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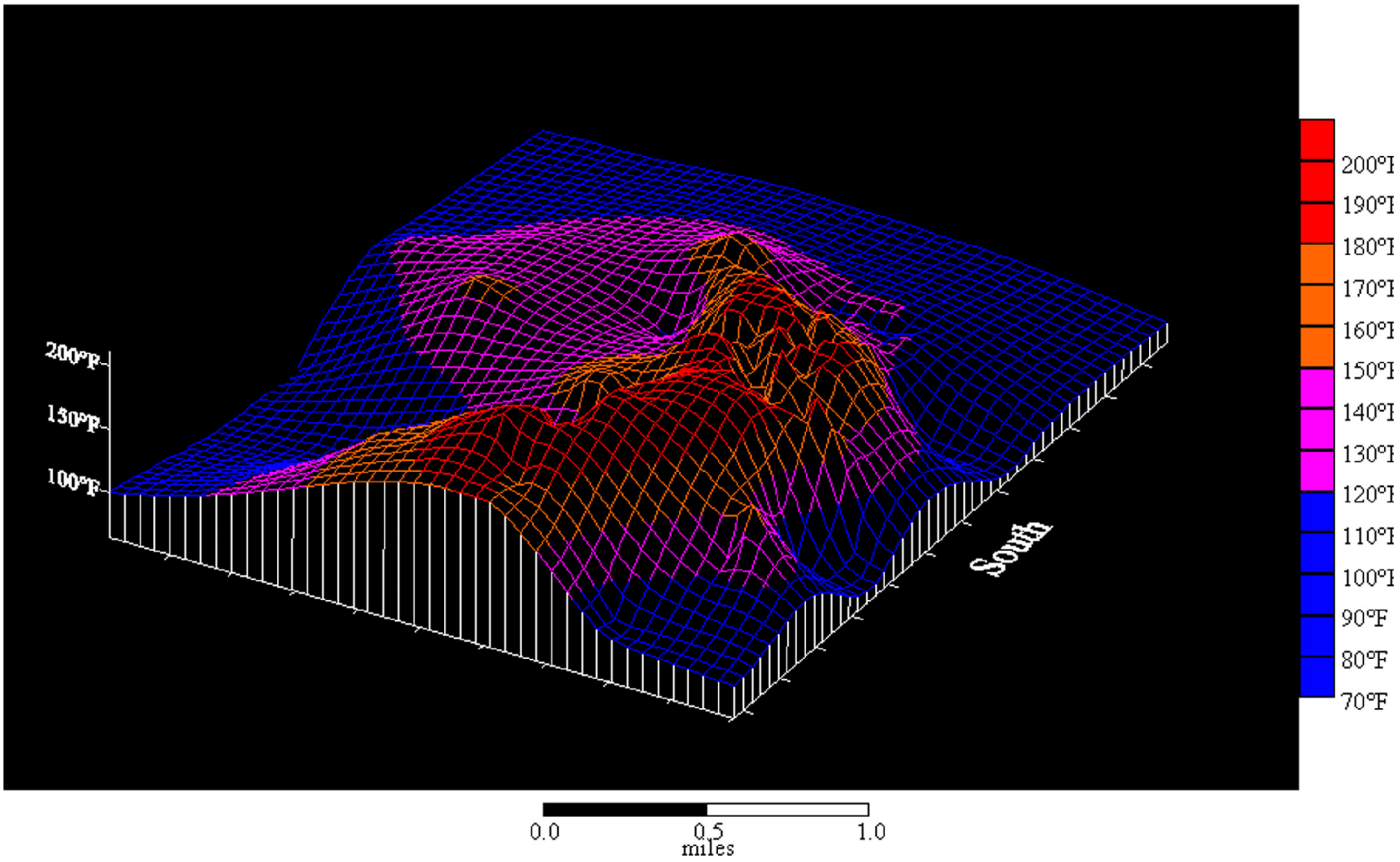
PHONE NO. (541) 885-1750



Temperatures of Residential Wells in the Moana Geothermal Area, Reno, Nevada

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

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Cover: Temperatures from residential wells in the Moana geothermal area, Reno, NV (Courtesy of Tom Flynn).

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GEO-HEAT CENTER
Oregon Institute of Technology
3201 Campus Drive
Klmath Falls, OR 97601
Phone: 541-885-1750
Email: geoheat@oit.edu

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EDITOR

John W. Lund
Typesetting/Layout - Donna Gibson
Graphics - Tonya "Toni" Boyd

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MOANA GEOTHERMAL AREA RENO, NEVADA 2001 UPDATE

Thomas Flynn
Mankato Enterprises

INTRODUCTION

The Moana geothermal area, in southwest Reno, supports the largest low-to-moderate temperature, direct-use development in Nevada. More than 250 geothermal wells, ranging from 10 to 1,000 feet in depth and 100ºF to 215ºF in temperature, have been drilled in an area of approximately 3 square miles. Residential and commercial development is concentrated in Sections 23 through 27, Township 19 North, Range 19 East, Mount Diablo Base and Meridan (Figure 1)

Geothermal development in the Moana area began in the early 1900s at the site of the former Moana Hot Springs. The city of Reno and former Nevada Governor John Sparks both took advantage of the proximity of the thermal water for heating the municipal swimming pool and supporting rudimentary geothermal aquaculture, respectively. By 1975, it is reported that 35 geothermal wells in the area were in use for residential space heating (Bateman and Scheibach, 1975). By 1984, the number of documented wells had increased to 143 (Flynn and Ghusn, 1984). There are more than 200 documented wells, but the present number probably exceeds 250. Figure 2 shows the historical development of wells (from this database) drilled between 1950 and 1995. The histogram shows clearly that the introduction of residential federal energy tax credits, amounting to 40% of the investment, between 1978 and 1985, resulted in a dramatic increase in well drilling and geothermal direct use. Important historical events that impacted energy supplies worldwide had a very limited effect on geothermal well drilling.

The Moana thermal anomaly is believed to be the results of forced convection of deeply circulating groundwater along north- and northwest-trending faults. Previous studies have provided inventories of wells drilled (Bateman and Scheibach, 1975; Garside and Schilling, 1979; Flynn and Ghusn, 1984). Miscellaneous engineering investigation of individual wells have been completed by the Geo-Heat Center, Oregon Institute of Technology. This is the first time subsurface temperature data have been used to delineate the patterns of temperature distribution in three dimensions in the Moana area.

Geothermal fluids in Moana are relatively dilute (800 ppm TDS) near-neutral pH, sodium-sulfate dominated waters. It is widely recognized that the Moana geothermal area is a typical, low-to-moderate temperature reservoir that is controlled principally by faults and fractures, and secondarily by lithology. Structurally and chemically similar thermal areas include Walley's Hot Springs, Hobo Hot Springs, and Saratoga Hot Springs in Douglas County. There is little or no relationship between the Moana geothermal area and the higher-temperature (350ºF) Steamboat geothermal area, located 15 miles to the south.

Most of these wells were drilled to meet the heating requirements of single family homes. Historically, residential geothermal wells were completed much like conventional water wells with steel casing, perforated near the bottom, and a cement-sealed annulus to a depth of 50 feet. Eight-inch diameter casing was typically used to accommodate either a steel or copper trombone-shaped downhole heat exchanger (DHE) and a small capacity submersible pump used to stimulate flow into the well. Many of these wells are completed in the hydrothermally-altered Kate Peak Andesite, which consists of various proportions of sand and "blue clay." The larger the percentage of clay, the less productive of the well, prompting the need for a submersible pump. Nevada regulations now prescribe a cement seal from the surface to the top of the thermal aquifer and have eliminated the pumping option unless a fluid injection well is available for the discharge. Several wells have been drilled for commercial properties, including casinos, churches, and a space heating district that supplies geothermally-heated water to more than 100 homes for a single well. The total estimated private investment in Moana is about $15 million dollars with an approximate annual savings of 500,000 therms of natural gas.

OBJECTIVES AND SCOPE

A database consisting of locations, depths, temperatures, temperature profiles, water levels, drilled dates, and in some cases, fluid chemical composition has been compiled for more than 200 residential and commercial geothermal wells in the Moana area. These data, when used in combination with existing geologic and hydrologic data, reveal the areal extent, possible structural controls and magnitude of the thermal anomaly. Contoured temperatures show that the highest temperature wells are distributed along two faults that intersect near the center of the thermal anomaly. Temperature logs from 80 geothermal wells were used to develop three cross-sectional slices through the thermal anomaly, revealing its approximate size, shape and subsurface temperature distribution to a depth of 1,000 feet. The diagrams show the shape of the presently exploited reservoir, which is the result of an uuncoordinated, quasi-wildcat drilling program that was, by most accounts, a success. It is not the intent of the author to provide or suggest any direction or recommendations for future development. Historically, geothermal well drillings has been guided by individual preferences and budgets; that tradition is likely to continue. This report does help to explain the variable success that well drillers have experienced in Moana. The data indicate that the geothermal reservoir is not uniformly distributed; its highest temperatures and productivities are located along specific fault segments.

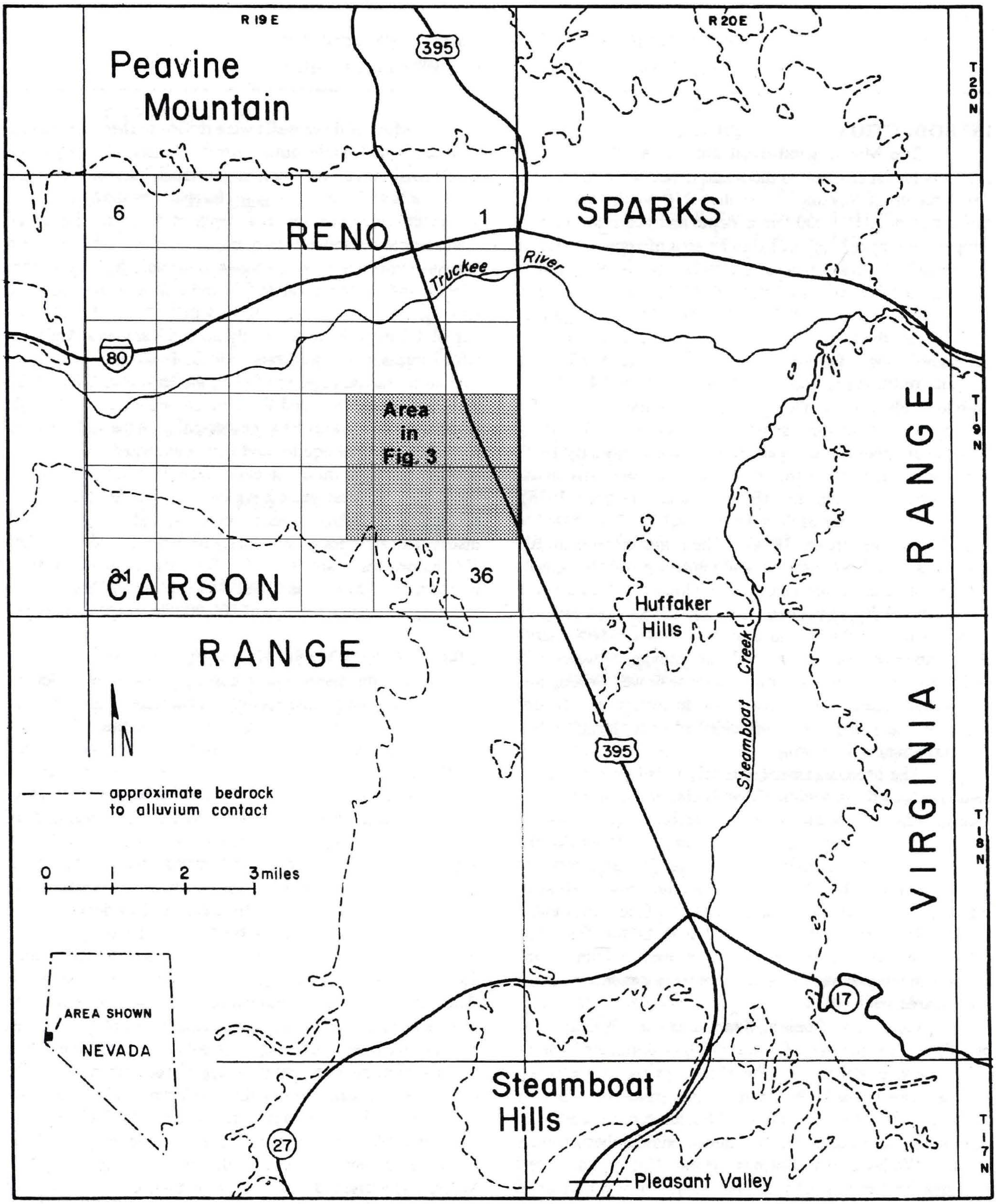

Figure 1. Location map showing the Moana geothermal area and the Steamboat geothermal area (modified after Bateman and Scheibach, 1975).

