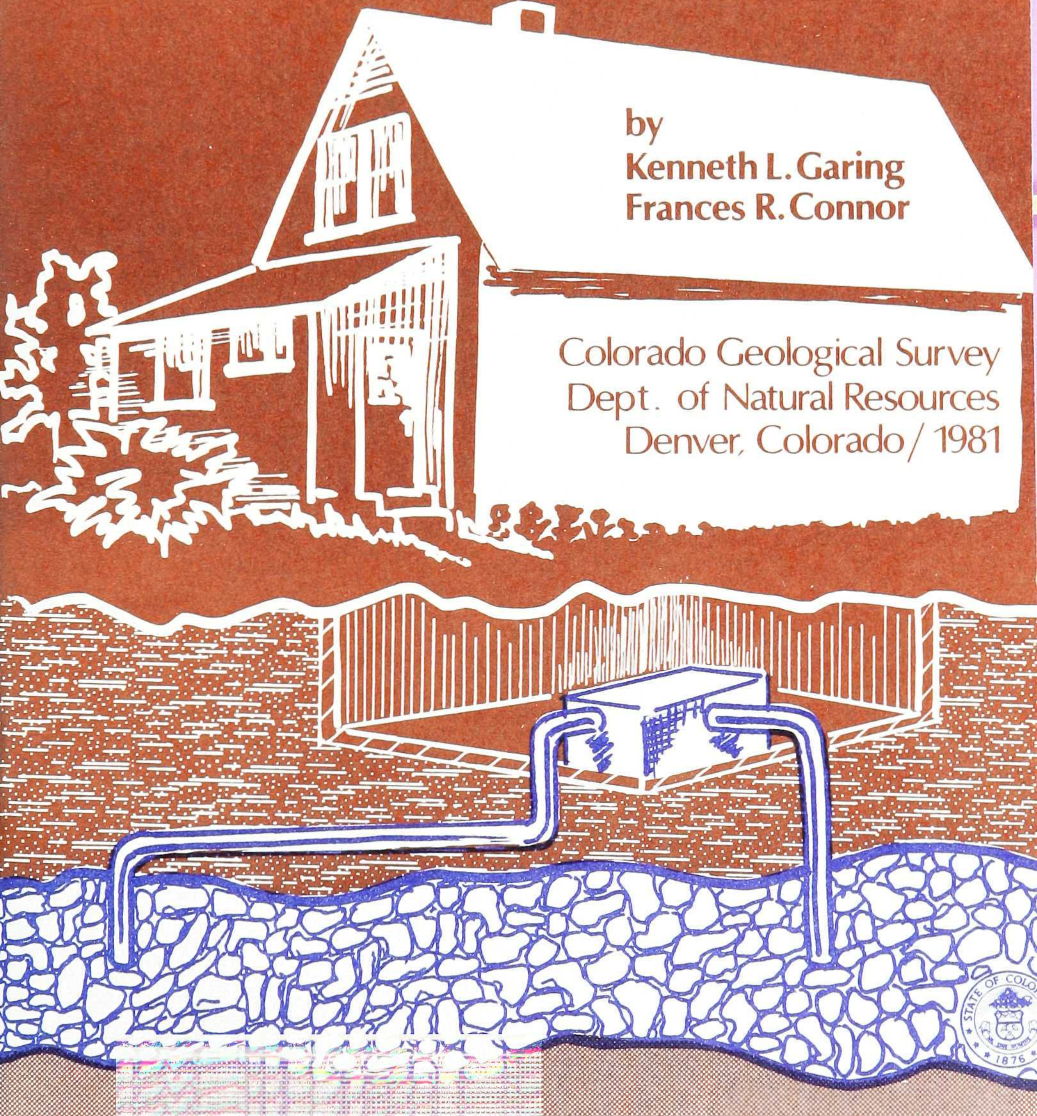
Groundwater Heat Pumps in Colorado

an efficient and cost-effective way to heat and cool your home



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Dept. of Natural Resources
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GROUNDWATER HEAT PUMPS IN COLORADO
AN EFFICIENT AND COST-EFFECTIVE WAY TO HEAT AND COOL YOUR HOME

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INTRODUCTION

Groundwater heat pumps are commercially proven systems used for residential and commercial space heating and cooling, that may represent a cost-saving alternate to conventional gas, propane, and electrical-based systems.

This pamphlet discusses the advantages and disadvantages of owning and operating a groundwater heat pump. The mechanism for operation of a heat pump is presented first. Information is then provided which allows potential users to estimate the size of the heat pump required for individual needs. Given this information and the economic analysis presented later in this pamphlet, a potential user can decide for himself whether the groundwater heat pump is a practical and worthwhile investment for his specific application.

A heat pump is a device that can extract thermal energy from a source and deliver it to another area. This ability to move heat from one region to another makes it possible for the heat pump to provide for both space heating and cooling. In the winter months, thermal energy is removed from the groundwater and used to heat a building. During the summer months, heat is extracted from a building and added to the groundwater flow.

The primary advantage to using a groundwater heat pump is that the annual operating costs can be much less than conventional heating and cooling systems. The payback on initial investment in certain regions of Colorado can be as short as 1.6 years. This value will vary with climatic conditions and local energy costs.

There are two basic types of groundwater heat pumps: water-to-water, and water-to-air. Each of the two types operates in a similar manner, with the mechanism for heat transfer to accomplish the heating and cooling being the only difference. Using a water-to-air heat pump, changes in room temperatures are accomplished directly in the heat pump by heating or cooling the building air. When using a water-to-water heat pump, the building air temperature is maintained indirectly by first heating or cooling water which is then pumped to individual rooms to provide the heating or cooling of the air in those rooms. Of the types described, the water-to-air heat pump is more common for residential use.

Air-to-air heat pumps are also available and have been widely used for nearly 20 years. This type of heat pump operates using outside air rather than groundwater as a heat energy source. The disadvantage of this type of heat pump is the large variation in air temperatures throughout the year. For groundwater-supplied heat pumps, the water temperature rarely varies more than 15°F between the summer and winter seasons. Large changes in outside air temperatures makes the air-to-air heat pump operate at efficiencies much lower than for groundwater heat pumps.

