# DIRECT UTILIZATION TECHNOLOGY, STATE-OF-THE-ART

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## INTRODUCTION

This paper is intended to convey some ideas as to how a geothermal project develops, and to point out considerations that lead to the selection of the actual hardware. Today's "state-of-the-art" provides a wide variety of materials and equipment that can be used in various combinations and configurations to perform a specific geothermal function. Most of the hardware is "off-the-shelf," and there is seldom need for custom designed specialty items.

To illustrate project development and equipment selection, an actual on-the-line geothermal application has been selected for discussion. This application involves space heating, potable hot water, and swimming pool heat for a small condominium. The four level condominium contains 11 units, a laundry, storage area, and a recreation room. The first thing discussed will be the geothermal well.

## PRODUCTION WELL

The condominium is located on the southwest slope of Mt. Hood at Government Camp at an elevation of about 3,800 feet. In early 1980, geological work was completed that indicated a good possibility for hot water at a reasonable depth on property adjacent to the condominium and exploratory drilling was begun.

The well was completed at a depth of about 2,000 feet in the late summer. Unfortunately, the well did not produce hot enough water for direct heating application. The well was filled in to a depth of 1,150 feet and reworked to produce from the bottom aquifer and a 900-ft aquifer. The well was tested at a flow of over 400 gpm of 70°F water. Water was of good quality with the exception that it contained about five parts per million of hydrogen sulfide ($H_2S$). With knowledge of water temperature and quality, a flow diagram for the condominium heat pump system was developed.

## FLOW DIAGRAM AND HEAT PUMP

Renovation of the existing lodge was underway in mid-1980 to convert the building to a condominium. Building plans were available, but the type of heating system had not been determined. Heat loss calculations were made to determine the peak heating required. Space heating for the building required 150,000 Btu/hr; heating the outdoor swimming pool required 250,000 Btu/hr; potable hot water required an additional 100,000 Btu/hr. Total peak heat required was 500,000

Btu/hr. As previously mentioned, the well water was not hot enough for direct heating, so the flow diagram (Figure 1) was developed based on a heat pump. Without getting into the details of heat pump technology, a heat pump uses the refrigeration principle to boost temperature to a useable level (Figure 2). In this application, it was decided that a 135°F output temperature was desirable. Commercially available machines will produce temperatures up to 150°F. Higher temperatures, up to 220°F, can be reached by putting two machines in series. Commercially available machines will produce up to five million Btu/hr, and larger capacities can be obtained using selected components. The selected heat pump, under the operating conditions shown, extracts 351,000 Btu/hr from the water, and uses 149,000 Btu/hr of equivalent electricity, to develop the 500,000 Btu/hr of total output. In heat pump language, this is a "coefficient of performance" (COP) of 3.36, which is obtained by dividing 500,000 by 149,000. It is a measure of the heat produced compared to the electricity used. The heat pump system could also be designed to produce space cooling. For this, heat would be injected into, rather than extracted from, the well water. However, the condominium is located where summer air conditioning is not necessary.