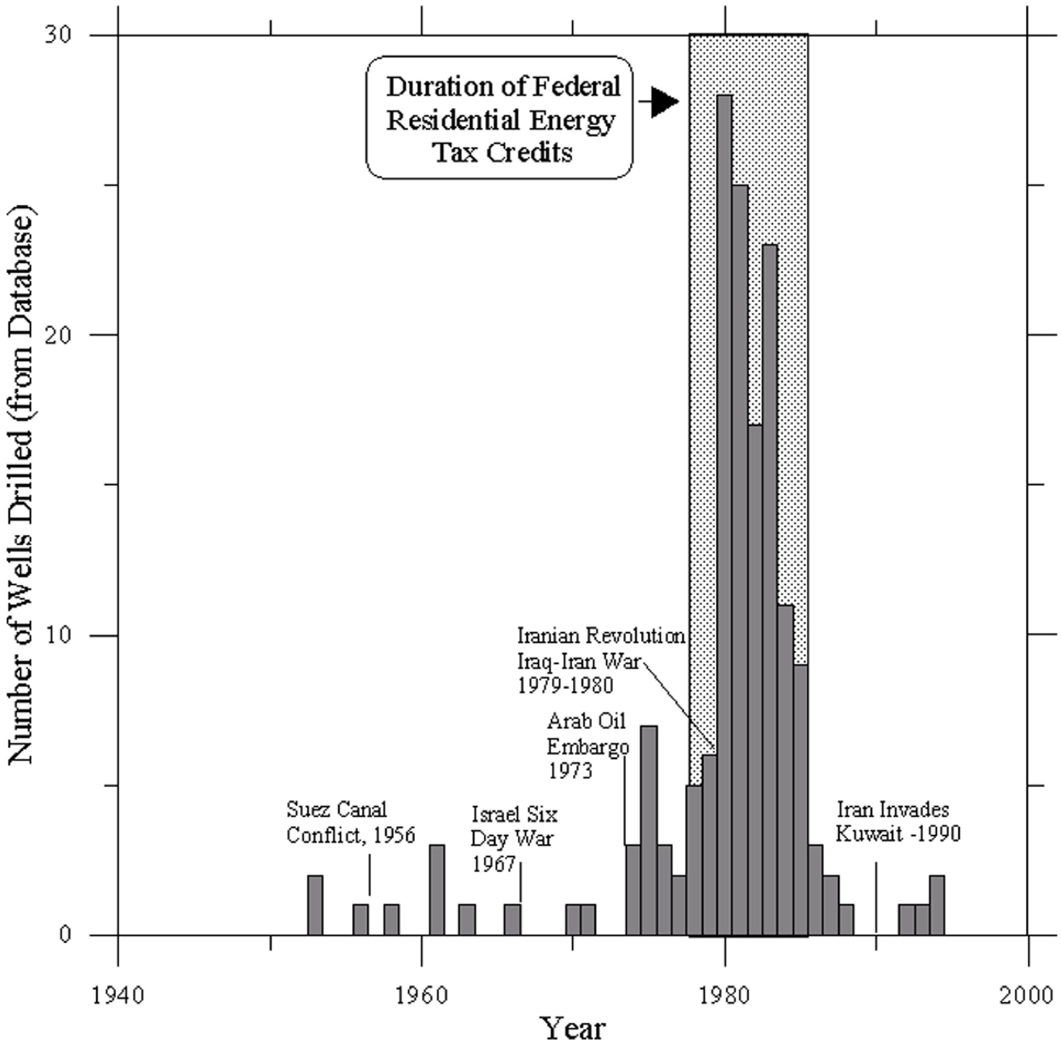

Figure 2. ***Histogram showing temporal distribution of geothermal wells drilled in the Moana geothermal area, T19N, R19E, MDB&M.***

PLAN VIEW MAP

Figure 3 shows the distribution of maximum measured temperatures in geothermal wells in the Moana area. Temperature contours close around and suggest two divergent linear trends: one to the north-northeast, associated with NNE-trending surface faults, and one to the northwest, which does not appear to be associated with any mapped faults. The maximum linear contour for the NNE trend is 180ºF; its length is less than 0.5 miles and it is about 0.25 miles wide. The larger, NW-trending trend has a maximum linear contour of 200ºF, which is about 0.75 miles long and 0.25 miles wide. As mentioned above, this trend is not parallel to any nearby mapped faults. It is, however, parallel to NW-trending faults (N50ºW) that are mapped in exposures of the Kate Peak Andesite, immediately southwest of the map shown here (Bonham and Rogers, 1983). Those faults have been mapped only in the Kate Peak Andesite, which is both the underlying bedrock and in some cases, the geothermal reservoir rock (the andesite is hydrothermally-altered to a "blue clay") in the Moana area.

The diagram suggests that the highest temperatures recorded in Moana are associated with the natural preferential flow along a limited length of existing faults in the basement and overlying sedimentary rocks. The temperature decrease occurs most rapidly immediately adjacent to the faults. The gradients is more gradual further from the faults as thermal waters mix with non-thermal groundwaters to the north, east and south. The western extent of the Moana thermal anomaly is not fully defined by this map due to a lack of data.

Additional plan maps that may be derived from this data set include: lateral variations in fluid chemical composition, especially silica, arsenic, boron and fluoride; depth-to-water; depth to the "blue clay," and depths to the 150ºF and 175ºF isotherms.

CROSS SECTIONS

Selected temperature profiles projected onto west-to-east cross-sectional slices through the thermal anomaly are presented in Figures 4, 5 and 6. Figure 4 slices through the southern end of the anomaly approximately through the center

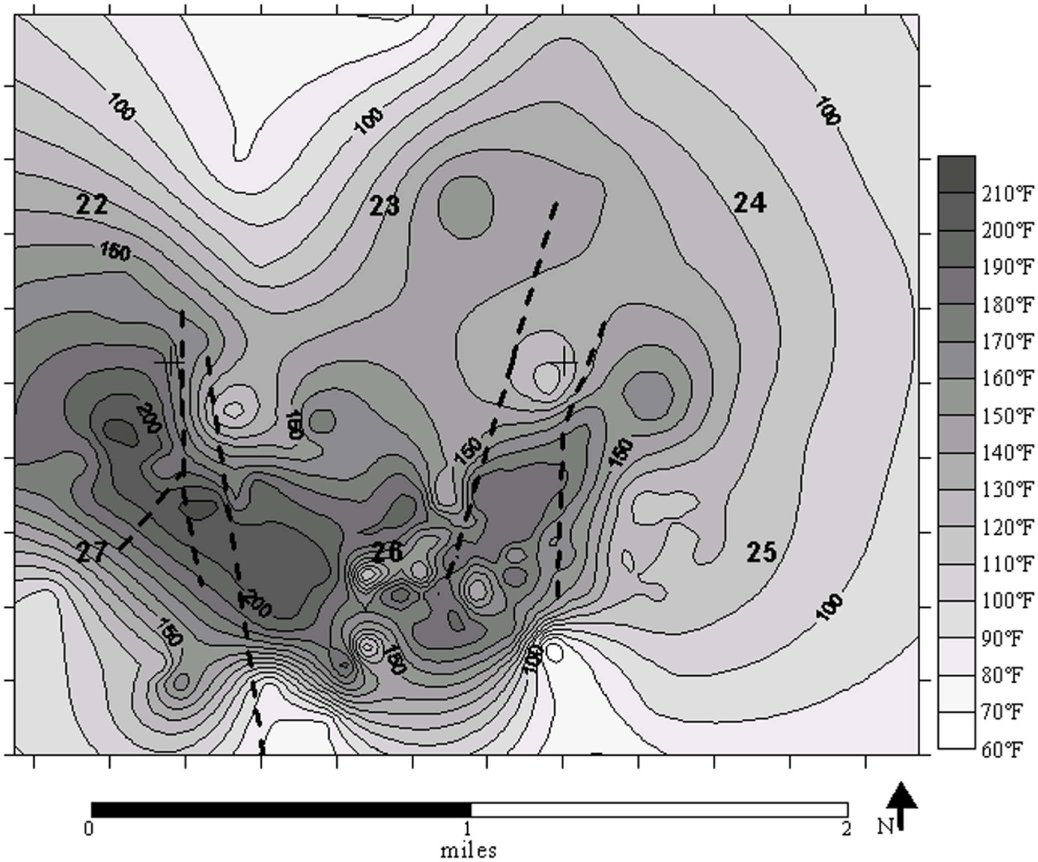

Figure 3. **Relationship between contours of maximum measured temperatures in residential geothermal wells and principal mapped faults in the Moana geothermal area, Washoe County, Nevada: T19N, R19E, MDB&M.**

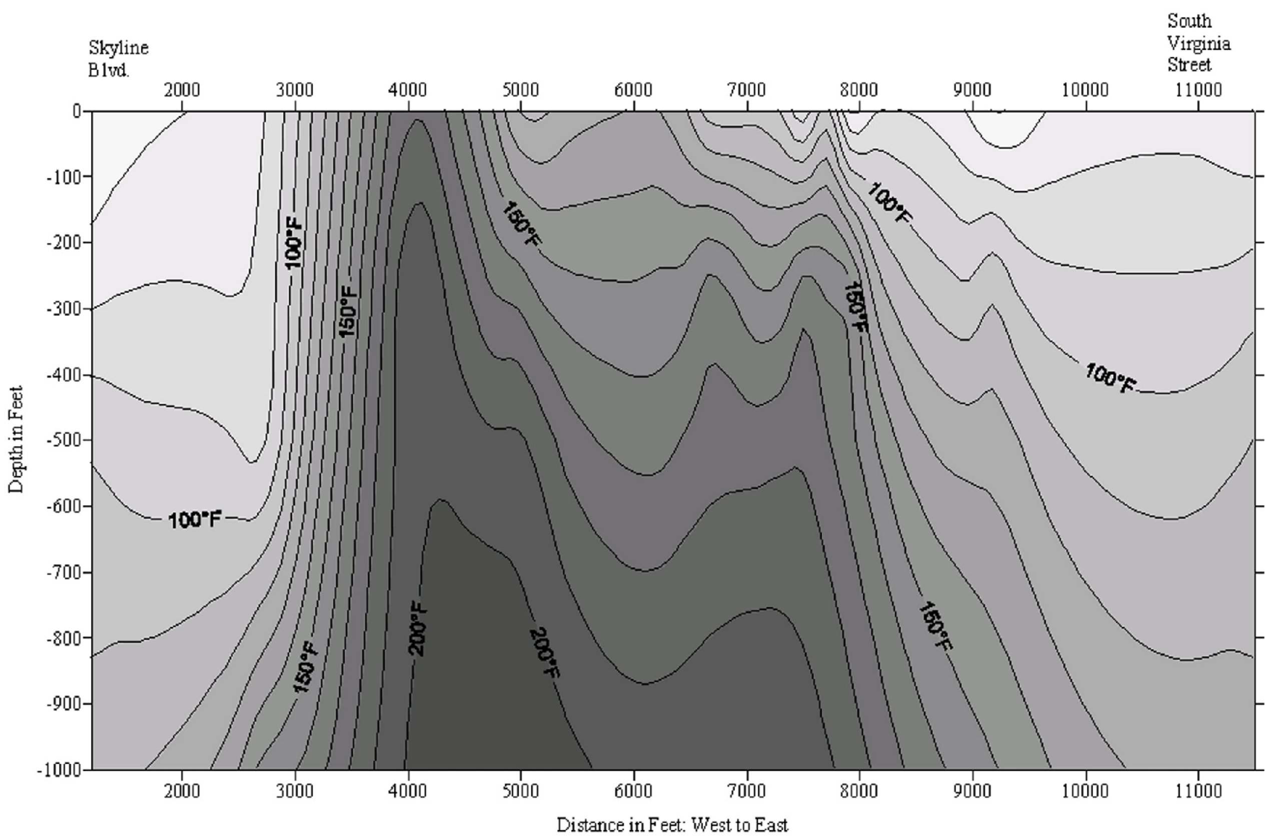

Figure 4. Temperature-depth model across the south end of the Moana geothermal field.

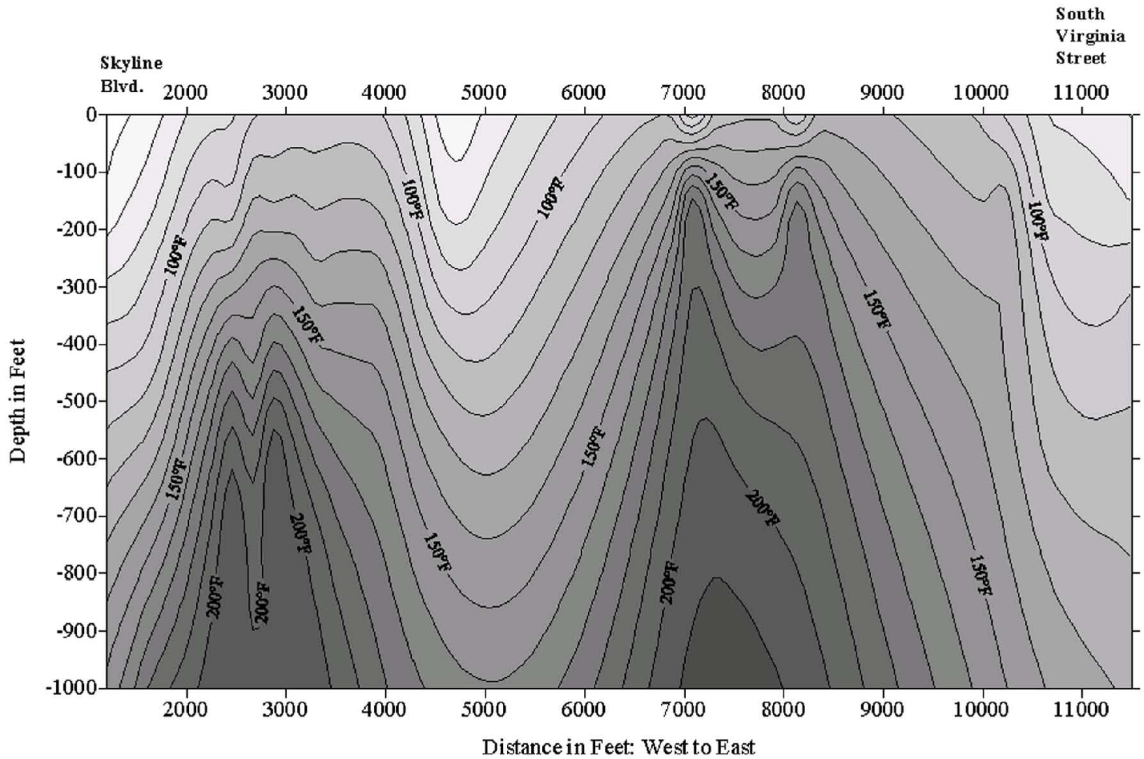

Figure 5. Temperature-depth model through the center of the Moana geothermal field.