A water well provides the groundwater necessary to operate the heat pump. A water pump may be needed to get the water to the ground surface. The outgoing water from the heat pump system may be injected into a second well or, in certain cases, discharged to a surface stream. If injection is used, the two wells must be separated by an adequate distance to avoid adverse interaction between the wells. Figure 1 schematically illustrates the equipment arrangement for a groundwater heating/cooling system.

Heat Pump Cycle

All heat pumps operate on the simple scientific principle that fluid absorbs heat when it evaporates into a gas and gives off heat when it condenses back

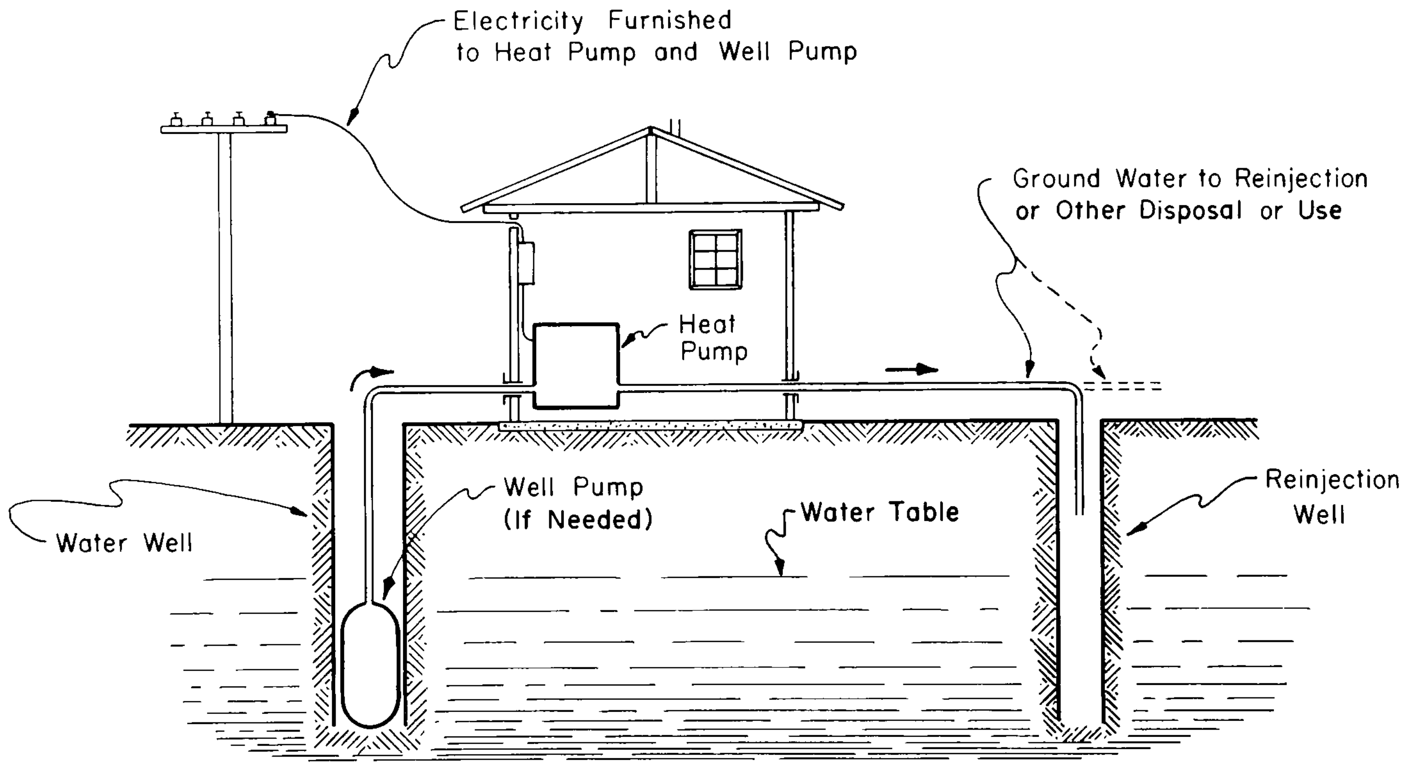

Figure 1. Typical arrangement for groundwater heat pump.

into a liquid. Groundwater heat pump operation is based on this principle using four mechanical components and a chemical refrigerant. The four components are an evaporator, a compressor, a condensor, and an expansion valve. The chemical refrigerant is the key to making a heat pump work. The refrigerant used in most groundwater heat pumps has a boiling point close to 0°F. To make the heat pump work, electrical energy must be added to operate the compressor and fan. Additional electricity will be needed if a well pump is required.

Figure 2 is a schematic diagram showing heat pump operation during the heating mode. The well water enters and flows through the groundwater heating coil of the heat pump. In this coil heat exchanger, a vapor-liquid refrigerant mixture absorbs heat from the groundwater and is evaporated to a vapor. In this heating case, this heat exchanger is considered the evaporator. From the evaporator, the vapor passes to the compressor where it is compressed to a higher pressure at a higher temperature. Leaving the compressor, the hot vapor passes to the household air heat exchanger. The relatively cool household air is blown through a coil, heat is transferred to the air as the refrigerant condenses, and the warm air then enters the house.

After passing through the condenser, the pressure of the refrigerant is relieved at the expansion valve. At this point, a cool liquid and vapor mixture is obtained and sent to the evaporator to repeat the whole process. Each of the above operations is performed continuously when the heat pump is operating.