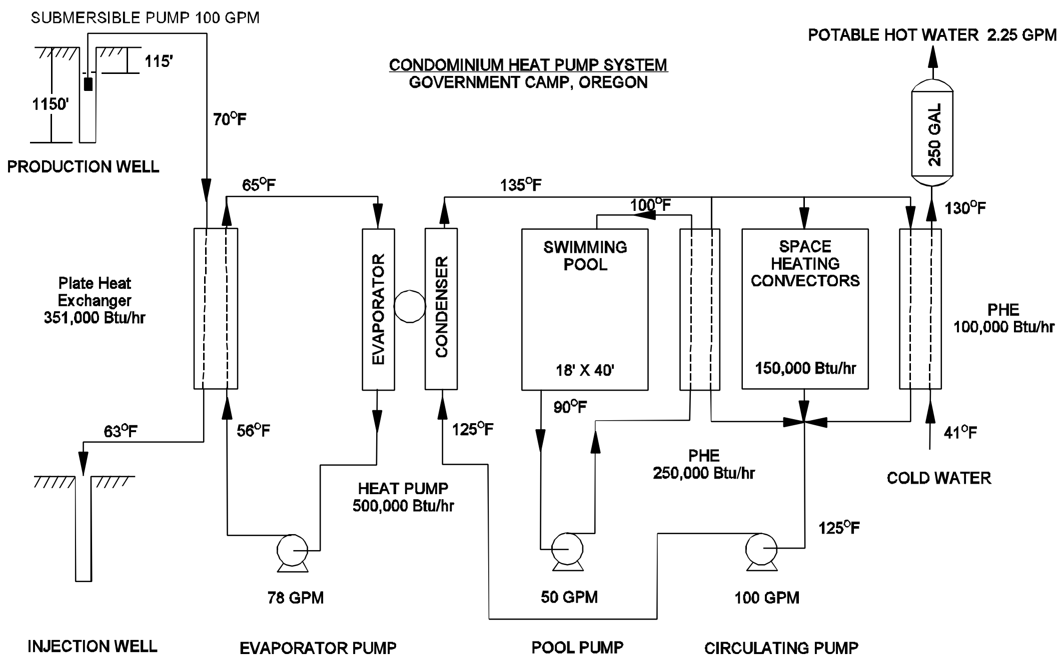


**Figure 1.**

Heat pump evaporators typically use copper or copper-nickel tubing. This heat pump is no exception. Though the well water is otherwise acceptable for direct use in the evaporator, the small amount of $H_2S$ is extremely destructive to copper alloys. Therefore, a heat exchanger was placed between the well water and the heat pump evaporator circulating water, which is high quality water. This heat exchanger is constructed of corrosion resistant type 316 stainless steel which is expected to give satisfactory life in this service. Since heat is extracted from a lower temperature water in the evaporator, there is a slight decrease in COP, about 5%, as compared to using the 70°F directly if that was acceptable. For any water source heat pump, the COP decreases as the heat pump output temperature rises, and increases as the heat pump input temperature rises (Figure 3). For this application, the net effect will be that the average COP will be higher than at the 500,000 Btu/hr design output. At lower heat loads, the condenser output temperature can be decreased below 135ºF, and the input temperature to the evaporator will rise slightly as the heat exchanger heat load decreases. This will raise the COP.

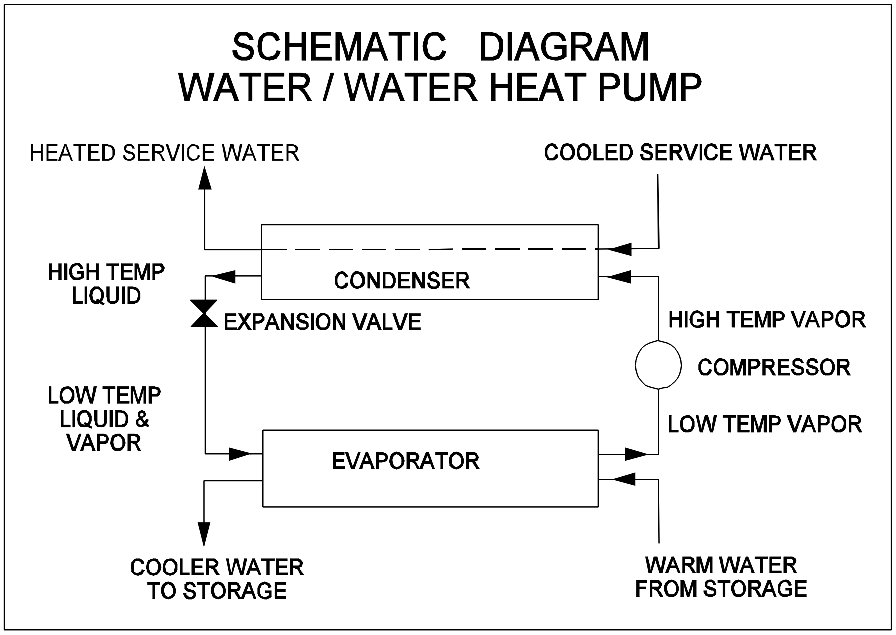


**Figure 2.**

## INJECTION WELL

Before the well pump can be selected, the method of disposing of the geothermal water must be decided upon. At Government Camp, it was permissible to inject the water using a relatively shallow well. The well was pump tested to determine the injection pressure needed to achieve the design flow rate. This pressure, plus system pressure drop, are added to the production well lift pressure to determine the total pressure that must be developed by the pump. In some cases, it is desirable to use a separate injection pump. The amount of injection pressure needed is dependent on the standing water level (static level) of the injection well. A high water level indicates the need for pressure, and frequently no pressure is necessary with low water levels. In an ideal situation with the production and injection well identical in design and accessing the same aquifer, pressure for injection would be needed if the drawdown of the production well exceeded the static level of the injection well. Drawdown is the difference in feet between the pumping level and the static level. For example, if the static level in both wells was 60 feet, the pumping level 115 feet, then the drawdown is 55 feet. This is less than the 60-ft static level, so no pressure would be necessary. Water level in the injection well would rise 55 feet, which is five feet below the surface level. Of course, this ideal system assumes identical wells, which is seldom the case. An injection well must be carefully designed and tested. This well was completed to 255 feet, cased with 12-in. pipe, and perforated at 140 feet to 160 feet and 185 feet to 195 feet. It accepted 200 gpm of injection water at 18 psi pressure, and 100 gpm at about 4 psi.