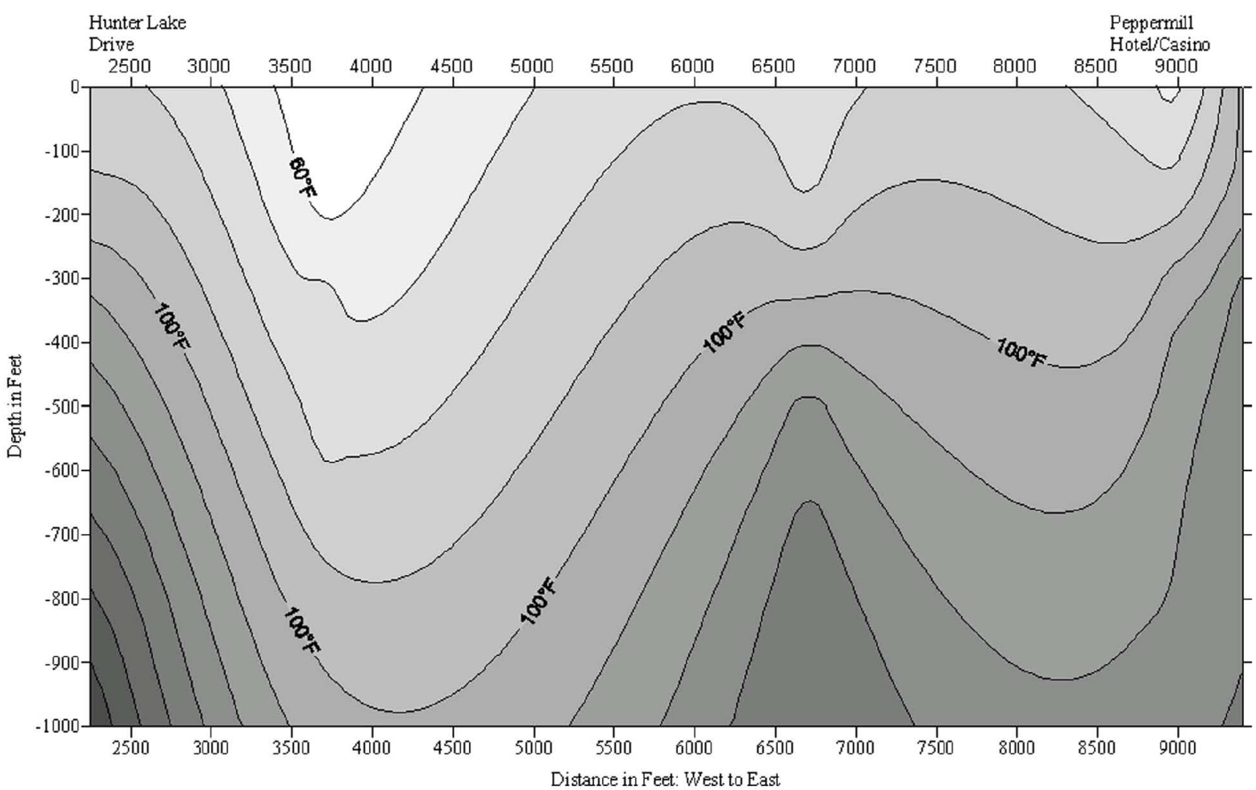

Figure 6. Temperature-depth model across the north end of the Moana geothermal field.

of sections 27 and 26. Two general observations can be made. The first is that the overall thermal anomaly appears as an abrupt, near vertical intrusion, on both the west and east, with the highest temperatures on the west. The second is that the thermal anomaly is bimodal, possibly indicating that the controlling faults have independent structural control over the thermal fluid dispersion in the near subsurface.

Figure 5 slices through the northern edge of sections 27, 26 and 25. This diagram suggests that the two nodes themselves may be bimodal, but that may also be explained by the distribution of data points and the extrapolation limits of the contouring program. The diagram does indicate that the two thermal nodes are now spatially separated by near one mile, and that the western node has began to "submerge" while the eastern node has begun to "emerge." The diagram shows the nearly vertically thermal contours, continuing to suggest a mechanism of forced convection along selected faults.

The final slice (Figure 6) cuts through the center of sections 22, 23 and 24, and shows that the thermal anomaly is deeper and more diffuse. Usable temperatures (120°F+) exceed 500 feet in places, which is the approximate economic limit for development. In addition to lower temperatures, well productivity is extremely variable due to the abundance of clay in the overlying sedimentary rocks.

LIMITS OF INTERPRETATION

Because this study relies largely on existing data points that have an intrinsic bias, it is important to acknowledge that there are limits to the interpretation. These data are not, in the strictest sense, statistically representative, because they are the result of the personal preferences and budgets of the resident population. The study is a pragmatic evaluation of the resource.

The plan view map (Figure 3) covers all or parts of sections 22 through 27, and is based on data from more than 200 geothermal wells. The contours plot the maximum measured temperatures at any depth in the well. This is a somewhat different approach from contour maps that plot temperatures at a specific elevation or those that plot and contour specific temperatures at various elevations.

Typically, temperature-depth profiles (temperature logs) in Moana are completed in wells during drilling, shortly after completion, or both. Temperature measurements typically begin at the top of the static water level, which may be in excess of 100 feet from the ground level. In some wells, especially those in close proximity to faults and fractures, natural forced convection results in very high well bore temperatures beginning at the static water level. Figure 7 illustrates two different wells in the Moana area: one profile

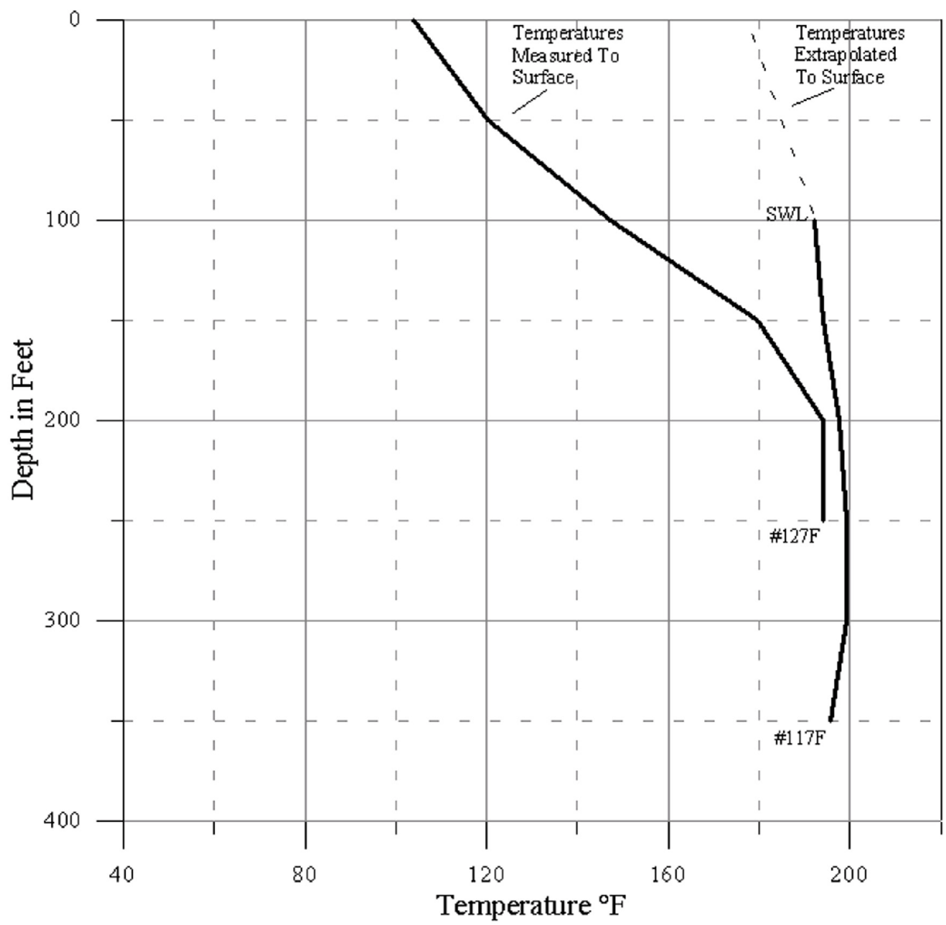

Figure 7. ***Temperature logs from two geothermal wells showing the results of measuring to the surface (#127F) versus extrapolating to the surface (#117F) if measurements begin at static water level (SWL).***

was measured from the surface to total depth, the other profile begins at a depth of 100 feet. In the absence of measured temperatures above the static water level, the program artificially extrapolates temperatures to the surface. As a result, it appears that a temperature of 175°F occurs at the surface in Figure 4; when in fact, there are no such measurements at the surface.

CONCLUSIONS

Direct-use geothermal development (well drilling) in the Moana area peaked in the early-to-mid 1980s. Seventy percent (70%) of the geothermal wells in this database were drilled between 1980 and 1985. Data from those wells and others were compiled and used to prepare a series of digital maps and cross-sections that delineate the areal extent of the thermal anomaly.

The data show that the Moana geothermal area is structurally-controlled by at least two near-vertical faults: one trends northwest, the other trends north-northeast. Residential wells are concentrated in the vicinity of these faults. Since 1995, well drilling has all but stopped due to depressed costs of natural gas and the added expenses associated with drilling and completing both a production and injection geothermal well. There has been renewed interest in geothermal direct use with the recent rise in the cost of natural gas. However, as Figure 2 illustrates, energy cost increases and/or global energy predicaments have a limited impact on residential development. A renewal of the federal residential energy tax credit program, for a portion of the private investment, is much more likely to promote new geothermal development.

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WELL PUMPS AND PIPING

Kevin Rafferty
Geo-Heat Center

Well pumps for larger geothermal applications are normally of the lineshaft, vertical turbine type with the electric motor located on the surface. This type of pump with oil lubrication and adequate allowance for thermal expansion has proven to be a reliable design. Unfortunately, it is not an economical selection for small residential and commercial applications. In fact, there really is no completely satisfactory solution to small flow rate, hot water well pumping applications. The two most commonly used options are conventional electric submersible pumps and jet pumps.

SUBMERSIBLE PUMPS

In the case of conventional submersibles, most manufacturers warrantee their submersible motors for continuous operation in water equal to or less than 86°F. To operate standard motors in water temperatures in excess of this value, a combination of strategies can be used. This involves assuring a minimum flow rate past the motor for cooling and possibly increasing the motor size. A major manufacturer (Franklin, 1999) of submersible motors recommends the following procedure:

> "A minimum water velocity past the motor of 3 ft/sec is required for applications in which the water temperature exceeds 86°F. For small applications, using a nominal 4" submersible motor, this would require a minimum flow rate of 15 gpm and the use of nominal 4" well casing or a 4" ID flow inducer sleeve. The sleeve is a sheet metal shroud that fits over the motor and forces the water to flow past the motor before entering the pump intake. Flow inducer sleeves are available from the motor manufacturer as an accessory."

In addition to assuring the minimum flow velocity past the motor is achieved, it may also be necessary, depending upon the water temperature, to increase the size of the motor as well. This is only necessary at water temperatures greater than 122°F for small motors (<5 hp), and water temperatures greater than 113°F for medium size motors (7.5 to 30 hps). Table 1 provides "Temperature Correction Factors" for submersible motors. The values in the table assume that other measures have been taken to assure a minimum velocity of 3 ft/sec past the motor as discussed above.

The required brake horsepower from the pump manufacturers curve is multiplied by the "Temperature Correction Factors" from Table 1. The resulting "corrected horsepower" is then used to select a motor with a "Service Factor Horsepower" of equal or greater value from Table 2.

Table 1. Temperature Correction Factor (Franklin, 1999)

Max. Water Temp.	<5 HP	7.5 to 30 HP
140	1.25	1.62
131	1.11	1.32
122	1.00	1.14
113 and below	1.00	1.00

Table 2. Service Factor Horsepower (Franklin, 1999)

Nominal HP	Service Factor HP
1/3	0.58
½	0.80
3/4	1.12
1	1.40
1 ½	1.95
2	2.50
3	3.45
5	5.75
7 ½	8.65
10	11.50
15	17.25
20	23.00

Example: Select a motor for an application in which the water temperature is 137°F and a break horsepower requirement of 2.1 hp. In a normal cold-water application, we might choose a nominal 2-hp motor for this duty. Based on the water temperature, however, a "Temperature Correction Factor" of 1.25 is selected from Table 1. Multiplying the correction factor by the required BHP results in a corrected horsepower of 2.63 hp. From Table 2, we would select a nominal 3-hp motor for this application. Since it is the smallest motor with a service factor horsepower higher than the 2.63 required.

This procedure can be used for applications up to a temperature of 140°F. As an alternative, or for water temperatures up to 167°F, a motor specifically designed for operation at higher water temperatures must be used. These motors are available from at least one manufacturer in sizes of 2 through 10 hp in 3-phase and 2-, 3- and 5-hp single phase. No special shrouding or sizing considerations apply. Since these motors are designed for oil field duty and are low-production products, a significant cost premium applies.

JET PUMPS

An alternative to submersible pumps is the jet pump. This is a type of well pump in which both the pump and electric motor are located aboveground and thus, special consideration related to submersible motors are eliminated. This type of pump recirculates a flow of water between the surface and a "jet" located below the water surface in the well. The configuration of the "jet" (more accurately a venturi) causes the recirculating water to draw in water from the well and deliver it to the surface. These pumps are less efficient than submersible pumps and for a given horsepower may produce only 20 to 30% of the flow as submersibles. Based on data available in the Geo-Heat Center, most jet pump systems have a maximum allowable water temperature of 140°F; though, we are aware of systems in which they have been successful at temperatures up to 180°F. These temperatures appear to be more related to the pump than to the downhole components (piping and jet). Jet pumps are limited to 1-1/2 hp and flow rates of approximately 10 gpm at a depth to water of 50 ft.

PRESSURE TANKS

Pressure tanks can be used to deliver hot water to a small heating system just as they are used for delivering cold water to the home. Older, air cushion-type tanks, in which the air is directly exposed to the geothermal water are not recommended. This type of tank allows the water to absorb oxygen from the air and greatly accelerates the corrosion of any iron and/or steel components downstream. Pressure tanks used for hot water applications should be of the "diaphragm" type. Most tanks equipped with a butyl rubber diaphragm have a maximum water temperature rating of 160°F. Some larger tanks are rated for as high as 200°F water. Be sure to verify that the tank you are using is rated for operation at a water temperature equal to or greater than the well water temperature.

PIPING

Pipe Sizing

The size of pipe necessary for a particular flow rate is determined by the pressure drop which is considered acceptable by the designer. Some general guidelines have been developed in the past for this purpose. Basically, the decision is based upon a balance between the pumping costs over the life of the line (to overcome the pressure loss) compared to the first cost of the pipe. Larger pipe costs more to buy, but results in lower pressure drop (and pumping cost) for a given flow rate. Based on maximum pressure loss rate of 4 ft per 100 ft of pipe recommended by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) in their energy consumption standard 90, the following maximum flow rates for various pipe sizes would apply:

Table 3. Recommended Maximum Flow Rates

Nominal Pipe Size (inches)	Maximum Flow Rate (gpm)
½	2
3/4	4
1	8
1 1/4	12
1 ½	22
2	40
2 ½	70
3	120
4	260
6	550

Plastic Pipe for Hot Water Applications

Both steel and copper pipe should be used with caution in direct-buried installations carrying geothermal water. Steel pipe is susceptible to both interior (from the geothermal water) and external (from soil moisture) corrosion. Of these, past experience has proven that the exterior corrosion is by far the most serious. Uninsulated steel pipe carrying hot water appears to have a useful service life of approximately 7 to 10 years. Copper pipe suffers less from exterior corrosion than steel, but is more susceptible to interior corrosion from the geothermal fluid. Most geothermal fluids contain some hydrogen sulphide, the compound that gives the water a rotten egg smell. Hydrogen sulphide is very aggressive toward copper. In addition, some geothermal fluids can rapidly (3 to 4 years) deteriorate the solder used to join the copper pipe. For these reasons, these otherwise standard materials have seen little use in geothermal applications, unless a heat exchanger is used to isolate the geothermal fluid.