The only difference in the mechanical operation of the heat pump when operating in the cooling mode is that the flow direction of the refrigerant is reversed. Figure 3 is a schematic representation of the cooling cycle. As seen from this figure, the

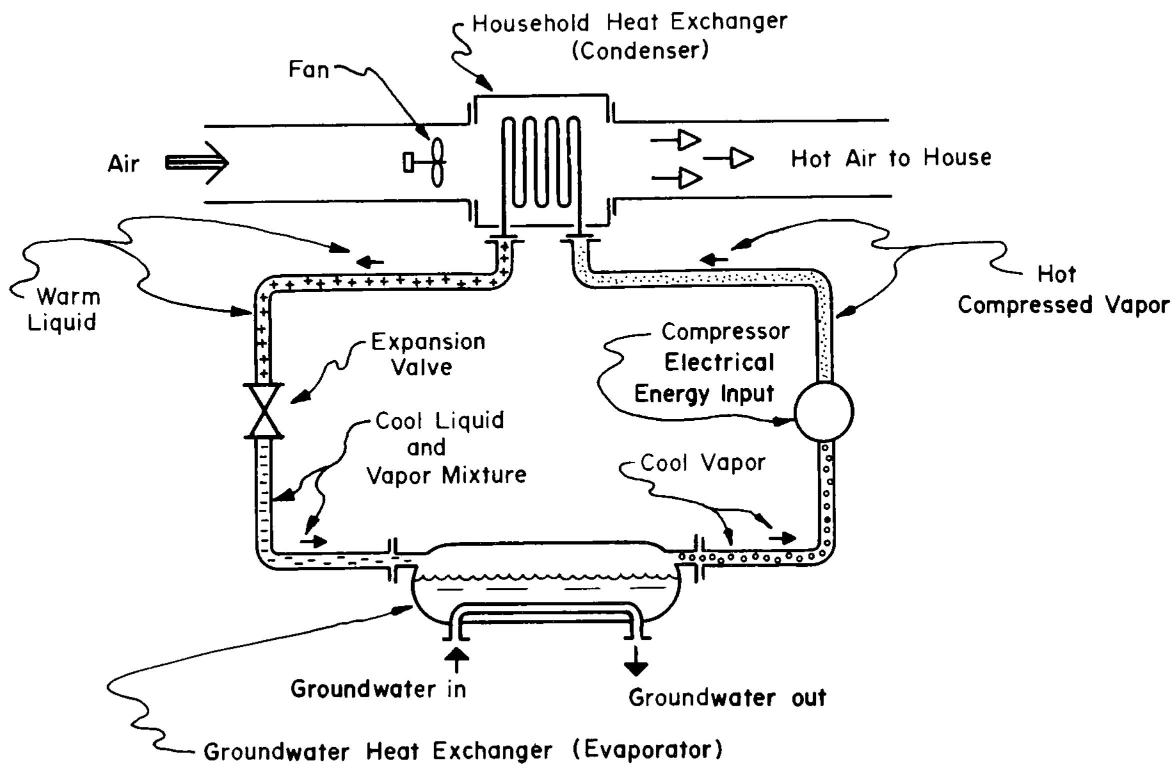

Figure 2. Groundwater heat pump operating in heating mode.

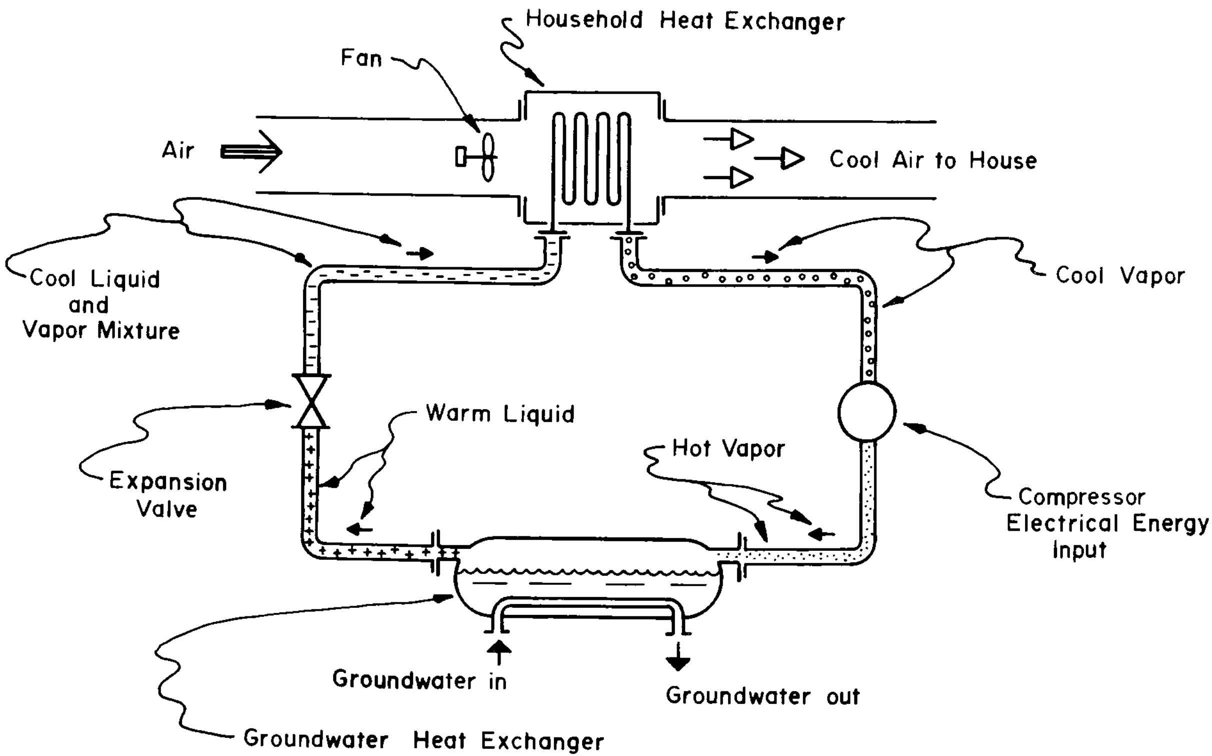

Figure 3. Groundwater heat pump operating in cooling mode.

hot vapor refrigerant leaving the compressor is routed to the groundwater heat exchanger. In this exchanger, the refrigerant is condensed to a warm liquid; the groundwater provides the necessary cooling. The warmed groundwater then exits from the heat pump for disposal or ultimate use. The refrigerant leaving the groundwater heat exchanger passes through the expansion valve where it is transformed from a warm liquid at high pressure into a low pressure, cool liquid-vapor-mixture. This cool liquid-vapor mixture enters the household heat exchanger where it is evaporated into a cool vapor. The heat for this evaporation comes from the warm household air, which is cooled as it passes through this exchanger. From this heat exchanger, the cool refrigerant vapor is sent to the compressor to be pressurized to start the entire process over again. The cooled air, meanwhile, is recirculated in the house.

