GEOTHERMAL DIRECT-USE
CASE STUDIES

GEOTHERMAL DIRECT-USE
CASE STUDIES

Prepared for

U.S. Department of Energy
National Renewable Energy Laboratories
Golden, CO

Prepared by

Geo-Heat Center
Oregon Institute of Technology
Klamath Falls, OR 97601
http://geoheat.oit.edu
541-885-1750

October 2005

DISCLAIMER

This material was prepared with the support of the U.S. Department of Energy (DOE Subcontract No. TAA-2-31490-01). These case studies were investigated and documented by Kevin Rafferty, Gene Culver, Tonya Boyd and John Lund of the Geo-Heat Center staff. However, any opinions, findings, conclusions or recommendations expressed herein are those of the Geo-Heat Center staff and do not necessarily reflect the view of USDOE.

CONTENTS

CALIFORNIA CORRECTIONAL CENTER
SUSANVILLE, CALIFORNIA

CCC in foreground, Honey Lake Valley and Diamond Mountains to the south.

Location: The California Correctional Center is located in Honey Lake Valley of northeastern California, about seven miles east of Susanville in Lassen County. The facility, operated by the state of California, was converted to geothermal heating in 1983. The facility houses around 5,800 minimum custody inmates, and some 1,100 custodial and support staff are employed at the 1,112-acre site.

Resource: Two wells, approximately 1,400 feet deep, were installed on a tract of land some two miles east of the site by the Carson Energy Group, Inc. of Sacramento (1981 and 1983). The wells are located just south of the Modoc Plateau volcanic region in lacustrine gravels and near-shore deposits of pluvial Lake Lahontan, which is cut by a small west-northwest striking lateral fault. The wells are owned and operated by the city of Susanville, the surface land owner, but a royalty is paid to the subsurface landowner. One well produces 169°F water and the other delivers 162 to 165°F water. In 2001, the casing on the hotter well collapsed and was deemed too costly to repair, and the cooler well has been used since then. Four binary power plants and a small district heating system in the city of Susanville also use geothermal heat in the area (170 to 230°F). The water has about 600 ppm with mainly sulfate, sodium, chloride, and bicarbonate species, and with trace amounts of hydrogen sulfide, boron and arsenic that exceed drinking water standards.

Utilization: Geothermal heat is used for 50 to 80% of the prison's space and domestic water heating, as well as for a medium-sized greenhouse. It is supplemented by the existing diesel-powered system. The geothermal heating is used for inmate dormitories, but generally not for the staff areas. Heat is supplied by a centralized force-air duct system to individual rooms. The estimated peak heating load is 158 therms/hr and the annual load is 434,000 therms for a utilization factor of 0.255 and a peak capacity of 4.65 MWt.

A 75-hp oil-lubricated pump produces about 300 gpm into an underground supply line (asbestos cement and iron piping) to the prison boiler room. After passing through a sand filter, the supply water is routed to one of two plate heat exchangers for space heating and a small heat exchanger for domestic hot water. Incoming water on the closed loop system is about 70^{o}F, and the outgoing water on the domestic loop is heated to about 124^{o}F using a stainless-steel plate heat exchanger. Water going out to the space heating loop is usually heated to 140 to 150^{o}F when needed in the waterline. Three 30-hp pumps produce flows in the space heating loop as needed. After being passed through the heat exchangers, the 140 to 150^{o}F geothermal water is sent to a medium-sized greenhouse about 500 yards to the east. Here a portion of the hot water is diverted and passed through a manifold heating system underneath two lengths of plant trays. This heating is used during cool periods to maintain a fairly constant temperature of 72 to 79^{o}F in the greenhouse.

After the geothermal water passes through the greenhouse, it is returned to the city and distributed to a dispersion area consisting of a 20-acre application area and a 200-acre evaporation pond. The water is sprinkled over the application area to either evaporate or drain into an overflow pond. Some of the water flows directly into a privately-owned pond that supports bass, waterfowl, deer and antelope. Cottonwood trees and other riparian species have established themselves around the perennial pond. The estimate temperature of the water coming into the pond is around 122^{o}F.

Operating Costs: The initial capital cost of the system installed in 1980 is unknown, and has probably been amortized over the past 22 years. The well are estimated to have cost around $180,000. At present, the state of California pays the city of Susanville $17,062 per month on a "take-or-pay" basis, which allows them to use up to 525,000 therms/year. This cost includes the well pump, electricity cost, maintenance and overhead for the city. In addition, the prison Chief Engineer of Plant Operation estimates that slightly less than $1,000 per year is expended for repairing pipe leaks (about one repair per year in the 10"-pipe) and for other routine maintenance work. This then works out to about $0.39/therm. If the measured usage exceeds the 525,000 therms/year, then a charge of $0.39/therm is accessed for the additional amount.

The city of Susanville, which supplies the geothermal water, budgets $150,000 per year for this operation. This includes: $22,500 for personnel, $20,500 royalty to the property owner (amounting to $0.04/therm), $70,500 for services and supplies (which includes $20,000 for utilities), and $36,500 for overhead (accounting, billing, etc.). This amounts to about $0.29/therm. The actual pumping energy use for the year 2001/2002 was 323,200 kWh at a cost of $27,205.

The competing fuel is natural gas, for which the city charges $1.22/therm, diesel at slightly under $1.00gal = $0.70/therm, and electricity at 6.9cents/kWh = $2.02/therm. Thus, the savings to the prison would be slightly over $36,000 per month as compared to natural gas supplied by the city and a saving of about $13,500/month compared to diesel. However, a recently installed state-owned natural gas pipeline in the area may replace many of the area's current geothermal operations, including that of the prison, the price yet to be determined. This may occur when the current contract runs out in 2007.

Environmental Impact: While the system does not have an injection well, the disposal of the geothermal water on the application area and associated ponds appear to have minimal environmental impact. There does not appear to be any corrosion or scaling problems in the system, especially since plate heat exchangers are used to isolate most of the secondary system.

Regulatory Issues: No major problems were encountered with the permitting process. The project required an environmental assessment for Lassen County, a discharge permit from the California Water Quality Control Board, and a well drilling and completion permit from the California Division of Oil, Gas and Geothermal Resources. If built today, the project would also require a wet lands permit.

Problems and Solutions: The only major problems are the replacing of the well pump bearings, bowls or shafts about every three years at a cost $10,000, and breaks in the supply line (about one per year) at a cost of $800/year. These, however, appear to be normal operating costs. They recently upgraded the variable-speed drive on the well pump from fluid coupling to variable frequency, due to the cost of replacement parts for the older system. One well did collapse after 20 years of use and is no longer used.

Conclusion and Recommendations: The system appears to be operating without major problems and is cheaper than current alternative fuel costs. Cheaper gas from a state-owned natural gas pipeline may replace the geothermal heat in 2007; however, the price has not been established at this point.

References:

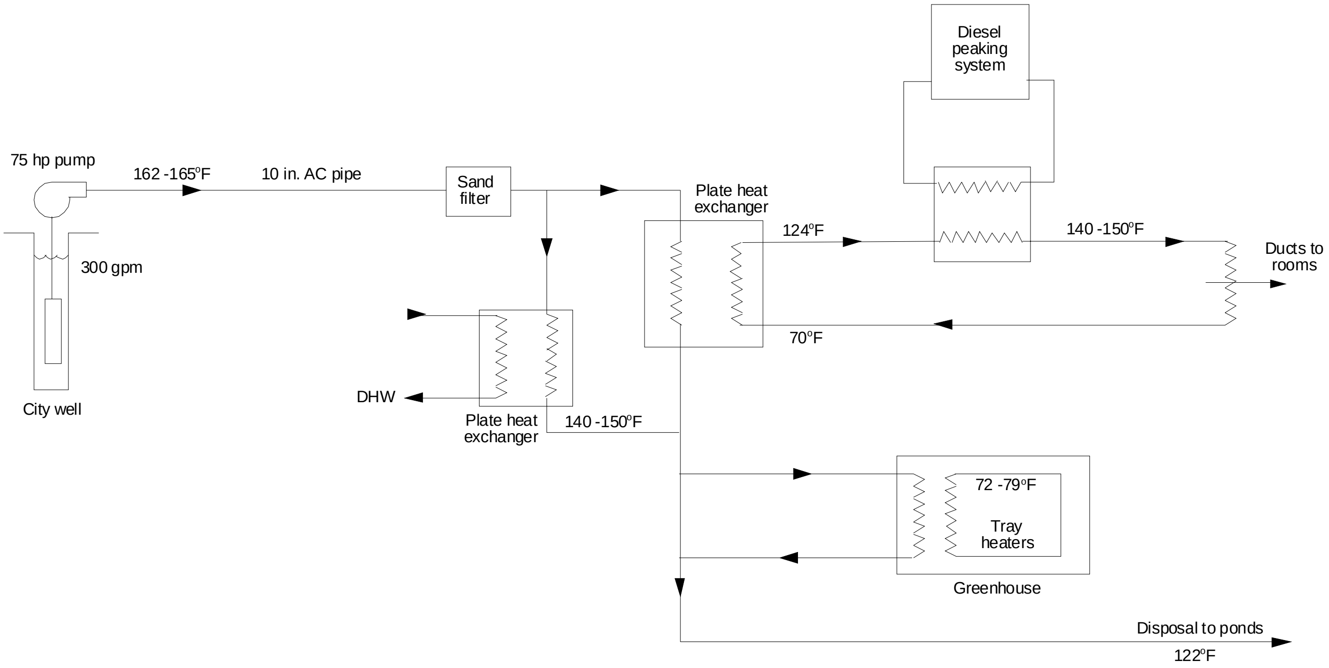
Miller, M. A., 2002. "Geothermal Heating at the California Correctional Center, Susanville, California," *Geo-Heat Center Quarterly Bulletin*, Vol. 23, No. 2, Klamath Falls, OR, pp. 16-19.

Culver, G., 1983. "Litchfield Correctional Facility Report on Projected Expansion," Geo-Heat Center, Klamath Falls, OR, 19 pp.

GeothermEx, Inc., 1991. "Recommendation for a Geothermal Fluid Injection Site, Litchfield, California," GeothermEx, Inc., Richmond, CA, 41 pp.

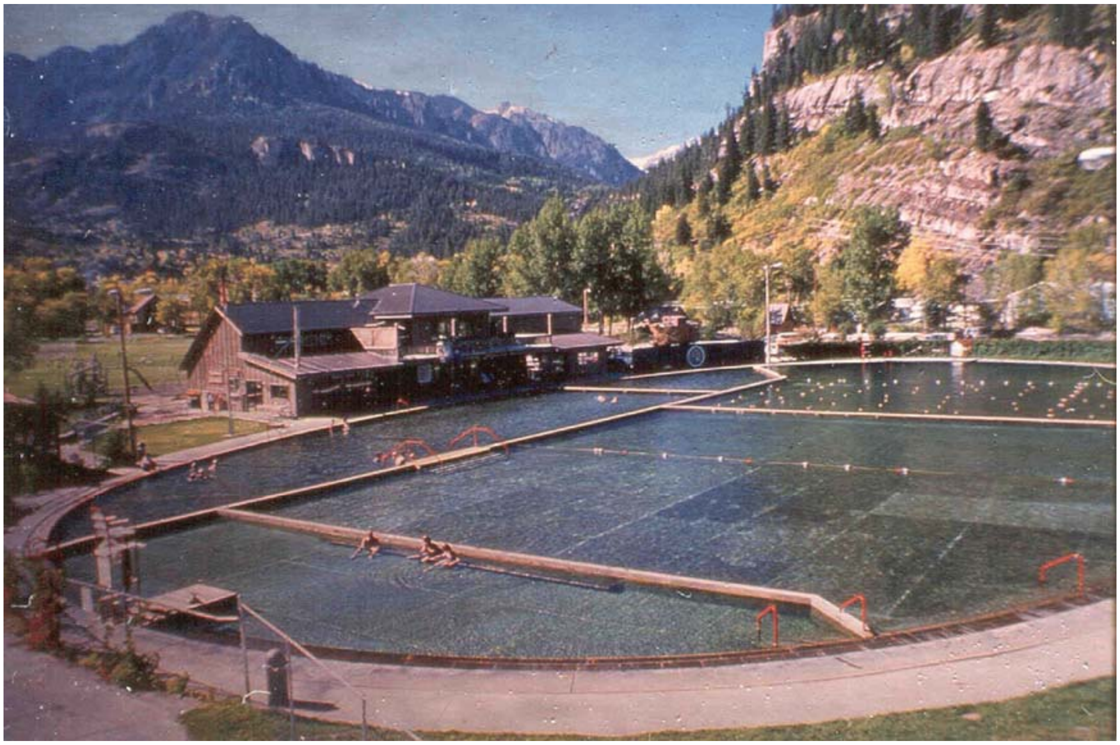
GeothermEx, Inc., 1982. "Drilling, Logging and Preliminary Well Testing of Geothermal Well Johnston 1, Johnston Farm, Lassen Country, California," GeothermEx, Inc., Berkeley, CA, 15 pp.

Berkeley Group Inc., 1986. "Review of the Litchfield (Carson Development) Project," Berkeley Group Inc., Oakland, CA, 50 pp.



California Correctional Center Geothermal Schematic

OURAY HOT SPRINGS POOL
OURAY, COLORADO



Location: The Ouray Hot Springs Pool is located on U.S. Highway 505 at the north end of the town of Ouray (about midway between Durango and Grand Junction). At an elevation of approximately 8,000 ft, the town is located in a valley surrounded by the 12,000 to 13,000 ft peaks of the San Juan Mountains making for an impressive setting. The original construction of the 125 x 150-ft ellipse shaped pool was completed in 1927 by the Ouray Recreation Association After two years of operation, the pool was taken over by the city and has been operated as a public facility ever since.

Resource: Numerous hot springs issue from locations both in and around the town of Ouray. These springs typically produce fluids in the 80 to 150^{o}F range depending on location and are used for heating the pool and some local privately owned spas and motels. The original plan was to use water from a resource on the pool site. Unfortunately, this proved insufficient so a trench was constructed to bring water from the Box Canyon Spring, approximately one mile to the south, to the pool. This resource proved to be sufficient to allow operation of the pool during the warmer months of the year and eventually the trench was converted to a pipeline. In the 1980s, the town decided to explore the development of a district heating system. Six test wells were drilled, two of which were near the pool. Though the district heating system was not developed, one of the wells is used to supply water to the pool and this additional source is sufficient to permit year round operation. At present, the pool receives approximately 120 gpm of 145^{o}F water through a pipeline from the Box Canyon Spring and approximately 134 gpm at 124^{o}F from well OX-2. The water chemistry for the springs varies somewhat, but is very hard (500 to 1,000 pm as $CaCO_3$), TDS of approximately 1,000 to 2,000; pH of 7 (field) and 8 (lab) and 500 to 1,000 ppm sulfate. Scaling is a problem in most cases.

Use: Water from the two sources described above is supplied to the pool and in the winter months to a heating system for the pool buildings (totaling approximately 5700 sq ft). For the pool itself, the combined flow from the spring and the well is delivered to a concrete tank on the west side of the facility. Here chlorine is added and the water is pumped to the filter room. The geothermal water is passed through two sand pre-filters to remove iron and manganese and then is mixed with pool water after it has passed through the main filters. Three distinct temperature zones are maintained in the pool--a small 104^{o}F section, a larger 98^{o}F section and the main portion of the pool is allowed to “float” using whatever geothermal water is left after satisfying the warmer sections. Temperature is maintained by manually adjusting valves which mix the geothermal water with the filtered pool water. Overflow from the pool is delivered to the Uncompagre River located adjacent to the facility.

In addition to the pool heating, a small flow is diverted from the Box Canyon Spring line to provide heating of the pool building. Geothermal water is supplied to a plate heat exchanger at a rate of 90 gpm. The heat exchanger produces 110^{o}F water which is circulated to the radiant floor/fan coil system in the building. This system provides approximately 288,000 Btu/hr (0.1 MWt) to the building with an annual use of 0.6 billion Btu. Assuming an average pool temperature of 75^{o}F and an average air temperature of 50^{o}F, the peak load is then estimated at 6.0 million Btu/hr (1.8 MWt). At 8,000 hours per year (assuming a few hours in the dead of summer where minimal heat is required), the estimated annual heating use is 48,000 billion Btu.

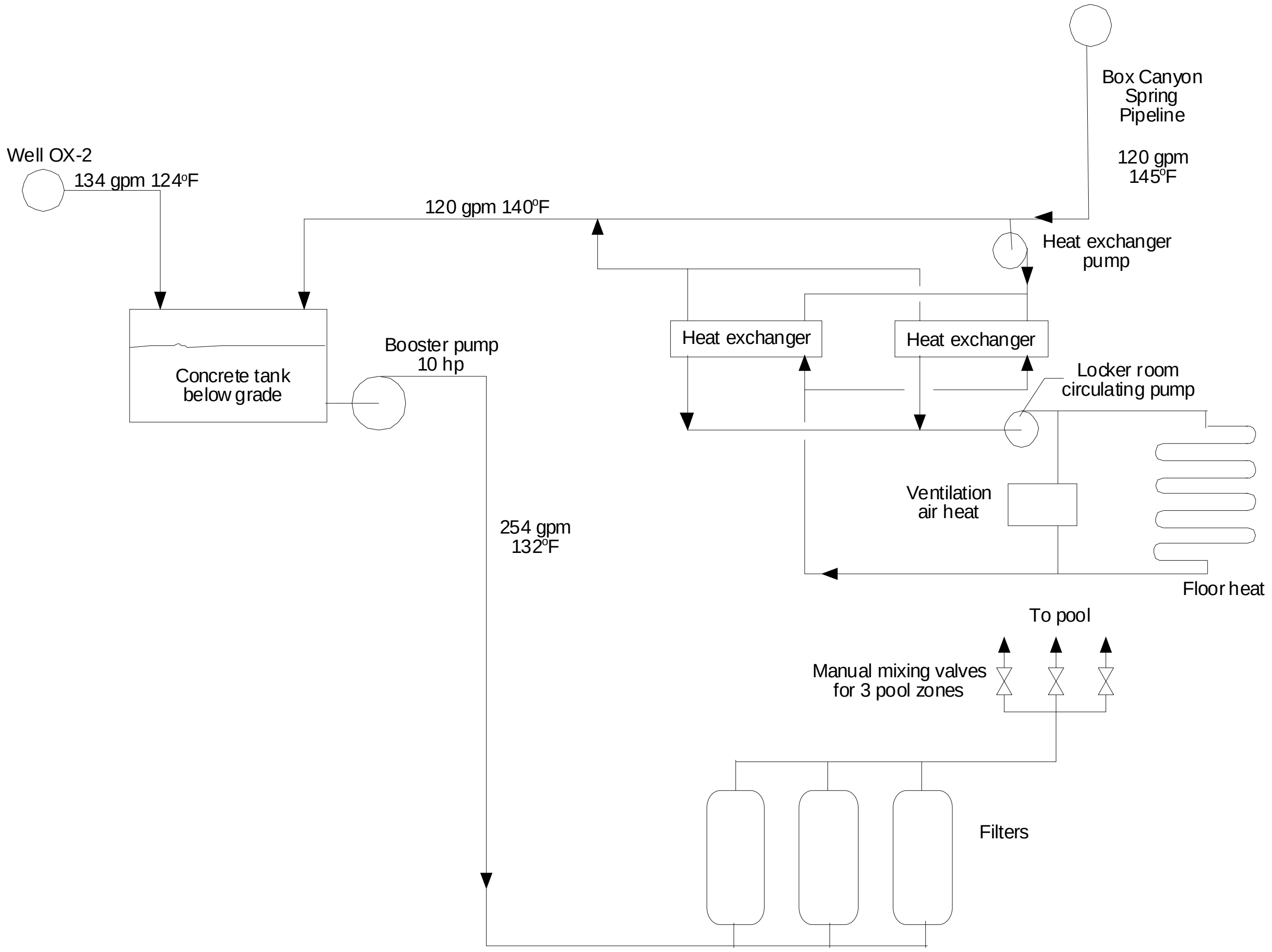
Operating Costs: No pumping of the geothermal fluids for this facility is required. The spring is located uphill from the pool and flows by gravity through the pipeline. Well OX-2 is artesian and no additional pumping is required. The only pump located on the geothermal side of the system is the one that transfers the water from the concrete tank to the pool filter room. The 15-hp pump operates continuously resulting in an annual cost of approximately $7,800. Aside from this, regular maintenance consists of replacing the sand in the geothermal pre-filters every six months. Once a year, the plate heat exchanger must be cleaned and descaled and this incurs a cost of $200. The original asbestos cement pipeline from the spring was replaced recently with 10" PVC material at a cost of approximately $20,000. Periodic descaling of the pipeline is performed annually at a cost of about $500. The total budget to operate the pool amounts to approximately $540,000 per year and revenues from its operation are $660,000 per year.