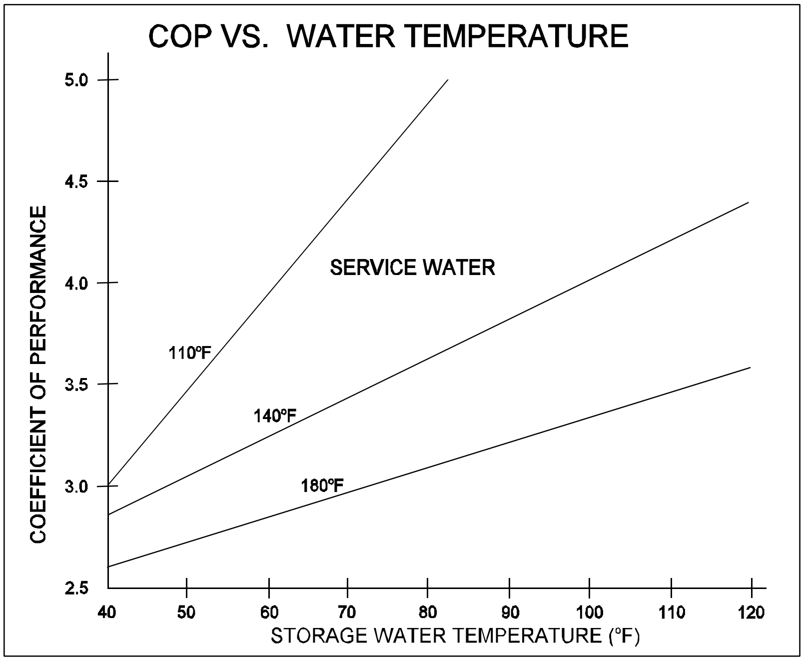


**Figure 3.**

**WELL PUMP**

Selection of the well pump is normally limited to the submersible type, or to vertical turbine pumps. Temperature and corrosive properties of the geothermal water are important considerations. If the water temperature is about 86ºF, the normal submersible pump used for potable well water cannot be used. However, properly designed and applied submersibles have operated at temperatures as high as 300ºF. The maximum permissible temperature is limited by the temperature that the electrical insulating material will withstand. Submersible pump components in contact with the well water are constructed of corrosion resistant alloys. For a very deep well, with very high lifts, the submersible pump is frequently the only choice.

If the lift is 800 feet or less, a vertical turbine pump should be considered (Figure 4). At water temperatures above 250ºF, the practical lift limit would be lower. The critical temperature problem is the selection and method of lubrication of the lineshaft bearings. If water high in solids is in contact with the bearings, problems are induced by salt deposits. Corrosion problems can be satisfactorily controlled by proper metallurgy selection. A turbine pump permits the use of a variable-speed driver (Figure 5). There are several advantages to using the driver installed between the electric motor and the impeller shafts. These include no-load starting, shock and vibration protection, and minimum horsepower requirements. The variable-speed driver works somewhat like an automobile's automatic transmission. Hydraulic fluid maintains a coupling between the motor shaft rotor and the impeller shaft rotor. The desired speed is obtained by the quantity of fluid in the coupling space between the rotors. These drivers are available in power ratings from 1 hp to 5,000 hp. The power saving aspects of variable-speed drivers are particularly important in geothermal space heating applications; where, average pumping rates are low, frequently 20% to 30% of design rates (Figure 6). For flows ranging from 20% to 60%, the electrical power savings is about 40% in a typical installation.