Rating Comparisons of Heat Pumps

The efficiency of a heat pump is measured by its coefficient of performance (COP). The definition of COP is:

$$COP = \frac{\text{total energy output from heat pump}}{\text{electrical energy input to heat pump}}$$

The output energy from a heat pump is dependent on the mode of operation. When heating a building, the COP is based on thermal energy added to the building. In warm months when cooling is required, the COP is based on the thermal energy removed from the building. The COP values for both heating and cooling vary with different input temperatures of the groundwater. Figure 4 shows the general trends in COP values with varying groundwater temperatures. As seen in this figure, the heat pump operates more efficiently for cooling with cooler groundwater temperatures; and for heating purposes, efficiencies are improved with warmer groundwater temperatures.

The heat pump typically is more efficient for both cooling and heating with inlet water temperatures ranging from 50°F to 60°F, and can be used cost effectively with temperatures ranging from 50°F to 80°F. Most of the groundwaters available in Colorado are in this temperature range.

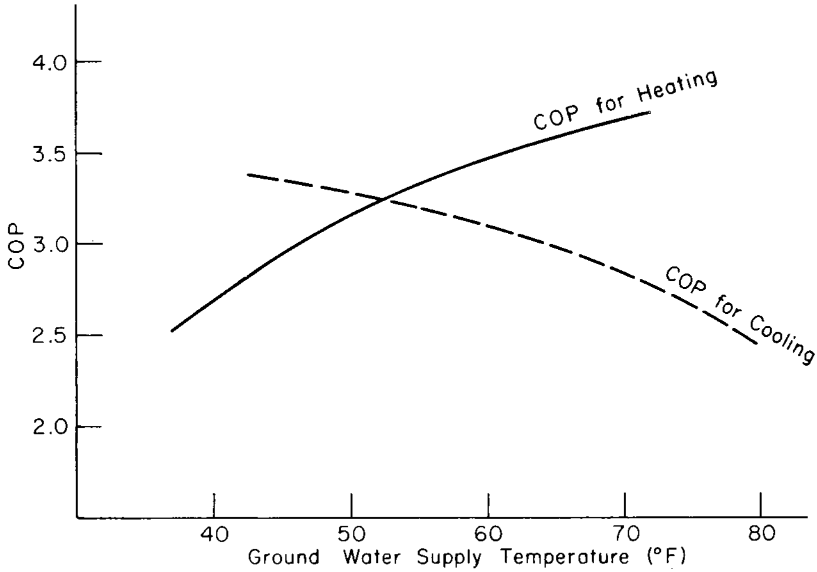

Figure 4. COP versus groundwater temperature (from Utah Water Research Laboratory, 1980).

The electrical energy input to the heat pumps consist of the input power for the compressor, fan, and controls. The energy output from the heat pump is the thermal energy extracted from, or added to, the groundwater and the electrical input. Since the thermal energy from groundwater is readily available, it is possible for the heat pump to produce more thermal heating or cooling than was input in the form of electrical power. This is why a heat pump may be economically attractive as compared to other heating systems.

The COP for groundwater heat pumps typically ranges from 2.5 to 3.4. For comparison purposes, the efficiencies, which could be considered as COP, for natural gas furnaces, propane heating, and electrical heating are 0.75, 0.70, and 0.98, respectively. The representative COP values for propane and natural gas heating vary greatly depending on elevation and air-to-fuel ratio. The low values of COP for these forms of heating are due, in part, to inefficiencies in burning, the requirement of a continuous pilot light, and the need to maintain an updraft in the flue. Table 1 shows the energy input and output for each of the heating systems.

Table 1. Energy input and output for four heating systems.

Heating System	COP (Efficiency)	Energy Input (Btu)	Energy Output (Btu)
Groundwater heat pump	2.5-3.5	1000*	2500-3500
Natural gas	0.75	1000	750
Propane	0.70	1000	700
Electric	0.98	1000	980

*Assumes thermal energy from groundwater is "free."

Requirements for Well Permit

At the present time, two divisions of the Colorado Department of Natural Resources have regulations regarding the drilling of wells, installation of pumps, and the use of groundwater in conjunction with groundwater heat pumps. An application for a permit to drill a well must be submitted to the Colorado Oil and Gas Conservation Commission.

This agency will forward the information provided to the office of the State Engineer, where determination will be made on the adverse affect, if any, on prior water rights. If water rights have previously been established, permits should be obtainable with few difficulties. If water rights have not been previously established, any plan for surface disposal of the water would require a careful determination of water rights and of aquifer source as well as the particular use to which the water will be put. In a residential groundwater heat pump system designed for return of the water to a disposal well for reinjection, a small-capacity nonconsumptive use probably can be established and the permitting process could then be concluded in three to four weeks.

Tax Considerations

Groundwater heat pumps have been specifically excluded as an energy conservation measure from both Federal and Colorado tax credit statutes.

Heat Pump Reliability

Groundwater heat pumps have been commercially available since the early 1950's. Until about 1960, their use was limited primarily to users of existing water wells. The popularity of this type of heating gradually increased throughout the 1960's, and a dramatic increase in its use occurred when energy prices rose markedly during the last decade. Today, nearly one in every fifteen new homes built uses some type of heat pump for heating and cooling.

The annual average maintenance costs for a groundwater heat pump have fallen from about $250 in

1955 to about $50 in 1979. The equipment requiring the greatest portion of the maintenance costs are the compressors. The compressors require about one-half of the total annual maintenance dollars. The other maintenance costs are related to fans, refrigerant leaks, or refrigerant flow control. The recent drop in maintenance costs have resulted primarily from improved reliability in the compressor portion of the groundwater heat pump. The annual maintenance cost of $50 per year is now very comparable to conventional heating and cooling systems. Other maintenance costs to be considered are related to the well and well pump. Normally, very low maintenance costs are incurred from the well. However, the annual upkeep costs for the well pump may vary from $5 to $50 per year, depending on pump reliability.