Piping, to deliver hot water from the well to the pressure tank or to the point of use, can be of a variety of materials. Plastic materials are often used to eliminate the danger of corrosion, both internal and external. The most commonly available plastic piping materials are PVC and CPVC. In both cases, it is necessary to evaluate the suitability of the pipe in terms of both temperature and pressure. Thermoplastic piping is characterized by a diminished ability to handle pressure at elevated temperatures. PVC pipe has a maximum service water temperature of 140°F and CPVC a maximum service temperature of 180°F. In both cases, the pressure rating of the pipe is greatly reduced at these temperatures. Table 4 provides pressure rating adjustment factors for PVC and CPVC piping at various water temperatures.

Table 4. PVC and CPVC Pressure Rating Correction Factors (NIBCO, undated)

Temperature	PVC	CPVC
70	1.0	1.0
80	0.9	0.96
90	0.75	0.92
100	0.52	0.85
110	0.50	0.77
120	0.40	0.70
130	0.30	0.62
140	0.22	0.55
150	NR	0.47
160	NR	0.40
170	NR	0.32
180	NR	0.25

Example: Calculate the maximum operating pressure for 2-in. PVC pipe at a temperature of 130°F.

Table 5 presents pressure ratings for both PVC and CPVC pipe at 73°F. To arrive at the maximum operating pressure for any other temperature, multiply the temperature correction factor from Table 4 times the 73°F pressure rating in Table 5.

From Table 5, the pressure rating at 73°F is 280 psi. At 130°F, a de-rating factor of 0.30 applies. This results in a maximum operating pressure for this application of 0.30 x 280 = 84 psi.

Table 5. Maximum Operating Pressure in PSI (NIBCO, undated)

Nominal Size	
½	600
3/4	480
1	450
1 1/4	370
1 ½	330
2	280
2 ½	300
3	260
4	220
6	180

The question of heat loss from buried piping is a frequent concern of small system owners. Whether or not the piping will lose enough heat to significantly reduce the temperature of the water at the other end of the line is worth some evaluation. Heat Loss from buried piping is influenced by the soil thermal conductivity, pipe material, water temperature and burial depth among other parameters. Figure 1 presents heat loss information for plastic (PVC and CPVC) pipe at a 3-ft burial depth for two different soil types and three different pipe sizes. The highest heat losses are experienced

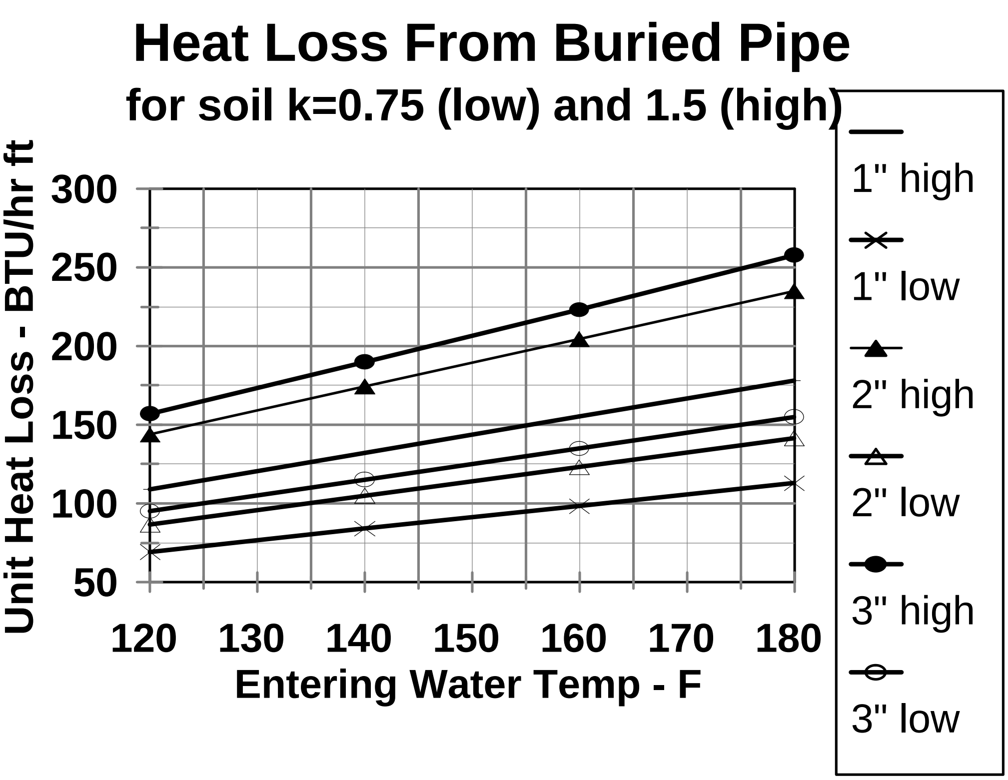

Figure 1. Heat loss from buried pipe (soil k - 0.75 (low) and 1.5 (high)).

in heavy damp soil, indicated as "high" (1.5 Btu/hr·ft) in the figure. Dry, light soil indicated as "low" (0.75 Btu/hr·ft) in the figure retards heat losses. Most soils will fall somewhere between these two. The descriptors high and low refer to the thermal conductivity (Figure 1) of the soil usually expressed in Btu/hr·ft°F. The figure provides heat loss in Btu/hr per linear ft. In order to determine the temperature loss in a line, it is necessary to know the length and the quantity of water flowing (gpm) in the line. The greater the flow rate, the lower the temperature change for a given situation.

Example: Calculate the heat loss and temperature drop for a 2-in. line, 250 ft long which is carrying 10 gpm of 150°F water. Assume worst case conditions for the soil.

From Figure 1, the heat loss per foot is approximately 1750 Btu/hr per linear foot using the curve for high heat loss (high soil thermal conductivity). The total heat loss for the line would be 175 Btu/hr x 250 ft = 43,750 Btu/hr.

The temperature drop in the line can be calculated by dividing the total heat loss by 500 x gpm; where, the gpm is the flow in the line, in this case 10 gpm. As a result, the temperature loss would be: 43,750 Btu/hr/(500 x 10) = 8.75°F.

For lines of a few hundred feet in length, the temperature loss is almost directly proportional to the water flow. For the above example, the temperature drop at 20 gpm would be approximately 4.4°F and at 2 gpm would be approximately 44°F. As a result, one method of controlling the temperature loss in a line is to maintain a flow that results in an acceptable temperature at the end of the line.

The above examples and discussion are based on what is referred to as the "steady-state" heat loss from a buried pipe line. This means that the line has been carrying the flow of hot water long enough that the surrounding soil has been heated up to an "equilibrium" condition. At initial start up, the temperature loss would be much greater than the values indicated since a great deal of heat would be required to raise all the soil around the line from it's undisturbed temperature to a value closer to the pipe temperature. This issue can also have implications as far as the way the line is operated. If a line is to carry only intermittent flow or if it is to carry widely varying flow, it is important to make the heat loss and temperature drop calculations at the worst case condition. For intermittent flow applications, it is sometimes useful to maintain a small, constant flow to stabilize the line temperature and avoid wide temperature fluctuations.

The obvious way to minimize heat loss from a buried line is to insulate the pipe or at least increase the thermal resistance between the pipe wall and the soil. Several methods are available to accomplish this task. The most common is pipe insulation of some type. In larger applications with long pipelines, pre-insulated pipe is often employed. This is a product that consists of a carrier pipe (through which the water flows), a layer of urethane foam insulation and a jacket to protect the insulation from soil moisture. The cost of pre-insulated pipe in the two inch size is on the order of $10 per foot higher than bare pipe material in the same size. As a result, small project developers are often interested in identifying other options to reduce heat loss from buried lines. One of the least costly approaches is to bed the pipe in a dry,

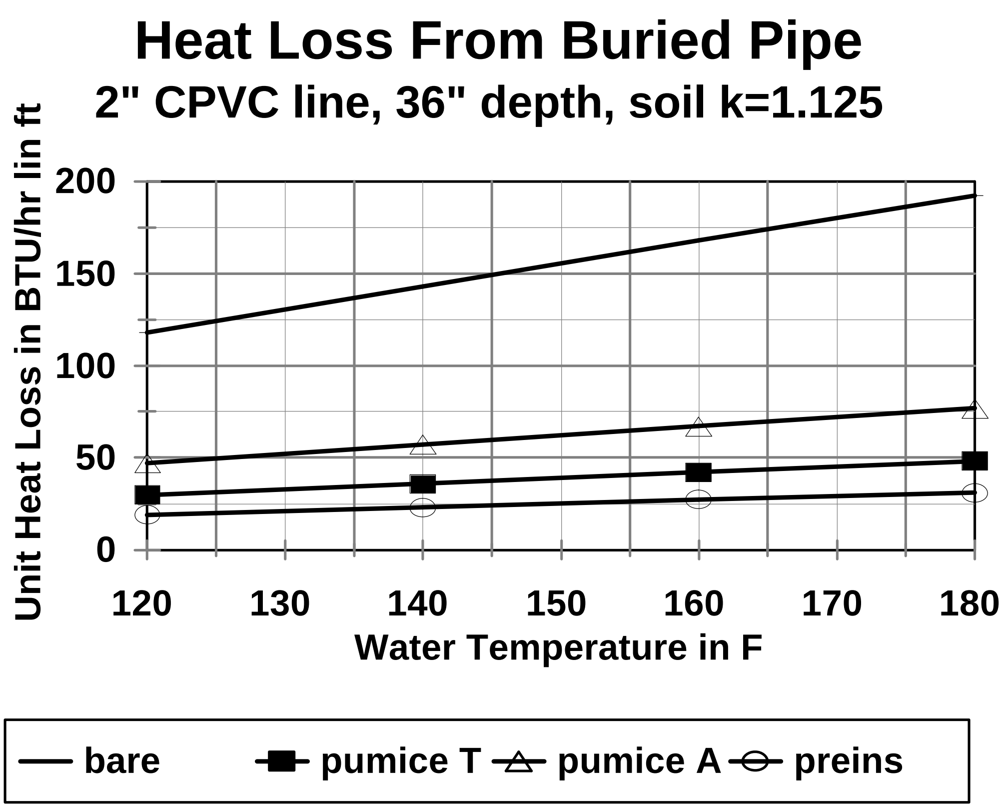

Figure 2. Heat los from buried pipe (2-in. CPVC line, 36 in. depth, soil k =1.125).

low thermal conductivity material that readily drains away any water from the pipe. A common material fitting this description is pumice. The thermal conductivity of dry pumice is approximately 0.085 Btu/hr·ft°F or about 10% that of most soils. This value is approximately 3 to 4 times that of commonly used pipe insulation materials.

The pumice is installed in the pipe zone in such a way that the pipe is surrounded by several inches of pumice on all sides. Figure 2 indicates the effectiveness of the pumice approach relative to an uninsulated line, and a pre-insulated line with 1inch of polyurethane insulation. In theory, the pumice (pumice T) will approach the performance of the pre-insulated line. In actual installations, however, experience has shown that the conductivity of the pumice is degraded by moisture in the soil. The actual performance of pumice is reflected in the curve labeled "pumice A." This constitutes approximately a 60% reduction in heat loss compared to the uninsulated line using a 6-in. thick layer of pumice around the line. At $10 per yard for the pumice and using a trench 12 in. wide, sheeting should be placed over the top of the pumice to protect it from vertical percolation of water in the soil. To prevent soil invasion of the pumice (which would raise its conductivity), a filter cloth can be used to line the ditch.

The black polyethylene pipe insulation available in tubular form at many home improvement stores is not intended for below grade installation. Though it is suitable for use in pipe temperatures up to 180ºF in many cases, it's performance under buried conditions is not known. Under no circumstances should it be installed on steel pipe in direct-buried applications. This type of insulation can trap moisture next to the pipe and greatly increase exterior corrosion.

HEAT EXCHANGERS IN GEOTHERMAL SYSTEMS

In large geothermal direct-use systems, it is common practice to isolate the geothermal water from the balance of the system using a heat exchanger. The geothermal water passes through one side of the heat exchanger and the heating system water the other side. Thin stainless steel plates separate the two water flows so that there is no actual contact or mixing. Only heat passes through the plates from the geothermal water to the "clean" water. The use of the heat exchanger eliminates the potential for corrosion or scaling in the heating equipment in the building. In large applications where there may be tens of hundreds of individual heating units, the cost of the heat exchanger relative to the value of the equipment it protects is favorable. For very small systems, such as those addressed in this document, it is normally more economical to use the geothermal water directly in the heating equipment and accept a shorter service life for the heating units.

An exception to this is in the heating of domestic hot water. A small version of the plate heat exchanger called a brazed-plate heat exchanger (BPHX) serves well in this application. It's performance does not reach the level of the larger plate exchangers and it cannot be disassemble to be cleaned, but it is cost effective for small domestic water heating applications. Rather than being held together with the heavy end plates, large bolts and gaskets of plate-and-frame heat exchangers, the heat transfer plates in BPHXs, as the name implies, are brazed together with copper. The copper is subject to attack by hydrogen sulphide in the geothermal water, but testing has demonstrated (Rafferty, 1990) that service lives of 7 to 12 years in most geothermal fluids can be expected. These are the type of heat exchangers recommended in the domestic hot water heating portion of this document.

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BUILDING SPACE HEATING

Kevin Rafferty
Geo-Heat Center

The most common type of space heating system used in homes in the U.S. is forced air. In most cases, the air is heated by a fossil fuel furnace or heat pump. Adapting an existing system to use geothermal heat or designing a system for new construction is a fairly straight forward process. The system consists of a finned coil, normally located in the supply air duct, a motorized valve to control the water flow in response to a signal from a thermostat, piping to deliver the water to and from the coil, and a few associated plumbing and electrical components.