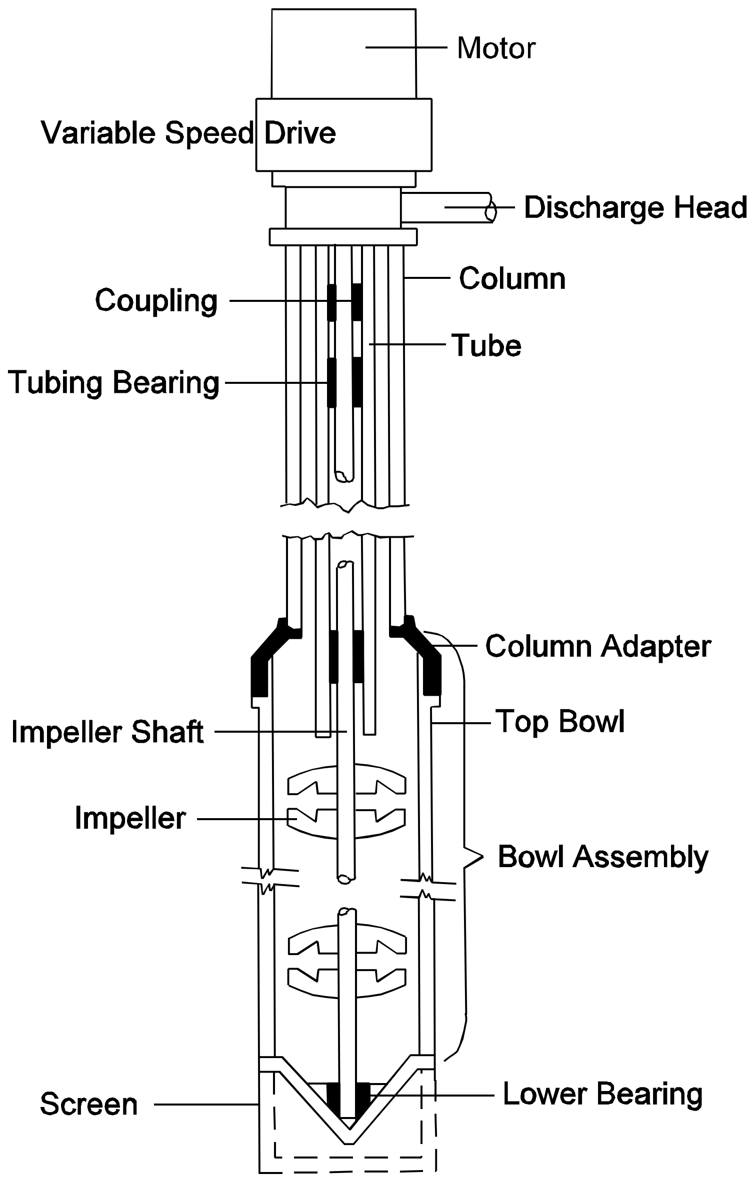


**Figure 4. Vertical turbine pump with variable-speed drive.**

The well pump installed at the condominium is a submersible pump. For this application, the pumping horsepower is quite low, and the additional cost for a vertical turbine pump with or without variable-speed driver could not be justified. In this low-temperature service, the 5-hp submersible is expected to perform satisfactorily, and the supplier has provided a guarantee. The pump was set at 150 feet with an expected pumping level at design flow of 115 feet. The static level is approximately 55 feet. Well piping is 2-1/2 in. black steel pipe. Standard weight pipe (Schedule 40) is used for the first 40 feet, and the last 10 feet of depth. Heavier pipe (Schedule 80) with a coal tar epoxy coating is used in between where the $H_2S$ corrosion environment is greatest.