Groundwater Availability and Water Chemistry

Groundwater supply necessary for proper operation of the heat pumps is generally available on the Colorado eastern slope and also in many areas of the western slope. In the mountain regions, the supply is highly variable. Table 2 lists 12 communities in the state and gives the approximate depth to groundwater supply. Available water temperatures range from 45°F to 70°F, a range acceptable for good heat pump operation. In all areas, an experienced local water well driller should be contacted for expected temperatures and for depths to groundwater resources.

If the groundwater is of poor quality, it is possible that corrosion and scaling may occur inside the heat pump. Iron, hydrogen sulfide, salts, carbonates, and sulfates are constituents which could result in corrosion and scaling. The performance of the heat pump is usually dramatically reduced when any scaling or corrosion occurs. Sand and other rock particles carried in the water can also be particularly harmful by lodging in the small control valves. This problem can be resolved by placing a screen in the well piping.

Table 2. Expected groundwater supply depth.

Community	Depth (ft)	Community	Depth (ft)
Alamosa	50	Grand Junction	75
Burlington	200	Lamar	200
Denver	200	Pueblo	200
Durango	150	Salida	100
Fort Collins	75	Steamboat Springs	200
Glenwood Springs	100	Sterling	150

In locations where the quality of the groundwater is good enough to be used directly for domestic purposes, treatment of the water for heat pump use is generally not necessary. In other locations, it may be necessary to change several of the internal heat pump parts to tolerate chemical constituents in the water. These mechanical alterations can often be made by the manufacturer. Most heat pump distributors will review individual well water analyses to determine if the available water is compatible with standard heat pump equipment.

SYSTEM DESIGN

This section describes how to estimate the peak heating load for a building and to then determine the necessary size of the heat pump. Using the peak heating value, the annual heating requirements can be calculated. These in turn are used in the economic analysis. A method to estimate groundwater flow needs and well pump sizing is also presented. A design example applying all this information is then presented at the end of this section.

Design Heat Load

The first step in sizing a heat pump is to calculate the heat load which the system must meet. This is done by determining the heat loss from the building. Equation (1) must be used to calculate heat loss for parts of the house exposed to the outside through walls, doors, windows, floors, and the ceiling. The total design heat load is then found by summing all of the terms plus an additional heat term used to account for outside air infiltration. For a typical house in Colorado, this infiltration value can be assumed to equal 9.6 Btu/hr for each square foot of area. This value is used in the design example presented later in this pamphlet.

$$Q = U \times A \times \Delta T \qquad (1)$$

where Q = peak residential heat loss in Btu/hr

U = heat transfer coefficient in Btu/hr x °F x ft^2)

A = exposed surface area, ft^2

ΔT = temperature difference between inside and outside conditions, °F

The U values used in equation (1) are simply numbers which relate how much heat is lost through certain materials. Table 3 lists U values for several of the more common building construction items.

The A term is the area through which heat is lost. The ΔT term in equation (1) is the temperature difference which must be maintained between inside the building and the outside. The inside temperature to be used in equation (1) is 65°F in the winter and 78°F in the summer, as recommended by the U.S. Department of Energy. The values to be used for outside temperatures are presented in Table 4. The winter value from Table 4 should be used for calculating the heating load and the summer values will determine the cooling load. The values in Table 4 have been compiled by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers, using weather data of the last 30 years. For example, the ΔT for heating in Alamosa would be 81°F, the difference between a 65°F temperature inside, and a -16°F outside temperature.

The previous section discussed the design conditions to supply heating requirements during peak winter conditions. However, in determining the payback period for the project, it is also necessary to determine the annual fuel consumption. Annual heating requirements are related to both the annual degree days and the design heating load. (Equation 2) Table 4 presents the annual degree days for 12 communities in Colorado. The following equation is used to estimate fuel consumption. The annual heat load will be used in economic comparisons.

$$F = \frac{H \times D \times 24}{\Delta T \times E \times V} \times C^{*} \qquad (2)$$

where F = annual quantity of fuel used, units depend on V value

H = design heat load in Btu/hr

D = degree days from Table 4

ΔT = temperature difference between inside and outside air temperature in °F

E = efficiency of fuel; for heat pumps, use COP value
for electric use--0.98
for gas furnace --0.75
for propane --0.70

V = heating values

electric	= 3413 Btu/kHw, F will be in kWh
gas	= 1000 Btu/ft^3, F will be in ft^2
propane	= 91,065 Btu/gal, F will be in gallons

C = correction factor; for most areas in Colorado, a value of 0.80 can be used

Table 3. U values for several construction types of buildings in Colorado (from ASHRAE, Inc., 1979) [Btu/hr x °F x ft^2.]

Construction Type	U Value
2x4 walls, 1/2" sheetrock, 1/2" plywood, 3/4" siding	0.26
2x4 walls, 1/2" sheetrock, 1/2" plywood, 3/4" siding	
R-11 insulation	0.072
R-19 insulation	0.045
2x4 walls, 1/2" sheetrock, 1/2" plywood, 4" brick	0.28
R-11 insulation	0.074
R-19 insulation	0.046
Concrete slab floor, no insulation	0.50
Concrete walls, no insulation	0.65
Single-pane windows	1.10
Double-pane windows	0.62
Ceiling and roof, asphalt shingles, 2x4 rafters, 1/2" sheetrock, no insultation	0.21
R-11 insulation	0.074

Table 3 (Cont.)