Regulatory/Environmental Issues: Since the pool was established in 1927, it existed long before most regulatory agencies and rules were developed. The pool operates as a “flow through” design and disposes directly to the Uncompagre River. This river does not support a fish population due to its natural water chemistry. In recent years, a chlorination system has been added to the pool and a residual chlorine level of 1.0 ppm is maintained in the pool water. This is well below the level required in conventional pools. Disposal of the water to the river is governed by a state surface disposal permit which specifies flow, TDS, temperature, chlorine and ammonia limitations.

Problems and Solutions: The very simple nature of the system results in a low incidence of operating problems at the facility. Other than the replacement of the pipeline mentioned in the above section, no major mechanical issues have surfaced with the system.

The drilling done by the town in the 1980s, though not directly connected with the pool, did cause some problem with one local spa. The spa claimed damage to their spring flow from the test drilling and a legal agreement was developed with the town to supply a small flow (30 gpm) to the spa owner as compensation. At this writing, a pipeline is being designed to deliver the flow from the existing Box Canyon line supplying the pool.

Conclusions and Recommendations: The pool is a very successful operation and one which generates substantial tourist activity for the town--the primary industry in Ouray. Given the age of the pool, the low level of maintenance is impressive.



Well OX-2
134 gpm 124°F
120 gpm 140°F
Box Canyon Spring Pipeline
120 gpm 145°F
Heat exchanger pump
Heat exchanger
Heat exchanger
Concrete tank below grade
Booster pump 10 hp
Locker room circulating pump
Ventilation air heat
254 gpm 132°F
Floor heat
To pool
Manual mixing valves for 3 pool zones
Filters

"GONE FISHING" AQUACULTURE PROJECT
KLAMATH FALLS, OREGON

Overview of the 72 15-ft x 100-ft fish ponds near Klamath Falls, OR.

Location: The "Gone Fishing" aquaculture project is located about 10 miles south of Klamath Falls, Oregon, near Merrill in the Lower Klamath Valley adjacent to the Klamath Hills. The original ponds were construct in 1984 and had limited use. The present facility, operated by Ron Barnes, started in 1990 using the effluent from a geothermal greenhouse operation on the Liskey Ranch on Lower Klamath Lake Road. In 1998, he purchased 80 acres of land just north of the greenhouses on the opposite side of the road. Today, the operation consists of 37 ponds located on the Liskey Ranch and 35 at the new location. The aquaculture ponds are used to raise 85 varieties of tropical fish (cichlids) that originated from Lake Malawi in East Africa's Great Rift Valley and from Central America. He sells 250,000 of the fish (3" to 4" long) annually to tropical fish wholesalers from Portland, OR to San Francisco, CA; shipped weekly by truck to Sacramento, and then by air to the various outlets.

Resources: The geology of the area consists of large normal fault blocks, typical of the Basin and Range province. The Klamath Hills are typical of these fault blocks, allowing geothermal waters that circulate at depth, and move to the surface in shallow aquifers. At the original location, a greenhouse complex consisting of four 6,000 square-foot buildings are heated using a peak of 400 gpm from six geothermal wells ranging in temperature from 80^o to 200^oF and all are around 100 feet deep. The newer set of ponds are provided geothermal water from a 460-foot deep well that pumps up to 300 gpm of 210^oF water. The water surface in the newer well is at 120 feet and the lineshaft pump bowls are set at 190 feet. The water from the wells is alkaline with a pH of 8.8 out of the wells, but the chemical composition of the pond liners (diatomaceous earth) and soil surrounding the ponds reduce the pH to about 7.5 as the water flows through the system. The water is primarily a sodium-sulfate type of about 600 ppm that can be used directly in the ponds without harm to the fish. This is about the same chemical composition as the water of Lake Malawi.

Use: At the greenhouse location, a 14,000-gallon steel railroad car tank is buried in the ground that receives water from one of the wells, and then supplies 180° to 185°F water to the greenhouses. Depending upon the outside temperature, the water leaves the greenhouses at 165° to 180°F; where, it is then piped to Barnes' original ponds that are kept at nearly a constant temperature of 80°F ±3°F; even though, the fish can easily tolerate ±10°F. The wastewater from the ponds is then fed to a holding pond where it is cooled and then used for stock watering and irrigation. The water from the newer well is stored in a similar railroad car tank of 14,000 gallons and then gravity fed through a 4-inch diameter aluminum pipe adjacent to the ponds. Each pond is then supplied 197°F water through 1-inch CPVC pipe. It quickly mixes with the pond water, causing no harm to the fish, and levels out the pond water at around 80°F. The pond water is kept within 3°F of the desired temperature. The wastewater, that is not lost through evaporation and leakage, is disposed of into the same stock pond. The flow to the ponds varies from 50 to 300 gpm depending on the outside temperature and wind, with an annual average of about 100 gpm. A few of the ponds, which are in a more porous soil, have to be lined with black plastic to prevent severe water leakage.

The temperature and flow rate into the various ponds is controlled manually by feel. Gate valves at each pond are then set to achieve the proper temperature. This "hand feel" method is felt superior to electronic control valves, as these often stick open and thus, "fry" the fish. It is felt that pond temperature is kept with ±3°F, sufficient for optimum growth.

It is estimated that the installed capacity of the newer facility, based on a peak of 300 gpm and a 10°F-temperature drop in the water, is 1.5 million Btu/hr or 0.44 MWt. Using an annual average of 100 gpm, the total energy use is then 4.38 billion Btu/yr.

Operating Cost: No cost figures are available for the original ponds constructed adjacent to the greenhouses. The new ponds and well construction in 1998 were funded by two Oregon Economic Development loans for a total of $100,000. The well cost $15,000 and the excavation for the ponds cost $15,000. The remainder of the funds were used for controls, pumps, piping and storage tank. Operating cost at the original site is at a fixed rate of $350 per month, since the resource is owned by Liskey Farms, Inc. There are no pumping power costs, since the ponds are filled with wastewater from the greenhouses. At the new location, the pumping power cost varies from $280 to $400 per month with an annual average of $350 per month. The cost of electricity is 5.7 cents/kWh; thus, an average of 6,140 kW are used monthly. Approximately $500 per month is used for repairs and maintenance. Thus, the total annual operating cost is approximately $9,000. Barnes estimates that by using the geothermal heat energy, that he avoids the use of about 24 million kWh in electricity annually, for a savings of $1,350,000.

Regulatory/Environmental Issues: The main concern originates from the Oregon Department of Fish and Game. They do not want any of the fish to escape into waterways in the area. As a result, a 200°F barrier is provided in the original pond area that would "cook" any escaping fish. In the newer pond area, very little if any water overflows out of the ponds, and the little that does, mainly during the winter months, goes into a holding pond. Barnes is considering raising Tilapia and in this case, Fish and Game will require him to have a greenhouse type structure over the raising ponds and tanks to prevent any fish from escaping or being picked up and dropped by birds. The harvested fish cannot be shipped to market live, and thus must be killed and frozen on site before shipping. Also the Oregon Department of Environmental Quality would regulate the waste discharge from the Tilapia ponds; thus, a filter system would have to be installed, and a closed circuit system used. Water disposal from the tropic fish ponds is not a problem, as 500 lbs of fish per pond provide little waste. Discharge from over 20,000 lbs/year would be regulated by DEQ.

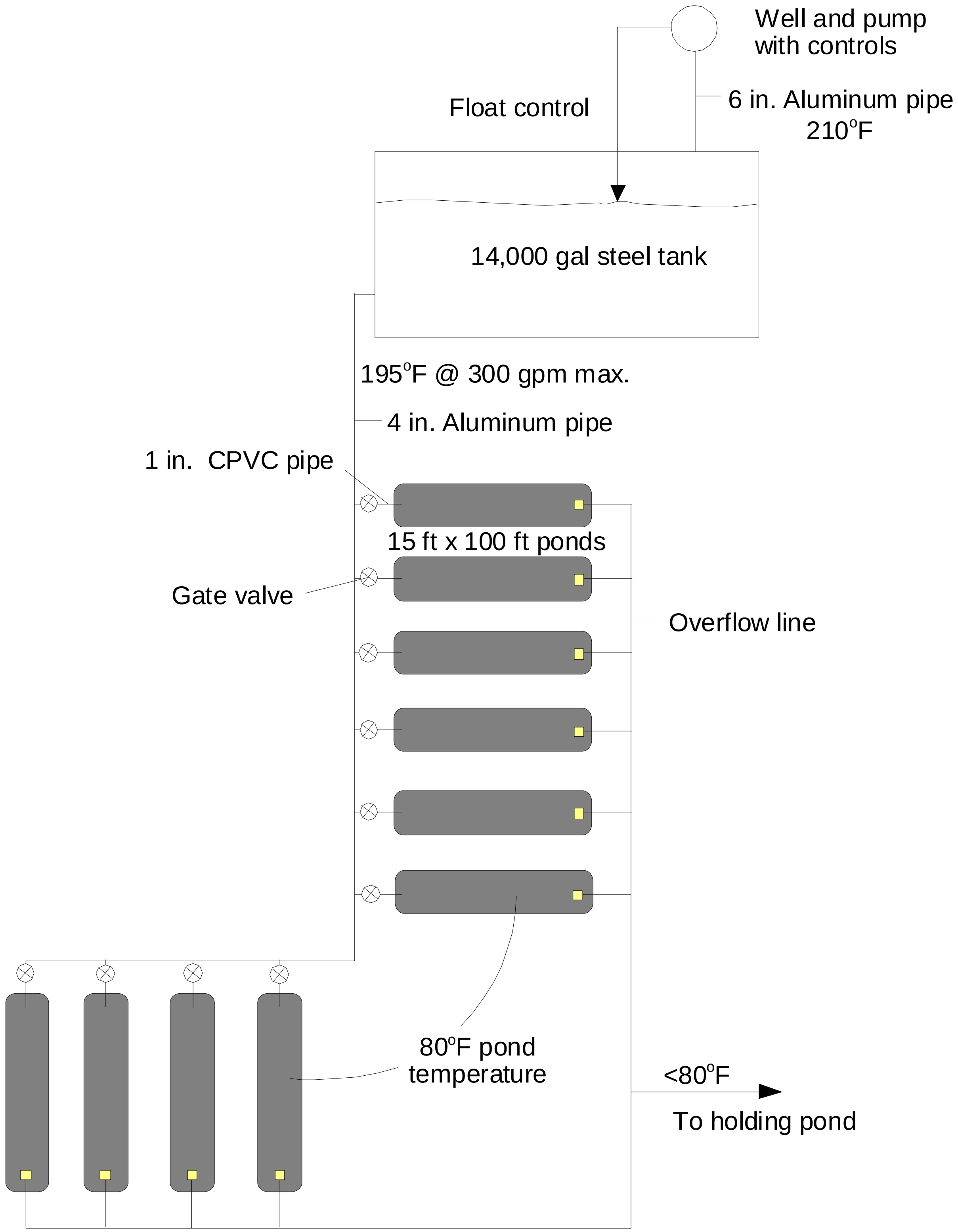
Problems and Solutions: Four main problems exist at the facility: 1) lack of cold water for cooling the ponds; 2) corrosion in the aluminum pipes; 3) taking of fish by birds; and 4) limited capacity of the resource. Since, this is a geothermal area, cold water is a problem for both the greenhouse and aquaculture facilities. Cold water is then provided by cooling geothermal water in holding ponds. Internal corrosion in the aluminum pipe is a problem in the new facility due to the 195^{o}F temperature of the water. In the facility adjacent to the greenhouses, the pipes have been in for over 20 years and have experienced no corrosion, as the water temperature is only 180^{o}F. Black iron pipe placed under roads have experienced external corrosion from the soil. Birds are a problem at the older facility, since the ponds are adjacent to irrigation canals where Egrets and other birds live. This is not a major problem in the newer facility - so all that is really done at this point is to scare them away when they are working around the ponds. The maximum amount that can be pumped from the newer well is 300 gpm, and this is often reached during the winter months, especially when there is wind. This would then limited the size of the proposed Tilapia facility. Based on consultations with engineers at the Geo-Heat Center, they will experiment with two methods to reduce the evaporation. Since evaporation from the ponds can contribution to as much as 50 to 60% of the total heat loss, a wind barrier, and bubble mat pond cover are being considered. The bubble mat, similar to ones used for swimming pools and hot tubs, would cover a portion of the pond, since some of the pond area must be exposed to the air to provide oxygen to the fish. Various combinations of 25, 50 and 75% pond coverage will be tried.

Conclusions: The "Gone Fishing" aquaculture operation appears to be successful, and plans are to expand from tropic fish to Tilapia. The success of the operation is due to two factors: 1) a readily source of geothermal energy, available at shallow depth with adequate temperature and flow; and 2) a operator/manager, Ron Barnes, who has the background and knowledge of aquaculture methods. He started small, and has increased in reasonable increments as he gained experience with using the geothermal resources. There are minor problems with corrosion of metal pipes, and efficient use of the resource, but these are being solved, and do not present a major expense and management problems.

References:

Clutter, Ted, 2002. "Out of Africa - Aquaculturist Ron Barnes Uses Geothermal Water in Southern Oregon to Rear Tropic Fish from African Rift Lake" in, *Geo-Heat Center Quarterly Bulletin*, Vol. 23, No. 3 (September), Klamath Falls, OR, pp. 6-8 [also published in *Geothermal Resources Council Bulletin* (Vol. 30, No. 2, March/April 2001), Davis, CA].

Lund, John W., 1994. "Agriculture & Aquaculture - Cascading the Geothermal Way" in, *Geo-Heat Center Quarterly Bulletin*, Vol. 16, No. 1 (November), Klamath Falls, OR, pp. 7-9.


Well and pump
with controls
Float control
6 in. Aluminum pipe
210°F
14,000 gal steel tank
195°F @ 300 gpm max.
4 in. Aluminum pipe
1 in. CPVC pipe
15 ft x 100 ft ponds
Gate valve
Overflow line
80°F pond
temperature
<80°F
To holding pond

MERLE WEST MEDICAL CENTER
KLAMATH FALLS, OREGON

Location: The Merle West Medical Center (MWMC)(formerly Presbyterian Intercommunity Hospital) is located in Klamath Falls which is in south-central Oregon. Elevation at Klamath Falls is approximately 4,100 ft and the local climate is characterized by an annual total of 6,500 heating degree days. The medical center complex is adjacent to the Oregon Institute of Technology (OIT) campus at the north end of the city of Klamath Falls. The hospital was originally constructed in 1964 and the geothermal system was added as a retrofit in 1976. Numerous building additions have been completed since--virtually all geothermally-heated.

Resource: The MWMC produces from the same aquifer serving the OIT campus and most of the other 550 geothermal wells in Klamath Falls. The water issues from a northwest trending fault bordering the east side of town. Water flows in a generally southwest direction from the fault mixing with cooler surface water as it proceeds. Temperature of the water tends to reach a maximum of approximately 220^{o}F nearest the fault. Water chemistry is relatively benign with a pH of approximately 8 and TDS of 800 to 1,000 ppm. Despite this, isolation is typically employed, since the fluid does contain a small amount (approx. 0.5 ppm) of hydrogen sulphide. MWMC is served by a single production well 1,583 ft in depth with a static level of 332 ft. The well was originally tested at a flow of 500 gpm of 195^{o}F water with a drawdown of 15 ft.

Use: The original geothermal system for MWMC was designed to provide space heat and domestic hot water to the 96,000-sq ft main building; a new 56,000-sq-ft addition; the adjacent 56,000-sq ft nursing home and snow melting for the main entrance area. Since that time, the approximate areas heated have grown to include 300,000-sq-ft main building; 45,000-sq-ft medical office building; 56,000-sq-ft nursing home and a 80,000-sq-ft residential care facility. The system as indicated in the attached schematic includes a production well producing a peak flow of 600 gpm of 195°F water and equipped with a 125-hp motor. The well pump is controlled to maintain a constant pressure at the upper end of the system. The water is delivered to a complex of six heat exchangers in the main building, one in the residential care facility and two in the medical office building. In all cases, loads are arranged in series such that a maximum delta T can be achieved. In general, flow control at each heat exchanger is provided by a 3-way valve which serves to either divert geothermal water through the heat exchanger or past it to subsequent loads. After passing through the plate heat exchangers, the fluid is delivered either to a final snow-melt system or diverted to the injection well collection tank. Two 15-hp injection booster pumps provide the pressure necessary to deliver the water to the injection well. The injection well is 1912 ft deep and was added to the system in 1990 (see regulatory section).

The estimated peak heating load for the buildings is 21 million Btu/hr (6.1 MWt) and the annual use is 22 billion Btu.

Operating Costs: Operating costs specific to the geothermal system are not maintained by MWMC. For purposes of accounting, however, costs are apportioned to different individual sub-facilities comprising the MWMC. For example, the 80,000-sq-ft residential care facility is billed approximately $0.024 per sq ft monthly to cover maintenance and capital improvements to the geothermal system. In addition, they are billed for the heat consumed as measured by an energy meter. Similar arrangements are in place for the other two major stand alone buildings.

The actual electrical energy input for the system in terms of operation is quite small relative to the quantity of energy produced. Based on an approximate design capacity of 21,000,000 Btu/hr, a total pumping requirement of only 165 hp is needed. The geothermal pumping is not separately metered but calculations indicate that approximately 430,000 kWh would be required on an annual basis to operate the systems production, snow melt and injection pumps.