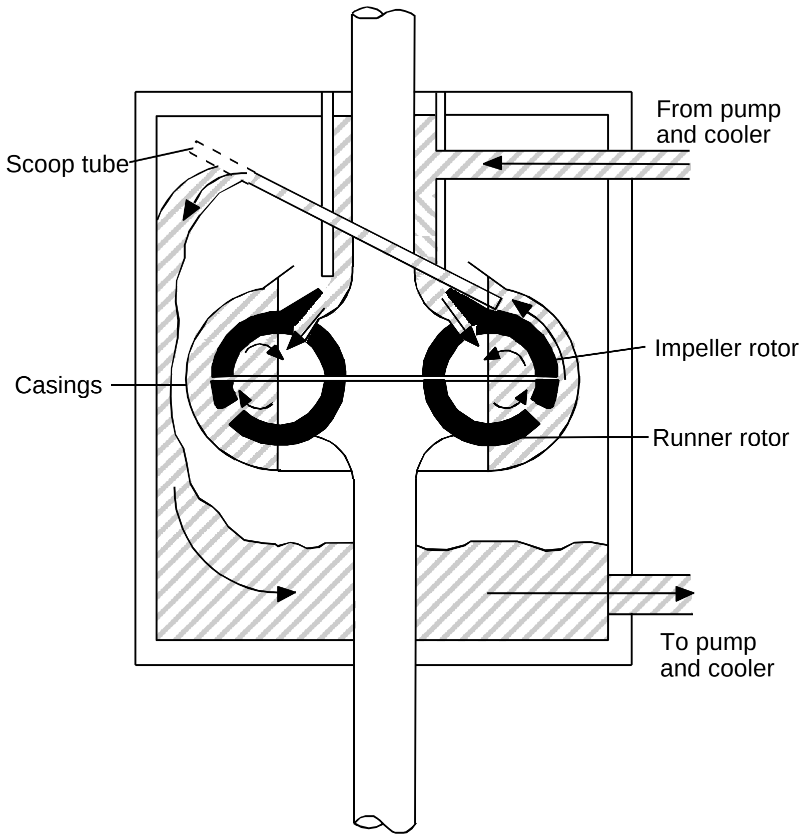


**Figure 5. Variable-speed driver.**

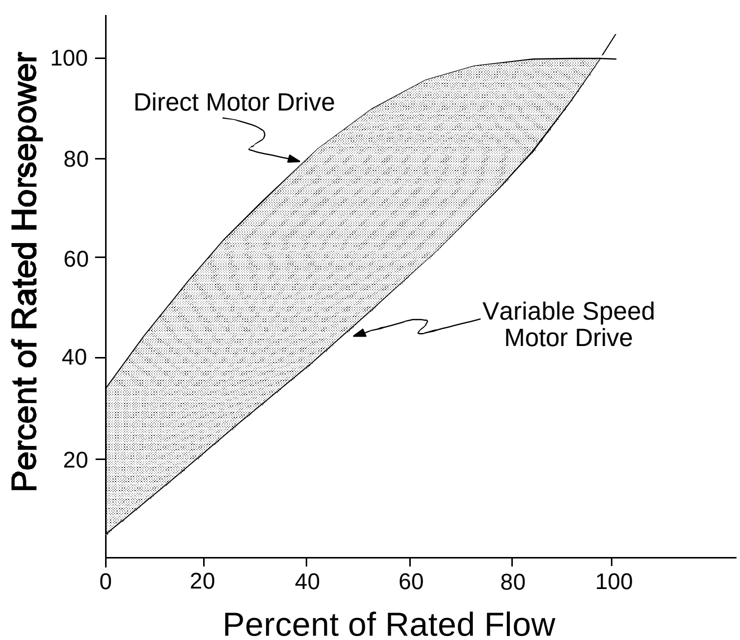


**Figure 6. Pump horsepower savings with variable-speed motor driver.**

## HEAT EXCHANGERS

As previously mentioned, a plate heat exchanger was selected to isolate the heat pump evaporator from the geothermal water for corrosion reasons (Figure 7). Other geothermal waters frequently are prone to deposit salts. Salt deposits decrease the effectiveness of heat transfer equipment and can ultimately restrict liquid flow through piping and equipment. Both problems can be minimized by using a two loop system, which isolates the geothermal water from much of the piping and equipment. If the transfer piping is to be protected, the exchanger should be located close to the well. The secondary loop is usually a closed loop circulating a treated water whose quality is monitored. The plate heat exchanger is well suited for this service. The exchanger consists of a sandwich of corrugated plates clamped together by rods. Points of contact between plates are sealed from leakage by gaskets.. The plates can be quickly disassembled for cleaning.

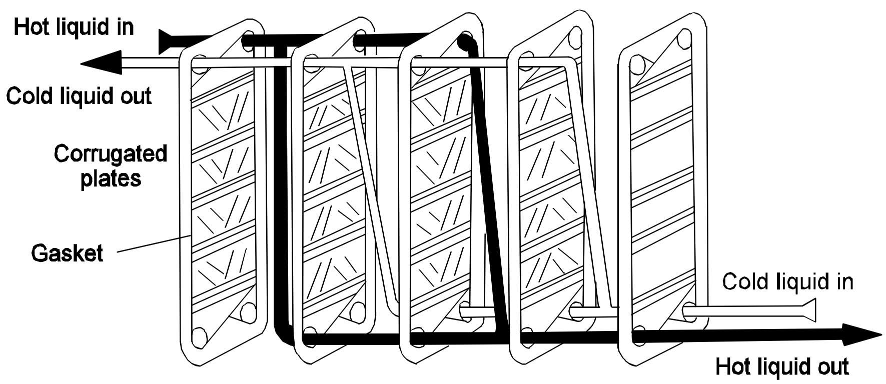


**Figure 7. Plate heat exchanger.**

Primary and secondary fluids are passed through alternate passages between the plates. Counter-flow conditions and high turbulence produce a very effective heat exchanger which is small in size. In addition, more than one service can be attached to a single frame. Temperature approaches of 5°F are easily obtained, as compared to about 20°F for the conventional shell-and-tube exchanger.

Seldom is mild steel acceptable for heat exchanger construction in geothermal applications. In corrosive resistant materials, the plate heat exchanger is less expensive than the shell-and-tube exchangers (Figure 8). When comparing 18/8 stainless steel exchangers of the two types, the plate heat exchanger costs about 60% of the cost of a shell-and-tube exchanger.

The plate heat exchanger for the swimming pool and the potable hot water were also less expensive than shell-and-tube exchangers, and were purchased on that basis.

## PIPING AND PIPING INSULATION

As previously mentioned, steel pipe, a portion protected externally with a coal tar epoxy, was used downhole in the well. Carbon steel is the most widely used metallic pipe in geothermal duty, and usually has an acceptable service life. Use of alloy pipe is restricted due to cost, and copper and aluminum piping are not acceptable because of their susceptibility to corrosion. There is a wide choice of non-metallic pipes that are inert to normal chemical compounds found in geothermal water. Temperature is a limiting criterion for selecting these pipes. Figure 9 illustrates the approximate maximum temperature for the various materials.