Construction Type	U Value
R-19 insulation	0.046
R-30 insulation	0.031
Doors, solid	0.32
Doors, hollow	0.21

Table 4. Annual weather design data

		Degree Days		Summer 2 1/2%		Winter 97 1/2%
	Elevation	Heating	Cooling	Dry Bulb	Wet Bulb	Dry Bulb
Alamosa	7546	8609	88	82	61	-16
Burlington	4165	5738	878	95	70	2
Denver						
Airport	5283	6016	625	90	64	3
City roof	5320	5505	742	90	64	8
Durango	6550	6930	188	86	63	4
Fort Collins	5001	6599	430	89	62	-4
Glenwood Springs	5823	6500	286	91	63	5
Grand Junction	4849	5605	1140	94	63	11
Lamar	3635	5402	1199	98	71	0
Pueblo	4639	5394	981	94	67	-1
Salida	7050	6910	108	84	59	-3
Steamboat Springs	6770	9523	18	84	61	-16
Sterling	3939	6638	664	93	68	-2

Water Flow Requirements

The groundwater flow rate required for the heat pump can be approximated using the rule of thumb that 3 gpm of groundwater is needed for every 12,000 Btu/hr of heating or cooling needed. The actual flow requirement will vary with water temperature and equipment manufacturer. Thus, a typical heat load of 48,000 Btu/hr would require a groundwater flow of 12 gpm.

Since groundwater heat pumps provide heated air at temperatures lower than provided by conventional gas furnaces, a larger volume of air must be circulated. This means that air ducts should be slightly larger than conventional systems or, as an alternative, a larger blower fan be installed in an existing system.

Water Well Pumps

The water well pump is an important part of a groundwater heating system. The well pump capacity and operation corresponds to the water demands of the heat pump. The operating costs incurred in the operation of this pump may be a significant fraction of the system's total operating costs. It is, therefore, important to size the well pump properly. A pump representative should be consulted for exact sizing. An equation to use for estimating the necessary horsepower is presented in equation (3). This value must be found to determine electrical costs to operate the pump.

$$hp = \frac{QHY}{3950 \cdot e} \qquad (3)$$

where hp = well pump horsepower

Q = water flow, gal/min

H = head lift, ft

e = pump efficiency (typically to 0.67)

The head lift the pump must provide is the rise in elevation of the water from the water table in the well to the heat pump and also all frictional losses in the piping system. The size of these pumps is normally the same size and capacity as those used in rural areas to provide domestic water.

Design Example

In previous sections, methods have been described to calculate the peak heating requirements, annual heating load, flow requirements, and pump size. An example using this information is now presented. The "typical" house for which the heating system will be designed is shown below:

Location:	Alamosa
Style:	1500 sq ft, one story
Walls:	1150 sq ft, 2x4 construction, R-11 insulation, 1/2" plywood, siding
Windows:	180 sq ft, double pane
Floor:	Concrete slab
Ceiling and roof:	1500 sq ft, asphalt shingles, 2x4 rafters, 1/2" gypsum, 5/8" plywood, R-19 insulation
Groundwater:	50 ft (Table 2)
Piping friction loss:	50 ft of head

Table 5. Summary of heat loss.

	U	A sq. ft.	T °F	Q BTU's/hr
Walls	0.072	1150	81	6,700
Windows	0.62	180	81	9,040
Floor	0.50	1500	15	7,950
Ceiling	0.046	1500	81	5,590
Doors	0.32	64	81	1,660
Infiltration				
[9.6 Btu/				14,400
(hr x °F x ft^2)]		1500		
Total				45,340

T = 81°F; this is for 65°F inside temperature and -16°F outside temperature from Table 4; for below ground, T = 15°F, 65°F inside and 50°F for ground temperature.

The heat pump must provide a peak heat load of 45,340 Btu/hr. Using the rule of thumb of 3 gpm per 12,000 Btu/hr, the well pump must provide a flow rate of about 11.5 gpm. With this flow of 11.5 gpm, a head lift of 100 ft, and an efficiency of 0.67, the required horsepower for the well pump is 0.43 hp.

The annual heating requirement with propane heating would be:

$$F = \frac{(45{,}340 \text{ Btu/hr}((8609)(24)}{(81°F)(0.70)(91{,}065 \text{ Btu/gal})} \quad (0.85)$$

$$= 1514 \text{ gal/yr of propane, or about } 140{,}000{,}000 \text{ Btu/yr}$$

This means that 1514 gallons of propane must be purchased annually to heat the home. At current propane prices, annual expenses would be $1030. Using the same method of calculation for the groundwater heat pump case, the annual purchased electric power is 8230 kWh, or 28,000,000 Btu/hr. At current electric costs, the annual heating expense for operating the heat pump is $467/yr.

ECONOMIC COMPARISONS

The key to whether a heat pump should be used rests on whether or not it will save the owner money. A simple straightforward method is presented in this section for determining the payback period for a groundwater heat pump. An economic comparison of groundwater heat pumps versus alternate heating and cooling systems requires review of first the initial purchase cost, and secondly, estimates of annual operating costs. The initial cost for purchase and installing the groundwater heat pump is presented in Table 6.

Table 6. Initial costs for heating and cooling systems.*

Equipment	Groundwater Heat Pump	Electric Baseboard	Electric Furnace	Propane	Natural Gas
Heating	$3000	$ 500	$1000	$ 900	$ 900
Cooling		1200	1200	1200	1200
Ductwork	400		400	400	400
Flue				100	100
Totals	$3400	$1700	$2600	$2600	$2600

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*Cooling provided with central cooling, except for electrical baseboard case where individual room units are used.

The figures in Table 6 do not include the costs for drilling a water well or for a well pump for the case where an existing well can not be used. A reasonable cost estimate for the well pump would be $500 including installation. The costs for groundwater wells are highly variable depending on such things as depth, ease of drilling, number of wells to be drilled, and other specific local conditions. Figure 5 presented the average cost for well drilling in Colorado. Local well drillers should be contacted for a more definitive cost estimate. The cost of a well is important since it influences the payback period for groundwater heat pumps.

For the economic analysis presented in this booklet, it has been assumed that only one well will be required and that this one well will be drilled to the depth indicated in Table 2. In areas requiring a second well for disposal, the total initial costs would be increased and, thus, the payback period would be longer. For users able to use existing wells, the payback period would be greatly reduced due to lower initial costs.

Annual operating costs are based on local energy costs and local climatic conditions. Table 7 presents the estimated annual heating and cooling costs for 12 selected Colorado communities. These costs are for the "typical" home described in the design example, a well pump set in a completed well, and local energy rates. The operating costs include well pump operation costs.