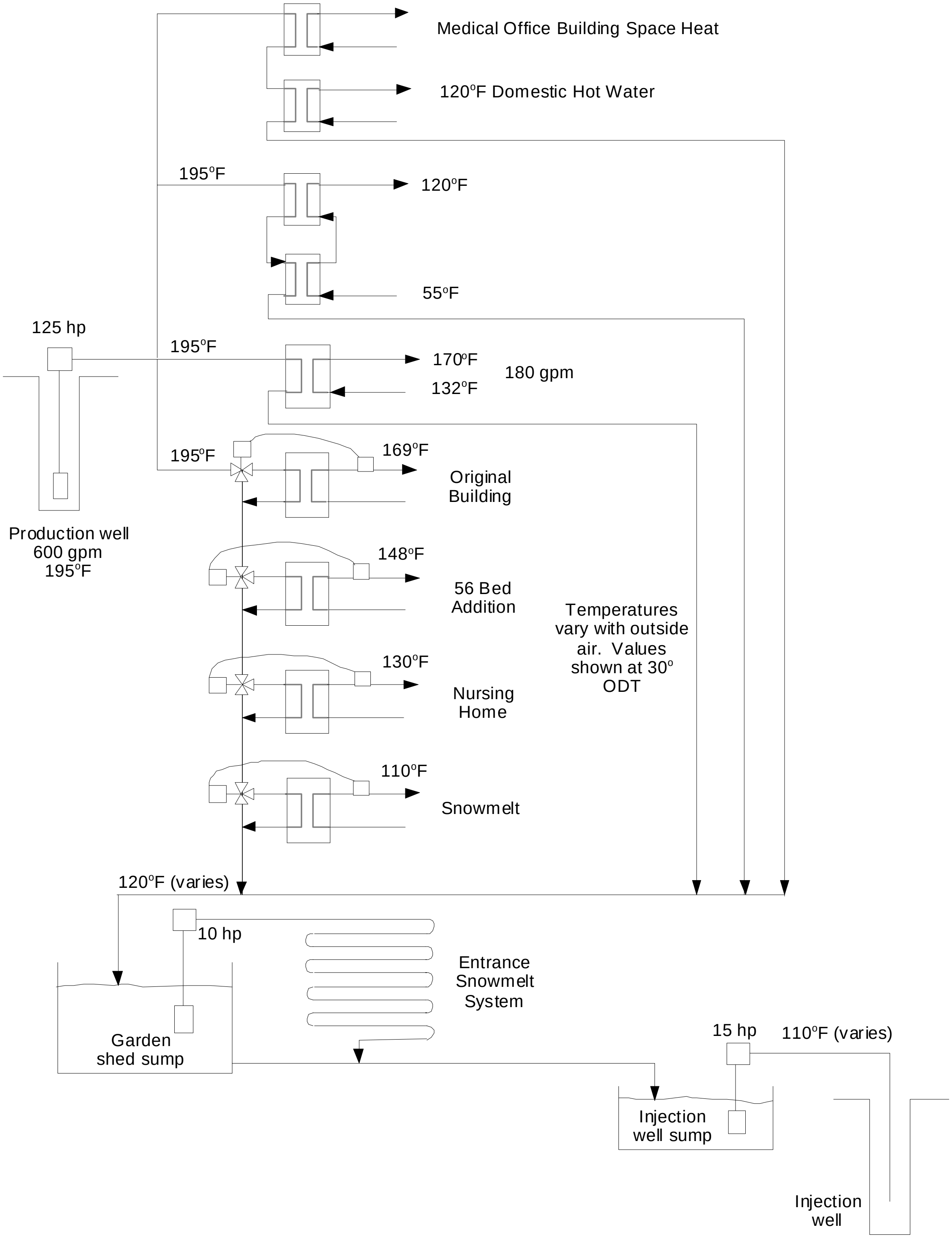
The MWMC engineering department performs all regular maintenance of the system and its director estimates that the equivalent of one full-time employee is required to handle the maintenance of the geothermal system.

Regulatory/Environmental Issues: Few regulatory issues are associated with the operation of a system like this in the state of Oregon. Well drilling and construction is permitted in the same way as normal water wells with a start card and well completion report required to be submitted to the Department of Water Resources. Since the system is located within the city limits of Klamath Falls, injection is the required method of disposal. The ordinance requiring injection was passed in 1985 and stipulated that all existing systems would have to commence injection by 1990. As a result, MWMC completed a well for injection in 1990 to comply with the ordinance. Prior to that time,

effluent was disposed of on the surface with drainage to Klamath Lake. Due to the age of the system, no permits were required. Injection requires only the submission of a one page summary form to the Department of Environmental Quality.

Problems and Solutions: The MWMC system has been in operation for nearly 25 years. In that period of time, numerous modifications have been made to the system some as the result of problems and some as the result of newly available equipment. The original design included a well pump controlled by a fluid coupling type of speed control. The well pump produced into a 4,000-gallon tank that was vented to atmosphere and from that point to the individual heat exchangers Relatively frequent well pump failures were experienced for a time and this was thought to be the result of a control sequence that maintained the pump in operation but at a speed that was insufficient to produce flow at the well head.. The control was reset to eliminate this mode of operation and pump life was then extended to an average of six years between overhauls where it remains today. In 1995, the pump was equipped with a variable-frequency drive for speed control and the tank was removed from the system entirely. The original design employed all shell and tube heat exchangers. This equipment was much larger than the current plate heat exchangers, more difficult to clean and less effective at heat transfer. In the mid-1980s, all of the original heat exchangers were replaced with plate and frame units. There has been some problems encountered with gaskets in the plate heat exchangers. Swelling has been encountered in some cases and this is thought to possibly be related to the small amount of oil in the geothermal fluid from the well pump (oil lubricated enclosed shaft type). Some problems have also been encountered with butterfly valve lining material. Fluroelastomer lined valves have been used but the cost is excessive and this problem is yet to be fully resolved. The injection system involves the use of a concrete sump in which “can” type vertical pumps are located. Originally, these pumps were standard, steel column, cast iron bronze fitted pumps. Due to the fact that the geothermal fluid is saturated with oxygen at this point in the system, the original pumps were plagued with failures. All stainless steel pumps were installed and these problems have largely been eliminated. A similar situation and remedy was experienced with the snow melt pumps located just upstream of the injection pumps. The original controls for the system were the standard pneumatic design of the day. These were replaced with a DDC system in 1990 and the operation and monitoring of the system was vastly improved according to the MWMC engineering department.

Conclusion: The MWMC system is one of the oldest large geothermal systems in the U.S. It has proven to be a reliable energy source for a critical facility for the past 25 years and has in the process accommodated substantial increases in capacity. The system currently displaces approximately 275,000 therms per year in natural gas purchases. In 1977, the total investment in the geothermal retrofit of $320,000 was expected to generate annual savings of approximately $104,000 per year when all additions envisioned then (total building area 275,000 sq ft) were completed. At this writing, the system is serving approximately 470,000 sq ft and as a result the savings have re-payed the original cost many times over.


Medical Office Building Space Heat
120°F Domestic Hot Water
195°F
120°F
55°F
125 hp
195°F
170°F
132°F
180 gpm
195°F
169°F
Original Building
148°F
56 Bed Addition
Temperatures vary with outside air. Values shown at 30° ODT
130°F
Nursing Home
110°F
Snowmelt
Production well 600 gpm 195°F
120°F (varies)
10 hp
Entrance Snowmelt System
Garden shed sump
15 hp
110°F (varies)
Injection well sump
Injection well

FAIRMONT HOT SPRINGS RESORT
FAIRMONT, MONTANA

Fairmont Hot Spring Resort as seen from the air.

Location: Fairmont Hot Springs Resort, formerly Gregson Hot Springs, is located in western Montana along I-90 between Butte and Anaconda. The resort sits in a valley at the base of Pintler Wilderness area and is near the Continental Divide. The resort consists of two Olympic-sized swimming pools and two mineral soaking pools, one of each located indoors and outdoors; two three-story guest room buildings with 158 rooms; a 130-seat main dining room; 60-seat coffee shop; 90-seat cocktail lounge along with several shops; and a 7,000-square foot conference center. All of the approximately 106,000 square foot area and pools are geothermally heated. There are plans to expand the conventional center. The resort and geothermal use dates back to 1869, with the current resort rebuilt in 1972 after collapse of walls and closure in 1971.

Resource: Several springs discharge about 760 gpm at 143°F from Tertiary volcanics associated with the Boulder batholith into ponds near the resort. Total dissolved solids are 559 ppm and the pH of the water is 8.41. A well, drilled in 1985 by the Montana Bureau of Mines to a depth of 600 feet provides a flow rate of 180 gpm of 170°F water. At times, the water temperature will vary from 165 to 175°F. During the summer months, the flow is reduced to 120 gpm.

Utilization: The geothermal water is pumped from the well with a 50-hp lineshaft pump that has 22 bowls set at 420 feet. The flow rate is controlled by restricting the flow into the pipeline with a valve. The water flow through a 2,500-foot long fiberglass pipeline into two 1500-gallon collection pits. From the pits, the water is piped to a central boiler room; where, a forced air system supplies heat to individual rooms. Plate heat exchangers are used to transfer the heat with the secondary closed-loop water going out at 160° and returning at 150°F. In addition, copper pipes in the ponds are used to preheat the domestic hot water. Normally, this is adequate to keep the domestic hot water at around 120°F; however, during colder periods the water is peaked with a fuel oil-fired boiler.

The geothermal water is also used directly to heat the two Olympic-sized swimming pools, each 85 by 212 feet in size, and two mineral soaking pools. Two 100 by 100 pyramid buildings and two three-stories lodging buildings are also heated. In the winter the space heating water is circulated by one 10-hp and two 7.5-hp pumps, and the pools used four 7.5-hp, three 5-hp and two 2.5-hp circulating pumps. The water enters the pools at about 110°F and exits about 98°F.

The water is then discharged to a drainage channel adjacent to the resort. The water goes into a collection pond and then is used by the Peterson Ranch for irrigation of crops (hay and alfalfa). Any chlorine in the water has dissipated by this time. Excess water, not used by the resort is bypassed directly into the local sewer line serving a nearby residential area, and ends up in a sewage lagoon adjacent to the property.

The estimated energy use is 6.48 million Btu/hr (1.90 MWt) and the annual energy use is 43.8 billion Btu. The estimated gross savings is around $500,000 per year (assuming fuel oil at $1.30 per gallon and 80% efficiency).

Operating Cost: Annual operating cost consist of two items: 1) electricity costs to run the various pumps, and 2) maintenance costs. The annual electricity cost for the pumps consist of $21,100 for the well pump, $2,700 for the 10 hp pump, $3,500 for the two 5-hp pumps, $12,000 for the pool pumps, $24,000 for the pool building heating system pumps, and $14,400 for the lobby and rooms three-speed motor blower fans, giving a total of $77,700. However, the only cost directly attributed to the geothermal system is the well pump and the 10-hp and two 5-hp pumps for a total of $27,300. The annual maintenance cost is for preventative maintenance amounting to about $3,500. Thus, the total annual operating cost due to the geothermal system is around $30,800. All other operating costs would be the same, regardless of the type of fuel used for heating.

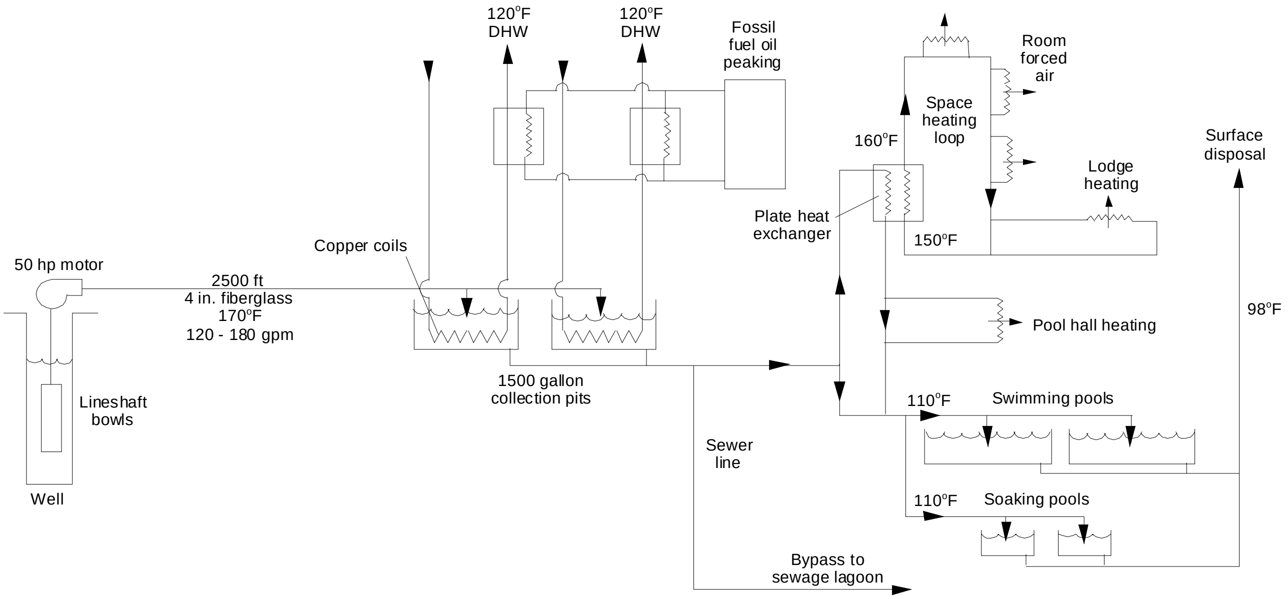
Regulatory/Environmental Issues: The only potential problem would be the disposal of the used water onto private land for crop irrigation and stock watering. Excess hot water that is not used goes directly into the local sewer line and is disposed into a sewage lagoon adjacent to the property. However, since the dissolved solids are under 600 ppm and the chlorine used to treat the pools water has dissipated by the time it reaches the ranchers property, there are no environmental impacts. The temperature of the disposed water has not been considered a problem. No permits are needed for the disposal of the water; since, both the source and disposal site are on private land. The local sewer district needs an EPA permit when it pumps down the sewage lagoon for disposal of the sludge. There was a well drilling permit required for the original drilling of the well.

Problems and Solutions: There has been some problems with scaling and corrosion; thus; they have used an acid type cleaner to try to control the deposits.

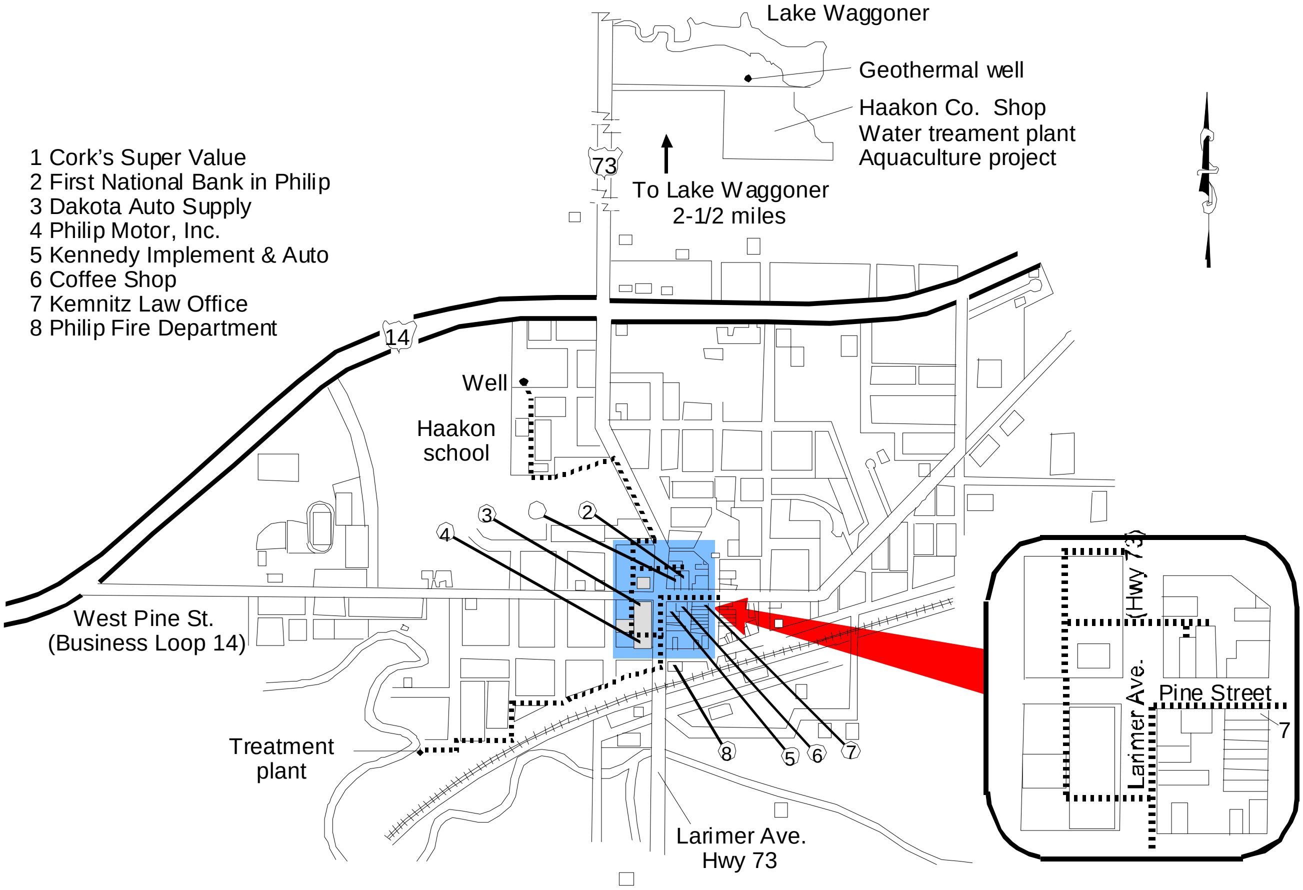
Conclusions and Recommendations: The system appears to be operating with minimal problems, both in utilization and in disposal of the fluids. The system cannot meet peak load in certain cases; thus, diesel fuel heat is needed to backup the system. Annual savings are large, and maintenance cost small. Using the geothermal water directly in the pools is a popular attraction for tourists. There are plans to expand the convention center.

References

Lienau, Paul J., 1993. Fairmont Hot Springs Resort, *Geo-Heat Center Quarterly Bulletin*, Vol. 14, No. 4, (March), Klamath Falls, OR, pp. 22-23.



GEOTHERMAL DISTRICT HEATING SYSTEM
PHILIP, SOUTH DAKOTA



Philip district heating system schematic.

<u>Location</u>: Philip, South Dakota in located in the southwestern part of the state, on U.S. Highway 14, about 87 miles west of Pierre. It has a population of about 1,100. The district heating project was one of 23 cost shared by USDOE starting in 1978. The city project was added on to the original USDOE cost shared project for the Haakon School, located on a hill above town. Waste water from the school has been used to heat eight buildings in the downtown area since the 1981-1982 heating season. The Philip Geothermal Corporation (for profit) was formed to maintain and operate the downtown system, and pays the school district for the use of the water.