SELECTING THE HEATING COIL

The heating coil is the heart of the system, and proper selection and installation will assure that air delivered to the space is of acceptable temperature and that the coil is properly integrated into the system. Issues which should be addressed in the process of foil selection include:

Heating load	Water temperature
Air pressure drop	Coil location
Duct work transition	Water flow

The heating load is the quantity of heat that the coil must deliver. This is calculated by the contractor using standard procedures long established for this purpose, the details of which are beyond the scope of this document. The building heat loss calculation provides a load the coil must meet. This value is expressed in Btu/hr and is normally the value associated with the heating requirement of the structure at the "design" outside condition. Depending upon construction and location, new homes may require on the order of 5 to 20 But/hr per square foot of floor space.

Hot water, air heating coils are normally designed for a specific application by an engineer or contractor. They are not simply purchased in convenient xxx Btu/hr sizes. As a result, the process of selecting a coil, even using the simplified procedure below, involves "juggling" several issues at once.

Before getting into the specifics of coil selection, it is necessary to define a few coil terms which you are likely to encounter. Hot water coils are basically a group of copper tubes arranged in rows to which the aluminum fins are attached (Figure 1). The tubes are arranged in rows and the greater the number of rows, the greater the ability of the coil to transfer heat. To a lesser extent, the output of a coil can be increased by adjusting the spacing of the aluminum fins. Fin spacing of 8 fin/inch to 12 fin/inch (FPI) is common in heating coils. A deeper (more rows) coil or closer fin spacing also imposes a greater pressure drop on the air passing through it. This increases the fan power necessary to push the air through the coil.

The velocity of the air passing through the coil is also important. Velocity is determined by dividing the flow (in ft^3/min or cfm) passing through the coil by it's face area in ft^2. Nominal coil velocity is 500 ft/min. Increasing the face velocity will greatly increase the pressure drop and require high fan power. An important consideration here is that duct work is often designed for air velocities of 2 to 3 times that recommended for coils. As a result, it is necessary when installing a coil to increase the size of the duct work near the coil to reduce the velocity to a value appropriate to the coil as illustrated in Figure 2. The selection of a heating coil is an effort to meet the heating load with a coil that minimizes the air-side pressure drop (and fan power), and also conforms to the capabilities. To adequately accommodate the pressure

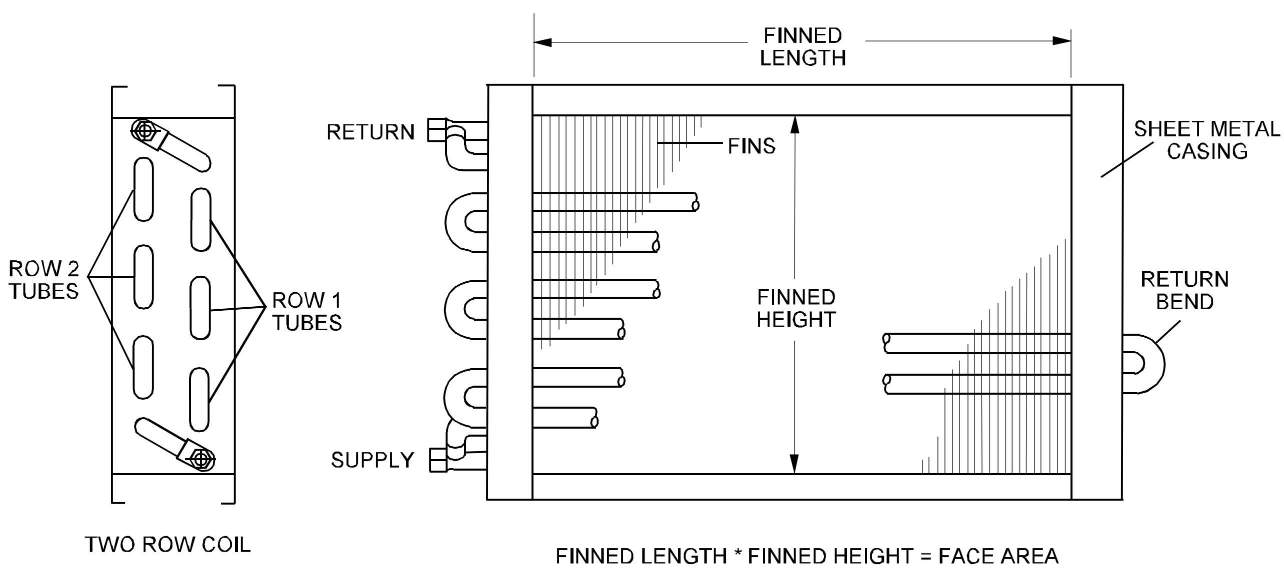

Figure 1.

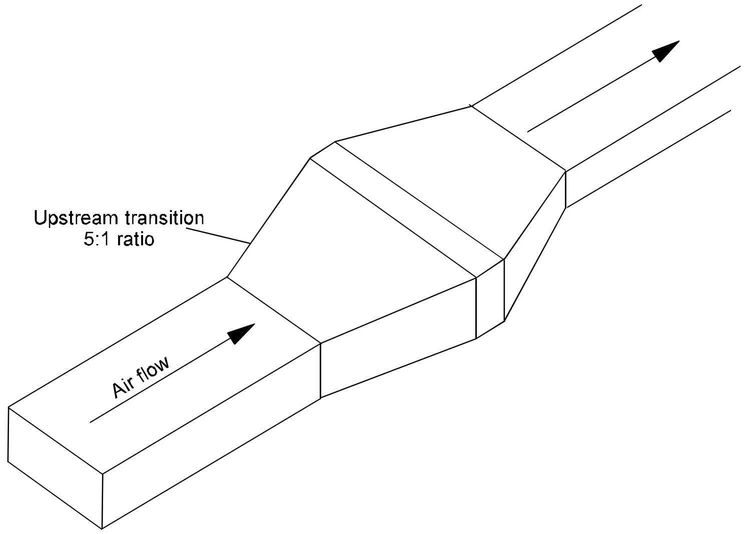

Figure 2.

losses in the duct work and cooling coil (if air conditioning is used), heating coil pressure drop should be limited to 0.25 in. w.g. (inches of water gage) if possible. It may be necessary to reduce face velocity to less than 500 ft/min in 3- and 4-row coils to achieve this loss.

The quantity of heat a coil can deliver is a function of the "face area" and the temperature difference between the water entering the coil (supply water) and the air temperature entering the coil. The face area of the coil is the effective area of th coil exposed to the incoming air stream. Manufacturers often measure this area as the finned height times the finned length. Figure 3 presents the heating capacity of coils in Btu/hr per square foot of face area. As you can see, a 2-row coil provides a substantial increase in capacity over a 1-row coil. The increase in output of a 3-row over a 2-row is much less and the same is true for a 4-row over a 3-row. The required heating load can be divided by the unit output ($Btu/hr \cdot ft^2$) to determine the face area required at a given coil depth. Table 1 presents information on the air side pressure drop for 1- to 4-row coils and correction factors for common fin spacing.

Selecting an air flow for the system can be approached in two ways. For systems where the space will be air conditioned, the air flow is fixed by the AC requirement. Most air conditioning systems operate at flows of between 350 to 450 cfm per ton of capacity. For applications in which AC is not employed, a flow can be selected based on the heating requirements. In this case, the designer has some latitude in the selection. A simple approach is to use the results form Figure 3. The load to be supplied by the coil determines the required coil face area in square feet. Multiplying the nominal face velocity of 500 fpm times the face area required results in the air flow. For example, assume a heating load of 50,000 Btu/hr and a water temperature of 130°F. Using a 2-row coil, this would require a face area of approximately 3.33 ft^2. At 500 fpm and 3.33 ft^2, an air flow of 1667 ft^3/min results. The fan serving this system would have to be capable of supplying approximately 1700 cfm at a pressure drop imposed by the sum of the heating coil, cooling coil (if used) and the duct system (duct, filter, return grilles and supply diffusers).

Table 1. Finned-Coil Air Pressure Drop[1]

Face Velocity Ft/min	ROWS 1	2	3	4
300	0.03	0.05	0.07	0.10
400	0.04	0.08	0.12	0.15
500	0.06	0.11	0.17	0.22
600	0.08	0.15	0.22	0.30

1. Based on dry coil, 8 FPI, 3/8" tubes for 70°F. For other fin spacing, multiply table value by 10 FPI by 1.18, 12 FPI by 1.32 and 14 FPI by 1.55.

Example: A home has a heating load of 42,000 Btu/hr and geothermal water at a temperature of 155°F is available. The home will have a 3-1/2 ton air conditioning system installed. Due to space limitations in the basement, coil height must be limited to 12 inches in height.

From Figure 3, it can be determined that a 1-row, 10 fin/in. coil would require approximately 4.2 ft^2 to meet the load. A 2-row coil would require 2.0 ft^2 to meet the load. The 1-row coil would have to be 50 inches wide to provide 4.2 ft^2 at a height limitation of 12 inches. Generally, it is good practice to limit coil dimensions to a maximum 4:1 length to height ratio. This assures more even flow through the coil and simplifies the fabrication of duct transitions. In this case, the 2-row coil appears to be a better choice (which would require a 24-in. wide coil).

To check the air side pressure drop, it is necessary to calculate the face velocity. Since the home will be air conditioned, this establishes the air flow for the system. Air conditioning systems typically operate at flows of 350 to 450 cfm per ton of capacity. Using a value in the middle of this range would result in a flow for this system of 1400 cfm. Based on the face area of the coil selected (2.0 ft^2), this would result in a face velocity of 1400 ft^3/min/2.0 ft^2 = 700 ft/min. This velocity is outside the recommended range.

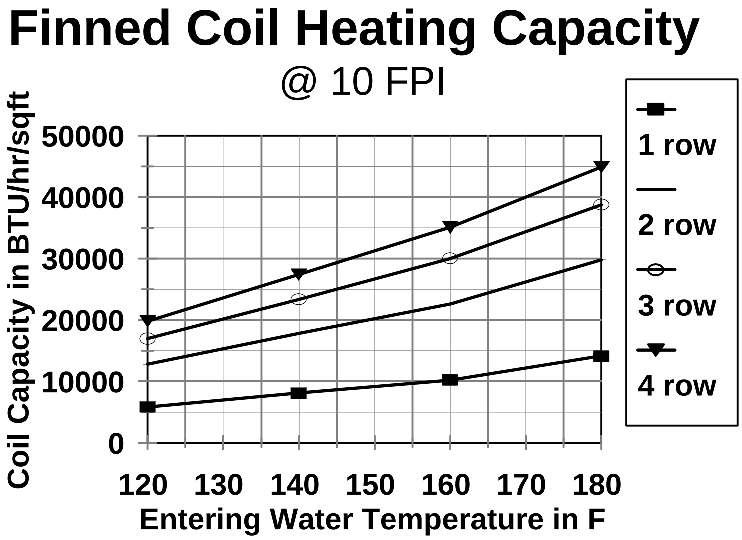

Figure 3.

Returning to Figure 3, we can select a coil with 8 fin/in. spacing. This coil would require 2.35 ft^2 of face area (12" x 28") to meet the load. This would result in a face velocity of 595 fpm, still a little on the high side, but from Table 1, we can see that the air side pressure drop is now a more reasonable 0.15 in. wg. The final coil selection would be 2 row, 8 fin/in., 12" x 28".

A contractor might use a 22" x 10" duct for the main supply air in this case. Since the coil selected is 12 x 28", a transition is required on each side of the coil to increase the duct size to the coil size. The transition on the upstream side of the coil should be gradual as possible. If possible, a 5:1 ratio should be used in the transition. In this case, the largest dimensional change is in the width (22" x 27"). This amounts to 3" on either end of the coil. As a result, the transition on the upstream side of the coil should be at least 5 x 3 = 15" long.

In retrofit applications, it is often difficult to install a coil and conform to the above recommendations for duct work transitions, air side pressure drop and face velocity. In many cases, the coil is installed very near the furnace and there is a choice of installing it in the return air or the supply air. The supply air outlet of most furnaces is relatively small and the air is flowing at a very high velocity (1000 to 2000 fpm). This is too high for a coil installation without a very large duct transition to slow the air. As a result, an installation in the return air is sometimes considered. From an air velocity standpoint, this is attractive since the return duct work is normally much larger than the supply air and thus, better able to accommodate the installation of a coil at reasonable face velocity. Two issues must be considered in a return air coil installation: temperature and mass flow. With the coil in the return air, the temperature of the air entering the furnace is much warmer than the furnace was designed for. The fan motor in the furnace depends on the flow of air around it for cooling. Most fan motors are designed to operate in a maximum ambient temperature of 104°F. Above this, the life of the motor will be reduced and it may be subject to shut down due to excessive internal temperature. As a result, return air coil locations should be limited to coil leaving air temperature of 100°F to 105°F.

In addition to the motor cooling consideration, the higher temperature of the air also reduces it's density. Because fans are a constant volume device, they move the same number of cubic feet of air regardless of its density. This means that the actual mass/pounds of air delivered to the space is reduced when the temperature of the air handled by the fan is increased. Reducing the mass (pounds) of air delivered, reduces the heating capacity of the air. The heating capacity of the system is directly related to the density of the air. A system in which the fan is handling 105°F air will have a capacity 6% less than that of a system in which the fan is handling 70°F air.

Control of a system with a hot water coil supplying the heat is a simple matter. As illustrated in Figure 4, a motorized valve (rated for the expected water temperature) is placed in the series with the coil (it can be placed in the supply or return water line). This valve responds to a call for heat from the thermostat and opens to allow hot water to flow to the coil. Increased comfort can be accomplished by using a valve equipped with an "end switch." On a call for heat, the thermostat causes the motorized valve to open and begin delivering hot water to the coil. When the valve is fully open, the end switch allows the fan to start. By delaying the fan start until water flow to the coil is established, the initial cold draft of unheated air to the space is eliminated.

The heating coil selection graph (Figure 3) was based on a water temperature drop of 35°F. Generally, with water temperatures of 115°F to 180°F, it is possible to achieve 30°F to 40°F temperature drop on the heating water. The higher the temperature drop, the lower the water flow required. At supply water temperatures of less than 115°F, it may be necessary to reduce water temperature drop to 25° or even 20° to achieve a practical coil design. By the same token, it is theoretically possible to achieve larger temperature drops with hotter water. At very large temperature drops, water flow can be reduced to the point that it negatively impacts heat transfer from the coil. As a result, the 30° to 40° range is suggested for most applications.