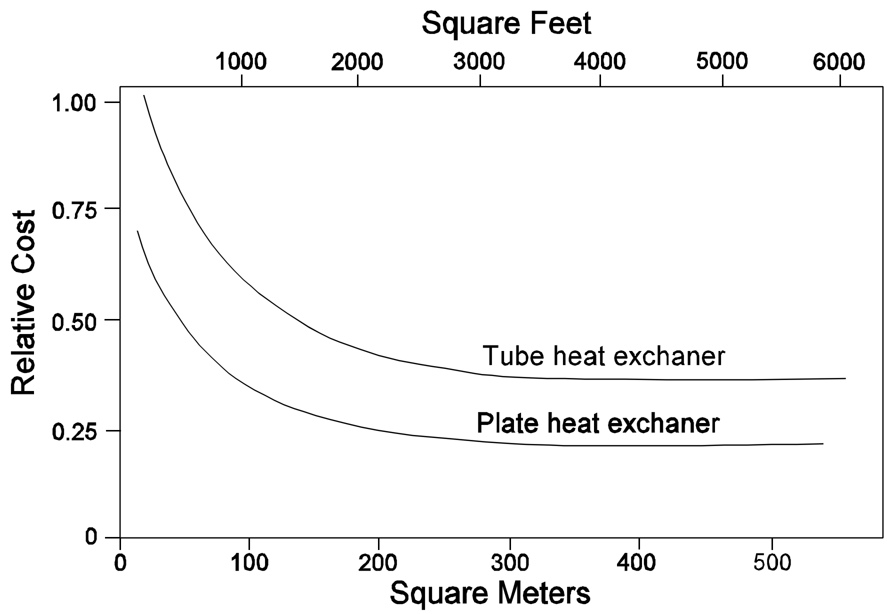


**Figure 8. Relative cost of stainless steel plate-and-tube heat exchanger.**

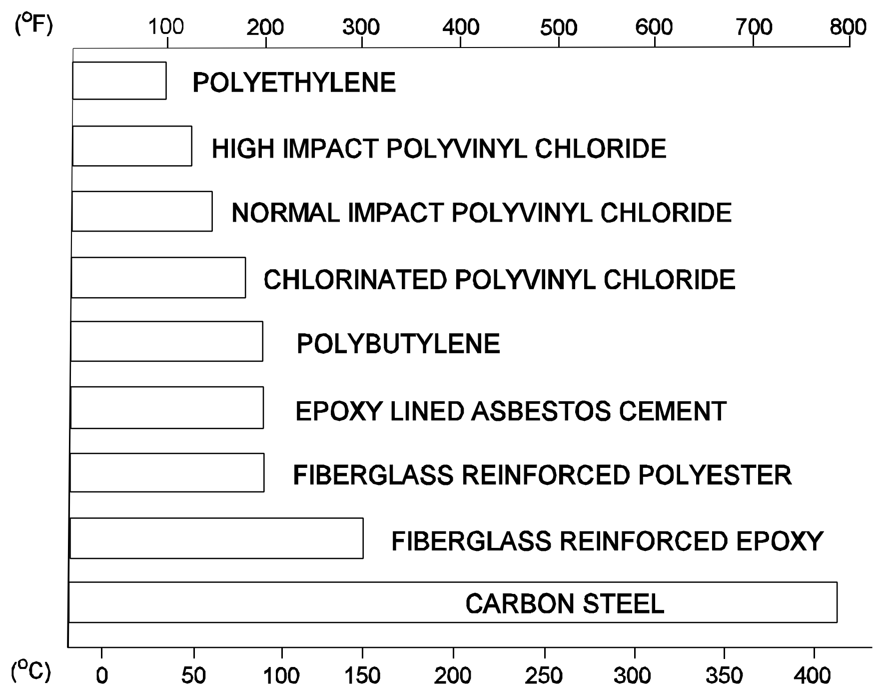


**Figure 9. Maximum temperature–piping materials.**

Polyethylene is at the low end of the scale with a maximum temperature tolerance of only 100°F. Carbon steel is at the high end of the scale, being useable in some applications above 700°F. Piping of each of these materials has its place in geothermal systems. Each has specific handling, assembly, thermal expansion and cost considerations. Generally speaking, the various piping materials are more expensive, the higher the temperature tolerance. However, the installation cost for the plastic is less expensive. They are light to handle, can be assembled with pressure joints, can be thermally welded, and most can be welded with solvents. Of course, local code requirements must be considered when selecting pipe.

Fiberglass reinforced epoxy pipe (FRP) is widely used in geothermal applications, since it can tolerate temperatures up to 300°F. Buried FRP pipe can be installed without expansion loops or joints, utilizing concrete constraining blocks at valves, turns, and branches. The FRP pipe costs the same as steel pipe, when comparing insulated steel pipe. FRP pipe, and other non-metallic pipes, are not subject to external corrosion that frequently destroys buried steel pipe.