<u>Resources</u>: The town overlies the Madison Formation which is a large-area aquifer. The aquifer has a demonstrated capability to produce geothermal water. A single 4,266-foot deep well was drilled in 1980 which provides a maximum artesian flow of 340 gpm at 157^{o}F. The dissolved solids content of the water is 1,112 ppm and a pH of 7.4. Radium-226 at 100 pCi/L as radium sulfate, must be removed from the spent water with a barium chloride mixture before discharging to the Bad River. The treatment plant has two 90 ft x 158 ft x 10 ft deep storage ponds that will each hold 374,000 gallons of the sludge. The geothermal fluid is first used by the grade school and high school before being sent to the city at around 140°F, and then is disposed of between 119 and 140°F, depending upon peak or no energy demand from the system. In warm weather, only 12 to 15 gpm is required.

Utilization: The geothermal discharge from the schools is transported in a single pipe through the downtown area. A disposal line begins at the upstream end of the business district and parallels the supply line from the schools to the last user on the system, the fire station. From there, a single line continues to the radium removal plants and disposal to the Bad River. The eight buildings connected to the system used either Modine heaters, unit heaters, or by piping in the floor. The bank building uses plate heat exchangers to isolate the geothermal fluid. The control points for the system are at the high school and the fire station. Equipment in the fire station controls system pressure and regulates flow through the business district loop. A motor operated flow control valve on the return line is set to be full open at 20°F and full closed at 65°F outside air temperature. A second valve maintains back pressure in the distribution piping to minimize calcite precipitation. When the outside temperature is below -10°F and hydronic fluid temperature is below 90°F, a backup boiler is turned on and automatically valved into the system.

Water leaving the business district flows to the water treatment plant where Radium-226 is removed. Barium chloride is added to the water at 2.6 ppm $BaCl_2$ at maximum flow. The solution is added at a baffled trough which empties into a pond. Sludge collects on the pond bottom at a rate of about 85 ft^3 per year. Sufficient liquid volume will be maintained throughout the pond's 30-year life. Radioactivity accumulates at 0.06 curies/year. At the end of the pond life, the sludge can be removed to a disposal site or mixed with cement to form the bottom for a new pond built directly over the old one.

The geothermal supplies 75 to 90% of the heating requirements of the eight buildings covering 56,500 ft^2. In addition, the floor slab of the chemical treatment plant building is heated with geothermal energy. A new bank building of 12,500 ft^2 will come online soon. The peak design delivery of the system (schools and business) is 5.5 million Btu/h (1.6 MWt), with an annual energy delivery of 9.5 billion Btu. The schools removes about 16°F and the business district about 11°F from the peak flow of 340 gpm, which is only about 83% of the system capacity. As a result, the city uses about 41% of the output of the system or 2.25 million Btu/h peak (0.65 MWt) and 3.9 billion Btu/yr. The heating season is normally from October 1st to May 1st.

Operating Cost: The capital costs of the entire system are estimated at $1,218,884 of which 77% was DOE funds. Annual operating and maintenance cost for the entire system is nearly $8,000 (updated from 1983 data). The initial retrofit costs to the city businesses was for cast iron heat exchangers at $30,000. However, due to corrosion, these were replaced with stainless steel heat exchangers. The Philip Geothermal Corporation now pays the school district $5,000, carries a $1,000 liability policy, pays taxes, and spends about $500 for repairs, for a total annual cost of about $6,500. Each user pays a share of the cost based on the percentage of water used. The total savings of all eight buildings is $120,000 annually, whereas the school district saves $200,000. Thus, the consumer pays about 20% of the corresponding cost of propane or fuel oil, the alternate fuel in the area.

Regulatory Issues: A discharge permit is required by the South Dakota Department of Environment and Natural Resources. This is renewed every two years. Samples of the discharge water (after the barium chloride treatment) are send to Pierre. EPA in Denver requires flow and temperature readings every two to three weeks. The Radium-226 must be reduced to 5 ppm (from 80 ppm) with a maximum daily reading of 15 ppm.

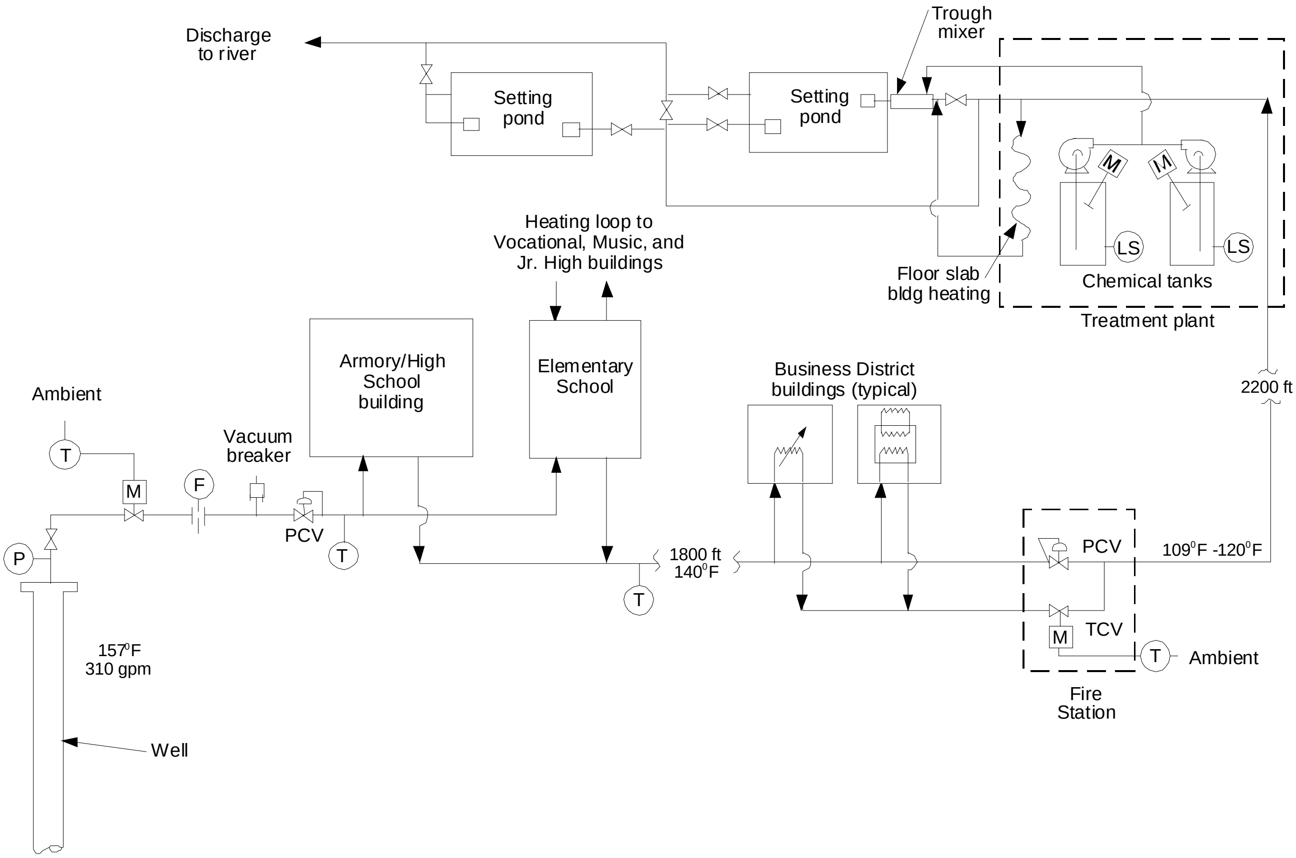
Problems and Solutions: The cast iron heat exchangers had to be replaced with stainless plate heat exchangers due to corrosion. Since then, there has been no problems with scaling and corrosion in the city system. However, the iron pipes in the school well have to be replaced every four to five years due to corrosion. Plugging of pipes at the water treatment plan has been a significant operating problem. Sulfate deposits initially partially plugged the mixer and pipe downstream, thus requiring frequent cleaning. Installation of the current trough system for the barium chloride additional and mixing has solved this problem. The pipe from the second cell to the creek has to be augered every two years at a cost of $250 to $300. The control system operation has been very satisfactory as far as the users are concerned; however, it has been unsatisfactory in terms of utilizing the resource efficiently. The system only supples 75 to 90% of the energy demands for the city buildings. A backup boiler is provided from the school system installation to peak the system during the colder periods (-10^{o}F outside and 90^{o}F fluid temperature).

Conclusions: Except for some inefficiency in the energy utilization, and the requirement for treating the Radium-226, the system appears to be operating well. Building owners are only paying about 20% of the corresponding cost for alternate fuels. However, it should be pointed out that the initial capital cost of the system was subsidized (77%) by a USDOE grant. The system probably would not have been feasible otherwise.

References:

Childs, F. W.; Kirol. L.D.; Sanders, R. D. and M. J. McLatchy, 1983. "Description and Operation of the Haakon School Geothermal Heating System," *Geothermal Resources Council Transactions*, Vol. 7, Davis, CA, pp. 579-584 (also reproduced in an abridged form in *Geo-Heat Center Quarterly Bulletin*, Vol. 18, No. 4, Dec. 1997, pp. 12-15).

Lund, J. W., 1997. "Philip, South Dakota Geothermal District Heating System," *Geo-Heat Center Quarterly Bulletin*, Vol. 18, No. 4, (December), Klamath Falls, OR, pp. 16-19.


Discharge
to river
Setting
pond
Setting
pond
Trough
mixer
Floor slab
bldg heating
M
M
LS
LS
Chemical tanks
Treatment plant
Heating loop to
Vocational, Music, and
Jr. High buildings
Armory/High
School
building
Elementary
School
Business District
buildings (typical)
2200 ft
Ambient
T
M
F
Vacuum
breaker
PCV
T
P
T
1800 ft
140°F
PCV
109°F -120°F
TCV
M
T
Ambient
Fire
Station
157°F
310 gpm
Well

MILGRO-NEWCASTLE GREENHOUSE
NEWCASTLE, UTAH

Location: The Milgro facility is located just west of the town of Newcastle, UT, approximately 37 miles west of Cedar City in southern Utah. The elevation of approximately 5,000 ft results in substantial heating requirements and below zero temperatures are commonly encountered in the winter. Milgro is the largest potted plant grower in the U.S. and in addition to its 1,000,000-sq ft geothermally-heated facility in Newcastle, it also maintains substantial conventionally-heated operations near Los Angeles.

Resource: The Newcastle area has long been recognized as rich in geothermal resources. Prior to the initial development of the Milgro facility, there were three other geothermally-heated greenhouses in the immediate area (all except one now owned by Milgro). There are currently numerous wells in the area producing water in the 190° F to 205°F range. The wells all penetrate sediments of the Escalante Valley consisting of alternating sequences of clay, silt, sand and gravel. The source of the fluids is thought to be from a buried point source associated with a range front fault approximately 3/4 mile southeast of the main production area (Blackett, 2001). The geothermal fluids flow laterally toward the northwest through the permeable portions of the sediments. Wells individually produce flows up to 1500 gpm.

Recently, production at the Milgro facility has fallen off in the #2 well. In addition, a new injection well, despite intersecting substantial intervals of apparently permeable materials, does not accept the expected flow.

Use: Two production wells equipped with vertical, oil-lubricated lineshaft pumps produce the flow for the system. The wells are both approximately 600 ft deep. Water from the two wells (1700 gpm at peak) is delivered to the greenhouse facility; where, the pressure is raised by individual 30-hp booster pumps for each of three 224,000 sq- ft-ranges. From the booster pump, the water is delivered to individual sub zones in each range where a 4-way valve diverts the water either to the heating tubes under the benches or to disposal. Prior to the development of the two most recent ranges (#4 and #5), the water was all disposed of in a single injection well or to the surface (when flows exceeded the capacity of the injection well). With the development of the two newest ranges, water previously disposed of directly is now routed through the new ranges.

In the original three ranges, heating is provided by half-inch diameter EPDM tubes installed under the benches. This places the heat at the plant root level for maximum effectiveness in potted plant production. In the two newer ranges, which were developed for cut flower production, heat is supplied by two different systems--½-inch diameter tubes on the floor and 1-1/4-inch diameter overhead finned pipe. Effluent water from the other three ranges is boosted by two individual pumps for ranges 4 and 5--one 7 ½ hp for the overhead finned pipe and one 15 hp for the tubes. The head house building is heated with 18 unit heaters connected to the distribution pipe to the ranges. All distribution pipe for the ranges is steel with grooved end joining and is located overhead in the head house. Typical greenhouse inside temperature is 72^{o}F day and 65^{o}F night and varies with the crop.

Disposal of the water is a combination of surface and injection. The first injection well was drilled in 1993 and for several years accepted almost all of the system effluent. It was equipped with a pressure diverting valve such that water in excess of what the well could accept was diverted to surface percolation ponds for disposal. A new injection well was drilled in 2002 with the hope that it would accept all of the system effluent.

Using a figure of 23 acres, the peak geothermal heating load is approximately 51 million Btu/hr (14.9 MWt) based on an outside design temperature of 0^{o}F. The annual use is approximately 93 billion Btu; assuming, that 75% of the sunlight hours, the sun meets the load.

Operating Costs: Operating costs, specific to the geothermal portion of the greenhouse are not available from Milgro; however, some general cost data can be inferred from available information. The total maintenance budget for the facility is $16,000 per month. This figure includes maintenance on the structures, vehicles, electrical systems, plant growing equipment and the geothermal system. An interesting point is that this amounts to less maintenance per square foot for the geothermal facility than for Milgro's conventionally-heated greenhouses in the Los Angeles area --though this is related to the fact that the conventionally heated structures are much older.

The geothermal system includes a total of approximately 485 hp in connected load associated with pumping (well pumps and booster pumps) and approximately 9 hp in unit heater fans. Assuming that the well pumps are operated in rough proportion to the heating requirements (#1 well pump is equipped with a variable-frequency drive) and that the booster pumps are operated more or less continuously in the heating season along with the unit heater motors, a total electricity consumption of 1,500,000 kWh per year would result. At a cost of $0.045 per kWh, this would amount to approximately $67,500 per year.

Regulatory/Environmental Issues: Geothermal fluids in Utah are regulated as “a special kind of underground resource.” The use of or injection of the fluid constitutes a beneficial use of the waters of the state and as such water rights are required from the State Division of Water Rights. In addition, rights to a geothermal resource or fluids are based upon the principle of “correlative rights” conveying the right of each landowner to produce his equitable share of underlying resources. Well construction and permitting is regulated by the Division of Water Resources of the Department of Natural Resources. Because all of the facilities fluids are injected no special environmental permits associated with disposal are required.

Problems and Solutions: Despite the very large size of this system, operation has been very reliable over the nine years it has been in operation. In general, the early problems were in the area of hardware and the more recent problems have been associated with the resource. The initial design of the system was based upon the use of plate heat exchangers to isolate the heating system from the geothermal fluid. Due to slow system response time, these heat exchangers were removed from the system in 1995. Since that time, geothermal water has been used directly in the heating equipment (primarily EPDM tubing). The relatively benign nature of the water (approximately 1100 ppm TDS, pH 8) has resulted in few problems. One area that was troublesome was that of control valves. These valves are used throughout the system to provide temperature control for individual zones in the ranges. Numerous failures of standard valves were experienced due to exposure to the geothermal water until replacement valves were coated internally with teflon. Well pumps encountered less than acceptable service life early on. In an effort to reduce failures in the bowl assembly, bearing lengths were increased and the result has been a typical service between overhauls for the pumps of approximately six years.

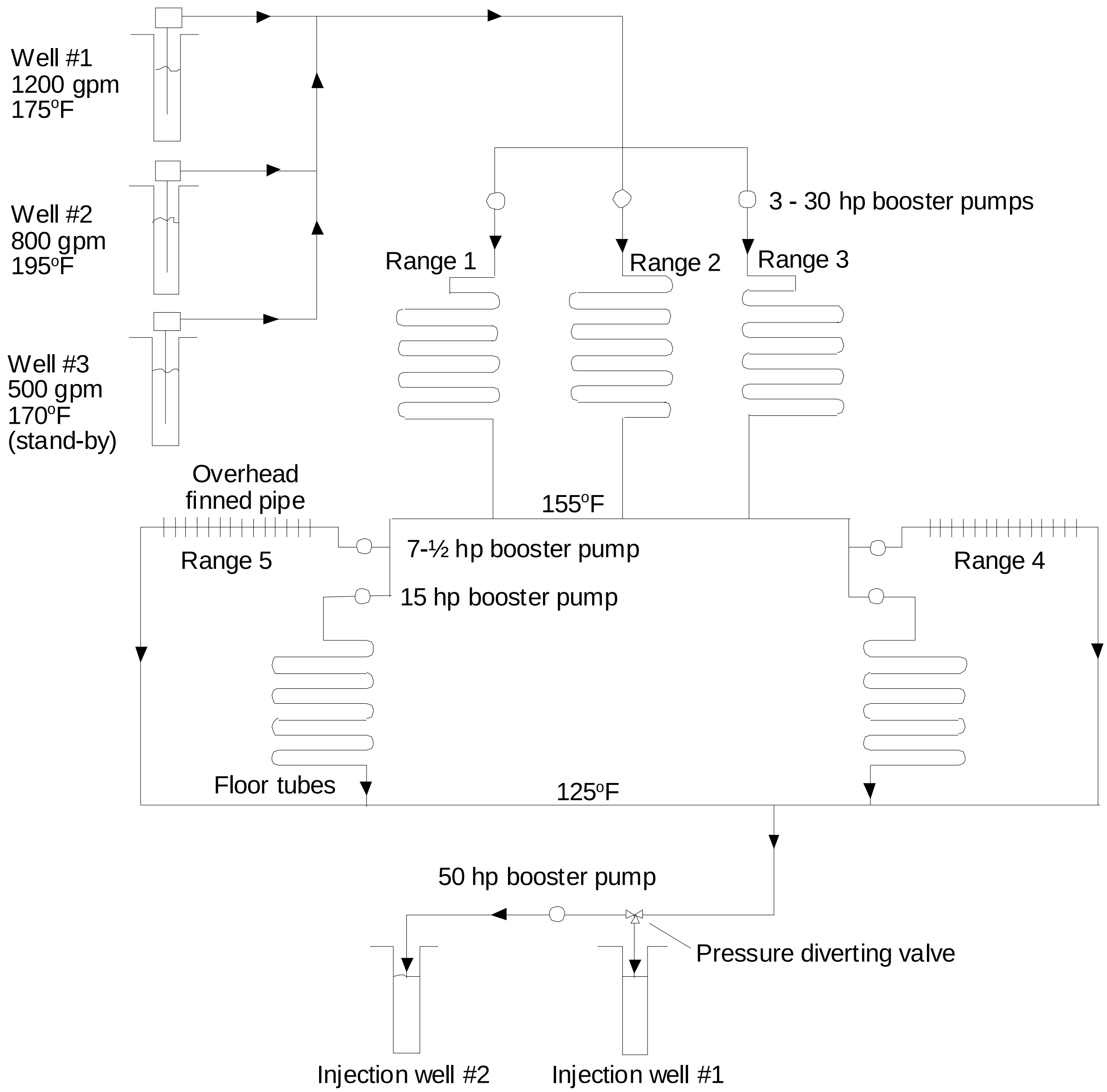
More recently problems have centered on wells and possibly the geothermal resource itself. An injection well was installed in 1993. This well was initially able to accept most of the system effluent however it periodically was necessary to pump the well to re-establish it’s ability to accept water. In addition, this well did not have a sufficient enough surface seal to prevent water from migrating up along the casing to the surface. This caused erosion of the area around the well head. Eventually this well’s capacity was reduced to the point that it would not accept a significant flow. A new injection well was drilled in 2002 several hundred feet north of the existing injection well. It is not clear at this point how much water this well will be able to accept.