To calculate the water flow required, the following formula can be used:

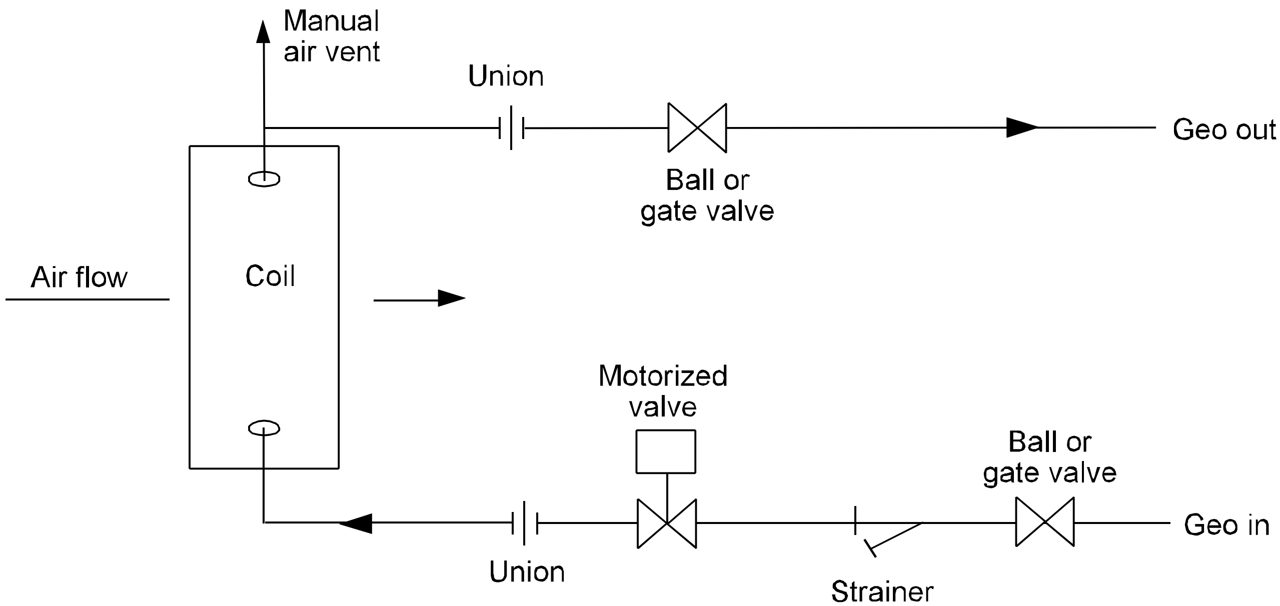

Figure 4.

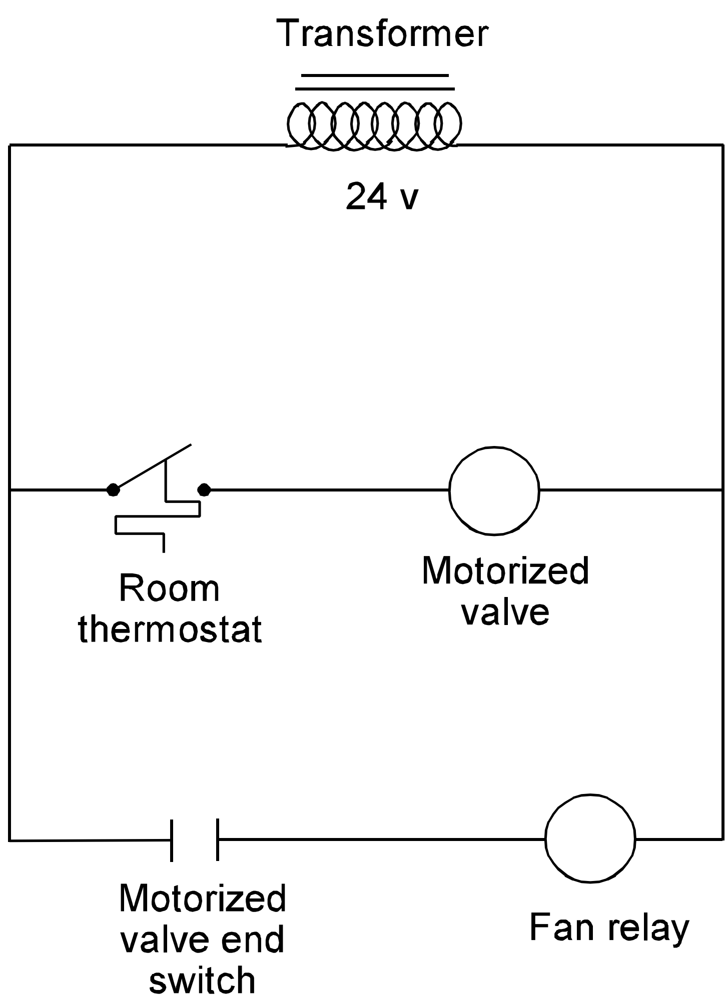

Figure 5.

Water flow rate in gpm = load/(500 x TD)

where:

Load - space heating load to be served by the coil in But/hr
TD - temperature drop on the water side °F

Example: A heating load of 50,000 Btu/hr is to be supplied from a coil. 120°F water is available.

Since the supply water is fairly low temperature, a TD of 30°F will be used.

Flow Required = 50,000/(500 x 30) = 3.33 gpm

Figure 5 presents a generalized diagram for the piping of a hot water coil. The strainer traps debris before it can enter the coil and helps to prevent clogging. Shut off valves at the entrance and exit of the coil facilitate maintenance. Union connections at the coil facilitate removal if necessary. The air vent at the highest point in the piping system is very important. This device allows the removal of air from the system. Air tends to migrate to the highest points in a piping network. If it is not removed, the system can become "air bound" and water flow reduced or completely blocked. Pipe size selection can be based on the criteria in the resource production portion of this publication. It is important to verify that the motorized valve is capable of closing against the pressure supplied by the system.

INSTALLATION NOTES

The air vent should be installed at the highest point in the piping. Automatic air vents are available but are not recommended due to a tendency to leak after a short period of service.

Coil should be piped in such a way as to be self venting–water entering at the bottom and exiting at the top.

Wiring diagram indicates only heating related connections. If air conditioning is to be installed, controls indicated would have to be integrated with cooling. Transformer may be unnecessary if cooling is installed.

Zone valves have limited ability to close against pressure, typically no more than 25 psi difference across the valve. If the system is such that a greater pressure across the valve can occur, a different type of valve must be selected or the system design modified.

An additional ball valve installed on the strainer blow-down connection facilitates screen cleaning.

In large commercial geothermal system installations, coils of the type described for use here are normally protected by the installation of an isolation heat exchanger. The additional cost of the heat exchanger (particularly in the small size necessary for residential systems) and related components (circulating pump, controls, expansion tank, pressure reducing valve, etc.,) are considered uneconomical for small applications. Since hydrogen sulfide is found in most geothermal waters and this chemical is known to attack copper (of which the tubes in the finned coil are constructed), it must be understood that the life of the coil, in many geothermal installations, will be less than in non-geothermal installations and as a result, the installation should be done with consideration of access for replacement.

A 115-v power source is necessary for the transformer. This is normally installed in the furnace (if one is used) or the air handling unit.

A control schematic for this arrangement appears in Figure 5.

MAJOR COMPONENTS AND FITTINGS

1. Hot water heating coil. ___ inches finned height x ___ inches finned length, ___ row, ____ fins/inch, with no more than ____ in wg pressure drop on the air side. To heat ____ cfm from ____°F to ____°F. Copper tubes, 5/8" OD, arranged in a counterflow configuration with respect to the air flow. Specific values determined by application. Cost varies with application,

   eg. 2 row, 18" x 24", 8 fin/in., $550

2. Control valve, motorized zone type, 24v, 3/4" piping connections, end switch equipped. Similar to White Rogers model 13A01-102,

   $170

3. Union, brass, copper, steel or CPVC depending upon the choice for piping, 1" connections, 2 required,

   Galvanized - $5 each

4. Manual air vent, brass construction, 1/8" connection,

   $6

5. Strainer, Y-type, 150 lb, stainless steel 20 mesh screen, 1" screwed connections,

   $30

6. Ball valve, 1", screwed or sweat depending on piping type, 2 required,

   Brass $20 each

7. Transformer, 115 v primary, 24 v secondary, 40 VA,

   $17

8. Fan relay, 24 v coil, contact rating compatible with fan motor required,

   $40.

DOMESTIC HOT WATER HEATING

Kevin Rafferty
Geo-Heat Center

Domestic hot water heating often requires higher temperature water than space heating does. This is due to the fact that heat is being transferred to a 120ºF or greater sink rather than the 70ºF air in a space heat application. There are several ways to configure a domestic water heating system. The two most common are storage recharge and instantaneous. There is also the possibility of using the geothermal water directly as makeup to the domestic hot water heater if the water chemistry permits.

STORAGE RECHARGE

The storage recharge method is illustrated in Figure 1. A small heat exchanger transfers heat from the geothermal water to the domestic hot water. To accomplish this, water is circulated from the water heater tank to the heat exchanger by a circulating pump. This pump responds to a thermostat positioned to monitor the temperature of the storage tank. On a call for heat, the thermostat enables both the circulating pump and a motorized valve located on the geothermal water line. Depending upon the temperature of the water, it may be advisable to add a tempering valve at the hot water outlet. This valve assures that water delivered to the home does not exceed a preset value (adjustable). This method can only be used when relatively high temperature water (>140ºF) is available. Properly designed, this approach to water heating can provide 100% of the energy requirements.

The following components would be suitable for a residential hot-water heating system with capacity of 50,000 Btu/hr (60 gal/hr recovery @ 100ºF rise). Approximate list prices for the components appear at the end of each description.

INSTALLATION NOTES

As with all construction in the home, acceptable practices vary. Always review the design with your local building inspector to verify approval prior to construction.

This layout (Figure 1) assumes the use of a conventional water heater to provide for emergency backup and storage. All piping between the components described and the water heater should be of 1" copper. Some regulatory jurisdictions may require a small expansion tank in the system.

It is important to carefully verify the connections on the heat exchanger. These devices will perform poorly if the entering/exit connections are reversed. The above arrangement (and pricing) are based on the use of a single-wall heat exchanger. In some jurisdictions, depending upon water chemistry a double-wall heat exchanger may be required. This does not alter the basic design of the system as it appears in Figure 1. The cost of the heat exchanger will be much greater, however. In addition, the storage recharge approach may become impractical at the lower end of the temperature range.

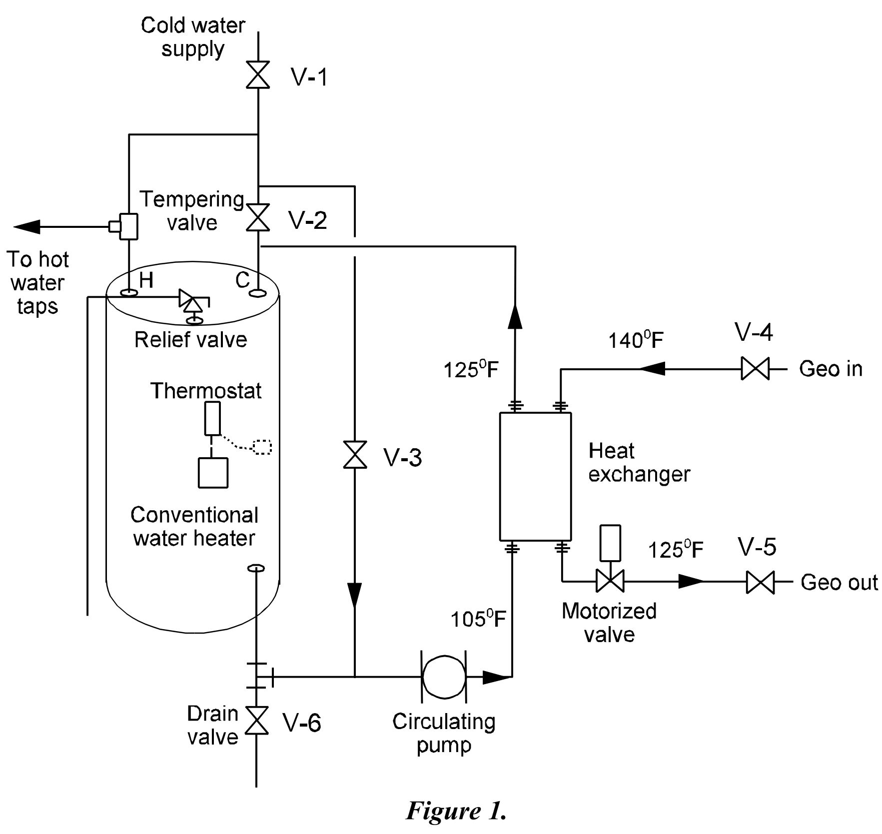

Figure 1.

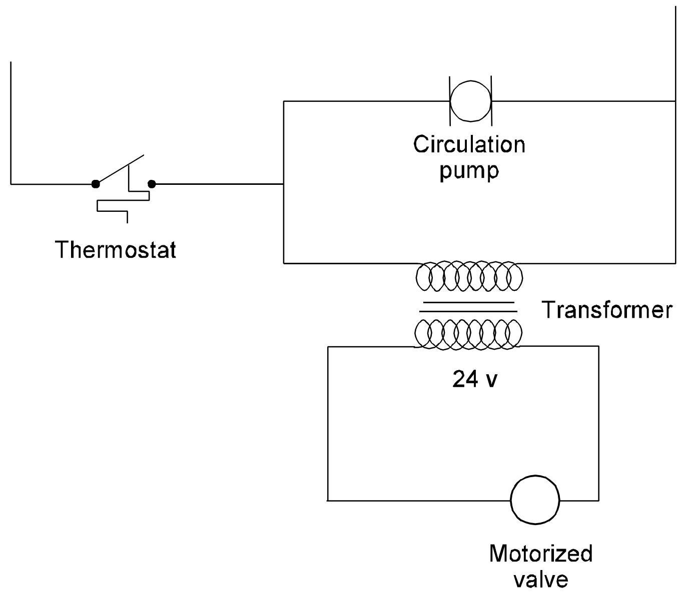

Figure 2.