Various piping insulating materials are used, sometimes field installed, or frequently factory installed, on the pipe. For long runs of pipe, factory installed insulation is usually preferred. One method is to foam approximately two inches of polyurethane between a polyvinyl chloride outer jacket and the inner pipe in sections of about twenty feet in length (Figure 10). This is a very effective insulation. Other satisfactory insulating materials are calcium silicate, 85% magnesia, mineral fiber, and cellular glass. These are usually purchased preformed to fit the particular pipe size.

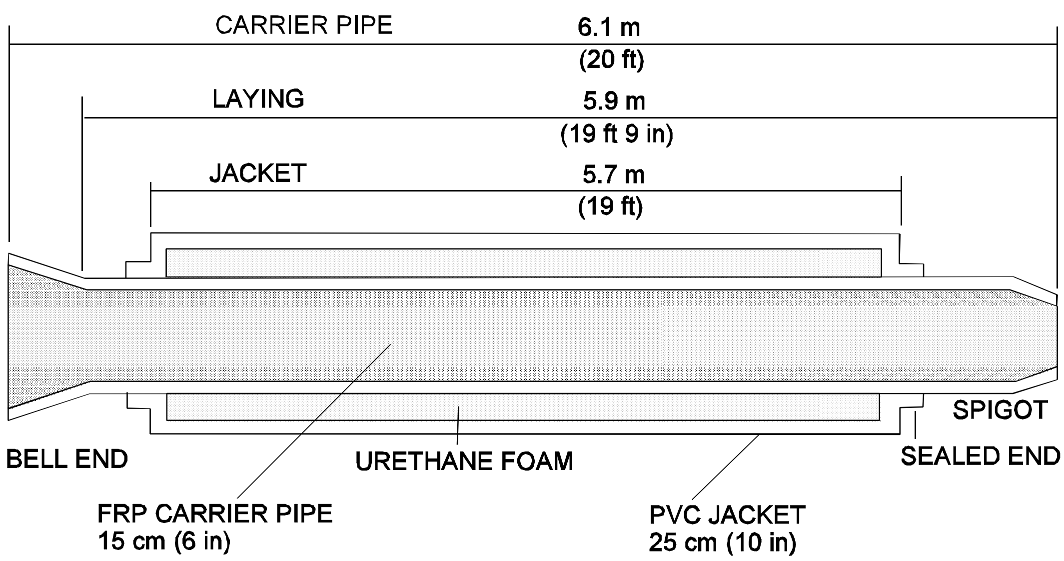


**Figure 10. FRP pipe.**

Sometimes, it is unnecessary to insulate the pipe. If a lower water temperature can be tolerated, the decision may be made on the basis of economics. Simply burying bare pipe can reduce heat loss by about one third. With a selected light, dry soil placed around the pipe, and enclosed in a wrap-around plastic film, an additional savings in heat loss can be achieved. The actual pipe material, whether plastic or steel, has no significant effect on the heat loss from buried pipe.

For the low-temperature piping at the Government Camp condominium, 2-1/2 in. PVC pipe was used. This pipe is inexpensive, and easy to assemble using solvent welding. The pipe exterior to the building was insulated with performed urethane and buried to a depth of three feet. The PVC inside the building was not insulated. The hot piping inside the building is copper, which is satisfactory since it does not come in contact with geothermal water. Copper meets the local code, and though expensive to purchase, it can be quickly installed. Piping was insulated with a wrap-around urethane type insulation.

## SPACE HEATING EQUIPMENT

Various methods of space heating are available. Five methods are shown on an attached graph (Figure 11), titled Temperature Range of Space Heating Methods. Bare tubes in masonry floors or ceilings can be used to space heat at entering water temperatures as low as 85°F. Finned tubes in forced air ducting can be used at temperatures as low as 105°F, forced air room convectors as low as 120°F, and natural air flow convectors down to 140°F. Radiators are not much good below 160°F. These are approximate design limits, and are not absolute. As entering water temperature increases, so does the number of options available. At 160°F, all five methods can be considered. The amount of water circulation varies considerably for each of the methods. The following is a comparison made for direct geothermal space heating at a load of 28,000 Btu/hr, based on maintaining a 65°F room temperature.

| Method | Water In (°F) | Water Out (°F) | Flow Rate (gpm) |
|---|---|---|---|
| Bare tubes in masonry slab | 85 | 81 | 14.00 |
| Finned tubes in forced air duct | 105 | 75 | 1.87 |
| Forced air flow room convectors | 120 | 85 | 1.60 |
| Natural air flow room convectors | 140 | 110 | 1.87 |
| Room radiators | 160 | 140 | 2.80 |