Production from well #2 has recently decreased by approximately 30%. It is not clear what the reason is for this since water level measurement facilities are not available in the wells. There has been some decrease in static levels (thought to be about 12 ft) but this should not be sufficient to eliminate key production zones. As a temporary measure, a pipeline is being installed to transfer water from another Milgro well located east of the wells #1 and #2. Production wells #1 and #2 have experienced drops in temperature of approximately 10^{o}F in the recent past. It is thought that the reduced flows and temperatures may be related to the ongoing drought in the area and the lack of complete injection of system effluent. These issues are the subject of ongoing work at this writing.

Conclusions: The Milgro-Newcastle greenhouse is one of the largest and most successful direct use applications in the country. The recent issues associated with the well performance are at least in part related to the substantial and rapid growth that the operation has undergone. It is expected that through careful monitoring and design, the local resource will be capable of supporting the existing and planned facilities well into the future.

References:

Blackett, R. E., 2001. "Newcastle Utah Small-Scale Geothermal Power Development Project." Report to NREL for Phase I Task II - Preliminary Well Development. Utah Geological Survey, Southern Regional Office.



KAH-NEE-TA SWIMMING POOL
WARM SPRINGS, OREGON

Location: The Kah-Nee-Ta swimming pool is located on the Confederated Tribes of Warm Spring Reservation in north-central Oregon south-east of Mt. Hood. The 600,000-acre reservation was formed in 1879 and settled by Paiutes, Warm Springs and Wasco tribes. The swimming pool is located adjacent to the Warm Springs River, a tributary of the Deschutes River. The resort was started in the early 1960s, and in addition to the swimming pool includes a lodge, an RV village with condos and tepees, and more recently, a gambling casino. A flood in February of 1996 cause major damage to the RV park and pool area, but they were rebuilt and available for use in 1997. Additional details can be found at their website: www.warmsprings.com.

Resource: The resource is located on the eastern flank of the Cascades, where there are numerous hot springs such as Breitenbush, Bagby and Austin.   Warm Springs is located east of these springs in the Columbia River basalts. These springs are associated with a high temperature resource and issue from north-south trending fault systems. The seven warm springs have been used by the local Indians for centuries. Today, the warm spring, on the banks on the Warm Springs River, produce about 400 gpm at 128^{o}F and are used to heat the swimming pool,   None of the other facilities on the resort/casino area are heated by geothermal energy due to the limitation on the flow rate from the springs. Piping hot water to the casino would require about a 1.5-mile pipeline with several 100 feet in elevation gain.

Utilization: Spring water at 128^{o}F is gravity fed from the warm spring adjacent to the river. The water flows first into a small concrete holding tank with capacity of 1,400 gallons (6x6x5 ft), and then into a larger one of 54,000 (30x30x8 ft) gallons, both located in the basement of the pool building. An overflow goes into a sump and then to the drain, dechlorinator and finally into the Warm Springs River.   From the smaller holding tank, the water at 128^{o}F is pumped through a filter and then through a brazed plate heat exchanger. The secondary side of this heat exchanger goes into a 400-gallon storage tank from which hot water is fed to the showers. Cold water, piped over the mountain from the water treatment plant at 52^{o}F is used to cool the shower water to 100^{o}F and in summer, used to cool the pool water. From the larger storage tank water at 125°F is pumped by three 20-hp pumps in parallel through a sand filter and chlorinator to the hot tubs and outdoor swimming pools. The two hot tubs are kept at 103°F and the 530,000 gallon outdoor pools are kept at 90 to 94°F, depending upon the season. The waste water from the hot tubs, pools and showers are then fed through the dechlorinators and disposed in the Warm Springs River. Finally, from the smaller holding tank, water is pumped through a sand filter into three indoor tubs in the Wanapine Spa which are kept at 103°F. Water is also pumped to the Tribal Bath House, for exclusive use of the tribal members, and to the Necsha Cottage, the larger rental facility on the grounds. Waste water from these three uses is again piped through the dechlorinator and into the river. The overflow rate from the smaller concrete tank is controlled by a temperature sensor between the overflow line valve to the sump which feeds into the waste water line.

The entire complex has a peak usage of 6.8 million Btu/hr for an installed capacity of 2.00 MWt. The annual use is estimated at about 30 billion Btu with a saving of around $400,000 compared to natural gas.

Operating Costs: Annual operating costs consist of two items: 1) electricity cost to run the various pumps, and 2) maintenance and chemical costs. The pumping cost for about 95 hp of circulation/booster pumps is estimated at $30,000 per year. The annual maintenance costs ($10,000), chemicals for the chlorinator and declorinator ($50,000) , and salary for one part-time maintenance worker ($15,000) is estimated at $75,000.

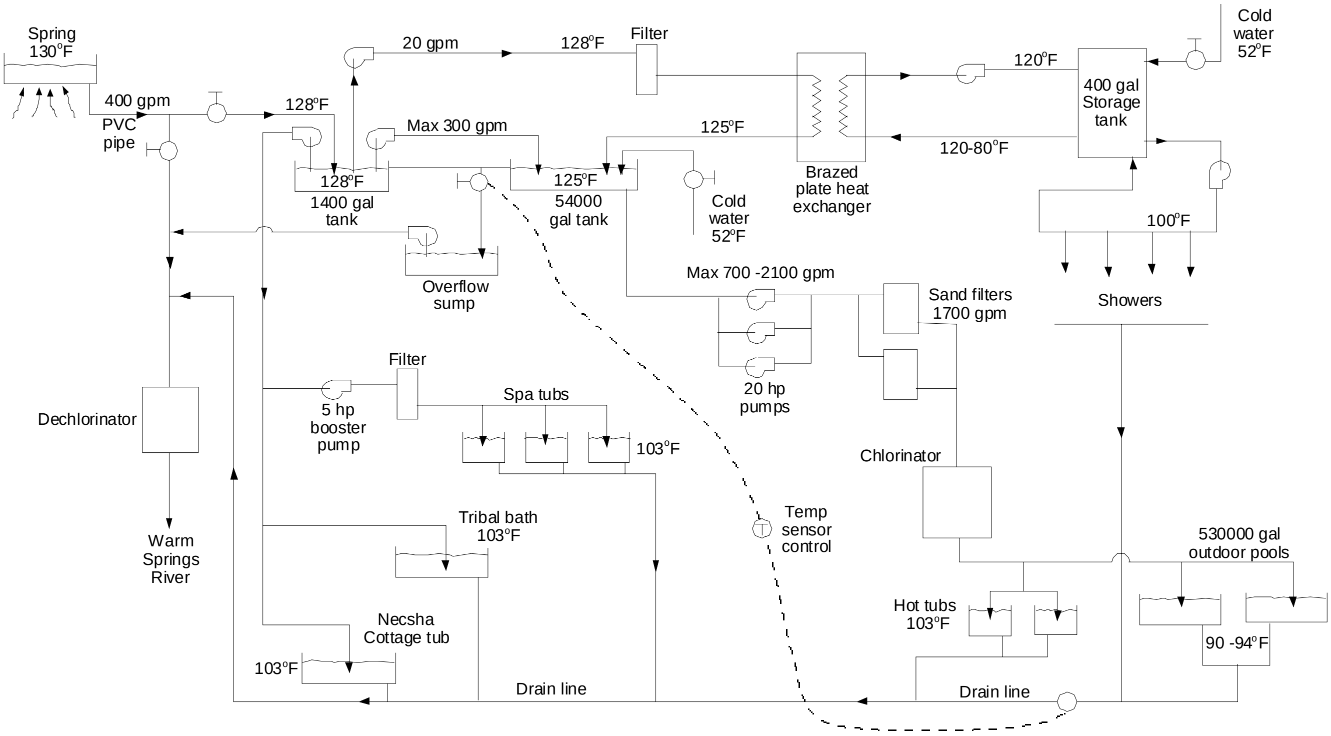
Regulatory/Environmental Issues: Since the facility is on reservation land, the tribes are their own steward. They, however, use the federal EPA standard concerning discharging the waste water into the Warm Springs River. This is accomplished by having a dechlorination filter at the end of the disposal line. The standards set by the tribes are higher than that required by the Oregon DEQ. One of the main concerns is the resortation of trout, steelhead and salmon to the river.

Problems and Solutions: Initially there were problems from iron oxide and algae depositions in the water. With the installation of the sand filters, this problem has been solved. After the 1996 floods they considered providing radiant floor heating to the service buildings adjacent to the pool along with heating the concrete slabs in the tepees; however, there was not enough flow to accomplish this. As mentioned above, piping hot water to the lodge/casino complex would require a 1.5-mile line pumping water uphill, which was not considered economical.

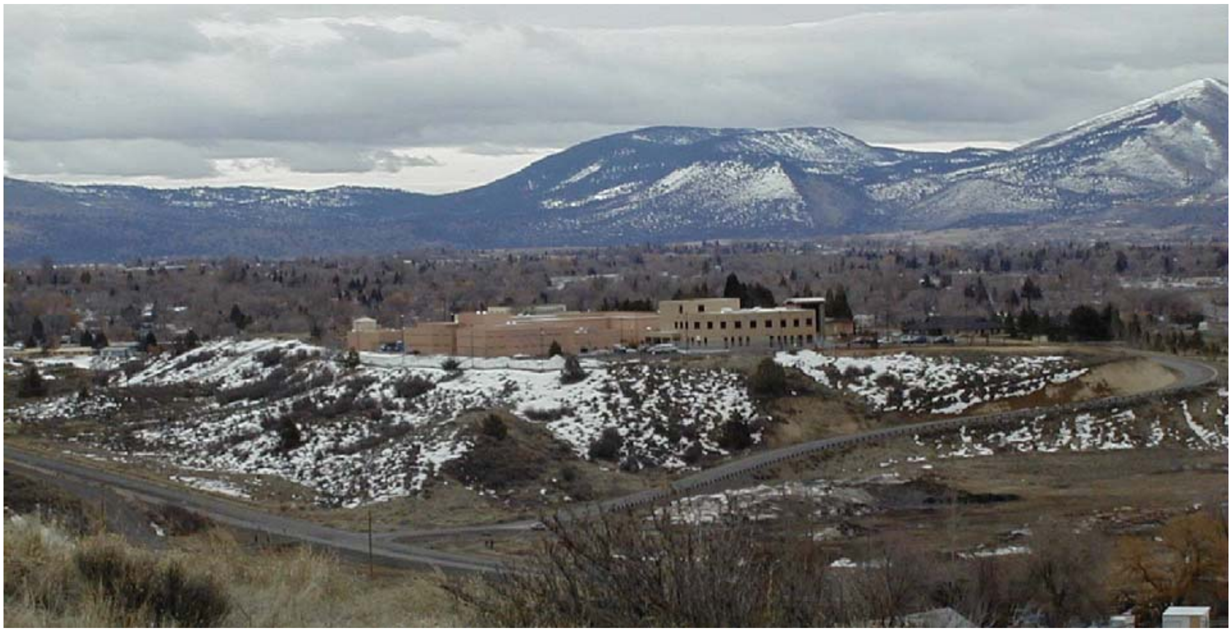
Conclusions: Even though the pool geothermal system is somewhat complicated, they appear to be using the heat at a minimum cost. In the future, they should consider supplying heat to the adjacent buildings.

References:

Oregonian Newspaper, Travel Section, June 8, 1997. "Kah-Nee-Ta: A Spirit of Survival." Portland, OR, pp. T1-T2.


Spring
130°F
400 gpm
PVC pipe
128°F
20 gpm
128°F
Filter
Brazed plate heat exchanger
120°F
400 gal Storage tank
Cold water 52°F
Max 300 gpm
125°F
120-80°F
128°F
1400 gal tank
125°F
54000 gal tank
Cold water 52°F
100°F
Overflow sump
Max 700 -2100 gpm
Sand filters 1700 gpm
Showers
20 hp pumps
Dechlorinator
Filter
5 hp booster pump
Spa tubs
103°F
Chlorinator
Warm Springs River
Tribal bath 103°F
Temp sensor control
530000 gal outdoor pools
Hot tubs 103°F
Necsha Cottage tub
90 -94°F
103°F
Drain line
Drain line

KLAMATH COUNTY
VANDENBERG ROAD COMPLEX



Location: The Klamath County Vandenberg Road Complex is located on the eastern edge of Klamath Falls in south central Oregon. Elevation at Klamath Falls is approximately 4,100 ft and the climate is characterized by an annual total of 6,500 heating degree days. The complex is on a hill top about 100 ft higher than the surrounding terrain and originally, somewhat isolated but some residential and businesses are recently developing nearby.

Resource: The complex well produces from the same aquifer as most of the other 550 wells in Klamath Falls. Geothermal water issues from northwest trending faults bordering the east side of town. Water flows in a generally southwest direction from the major faults cooling and mixing with surface water as it proceeds. Temperatures reach a maximum of 220^{o}F nearest the fault. At 151^{o}F, the well serving the complex is 10 - 15^{o}F warmer than nearby wells, but it is also deeper. Water chemistry is relatively benign with pH of about 8 and total dissolved solids of 800 - 1,000 ppm. Isolation heat exchangers are typically used since the water contains approximately 0.5 ppm hydrogen sulphide.

The county complex utilizes one production well 1,400 ft deep. The original pump test produced 760 gpm of 151^{o}F water with a drawdown of 38 ft. A note on the pump test report reads “Well is capable of pumping more water. We need a larger test pump.”

Water is injected into a 1,154-ft deep well that tested 210 gpm at 134^{o}F with no measurable drawdown.

Utilization: The history of the complex is somewhat sketchy. Some of the drawings and most of the mechanical specifications for the buildings kept by the county were lost or misplaced after the September 1993 6.0 earthquake. County building and engineering departments were moved and split up several times because their offices were badly damaged and temporary offices were utilized.

Work at the site started on August 10, 1960, when a cable tool well drilling rig was moved in. The well, now the injection well above, was completed as a production well at 1,154 ft on June 10, 1961. A second well, the original injection well, was completed in October 1962 at 205 ft and accepted 75 gpm with water level raising from 130 ft to 82 ft below the casing top.

The Juvenile Detention Home, located near the wells, was the first building at 18,300 sq ft. It was occupied in late-1962. The home had radiant floor heating and domestic hot water supplied by tube-and-shell heat exchangers. The well was equipped with a 7 ½-hp 88-gpm submersible pump set at 150 ft.

In 1954, the County Health Department building, about 5,500 sq ft, now the County Sheriffs Office, was occupied. The building had two heating air handlers (no cooling) supplied from a hot water boiler, probably oil-fired.

About 1974, the Mental Health building at 3,880 sq ft was built. The heating system is believed to have been one or more oil-fired forced-air furnaces. About the same time, there was a small, about 600 sq ft, addition to the Juvenile Detention Home. Heating was by radiant floor utilizing the existing system.

In 1979, the Oregon State University County Agriculture Extension Office was built. The building was 8,440 sq ft, and had eight air-source heat pumps for heating and cooling.

In 1982, drawings for the retrofit of the well house for the Juvenile Home called for replacement of the tube-and-shell heat exchanges with a plate-and-frame exchanger, connection to existing underground insulated piping to the Health Dept., Mental Health and Extension buildings, and the addition of a plate-and-frame exchanger and cooling tower, a four-pipe system. These drawings show a fluid coupling variable-speed drive on the wellhead. It appears that some time earlier, the Juvenile Home radiant floor system had failed and been replaced by four fan coil units, and the County Health, Mental Health and Extension Offices had been converted to geothermally-heated four-pipe heating and cooling system. It is believed the fluid coupling and motor were 25-hp, but no records could be found.

In 1988, the new well for the then proposed County Jail was completed (above) at 1,400 ft and 151°F. The well was located off the hill and nearer known higher temperature wells, but does require about 100 ft of lift from the well to the buildings, about 200 ft total lift at current flow rates (100 ft pumping level).

The County Jail, 42,600 sq ft, was completed in 1990. The production well serving the Juvenile Home, County Health, Mental Health and Extension Offices converted to an injection well and the entire complex supplied from the new well. The system schematic is shown. Flows shown are peak design from drawings and are probably never that high. The jail has six fan coils, reheat boxes and unit heaters supplied from a main stainless steel plate heat exchanger. A separate heat exchanger supplies hot water for showers, kitchen, laundry, etc.

The Community Corrections Center, 19,500 sq ft, was occupied in 2003. The heating is provided by two large air handlers with hot water coils and a number of reheat boxes. The building is supplied from the main heating heat exchanger in the jail’s mechanical room.

In January of 2004, a 9,000-sq ft addition to the Juvenile Home was occupied. The heating system utilizes two fan coils and reheat boxes supplied from the heat exchanger outside the home.

Currently, the total building area is just under 100,000 sq ft with future additions in planning stages. The design peak load is unknown; since, most of the specifications are not available, but is estimated at approximately 5.6 million Btu/hr plus domestic hot water. A totalizing flow meter indicates the average flow for the year of 207 gpm. The pump motor is on a variable-frequency speed control, but the control system is not yet completed so it is on manual control. There are, however, flow control valves at the mechanical room responding to heating requirements. Monthly average flows vary from a high of 325 gpm down to 116 gpm.

Operating and Maintenance Costs: Practically nothing is known about operating and maintenance prior to the current maintenance staff, about 10 years. It is believed the submersible 7 ½-hp pump was repaired or replaced at least once, perhaps twice. The 25-hp variable-speed drive and pump were probably never repaired or replaced, but their life is unknown.

The existing heat exchangers in the jail mechanical room were cleaned about 1995 when it was noted that the pressure drop across the exchangers had increased. At that time, corrosion products from the well were found in the exchangers geothermal side. There was also some scale buildup on the clean water side assumed to be from lack of corrosion/scale inhibitors in the closed loop. Shortly thereafter, pressure drop across the exchangers began to increase again and it was apparent the pump needed to be pulled and repaired. It was also obvious that the 120-hp motor, variable-speed fluid drive and 12-in. pump bowls were oversized for the existing load; so, it was decided to replace them with a smaller pump and variable-frequency drive.

On pulling the pump, it was found that about 100 ft of pump column was corroded. The 120 ft below the pumping water level and the pump were in good shape.

In August of 1997, the pump was replaced by a 9LA 14-stage pump with 9-in. bowls, 100 ft of new column, new shaft, oil tube and bearings, and a 60-hp motor with variable-frequency speed control. Although the shaft, oil tube and bearings were in good condition, the new pump required a smaller shaft; so, the assembly was replaced. The pump was salvaged and put in service without repair in an irrigation well, where it remains today. Total cost was $37,492.50.

At the same time, the jail mechanical room heat exchangers were cleaned and new gaskets installed. Total cost was $2,300. The exchangers are currently (February 2004) in good condition with no leaks.