Estimated years for payback in the operation of groundwater heat pumps are shown in Table 8. The payback figures are calculated by dividing the annual operational savings into the incremental costs of the groundwater heat pump versus the alternative. The cost of a heat pump system is determined by adding the cost of one well, a well pump, and value of equipment listed in Table 6. At

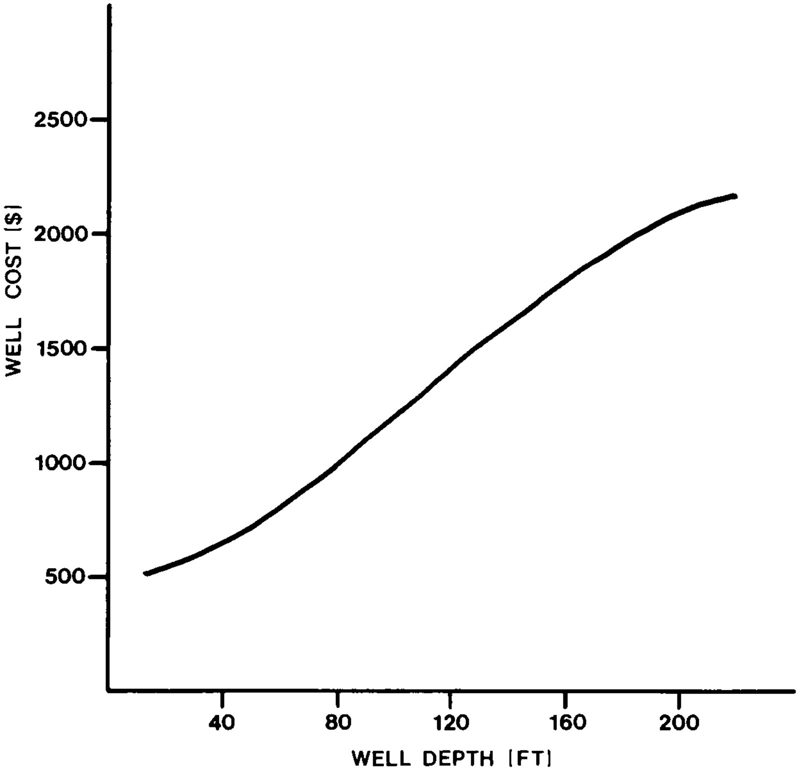

Figure 5. Well costs for groundwater wells.

Table 7. Annual operating costs for heating and cooling systems $/yr.

Community	Heat Pump COP 3.5		Electric		Propane		Natural Gas	
	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
Alamosa	520	--	2220	--	1030	--	500	--
Burlington	476	--	1700	--	690	--	350	--
Denver								
Airport	431	84	1550	106	720	106	350	106
City roof	403	86	1420	116	660	116	320	116
Durango	481	24	1880	30	830	30	420	30
Fort Collins	369	80	1500	94	790	94	380	94
Glenwood Springs	349	53	1230	61	748	61	355	61
Grand Junction	355	142	1450	214	670	214	330	214
Lamar	321	138	1130	208	650	208	330	208
Pueblo	290	178	1110	278	650	278	310	278
Salida	545	--	2230	--	830	--	420	--
Steamboat Springs	509	--	1910	--	1140	--	570	--
Sterling	443	84	1710	112	800	112	310	112

Alamosa, the total cost of the groundwater heat pump is $4500, $3400 for heat pump equipment, $600 for one well, and $500 for the well pump. The incremental cost of the groundwater heat pump is $2800. The $2800 figure is the difference between $4500 for the heat pump and $1700 for the least expensive electric system. The annual savings in operational costs are $1700, the difference of $2220 for electric heating and $520 for heat pump operation. Therefore, the annual savings in operational costs for a groundwater heat pump versus an electric system in Alamosa will pay for the increased initial cost in 1.6 years. If an existing well could be used in the Alamosa area, the payback would be reduced to about 1.3 years. On the other hand, if two wells were needed, the payback period would increase to two years.

Table 8. Payback in years for groundwater heat pumps versus other systems.

Community	Heating-Type		
	Electric	Propane	Natural Gas
Alamosa	1.6	3.3	*
Burlington	3.5	11.4	*
Denver			
Airport	3.8	10.9	*
City roof	4.2	12.2	*
Durango	2.9	8.7	*
Fort Collins	2.7	5.1	*
Glenwood Springs	3.8	6.2	*
Grand Junction	2.7	5.7	45
Lamar	5.0	8.8	44
Pueblo	4.8	7.6	29
Salida	2.0	8.8	*
Steamboat Springs	3.1	5.5	57
Sterling	3.1	8.1	*

*With current costs for natural gas, the operating costs for heat pumps are slightly more than natural gas.

The higher payback periods in the natural gas columns are due to the close annual operating costs between heat pumps and this form of heating. If the cost of natural gas continues to increase at a faster rate than electricity, then the payback will be reduced. It should be pointed out that the payback periods listed assume a heat pump with a COP of 3.5. It is possible for heat pumps to operate at COP in excess of 4 for several of the heat pumps currently on the market. If the COP is increased, the payback periods will be reduced by a proportional amount.

SUMMARY

Groundwater heat pumps are reliable and commerically available to both heat and cool a building. They are currently cost-competitive with propane and electric systems, and are more efficient than conventional furnaces. When other uses for the groundwater are available and flow rates are adeqauate to accommodate the total requirements, heat pumps can be competitive with natural gas systems as today's energy costs. The heat pump can be used for commercial application as well as the private residence. With the larger the heat load, the payback period is usually shorter. This booklet should be used in the preliminary selection of equipment and overall planning for a heat pump system to provide energy-efficient space conditioning. The use of groundwater systems is highly site specific and the owner is urged to check with a local heat pump representative concerning specific applications. A detailed listing of heat pump manufacturers and their Colorado representative is given in Appendix A.

BIBLIOGRAPHY

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Cooling and Heating Load Calculation Manual. Work performed under Contract No. H-2303 for the Office of Policy Development in Research, U.S. Department of Housing and Urban Development. ASHRAE GRP 158, New York, New York, 1979.