The largest flow requirement listed is for the bare tubes in masonry (14.0 gpm), because the low temperature of the inlet water permits only a small temperature drop of 4°F. It may be seen that finned tubes in ducting is a very effective method of transferring heat. In this example, the discharge water is cooled to 75°F, an approach of 10°F to the room temperature of 65°F. Low discharge water temperature is important in direct heating geothermal applications to maximize the utilization of the resource. However, it is not important in heat pump applications, since discharge water is returned for reheating. The heat pump normally works with 10°F to 20°F rise in temperature on the circulating water stream. The condominium heat pump works with a 10°F rise; that is, the water returns to the condenser at 125°F and leaves at 135°F. The hallways are heated with forced air flow room convectors, and natural air flow baseboard type room convectors are used for room heating. The average water temperature in the condominium convectors is 130°F (which is a good lower limit for the average temperature in natural air flow convectors). At lower average temperatures, the length of the convectors becomes excessive. Baseboard convectors are an inexpensive and attractive method of heating.

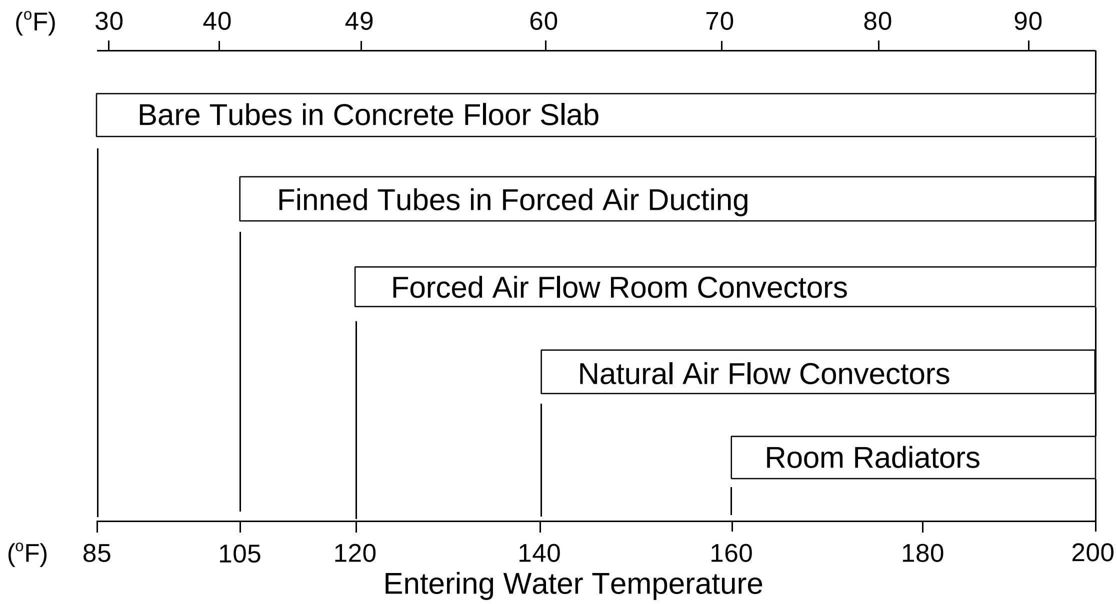


**Figure 11. Temperature range of space heating methods.**

## CONCLUSION

If a geothermal resource exists, materials, equipment and technology are available to match the resource to the job. Technical assistance and information on geothermal applications are available from the Geo-Heat Center at Oregon Institute of Technology.

## ACKNOWLEDGMENTS

The author wishes to acknowledge the kind cooperation of the following individuals:

| | | |
|---|---|---|
| Mitchell Gensman | Kirk McGraw | Frederick T. Smith |
| Project Engineer | Sales Engineer | Co-Owner |
| McKinstry Co. | Oregon Air Reps | Thunderhead Lodge Condominiums |
| Portland, OR | Portland, OR | Government Camp, OR |

## REFERENCES

1. Direct Utilization of Geothermal Energy: A Technical Handbook, Geothermal Resources Council, Chapter 4, 1979.

2. Equipment Used in Direct Heat Projects, Gene P. Ryan, Geo-Heat Center, Oregon Institute of Technology, April 1981.

3. Heat Pumps, Space Heating Applications, Gene P. Ryan, Geo-Heat Center, Oregon Institute of Technology, August 1980.

4. The Hydronics Institute, "Installation Guide for Residential Heating Systems," No. 200, 1979.

5. American Society of Heating, Refrigeration and Air-Conditioning Engineers Handbook, Equipment 1979, Chapter 9, Air Heating Coils, pages 9.1-9.4; Chapter 28, Radiators, Convectors Baseboards and Finned Tube Units, pages 28.1-28.6; Chapter 30, Centrifugal Pumps, pages 30.1-30.4.