As noted above, the DDC controls for the jail have not been completed; so, the pump is on manual speed control at about 40% speed. Immediately after the new pump was installed, total power costs for the jail were over $1,000 less per month. Since there were no other changes, it was attributed to the pump–a simple payback of less than three years.

At the time the pump was installed, an electricity meter was installed on the pump with the thought of charging individual buildings a share of pumping costs based on building size. This never occurred;

however, the use was recorded over 19 months, August 1997 - March 1999. At current electricity cost, the average cost per month would be $953.

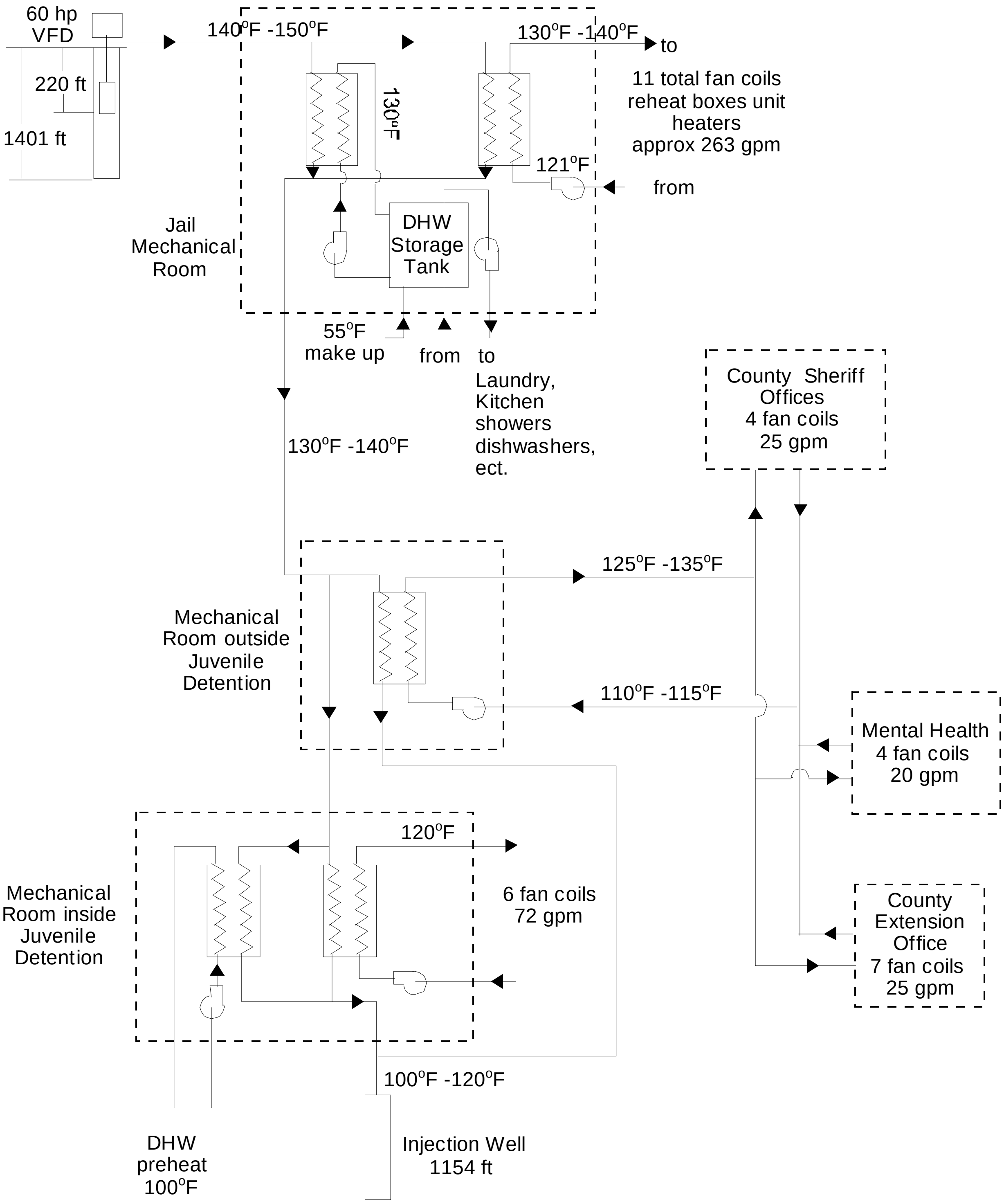
Totaling the gallons pumped for the same months (albeit different years) and assuming a temperature drop of 30°F, the cost of natural gas replaced by geothermal would be $18,500 per month.

Regulatory/Environmental Issues: There have been no problems. Drilling low-temperature geothermal production and injection wells in Oregon requires only a start card and completion report (depth, lithology, water bearing zones, casings); unless, it is in a critical water area. The system was designed to meet the city ordinance geothermal injection requirement.

Problems and Solutions: Aside from the oversized pump and corrosion of the pump column noted above, the only problems have been with the outdated pneumatic controls. These are being converted to DDC also as noted.

Conclusions and Recommendations: The original 120-hp pump was grossly oversized. It was sized either based on the maximum well capacity or plans to greatly expand the facilities, which never came to fruition.

The system has operated without any major problems for some 40 years and grown over 5 ½ times the original size, while changing system configuration as growth required. Currently, the system is saving $210,000 in operating cost per year.


60 hp
VFD
220 ft
1401 ft
140°F -150°F
130°F
130°F -140°F
to
11 total fan coils
reheat boxes unit
heaters
approx 263 gpm
121°F
from
Jail
Mechanical
Room
DHW
Storage
Tank
55°F
make up
from
to
Laundry,
Kitchen
showers
dishwashers,
ect.
130°F -140°F
County Sheriff
Offices
4 fan coils
25 gpm
125°F -135°F
Mechanical
Room outside
Juvenile
Detention
110°F -115°F
Mental Health
4 fan coils
20 gpm
120°F
Mechanical
Room inside
Juvenile
Detention
6 fan coils
72 gpm
County
Extension
Office
7 fan coils
25 gpm
100°F -120°F
DHW
preheat
100°F
Injection Well
1154 ft

RESIDENTIAL DOWNHOLE HEAT EXCHANGER
KLAMATH FALLS, OREGON

Location: Klamath Falls, Oregon is located on the western edge of the Basin and Range physiographic province on the east flank of the Cascades approximately 30 miles north of the California border. It is located in a graben structure about 10 miles wide flanked by horst blocks rising over a 1,500 feet with steeply dipping normal faults trending in a northwest-southeast direction. Upper Klamath Lake, a shallow body of water about 35 miles long, dominates the graben.

Resource: Geothermal wells and springs are widespread in the Klamath Falls area. The springs were prevalent over 100 years ago and were used by the Indians and early European settlers. However, due to pumping from wells, all of the springs no longer flow on the surface. Today more than 500 hot water wells have been drilled in the area, most of which are located along the eastern edge of the graben taping into the upflow zones along the fault system. Hot water, heated at depth, migrates up along these fracture zones and then flows southwesterly in permeable zones of volcanic cinders and fractured lava flows. Wells were drilled in the area, starting around 1930, to provide space heating for local residences using downhole heat exchangers (DHE). These DHEs consist of a closed loop of pipe in the well with city water in them extracting heat from the well water. The DHE conserve the resource by extracting only heat from the well water, and can provide space heating and domestic hot water to individual homes, several homes or even schools and businesses in the area. A typical residential well can provide up to about 250,000 Btu/hr (0.1 MWt) of energy, and installations with multiple DHE, such as for schools, provide about 10 times this amount of energy. Well depths in the city vary from 100 to 1,800 feet, with 300 feet being the average. Temperatures vary from 120 to 220^{o}F, with 140^{o}F and above considered desirable for providing sufficient energy using a DHE.

Utilization: The DHE example selected from Klamath Falls serves two residences from a single well. The system design is fairly simple, but typical of others in the city that provides both space and domestic hot water heating. The well is 200 feet deep, with a temperature of 196^{o}F at the top, and 204^{o}F at the bottom (when drilled). The static water level is 75 below the casing top. The well was drilled in 1954 and cased to the bottom with a 10-inch diameter casing, which is perforated just below the water surface and at the bottom of the well in the live water area. The perforations are about 0.5 inches wide and 6 inches long for a total distance of about 15 feet at each location. The casing is sealed with cement from the surface down to 21 feet, and then the annulus is open below this point providing about a 1-inch clearance. The perforations and opening between the casing and wellbore allows a vertical convection cell to develop, bringing the hotter water from the aquifer (live water zone) at the bottom to the top.

Originally there were four DHEs in the well, two 2-inch diameter closed-loop pipes for the space heating and two 3/4-inch diameter open loop pipes for the domestic hot water heating--one set for each home. After 19 years of service (1974), the black iron pipes were replaced due to corrosion at the water line. The two 2-inch diameter heating loops were replaced with a single 2.5-inch diameter heating loop which is now shared by both homes. Since the domestic hot water is a consumptive system, the two loops for this system were retained.

The space heating system consists of baseboard hot water radiators on a two-pipe system with flow control valves on each heating unit. A motorized valve on the return leg of the heating loop controls the flow via a thermostat. Recently, a solid state controller hooked to a storage battery was installed in case of a power failure. A 10-gallon expansion tank is connected to the high point in the heating system, and pressure reducing and relief valves are part of the cold water supply line used to initially fill the heating loop. City water is also provided to the domestic hot water loops in an open system. There is no storage tank for the domestic hot water, and there is also no circulation pump on the space heating loop, as the circulation is produced by normal thermal syphoning.

The estimated utilization of the system for both houses is about 164 million Btu/yr (48,000 kWh). The maximum capacity of the well is probably 10 times this utilization, but obviously it has not been plumbed or tested to this amount, which depends upon the aquifer flow and efficiency of the vertical convection cell.

Operating Cost: The original cost of the well was $2,400 and $800 for the DHE for each house. Thus, each homeowner paid about $2,000 for the system. At today's prices, the well would cost around $10,000 and $3,000 for the three DHEs. The annual O & M cost are only for the electricity to run the motorized valve and the equivalent annual cost of replace parts of the DHE on about a 25- year interval, amounting to probably less than $100 per year. The estimated annual heating and domestic hot water cost for the two homes at about 4,500 sq ft total of heated space using natural gas would be about $1,800 per year or $2,900 per year for electricity, plus $5,000 for the capital cost of two furnaces and hot water heaters. This would give a simple payback of five and three years, respectively.

Environmental Impact: Initially, to prevent corrosion of the DHEs at the water-air interface, several pounds of paraffin were placed in the well. This was considered a pollutant to the groundwater; thus in 1974, after the DHEs were replaced, a steel plate was welded to the top of the water to limit air (oxygen) entering the wellbore. This is the recommended procedure today.

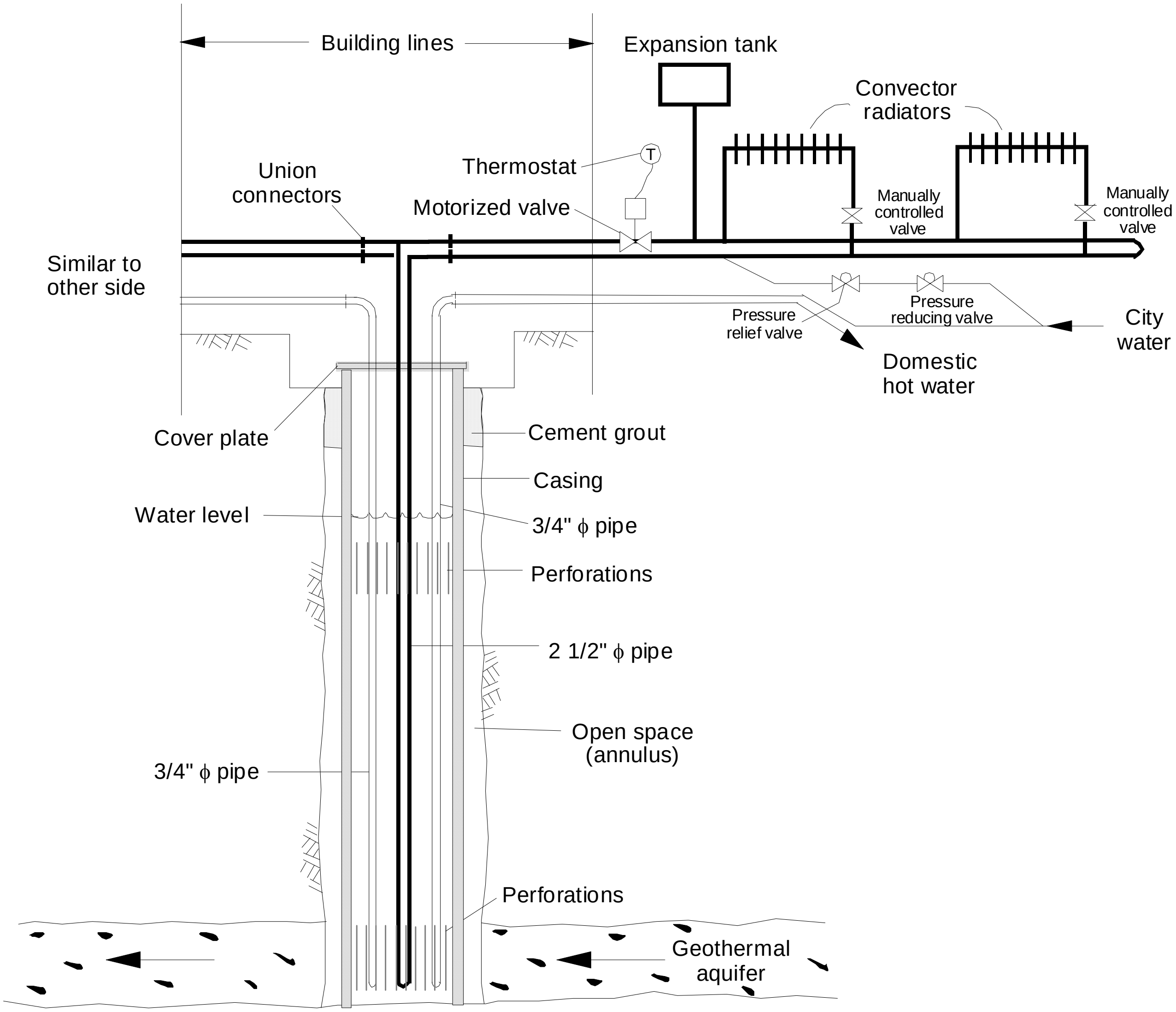
Regulatory Issues: Drilling a geothermal well with less than 250^{o}F temperature is under the jurisdiction of the Oregon Department of Water Resources (DWR). Wells that exceed this value are under the jurisdiction of the Department of Geology and Mineral Industries (DOGAMI). A drilling log must be filed by the driller to the state (DWR) once the well is completed. The well casing must also be sealed from the surface down to competent formation or to 21 feet below the surface. The City of Klamath Falls passed an ordinance in 1990 to prevent the dumping of geothermal water in the storm sewer or waterways – all water must be reinjected into the same aquifer. Since only heat is removed from a well using DHE, this ordinance does not apply.

Problems and Solutions: The only major problem was the corrosion of the DHEs at the air-water interface. These were replaced in 1974 at a cost of about $500. The homeowners were able to save on purchasing new pipe, as the two space heating DHEs, were replaced with a single DHE. There has been no corrosion problems since this date. Typical life of DHE in Klamath Falls wells average 14 years. Recently, the pressure reducing and pressure relief valves on the city water supply side connected to the closed loop DHE had to be replaced; as, they were causing high pressure in the system, producing leaks.

Conclusions: This system has been operating with few maintenance problems and low annual costs. This is an ideal configuration providing the resource temperature is at least 140^{o}F. It also conserves the resource as only heat is removed from the water. The design of these system is extremely simple; however, more complex systems can be found in the city and are documented in the reference below.

References:

***Geo-Heat Center Quarterly Bulletin*, Vol. 20, No. 3 (September 1999). "Downhole Heat Exchangers," Klamath Falls, OR, 28 p. (available on the GHC website: http://geoheat.oit.edu/bulletin/bull20-3/bull20-3.pdf).**


Building lines
Expansion tank
Convector radiators
Union connectors
Thermostat
T
Motorized valve
Manually controlled valve
Manually controlled valve
Similar to other side
Pressure relief valve
Pressure reducing valve
City water
Domestic hot water
Cover plate
Cement grout
Casing
Water level
3/4" ϕ pipe
Perforations
2 1/2" ϕ pipe
Open space (annulus)
3/4" ϕ pipe
Perforations
Geothermal aquifer

REACH, INC. JUNIPER PROCESSING PLANT
KLAMATH FALLS, OREGON

Location: REACH (Rehabilitation, Employment and Community Housing) Inc. (in the buildig formerly occupied by Maywood, Inc.) is located just outside the Klamath Falls city limits. REACH is a non-profit organization which has found a niche in the specialty area of the selective and environmentally-friendly removal of juniper and also finding uses for the entire tree. They are currently planning on expanding operations in the building such as adding two drying kilns. The 110,000 sq ft building was constructed in 1976. REACH has been in the building since 1993 and incorporates vocational-rehabilitation programs with their workforce. About a third of their gross income is from mill work and a third from the juniper products.

Resource: Klamath Falls is located on the western edge of the Basin and Range Physiographic province, and is situated in a graben structure. Geothermal waters upwell along faults to the northeast as high as 220°F and then flow down gradient to the southwest. REACH is located in this outflow zone where the water is cooler.

REACH is served by a single production well, 1520 ft deep, which had a temperature of 118°F when drilled. The well was pump tested at a flow of 320 gpm with a 115 ft drawdown. The maximum flow rate for the pump is 535 gpm. This is the lowest temperature well in Klamath Falls for direct-use. The well is currently producing at 105°F.

Utilization: The well located adjacent to the building has a 75 hp motor running a lineshaft pump. The system is operated from approximately October to April, 24 hours a day. The original system was designed by Balzhiser and Colvin Engineering with nine air handling units (378,000 Btu/hr) and four make-up air handlers (1,856,000 Btu/hr). Because Maywood had a large number of machines with high air volume dust collectors, a large amount of make-up air was required. The nine air handling units have a four-pass coil system (106” x 27", 14 fins/in) and the four make-up air handlers have an eight-pass coil system (83" x 30", 14 fins/in). There have been two smaller HVAC systems installed for the office and a small fan coil unit installed in the shaver room that has been added to the building. The system was installed with pneumatic controls.

The geothermal water is run directly through the system. The system currently utilizes only four air handlers since REACH has fewer machines generating less dust; so, the make-up air heaters are not required. The two office units and the fan coil unit are being used at this time. The water enters the system at about 105^{o}F and is then discharged to a drainage ditch at 95^{o}F. The drainage ditch combines with the Klamath County Maintenance shop geothermal discharge water which will end up in Lake Ewana. The system has a parallel flow with supply and return lines.

Operating Costs: There are several costs associated with operating the system: 1) city water used to cool the oil in the fluid coupling system, 2) maintenance of the pump and replacing of the coils in the system, and 3) electricity to run the pumps. The costs for the water and electricity are not separated out for the system, but an estimate can be made.