Collie, M. J. (ed.). Heat Pump Technology for Saving Energy: Noyes Data Corporation, Park Ridge, New Jersey, 1979.

Colorado Division of Water Resources. Permit Application Form. Colorado Department of Natural Resources, Robert Longenbaugh. [n.d.]

Goering, S. W., Garing, K. L., Coury, G. E., and Fritzler, E. A. Residential and Commercial Space Heating and Cooling with Possible Greenhouse Operation; Baca Grande Development, San Luis Valley, Colorado. Final Report. IDO/78ET28455-3, U.S. Department of Energy, Division of Geothermal Energy, May 1980.

National Water Well Association. A Groundwater Heat Pump Anthology. Worthington, Ohio.

Piro, Frank. Rules and Regulations, Rules of Practice and Procedure for the Development and Production of Geothermal Resources and Geothermal Resources Act. State of Colorado, Oil and Gas Conservation Commission, Department of Natural Resources. [n.d.]

Reistad, G. M., and Means, P. Heat Pumps for Geothermal Applications: Availability and Performance. Final Report. Work performed under Contract No. FC07-791D12020, Department of Mechanical Engineering, Oregon State University, Corvallis, Oregon, for U.S.

Department of Energy, Division of Geothermal Energy, May 1980.

Utah State University. Groundwater Heat Pump Equipment Selection Procedures for Architects, Designers, and Contractors. Utah Water Research Laboratory, Extension Service, Mechanical Engineering Department, March 1980.

APPENDIX A

GROUNDWATER HEAT PUMP MANUFACTURERS

Company	Local Representative
American Air Filter 215 Central Avenue Louisville, Kentucky 40201 (502) 638-0325	American Air Filter Building 3F 14 Inverness Drive East Englewood, Colorado 80112 Robert Heaps (303) 779-0888
American Solar King Corporation 7200 Imperial Drive P.O. Drawer 7399 Waco, Texas 76710 (817) 776-3860	American Solar Engineering and Supply 2087 Clarkson Denver, Colorado 80205 (303) 831-1091
California Heat Pump 4051 Northwest 3rd St. Oklahoma City, Oklahom Oklahoma (405) 949-9119	CFM Company 2735 South Raritan St. Englewood, Colorado (303) 761-2291
Carrier Corporation Carrier Parkway P.O. Box 4808 Syracuse, New York 13221 (315) 432-6000	Sigler-Faigen 2869 South Shoshone Englewood, Colorado 80110 Ed Hoover (303) 761-5461
Climate Master Products, Inc. Division of Weil McClain Company 2000 West Commercial Boulevard Ft. Lauderdale, Florida 33309 (305) 776-1961	Westcon 4860 Acoma Street P.O. Box 16344 Denver, Colorado 80216 (303) 892-5515

APPENDIX A (continued)

Company	Local Representative
Command Aire Corporation P.O. Box 7916 3221 Speight Avenue Waco, Texas 76710 (817) 753-3601	None
Elm Brock Refrigeration, Inc. 2100 Enterprise Avenue Brookfield, Wisconsin 53005 (404) 784-0104	None
Florida Heat Pump Corporation Division of Leigh Products Company 610-SW 12th Avenue Pampano Beach, Florida 33060 (305) 781-0830	None
Friedrich Air Conditioning and Refrigeration Company 4200 North Pan Am Expressway P.O. Box 1540 San Antonio, Texas 78295 (512) 787-2100	Westcon 4860 Acoma Street P.O. Box 16344 Denver, Colorado 80216 (303) 892-5515
Heat Exchangers, Inc. Kold Wave Division 8100 North Monticello Skokie, Illinois 60076 (312) 679-0300	Distributors Inc. of Colorado 2700 West 6th Avenue Denver, Colorado 80204 (303) 623-1236

APPENDIX A (continued)

Company	Local Representative
International Energy Conservation Systems, Inc. 1775 Central Florida Parkway Regency Industrial Park Orlando, Florida 32809 (305) 851-9410	None
Mammoth Division Holland Plant 341 East 7th Street Holland, Michigan 49423 (616) 399-0400	Long and Associates 2080 West Cornell Ave. Englewood, Colorado 80110 (303) 761-7493
Singer Auburn, New York (315) 253-2771	B & B Associates 3730B Paris Street Denver, Colorado 80239 Dave Medvec (303) 371-0052
Solar Energy Resources Corporation 10639 Southwest 185th Terrace Miami, Florida 33157 (305) 233-0711	None
Tempmaster International Energy Conservation Systems, Inc. 1775 Central Florida Parkway Orlando, Florida 32809 (305) 851-9410	None

APPENDIX A (continued)

Company	Local Representative
Thermal Energy Transfer Corporation 9550 Liberty Road Drawer C Powell, Ohio 43065 (614) 889-6660	None
Vanguard Energy Systems 9133 Chesapeake Drive San Diego, California 92123 (714) 292-1433	Eben Gramer, Inc. 241 Charros Drive Golden, Colorado 80401 (303) 526-0307
Weather King Division of Anderson Products 4501 East Colonial Drive P.O. Box 20434 Orlando, Florida 32814 (305) 894-2891	Universal Plumbing Supply Company 4950 North Park Drive P.O. Box 7610 Colorado Springs, Colorado 80993 (303) 598-6611
Westcorp, Inc. Subsidiary of Vaughn Corporation 15 Stevens Street Andover, Massachusetts 01810 (617) 470-0520	Allen Posen and Associates 7344G South Alton Way Englewood, Colorado 80112 (303) 771-6160
Westinghouse Electric Corporation Commercial Industrial Air Conditioning Division P.O. Box 2510 Stalinton, Virginia 24401	Long and Associates 2080 West Cornell Avenue Englewood, Colorado (303) 761-7493

APPENDIX A (continued)

Company	Local Representative
York Division Borg Warner Corporation P.O. Box 1592 York, Pennsylvania (717) 846-7890	Westburne Supply, Inc. 417 Quivas P.O. Box 5187 Denver, Colorado (303) 534-5111