Zone valves typically are capable of closing against no more than a 25 psi pressure difference across the valve. If the system design is such that a greater pressure difference will occur, a different type of valve should be selected or measures should be taken to reduce the pressure differences across the valve.

Not addressed above is a source of 115-v electricity for the system. Power is required for the circulating pump and the transformer.

The remote bulb of the thermostat must be positioned in such a way that it can sense the temperature of the water in the tank or the tank wall. It can be placed between the tank itself and the insulation if there is access for this. In some cases, on electric water heaters the lower thermostat for the electric element can be disconnected from the water heater circuit and used in place of the remote bulb thermostat. It must be temperature adjustable for this to be practical. In all cases to achieve maximum savings from an arrangement such as this, the thermostat controlling the conventional heating source (electricity, gas, oil, etc.) must be set LOWER than the thermostat controlling the geothermal portion of the system. At least 5 to 10°F lower is advisable. As an alternative, the conventional heating source can simply be disabled (turning off the breaker or shutting off the fuel source).

For normal operation, V-2 and V-6 in Figure 1 are closed. All other valves are in the open position.

Since hydrogen sulfide is found in most geothermal waters and this chemical is known to attack copper (the brazing material for the heat exchangers), it must be understood that the life of the heat exchanger, in many geothermal installations will be less than in non-geothermal installations. Testing of brazed-plate heat exchangers in geothermal fluids has confirmed a time to H_2S induced failure of 7 years in fluids containing approximately 5 ppm H_2S to 12 years in fluids containing 1 ppm H_2S. These values are considered acceptable in view of the low cost of the exchangers.

MAJOR COMPONENTS AND FITTINGS

1. Brazed-plate heat exchanger - designed to heat 5 gpm from ____ °F to ____°F using 3.5 gpm of hot water entering at ____°F and leaving at ____°F. Pressure drop on the cold side not to exceed 3 psi and 3 psi on the hot side,

$300

The temperatures, flows and pressure drops on the hot water (geothermal) side of the heat exchanger depend on the temperature of the geothermal water available at the heat exchanger. Suggested values appear in the following table. Actual values will vary somewhat from manufacturer to manufacturer.

Hot Side		**Cold Side**		**Avg.**
In	**Out**	**In**	**Out**	**Tank Temp.**
140	110	105	125	115
145	115	105	125	115
150	120	110	130	120
155	125	110	130	120
160	130	115	135	125
165	135	115	135	125
170+	140	120	140	130

2. Circulating pump, 5 gpm @ 10 ft, wet rotor, in-line, single-stage circulator pump, 115-vac, 1/25-hp motor. Similar to Grundfos model UP15-18B7,

$220

3. Hydronic zone valve - motorized, 3/4" connections, 24-vac operation. Similar to White-Rogers model 13A02-102,

$170

4. Remote bulb thermostat - 90ºF to 150ºF adjustable set point, differential adjustable 5ºF to 30ºF. SPST switch, close on temperature fall,

$95

5. Relay 24-vac coil, NO contacts rated at a minimum of 10 amps FLA,

$40

6. Tempering valve, brass construction, 3/4" connections, adjustable set point 120ºF tp 160ºF, maximum temperature 180ºF, maximum pressure 150 psi. Similar to Watts #70A-3/4.

$44

7. Ball valve, bronze construction, 1" sweat-type connections, 6 required,

$15 each

8. Union, dielectric-type copper sweat x iron pipe connections, 1" size, 4 required,

$8 each

9. Transformer, 115-v primary/24-v secondary, 40 VA,

$17.

INSTANTANEOUS WATER HEATING

Instantaneous water heating is a strategy that can be used with any water temperature. When higher water temperature is available, this strategy can meet nearly 100% of the water heating needs (only tank standby losses would be met by the conventional fuel source). At lower water temperatures, this method supplies only a portion of the water heating needs with the conventional water heater supplying the balances. The major difference between this approach and the storage recharge above is that this design is based on providing all the heat to the water before it enters the water heater tank. The heat exchanger must have mush greater capacity to accomplish this and as a result, it is more expensive than the heat exchanger used in the storage design. The advantage of this design is that it is simpler in terms of the components required and it can make use of lower temperature water for which the storage recharge method is not practical.

Figure 3 presents a layout of the instantaneous water heating arrangement. Cold water, passes through the heat exchanger on its way to the water heater. When the flow switch senses flow in the line, it signals the hot water control valve to open and supply water to the heat exchanger. A requirement for fast response, the valve used in this application must be a solenoid or other fast opening design. In addition, the heat exchanger should be sized to minimize pressure drop in the hot water line. These valves can be noisy when switching positions and consideration of this should be reflected in the installation location.

INSTALLATION NOTES

As with all construction in the home, acceptable practices vary. Always review the design with your local building inspector to verify approval prior to construction.

This layout assumes the use of a conventional water heater to provide for emergency backup and storage. All piping between the components described and the water heater should be of 1" copper.

It is important to carefully verify the connections on the heat exchanger. These devices will perform poorly if the entering/exit connections are reversed. The above arrangement (and pricing) are based on the use of a single-wall heat exchanger. In some jurisdictions, depending upon

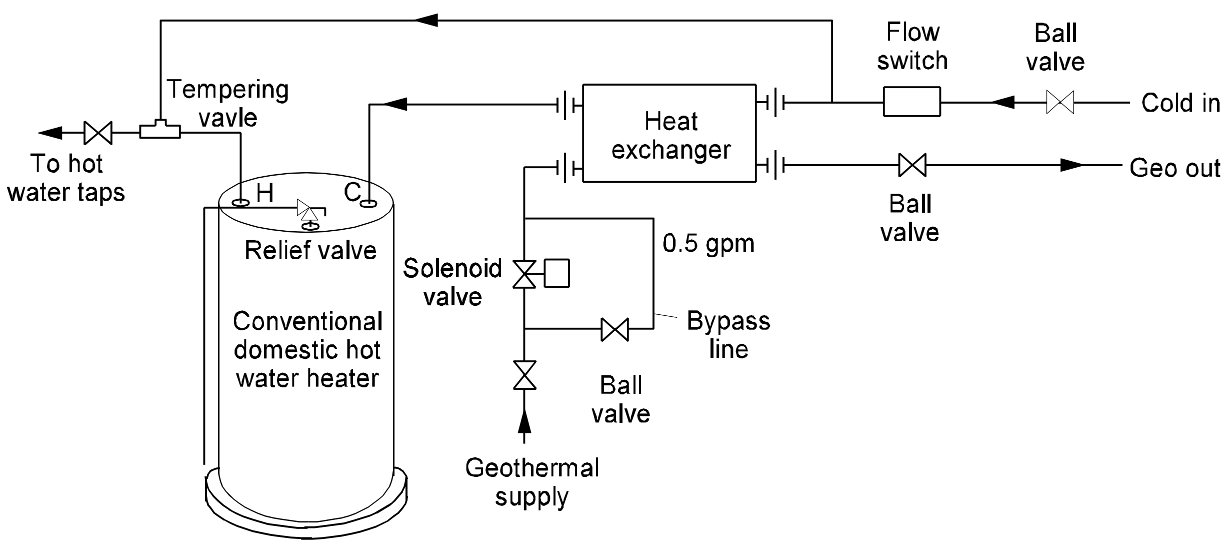

Figure 3.

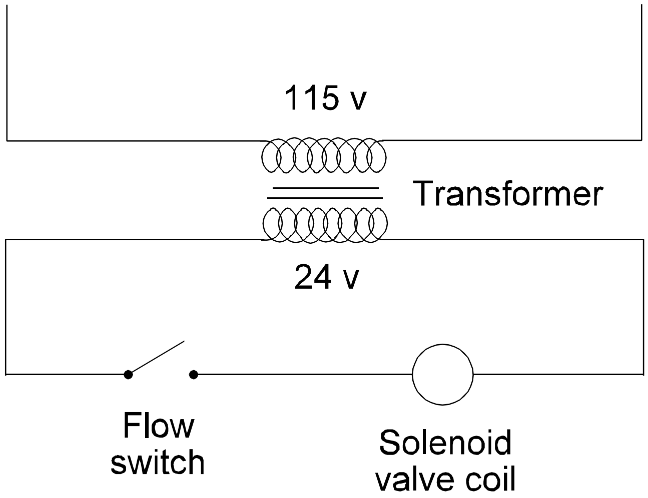

Figure 4.

water chemistry, a double-wall heat exchanger may be required. This does not alter the basic design of the system as it appears in Figure 3. The cost of the heat exchanger will be much greater, however. In addition, the storage recharge approach may become impractical at the lower end of the temperature range.

MAJOR COMPONENTS AND FITTINGS

1. Brazed-plate heat exchanger. To heat 5 gpm from ____°F to ____°F using ____ gpm of water entering at ____°F and leaving at ____°F. Type 304 or 316 stainless steel plates with 99%+ pure copper brazing material. Pressure drop not to exceed 2 psi on the cold side and 7 psi on the hot side.

   The following table lists temperatures and flow rates for brazed-plate heat exchangers sized to provide 5 gpm of heated water at various hot water temperatures. Exit water temperatures on the hot side for these selections varied from 75 to 80°F.

2. Solenoid valve, 3/4" connections, 2-way, brass construction, Buna N seals, 180°F maximum temperature, 24-v coil, 0-100 psi operating pressure differential, normally closed. Similar to Asco #8210G95 valve,

   $78, coil $18

3. Flow switch, mechanical, brass body, 1/2" connections, equipped for replaceable orifices to adjust flow sensitivity, 400 psi, 180°F rated, SPDT switch 15 A @ 125-v. Similar to Omega FSW-30,

   $141

4. Ball valve, 1" bronze construction, 3 required,

   $15 each

5. Tempering valve, brass construction, 3/4" connections, adjustable set point 120°F to 160°F, maximum operating temperature 180°F, maximum operating pressure 150 psi. Similar to Watts model 70A-3/4.

   $45

6. Transformer, 120-v/24-v, 40 VA,

   $20

7. Union, 1", dielectric type, copper sweat x iron pipe connections 1", 4 required,

   $8 each

8. Ball valve, 1/2" bronze construction,

   $11.

Hot Water °F	**Hot Flow gpm**	**Entering Water Cold °F`**	**Leaving Water Cold °F**	**Btu/hr**
100	8.7	55	95	100,000
105	7.9	55	98.5	109,000
110	7.1	55	102	117,000
115	6.6	55	105	125,000
120	6.1	55	108	132,000
125	6.0	55	112	142,000
130	5.6	55	115	149,000
135	5.6	55	120	162,000

SMALL GREENHOUSE HEATING

Kevin Rafferty
Geo-Heat Center

Heating of commercial greenhouses is accomplished with a variety of different systems, the choice of which is usually made by the grower based on the type of plants being grown. For a small "backyard" type greenhouse, among the simplest heating systems is the hot water unit heater. This device consists of a hot water coil with a propeller fan attached. Air distribution is normally through a "poly tube"–a thin clear plastic tube perforated with holes. The tube is normally hung from the ceiling, but can also be installed on the floor. Unit heaters are a practical method of greenhouse heating at supply water temperatures down to approximately 140°F to 150°F. Below this range, heat output is reduced by more than 50% and the cost of larger equipment becomes an obstacle.

GREENHOUSE HEATING REQUIREMENTS

The first step in the process is to determine the heating requirement for the greenhouse. The heating requirement for a greenhouse is a function primarily of the temperature difference between the inside and the outside, the materials of construction. One of the most common small greenhouse structures is a 30-ft wide, Quonset-style covered with a double layer of plastic sheet. The length of the house can be adjusted to accommodate the needs of the grower, but 96 ft is a common length. Assuming a 65°F inside temperature and a 10°F outside temperature, this house would have a heating load of approximately 90 Btu/hr per square foot of floor area. To adjust for other construction, multiply by 1.6 for glass, 1.65 for single plastic and 1.4 for single fiberglass. For other inside or outside temperature differences simply ratio, the heat loss per square foot above by the 55°F used for this example. These values are valid for small greenhouses. As floor area increases, the unit heat loss (Btu/hr·ft^2) decreases due to the lower impact of walls and infiltration of cold outside air.

UNIT HEATER EQUIPMENT

Unit heaters are sold based on heating capacity. This heating capacity, appearing in many greenhouse equipment catalogs, is based on 60°F entering air and assumes that the unit will be supplied with either 2 psi steam or 200°F water. Operation of these units at lower water temperatures, as is the case in most geothermal applications, will result in reduced capacity. As a result, the first step in the selection of the equipment is to adjust the catalog capacity to the conditions present at your site. To do this select, the correction factor from Table 1 that corresponds to the water temperature available to the unit heaters. If the catalog data is based on steam, use the values in the left column. If it is based on hot water, use the values from the right column.

To determine the heating capacity of a unit heater, multiply the capacity shown in the catalog by the appropriate factor from the table below. For example, if 155°F water is available to the unit heater and the catalog is based upon 2 psi steam, the correction factor would be 0.62 (between 150 and 160°F), the capacity of a unit heater rated at 121,000 Btu/hr would actually be 0.62 x 121,000 = 75,020 Btu/hr at the supply water temperature available.

Table 1. Unit Heater Temperature Correction Factors

Water Temp °F	Correction 2 psi Steam	Correction 200°F Water
110	0.32	0.36
120	0.39	0.43
130	0.45	0.50
140	0.52	0.57
150	0.58	0.64
160	0.65	0.71
170	0.71	0.79
180	0.77	0.86
190	0.84	0.93
200	0.90	1.00

For small greenhouses, equipment selection is simply a matter of determining whether the heating requirement of the structure can be met by a single unit or whether more than one will be necessary. For the example 30 x 96' greenhouse, with a heating load of 260,000 Btu/hr and an available water temperature of 160°F, the selection would be as follows:

Table 2. Manufacturers Catalog Data

2 psi Steam Capacity	Corrected Capacity (160°F)	Fan hp	List Price $
18,000	12,800	1/60	300
33,000	23,400	1/25	400
47,000	33,400	1/12	525
63,000	44,700	1/12	565
86,000	61,100	1/8	740
121,000	85,900	1/6	820
165,000	117,000	1/3	900
193,000	137,000	1/3	1,200
290,000	206,000	½	1,500

Since the heat loss of the structure is greater than the largest unit, this application will obviously require more than one unit. In this case, two of the units with a corrected capacity of 137,000 Btu/hr would together have a capacity of 274,000 Btu/hr, slightly more than the required load of 260,000 Btu/hr.