They use about 114,100 ft^3 of water per heating season for cooling the oil in the fluid coupling system which has an annual cost of about $970. They use approximately on average 1000 kWh/day of electricity more during the heating season, which could be attributed to the running of the pump. If the system is run for eight months out of the year, we can assume they use 240,000 kWh for the heating system for a cost of $16,000. The cost of the electricity is approximately $.07/kWh. The total operating cost for the system is, therefore, almost $17,000.

They replace either one or two coils a year with cost of about $6,000 per coil including labor. This would make a maintenance cost average of $9,000 per year.

It has been estimated that the well pump has been pulled twice since it was first installed. The impellers were replaced at a cost of $12,000, but there is no information about additional repairs at those times.

Regulatory/Environmental Issues: Since the system is located outside the city limits of Klamath Falls, REACH is not required to reinject the geothermal fluid after use. The geothermal is surface disposed of to a ditch which combines with the County Maintenance discharge, which then flows to Lake Ewana.

They obtained an Industrial Geothermal Permit in January 2004 from the Department of Environmental Quality (DEQ). This permit authorizes them to discharge their spent geothermal fluids into the waters of the state while they are in compliance with all the requirements, limitations, and conditions set forth in the permit. The parameters and limitations they must meet are:

Flow	shall not exceed the natural geothermal source flow

Temperature	shall not exceed the geothermal source temperature
pH	shall be between 6.0 - 9.0
Other Pollutants	no biocides or water treatment chemicals shall be discharged

All of these measurements are to be taken monthly and a report submitted at the end of the calendar year to DEQ.

Problems and Solutions: Since they are using the geothermal water directly in the system, this has been causing corrosion problems in the coils. They run the system at 20 psi for that is all the pressure the coils can handle without leaking. When REACH bought the building, there were replacement coils left in the building: thus, they have not bought any new coils since they started operation in the building. Due to the corrosion of the coils, they are only running 3 or 4 heaters at a time. They do not use the make-up air handlers as the coils will clog very rapidly. The pneumatic controls are also not working on the system.

Switching to a smaller variable-frequency pump ($36,000) with DDC system controls ($13,000) would greatly increase the efficiency of the system. The corrosion in the coils can be eliminated by placing a plate heat exchanger ($7,500) in the system as the geothermal water enters the building. This would allow clean city water to be run through the coils instead of the more corrosive geothermal water. This would mean that all the coils (9) should be replaced at the time the heat exchanger is installed. This would extend the life of the coils. They are looking into to ways to make the heating system more efficient.

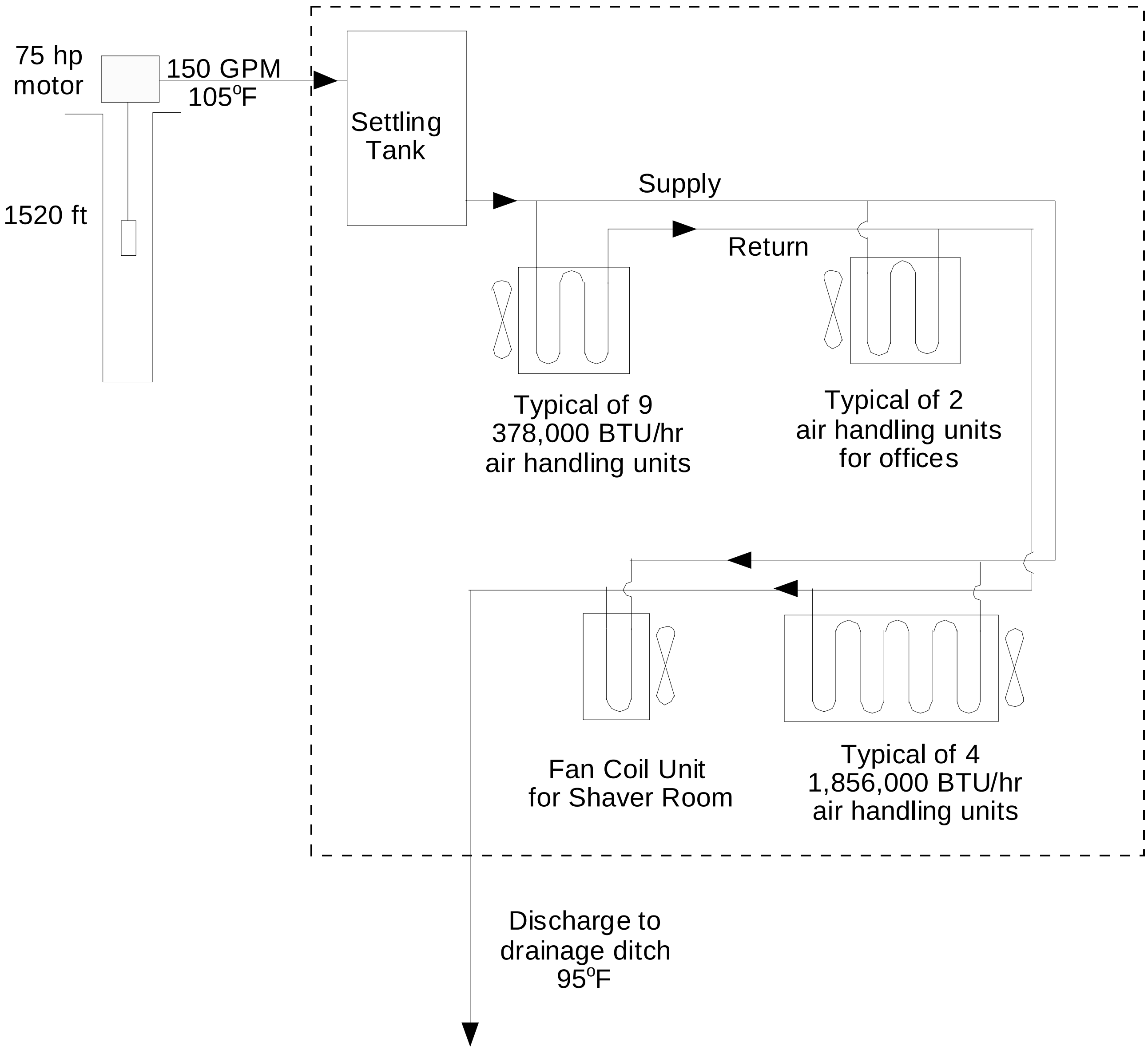
Since the well is only cased for the first 600 feet, it appears that some sloughing has occurred near the bottom, as the temperature has dropped from 118°F to 105°F.

Conclusions: The system seems to be supplying adequately heat to the building, as the workforce only needs about 60°F room temperature. However, an overhaul of the system including cleaning the well, appears to be necessary to make efficient use of the resource.

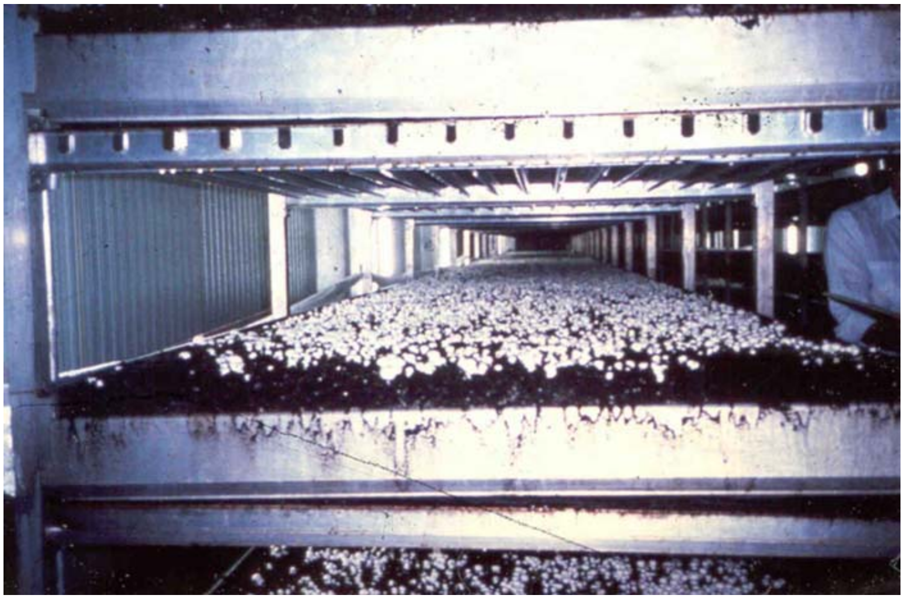
The present installed capacity is about 0.5 MWt, utilizing 8.2 billion Btu/yr at a savings of $75,000/yr (compared to natural gas).

References:

Lienau, Paul, 1976. "Maywood Industries of Oregon uses 118°F Well for Heating," *Geo-Heat Center Quarterly Bulletin*, Vol. 2, No. 2, p 3-4.


75 hp motor
150 GPM
105°F
1520 ft
Settling Tank
Supply
Return
Typical of 9
378,000 BTU/hr
air handling units
Typical of 2
air handling units
for offices
Fan Coil Unit
for Shaver Room
Typical of 4
1,856,000 BTU/hr
air handling units
Discharge to
drainage ditch
95°F

OREGON TRAIL MUSHROOMS, VALE, OREGON



Location: Oregon Trail Mushrooms is located on the east edge of Vale, Oregon, 15 miles west the Oregon-Idaho border. Elevation is about 2,240 ft. Winter temperatures reach -20°F and summer temperatures 100°F. The mushroom plant construction was financed through the USDOE Loan Guarantee Program and began production in 1986. Initially, 2,500 tons of white button mushrooms were produced annually. Production now includes other varieties and has increased to 4,000 tons annually. There are 130 employees year round.

Resources: Vale has long been known for its geothermal resources. There are several hot springs in the area. The mushroom plant is on the previous site of hot springs. A geothermally-heated greenhouse, and a slaughter house still utilizes geothermal hot water for cleaning and hog scalding. There was a large geothermal swimming pool and sanatorium just across the highway and several nearby homes also utilize the hot water. Temperature of 198.5°F with total springs flow of 20 gpm and a 140-ft well were reported by Russell in 1903. Today, wells that more accurately target the resources have temperatures above 220°F. In the hotter wells, pH ranges from 7.2 to 8.3, TDS is about 1,000 with SiO_2 74 to 113 ppm, Cl about 370 ppm and F 6.1 to 6.6 ppm.

The resource appears to be the result of deep circulating water rising along fractures in completely silicified sandstone and conglomerates along the Willow Creek fault zone. Although there is anomalous heat flow (at least 3 times the surrounding area) in an area about two miles wide and 10 miles long along the fault zone, the only surface manifestations and 29 wells are in an area of about 40 acres between the northern end of Reinhardt Buttes and the Malheur River (Gannett, 1988).

Utilization: 250 gpm of geothermal fluid at 220°F is pumped from one 250-ft deep well by an oil-lubricated vertical lineshaft 20-hp pump. A similar well with a 10-hp pump is available as standby. Geothermal fluid flows through two plate-and-frame titanium heat exchangers in series, which supply 213°F hot water to a 400-ton lithium bromide chiller and growing room where fan coil units are supplied with 191°F hot and 40°F chilled water via a 4-pipe system. The geothermal effluent is also provided to five homes for space and domestic hot water heating, a swimming pool located about one mile away in the city and to a corn dryer (in season), and/or injected into two injection wells.

The growing medium, a mixture of wheat straw, chicken manure, gypsum, alfalfa seed screenings and urea is composted off site and trucked to the plant. The compost is then moved by conveyor to one of three pasteurizing rooms; where, it is held for a 7-day controlled heating and cooling schedule. Maximum pasteurizing temperature is 140^oF. Air is forced through the compost via tunnels and grated floors. After pasteurization, the compost is moved to the growing rooms by conveyor. There are 42 growing rooms, each 20 ft wide, 85 ft long and 12 ft high with removable ends to facilitate conveying compost in and out. Compost is loaded into six shelves on either side of a corridor providing a growing area of 4,320 ft^2 per room. Spawn is added and the room is held at 80^oF and 94% relative humidity for 35 days when the first crop is harvested. Rooms are held at 64^oF and 94% relative humidity for a 21-day growing period during which three crops are harvested. Harvesting is done by hand. Temperature and humidity are closely controlled by a central computer system. After harvesting, mushrooms are sent to chill rooms for sorting, packaging and storage awaiting shipment. Chill and storage areas are cooled by centrifugal (electric) chillers.

The geothermal system provides about 5 x 10^6 Btu/hr (1.47 MWt) (depending on outdoor air conditions) and replaces about 430,000 therms of natural gas annually to the mushroom facility; plus provides heat for the homes, pool and corn drier.

<u>Operating Costs</u>: Operating costs for the geothermal system are minimal. Geothermal fluids are limited to the two heat exchangers and a small amount of piping. There have been no problems with the piping, but one set of pump bowls have been replaced since plant startup. Stainless steel plates in the heat exchangers were replaced with titanium and there has been no problems, not even cleaning since then. Maintenance personnel stated that it cost less than $500 per month to operate the chiller including maintenance and pumping, and that a chiller of equal duty would cost at least $500 per week.

<u>Regulatory/Environmental Issues</u>: None after obtaining production and injection well permits.

<u>Problems and Solutions</u>: Shortly after plant startup, it was noted that wells supplying the five homes, the corn drier and a slaughter house were declining in both water levels and temperatures. Oregon Trail Mushrooms obtained the water rights for the five home wells in exchange for a guaranteed supply of effluent water sufficient to meet their needs. They no longer have pumping nor pump and well maintenance costs. The corn drier owner maintains his rights, but agreed not to pump so long as he is supplied with sufficient effluent. All effluent ultimately is injected into Oregon Trail's injections wells. Since the homes and drier wells are not used, the slaughter house well has stabilized and the owner continues on his original system. The remainder of the 29 wells in the immediate area are not used.

As noted above, there were problems with the stainless steel heat exchangers leaking at the gaskets. Converting to titanium has solved the problem.

At plant startup, the temperature at the production wells was 228^oF. This has dropped to 220^oF, probably due to lower water levels allowing cool water intrusion from the river, the injection wells, or the other side of the fault where wells were historically cooler by 20 - 40^{o}F. The temperature drop caused a decrease in the capacity of the lithium bromide chiller. This was somewhat offset by running chilled water through the heating coils when cooling the grow rooms. Also, when a few of the coils needed replacing, higher capacity coils were installed. Now they plan to add more grow rooms–hence, the recent installation of a booster boiler in the closed chiller circuit. It has not yet been operated except for testing. Also planned are modifications to the piping to handle additional load and changing fan coils to increase efficiency.

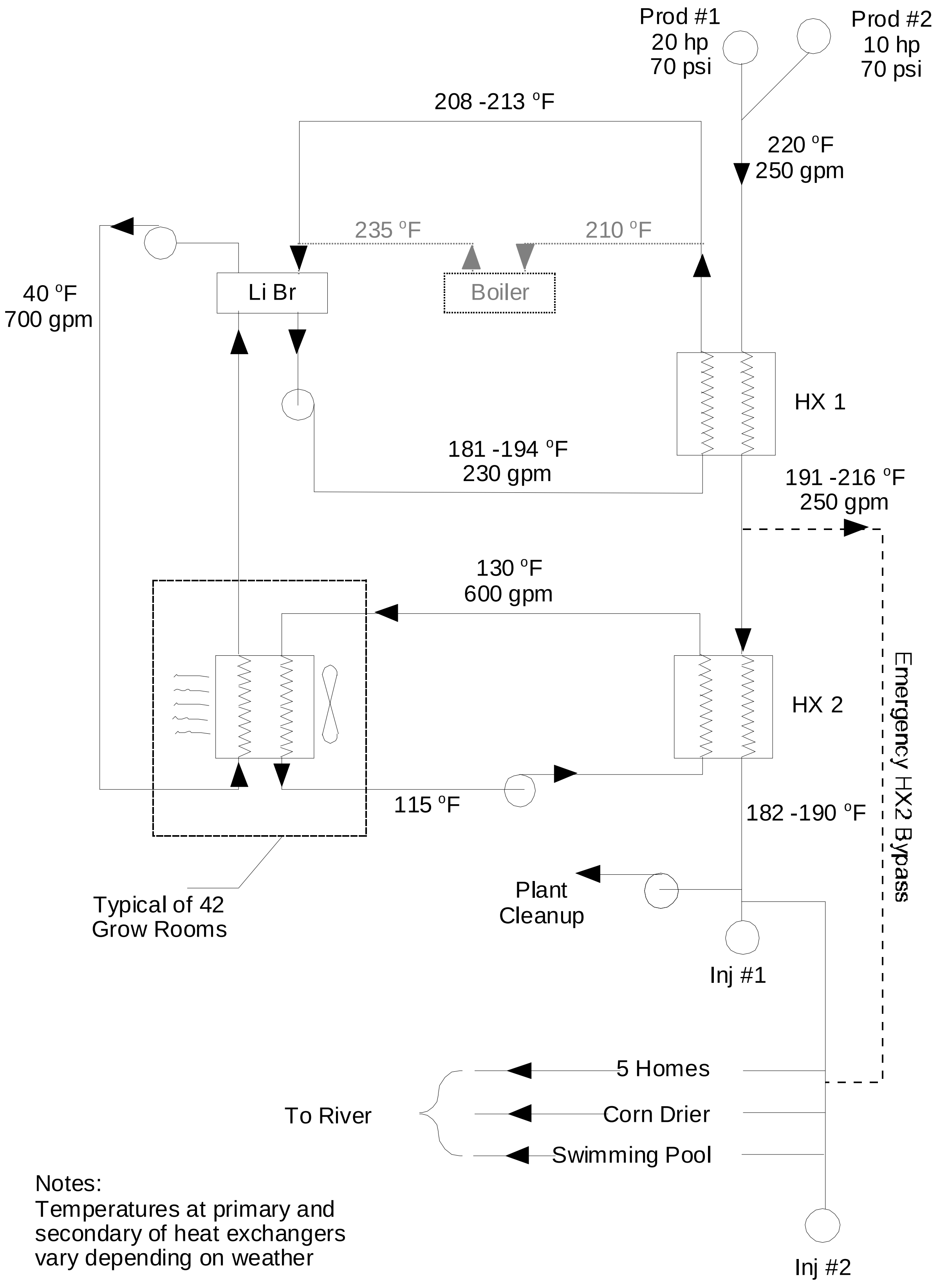
Conclusions: This is a very successful project that is the result of the USDOE Loan Guarantee Program. The plant has expanded and increased production since startup and continues to expand.

Lithium bromide chillers, while not common in geothermal applications, are economical where temperatures of 220^{o}F are available.

Where there is interference between wells of a number of owners and uses, reasonable people can probably reach an agreement that is beneficial to all.

References:

Gannett, Marshall W., 1988. "Hydrogeologic Assessment of the Developed Aquifer Near Vale, Oregon." State of Oregon Water Resources Department. Open-File Report No. 88-04.



Notes:
Temperatures at primary and
secondary of heat exchangers
vary depending on weather

FISH BREEDERS OF IDAHO INC.
HAGERMAN, IDAHO

Location: The aquaculture facility is located along the Snake River, approximately 30 miles northwest of Twin Falls, Idaho and near the town of Hagerman. There are also several greenhouse operations, hot springs spa/resorts and residential heating within about three miles in either direction along the river. Elevation is about 3,800 ft ASL and average annual temperature about 50°F. The operation began in 1973 after drilling the first well.