The heating capacity of this equipment is also influenced by water flow rate. Manufacturers ratings are normally based upon a temperature drop (entering water temperature - leaving water temperature) of 20ºF. Using a larger temperature drop (lower water flow rate) will reduce the output of the unit since the average water temperature is lower. To correct for other than a 20ºF drop, multiply the temperature corrected capacity by 0.93 for a 25ºF drop, 0.87 for a 30ºF drop and 0.72 for a 40ºF drop.

INSTALLATION OF UNIT HEATERS

The standard installation of unit heaters consists of hanging the unit at one end of the structure and discharging the supply air toward the opposite end. In longer houses (>125 ft), it is advisable to install units at both ends to assure even heat distribution. For the example house, the two units could be installed at one end. Figure 1 provides a diagram of a typical installation.

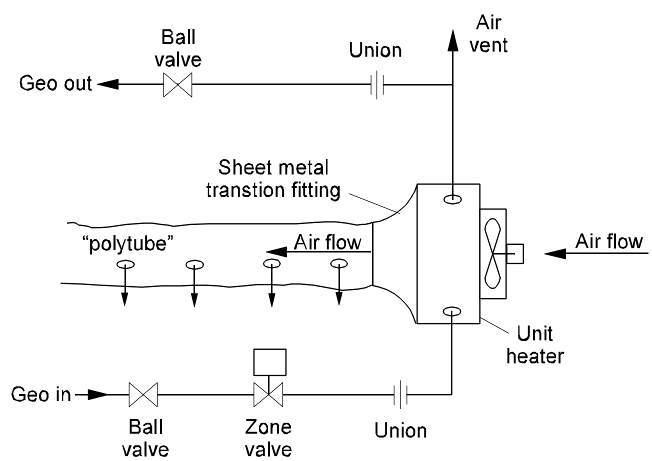

Figure 1.

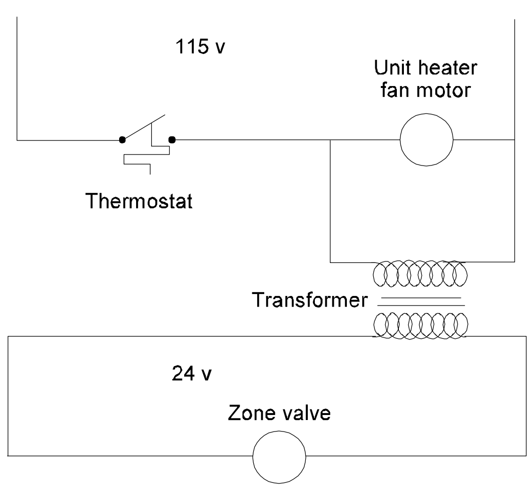

Figure 2.

MAJOR COMPONENTS AND FITTINGS

1. Unit heater(s): hot water, horizontal type, propeller fan, 115-v motor, copper water coil suitable for operation at 150 psi/350ºF. Size and number as required. See Table 2 for approximate pricing. Similar to Dayton 1H200 series or Modine HS model.

2. Motorized zone valve, 3/4" connections, 24-v coil, see note regarding closing against pressure in the space heating components list,

   $170

3. Air distribution poly tube - clear plastic, minimum 3 mil thickness, 18" diameter for air flows to 3000 cfm, 24" diameter for greater flows, 3" diameter holes located at 30º from the horizontal (4:00 and 8:00 positions),

   0.30 $/ft

4. Poly tube adapter for unit heater. Attaches poly distribution tube to unit heater. Can be fabricated locally by a sheet metal shop or ordered by a greenhouse supply firm. Dimensions vary with unit heater manufacturer,

   $120

5. Union, copper, steel or CPVC depending upon piping material choice. Size equal to water connections on water heater. 2 required per unit heater.

6. Ball valve, as per description in earlier components list, 2 required per unit heater, size varies with unit capacity,

7. Air vent manual, brass construction, 1/8" connection,

   $6

8. Thermostat, heating only, low voltage, similar to White Rogers model 1E30,

   $46.

TEMPERATURE "BOOSTING"

Kevin Rafferty
Geo-Heat Center

Owners of low-temperature geothermal resources often ask whether it is practical to raise the temperature of geothermal fluid using conventional fuels. For example, if a well produces water at a temperature of 150°F and a nearby industrial process requires hot water at 185°F, is it practical to "boost" the temperature of the geothermal fluid with a boiler to meet the requirements of the use? We have never seen an application in which this strategy was feasible.

The reason is primarily due to the way in which heating systems, space heating or industrial process are operated. Figure 1 presents a simplified diagram of a closed-loop heating system in a building. Hot water is supplied from the boiler at a temperature of 180°F. The water passes through the heating system and is returned to the boiler at a temperature of 160°F. All of the supply water returns to the boiler to be reheated. No cold water, which must be pre-heated, is added to the system. In order for a geothermal resource to contribute to the energy requirements for this system, it must have a temperature greater than 160°F. Anything less than this would require heat to raise the geothermal water to the lowest temperature of the process (160°) plus the energy required by the process itself. Using a geothermal fluid in this way (beginning at a lower temperature than the process minimum and boosting it) would actually result in an increase in conventional energy consumption. The ability to supply energy to the process is complicated by the nature of the controls on some systems. At less than peak load, many systems return water to the boiler at higher temperatures, in a linear relationship to load. For example, at 100% load, the return temperatures is 160°F,at 50% load 170°F, at 25% load 175°F and so on. This complicates the ability for a low temperature resource to contribute to the energy requirement.

In processes where large amounts of cold "make-up" water are added (open system), there is very good potential to use geothermal resources which produce fluids at a temperature less than the minimum of the process. Domestic hot water heating is an excellent example. Consider a domestic hot water system serving a restaurant where the tank is maintained at a temperature of 160°F. A nearby geothermal resource produces 120°F water. Obviously, this is too low to supply any heat to the storage tank of the system, but it is able to preheat the water sufficiently to meet a portion of the heating requirements. In this case, cold water at 55°F, on it's way to the water heater could be raised to approximately 110°F with the geothermal water. The entering cold water can never be heated to the geothermal water temperature (in this case 120°) due to temperature losses which occur in the heat exchanger. The preheating of the cold water could reduce the total energy required for water heating in this case by approximately 48%. Domestic water heating is one of the most favorable examples for the use of geothermal resources less than the process temperature. This is because all of the water entering the system is make up and must be heated. In many processes, make-up requirements are much smaller and savings to be generated correspondingly smaller.

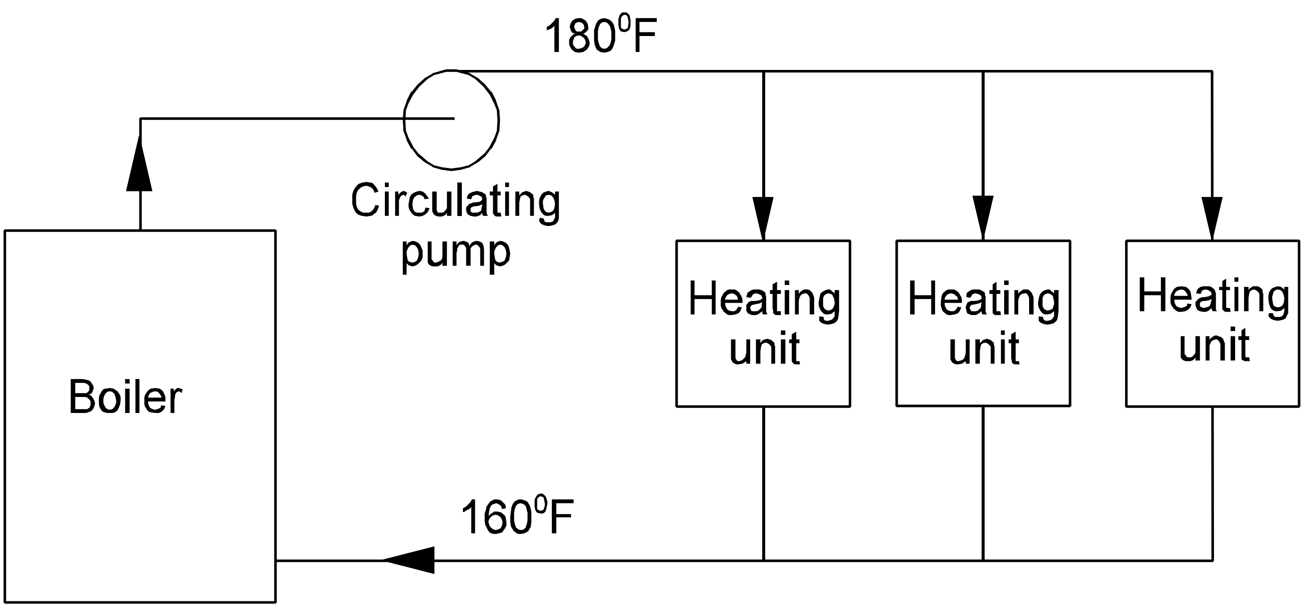

Figure 1.

GEOTHERMAL PIPELINE

Progress and Development Update
Geothermal Progress Monitor

MEETINGS

Elko Nevada One-Day Geothermal Seminar

The Nevada Water Resources Association (NWRA) and the Geo-Heat Center will be co-sponsoring a one-day seminar on geothermal issues in Elko, NV on October 25, 2001. The seminar will include presentations on geothermal resources, regulatory aspects, electric power generation and direct use. A tour of the Elko County School District and Elko Heat Company district heating systems is included along with a panel discussion on the state and federal regulatory issues.

The NWRA is the association for groundwater related professionals in the state of Nevada and as a service to its members and the public, it regularly sponsors seminars around the state on issues of interest in the area of groundwater. The seminar will be held at the Elko Convention Center from 8:00 AM to 5:00 PM on October 25th. The meeting is open to the public for a registration fee of $65 before October 19th and $75 after that date. For more information contact Donna Bloom of NWRA at 775-626-6389 or donna30@sprynet.com, or Kevin Rafferty of the Geo-Heat Center at raffertk@oit.edu or 541-885-1750.

The 23rd New Zealand Geothermal Workshop

The Geothermal Institute and the New Zealand Geothermal Association will host the 23rd NZ Geothermal Workshop at the University of Auckland on 7, 8 and 9 November 2001. The meeting will be forum to exchange information on all aspects of exploration, development and use of geothermal resources worldwide. Contact: Mike Dunstall, Geothermal Institute: Fax. 64-9-373 7436 or email: geo.wshop@auckland.ac.nz.

CALIFORNIA

Middletown - Calpine Corp. Opens Geysers Geothermal Visitor Center

On May 11, Calpine Corp. dedicated its new Geothermal Visitor Center at a Grand Opening ceremony in Middletown, CA. Citizens concerned about the energy crisis can now see first-hand how electricity if made using geothermal steam. The center offers free admission, parking, and tours led by knowledgeable guides in air-conditioned minibuses to one of Calpine's operating geothermal power plants at The Geysers--the world's largest geothermal project.

The newly completed, 6,500-square-foot visitor center uses state-of-the-art energy efficiency technology and geothermal heat pump to heat and cool the building. The heat pump installation, designed by Robert Anderson, Architect, consists of 20 vertical bore holes each 250 feet deep using a closed loop system to operate 5 units in the building for a total of 22 tons (264,000 Btu/hr cooling capacity). The Water Furnace units can be viewed through a glass door in the visitor center. The installation cost about $76,000.

Regular operating hours for the visitor center are 9:00 AM to 4:00 PM Thursday-Monday. Free bus tours are offered at 10:00 AM, 12:00 PM and 2:00 PM. Tour reservations are required. The center is located just north of the famous Napa Valley wine country at the intersection of Highway 29 and Central Park Road in Middletown, just south of Highway 175. For more information, contact the Calpine Geothermal Visitor Center, 15500 Central Park Road, Middletown, Ca 95461. Phone: 866 GEYSERS; website: www.geysers.com.

IDAHO

GEA/GRC Award Honors Geothermal Boise

A highlight of the U.S. Department of Energy Idaho Geothermal Energy Stakeholders Workshop on May 31 was the presentation of a 2001 GEA/GRC Geothermal Excellence Award to the city of Boise, Idaho. Accepting the award from GRC Executive Direct Ted Clutter and Geothermal Energy Association Executive Director Karl Gawell was Boise Public Works Department Director William J. Ancell. Boise provides a showcase of geothermal development, a valuable history of geothermal operating experience, and a clear demonstration of the longevity of a properly managed geothermal resources. The Warm Springs Water District, the country's first geothermal district heating system was established here in 1892. This project was later joined by three additional systems, serving the Veterans Administration complex, downtown Boise and the Capitol Mall. Today, these systems have an installed capacity of 40 MWt and supply 170 billion Btu of heat energy annually. (Source: *GRC Bulletin,* 30/3).

ITALY

IGA Geothermal Calendar 2002

The International Geothermal Association, based on the success of their geothermal 2000 calendar, are soliciting all amateur geothermal photographers to submit photographs for the 2001 calendar. Color photos are preferred and they would appreciate photographs that highlight the inherent beauty of geothermal areas, by showing how environmentally-friendly we are, or the unusual applications of geothermal energy. Photos can be sent by mail or email to IGA Secretariat, c/o Erga Grouppo Enel, 120 Via A. Pisano, 56122 Pisa, Italy or email: igasec@enel.it.

UNITED KINGDOM

Queen's Award Honors District Heating System

On June 5, the Queen's Award for Enterprise for Sustainable Development 2001 was awarded to the district energy heating system in Southampton, England. Marking the occasion, the Queen's Award flag was raised at the Heat Station, which lies at the center of the United Kingdom's most commercially successful and technologically innovative district energy development. According to news sources, "The system takes an element of its energy from a geothermal heat source through a well in the city center that extracts sea water from a mile underground that was trapped there in prehistoric times."

In partnership with Southampton Geothermal Heating Co., Ltd. (a member of the Utilicom Group), the city's "world-class" development was 14 years in the making. It provides hot water (for heating and domestic use) and chilled water (for air conditioning) to commercial and residential consumers, including four hotels, a hospital, colleges, television and radio studios, civic buildings and a major new retail development, WestQuay.

Geothermal heat sources are not widespread in the United Kingdom, being either too small or low in temperature for commercial exploitation. The principal energy component for the Southampton district heating system is waste heat produced by conventional power plants, which are "the cornerstone of the England's sustainability and carbon emission policy." (Source: *GRC Bulletin,* 30/3)