Resources: The resource is known as the Banbury Hot Springs area. Most of the wells are in an area about 10 miles long by one mile wide. The occurrence of thermal water in the area appears to be fault controlled. The better (higher flow and temperature) wells occur on the downthrown side of the fault. Temperatures range from 77 to 162°F. Water quality is generally good– pH 7.9 - 9.5, total dissolved solids 230 - 420 mg/l with higher temperature fluids having higher pH and TDS. Artesian heads range from slightly above, to 360 ft above, land surface. Based on heat flow data, depth of circulation to attain the highest temperatures in the wells is about 4400 ft and since most wells are only 420 - 700 ft deep, convective transport along faults is indicated. Probable maximum temperature based on geothermometers is about 195°F.

Fish Breeders of Idaho utilizes eight wells with temperatures ranging from 90 - 95°F. Most of the wells are about 500 ft deep–one at 1,100 ft hit the main flow at 500 ft, which increased very little in flow or temperature beyond that depth. Wells have shut-in pressure of about 40 psi (92 ft). Total flow is 6,000 gpm, but has declined to about 4,000 gpm as more wells have been drilled in the area. Seven of the wells are fairly high in the river canyon–the deeper 1,100 ft one being at the lowest elevation and has the lowest flow–only 200 gpm. It may have been drilled through the fault and into less fractured formation below the 500 ft depth.

Utilization: This site is ideal for warm water species. The wells (expect one) are near the top of the canyon; so, water flows down a quarter mile with an 80 ft drop. Raceways are interspersed with rocky brook-like channels that help add oxygen utilized by the fish.

Stocking starts with the water flow at the top with channel catfish, followed by lower oxygen tolerant blue catfish (350,000 - 400,000 lb/yr combined), to even more tolerant tilapia (100,000 - 200,000 lb/yr) near the bottom, then to settling ponds where solid waste is removed. More oxygen is added and water cooled in the rocky brook on its way to the river. Starting in 1994, in the lower portion, water is diverted to alligator houses (1,000 6-footers/yr) and outdoor ponds for 1,000 lb 10 - 14 ft breeding stock. The alligators are fed dead fish from this site and from the numerous nearby cold water fish farms (trout). Since the fish are cleaned on site, the alligators are also fed the entrails.

In winter, about 1,000 gpm of cold water from shallow springs is mixed with geothermal to maintain correct growing temperatures. In summer, 4,000 - 5,000 gpm is obtained from an irrigation canal.

Fish Breeders of Idaho also has a fish processing plant and a cold water fish farm that raises a million pounds of trout and 200,000 lb of sturgeon annually at another location. It is planned to move some of the sturgeon to the geothermal site for faster growout in the warmer water.

Operating Cost: There are no pumps, pipes, heat exchangers, valves, etc. Operating cost is zero for the geothermal system.

Assuming a 50 ^{o}F temperature increase if river water was used, at current natural gas rates, the cost to maintain optimum growing temperatures would be about a half a million dollars per month. The estimated capacity is 8.8 MWt and annual use is 210 billion Btu.

Regulatory/Environmental Issues: During the late-1970s and early-1980s, there was a large increase in the number of wells in the area. As a result, artesian heads and flows decreased. The Idaho Water Resources Department instituted a “Ground Water Management Area” in 1983 meaning that no new commercial well water rights will be issued.

There have been concerns voiced about geothermal uses thermally polluting the Snake River. Most of the users discharge relatively cool effluent so nothing has come of the concerns to date. This may become a problem in the future that all the geothermal users in the area are aware of.

As with most confined animal operations (i.e., feed lots, dairies and fish farms), run off or effluent contains elevated phosphorous levels. This is another future problem for Fish Breeders of Idaho–as well as all other confined animal operations. Fish Breeders is investigating the use of certain varieties of barley that contain less phosphorous as a substitute for the fish meal. They are also looking for ways to remove the phosphorous from the effluent.

Problems and Solutions: As noted above, there have been problems with resource decline and the potential problems of thermal pollution and phosphorous.

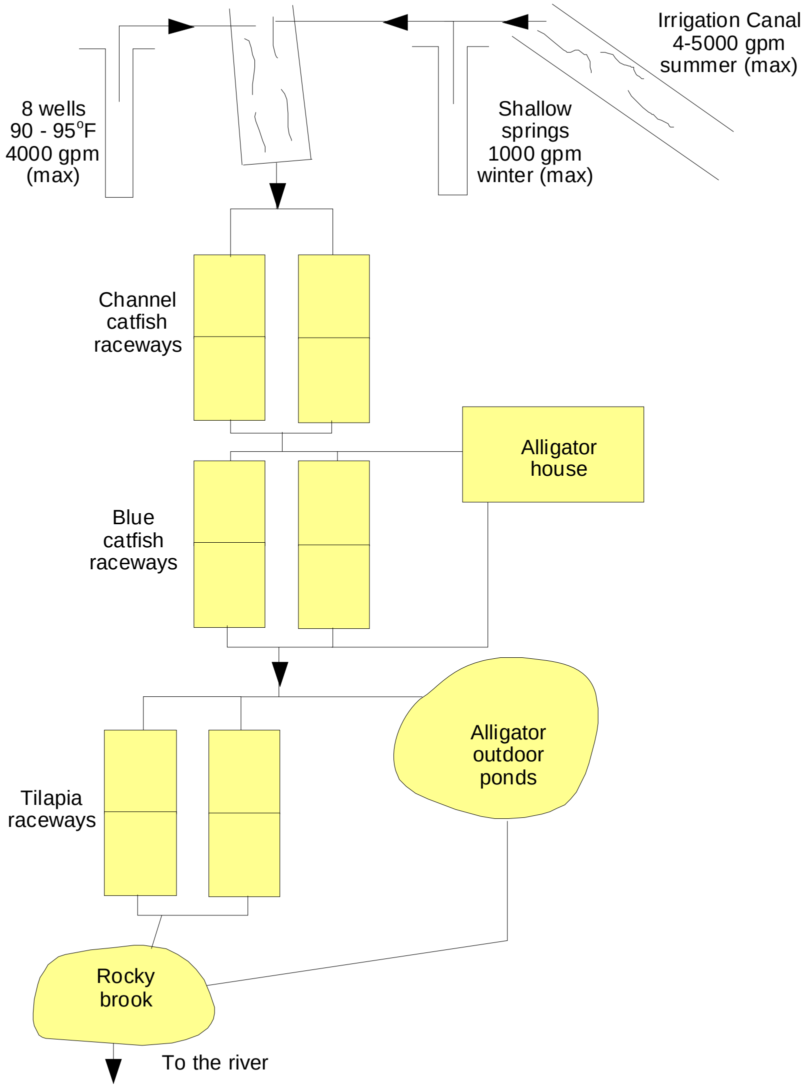
Well pressures and flow seem to have stabilized somewhat since the water management area was instituted. The past several years of drought in the region has undoubtedly had some effect; so, restrictions on increased water use are difficult to access.

They are aware of the potential for thermal pollution and elevated phosphorous and are attempting to solve the problems before legal restrictions are enacted.

Conclusions: This is an ideal site with both good quality warm artesian and cold water available up slope providing simple and economical design and operation. This combined with the operator's knowledge, experience and business acumen have combined to make a very successful operation.

References:

Clutter, Ted, 2002. "Gators in the Sage," *Geo-Heat Center Quarterly Bulletin*, Vol. 23, No. 2 (June), Klamath Falls, OR, pp. 8-10.



CANYON BLOOMERS
(Formerly M & L Greenhouses)
HAGERMAN, IDAHO

Location: These greenhouses are located along the Snake River, approximately 30 miles northwest of Twin Falls, Idaho and near the town of Hagerman. There are also several more greenhouse operations, a catfish/tilapia/alligator farm, hot springs spa/resorts and residential heating within about three miles in either direction along the river. Elevation is about 3800 ft ASL and average annual temperature about 50^{o}F.

Resources: The resource is known as the Banbury Hot Springs area. Most of the wells are in an area about 10 miles long by one mile wide. The occurrence of thermal water in the area appears to be fault controlled. The better (higher flow and temperature) wells occur on the down-throw side of the fault. Temperatures range from 77 to 162^{o}F. Water quality is generally good–pH 7.9 - 9.5, total dissolved solids 230 - 420 mg/l with higher temperature fluids having higher pH and TDS. Artesian heads range from slightly above, to 360 ft above, land surface. Based on heat flow data, depth of circulation to attain the highest temperatures in the wells is about 4400 ft and since most wells are only 420 - 700 ft deep, convective transport along faults is indicated. Probable maximum temperature based on geothermometers is about 195^{o}F.

Canyon Bloomers utilizes two wells, one 505 ft deep will produce about 400 gpm at 107^{o}F; the other 1,000 ft deep produces about 250 gpm at 130^{o}F.

Utilization: M & L Greenhouses started operation in 1970 with one greenhouse using propane and electricity for heating. In 1974, the 107^{o}F well was drilled and the greenhouse converted to geothermal. Currently, there are 20 houses of 5,000 sq ft each. Geothermal at 130°F is used in fan coil units, then cascaded to radiant floors in 16 of the houses. The remaining four use water cascaded from the 16 in their radiant floors. Water is also cascaded to radiant floors in the large office and shop, and to a swimming pool. Three houses have table top heating using 107°F water and the owners residence uses mostly 107°F water in radiant floors, but can be switched to 130°F water if needed. Total peak flow is 450 gpm providing an estimated installed capacity of 1.9 MWt. Annual energy use is estimated at 14.3 x 10^9 Btu/yr.

Canyon Bloomers is a contract grower supplying 2,000 varieties of annual spring plants to large retailers. Their growing season starts about mid-December and finishes in late-June.

Operating Cost: Operating costs for the geothermal system is minimal; since, the wells have an artesian head. Wellhead pressure in the shallower 107°F well varies from 60 psi down to 20 psi at peak flow. A booster pump is required only when wellhead pressure is down near 20 psi. The other well is not pumped. Fan coil units last about 15 years and cost about $2,600. The black steel piping has had no problems. "Sometimes weak acid is run, through the pipes to clean them," the owner reported.

Regulatory/Environmental Issues: During the late-1970s and early-1980s, there was a large increase in the number of wells in the area. As a result, artesian heads and flows decreased. The Idaho Water Resources Department instituted a "Ground Water Management Area" in 1983 meaning that no new commercial well water rights will be issued.

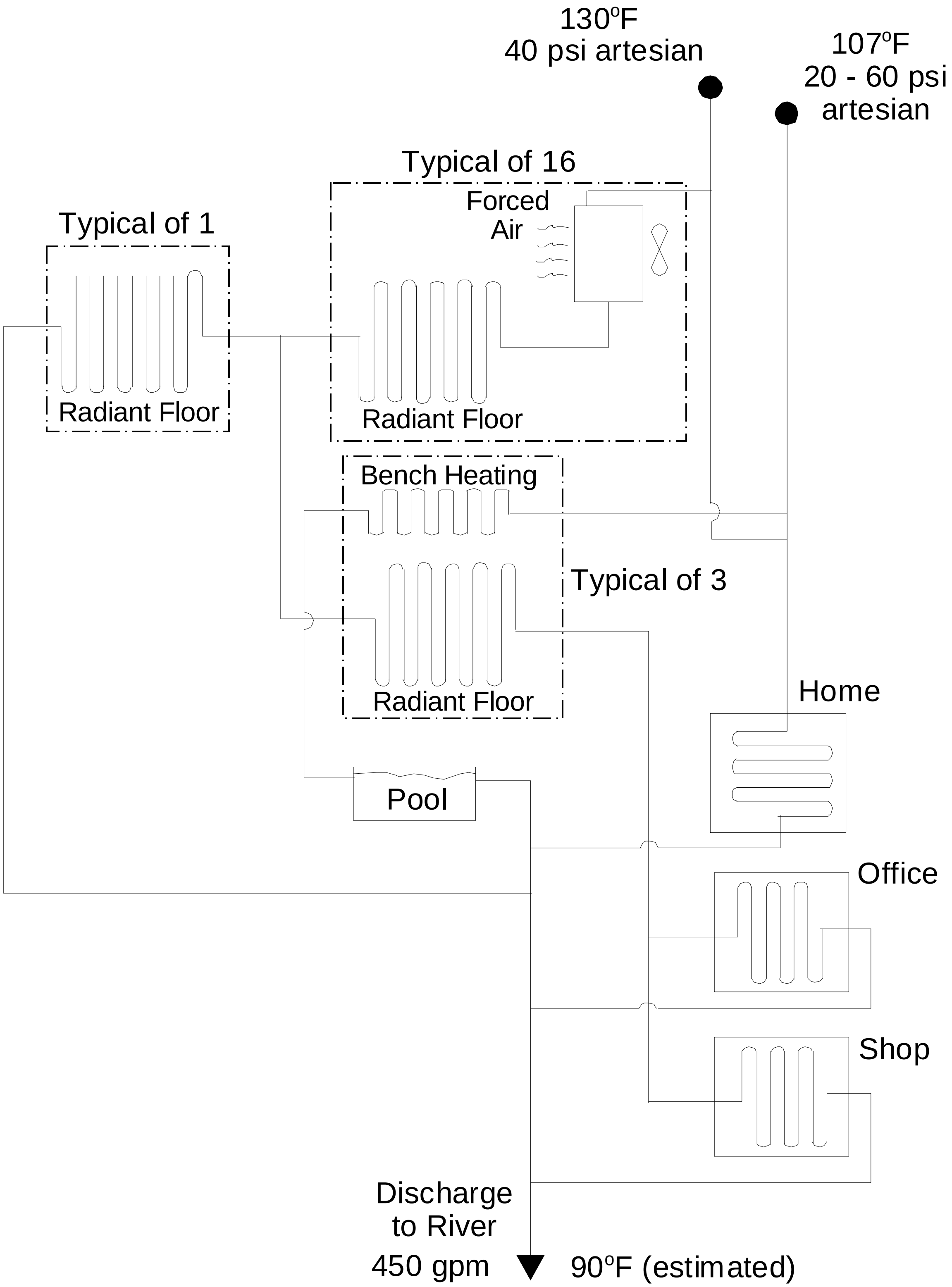
There have been concerns voiced about geothermal uses thermally polluting the Snake River. Most of the users discharge relatively cool effluent so nothing has come of the concerns to date.

Problems and Solutions: Aside from the artesian head loss, there have been no major problems. Very early on, it was learned that copper piping rapidly corroded and galvanized piping tended to scale and plug, but since the operation was small, the conversion to black iron was fairly easy and inexpensive.

Conclusions: This operation demonstrates the feasibility of utilizing very low temperature geothermal resources. Several of the greenhouses, the residence, shop and office are heated by 107°F geothermal water. The operation started small and grew as the owner learned greenhousing and geothermal, and was not afraid to try using the lower than normal temperatures.

Reference

Street, Leah, 1985/ "In Southern Idaho - Greenhouse Use Geothermal Heat to Cut Energy Bills," *Geo-Heat Center Quarterly Bulletin*, Vol. 9, No. 2 (Fall), Klamath Falls, OR, pp. 3-5.


130°F
40 psi artesian
107°F
20 - 60 psi
artesian
Typical of 16
Forced
Air
Typical of 1
Radiant Floor
Radiant Floor
Bench Heating
Typical of 3
Radiant Floor
Home
Pool
Office
Shop
Discharge
to River
450 gpm
90°F (estimated)

CALPINE GEOTHERMAL VISITOR CENTER
MIDDLETOWN, CALIFORNIA

Location & Background: The Calpine Geothermal Visitor Center is located in Middletown, California, about 70 miles (113 km) north of San Francisco. It is a single-story, 6,000 ft^2 (560 m^2) building and is the visitor center for The Geysers geothermal field, the largest geothermal power generating operation in the world. The visitor center building has incorporated a number of "green" features, one of which is a geothermal heat pump system. Completed in 2001, the building has a lobby area, an exhibit hall featuring geothermal power displays, small offices, a conference room, a kitchen, and a multipurpose room (Figure 1).

Average high temperatures in the area in July are about 92^{o}F (33.3^{o}C) and average low temperatures in January are about 35^{o}F (1.7^{o}C). There are approximately 2800 heating degree days and 800 cooling degree days per year [65 ^{o}F (18^{o}C) base].

System Description :

Ground Source System: The ground source system (shown in Figure 1) is the vertical closed loop type consisting of 20 vertical boreholes, each 225 ft (69 m) deep, for a total length of 4500 ft (1372 m). The boreholes are installed in a 4 x 5 grid pattern with 20-ft (6.1-m) spacing. A single u-tube heat exchanger is installed in each borehole and the heat transfer fluid is pure water. The borehole field is piped in a reverse-return arrangement.

The mean annual ground temperature in this location is about 62^{o}F (16.7^{o}C). The loop field was installed in an alluvial fan deposit, consisting of cobbles and boulders.

Interior System: The total installed heat pump capacity is approximately 25 tons (88 kW). As each room in the building has a different use and variable occupancy rate, the building was designed so that each room is a separate zone. Space conditioning for the lobby, offices, and exhibit hall is accomplished with vertical water-to-air heat pumps installed in closet spaces. Space conditioning for the other areas (conference rooms, hallways, restrooms, and kitchen) is done with horizontal water-to-air heat pumps hidden in the attic. Ventilation air is ducted through the attic space to individual heat pumps. A 1 ton water-to-water heat pump installed in the kitchen is used for domestic hot water heating. For energy efficient pumping, a separate water circulator is installed on each heat pump. A schematic of a typical heat pump layout is shown in Figure 2, and a photograph of the 6-ton (21 kW), vertical unit and flow center serving the exhibit hall is shown in Figure 3.

Project Costs: The total geothermal heat pump heating, ventilating, and air-conditioning (HVAC) system cost in 2001 was $78,000, or approximately $13/ft^2 ($140/m^2). From Means construction cost data (2000), the median HVAC system cost for a similar building (a community center) is $9/ft^2 ($97/m^2). Therefore, it is estimated that the geothermal heat pump system capital cost was about 44%, or $24,000 greater than a conventional system.

System Performance And Operating Cost: Electrical energy consumption for the Calpine Visitor system for the year 2004 is shown in Figure 4. The data shown in Figure 4 represent the total electrical energy consumption for the building, and therefore the exact HVAC system energy use is not known. The total electrical energy consumption for 2004 was 80,120 kWh.

In order to compare performance of the geothermal heat pump system to a conventional HVAC system, the building performance was simulated using eQuest, which employs the DOE-2 building simulation engine. For this simulation, building use and occupancy profiles for a community center were chosen. The conventional HVAC system modeled was a multi-zone rooftop unit with forced-air natural gas heating and DX cooling.

Results of the simulated energy consumption of the conventional system are shown in Figure 5. A review of Figure 5 shows that a conventional HVAC system at the Calpine Visitor Center would consume a total of 86,400 kWh of electrical energy and a total of 597.65 million Btu (63 GJ) of natural gas.

Assuming an average cost of electricity of $0.10/kWh and an average natural gas cost of $0.85/therm ($0.3/m^3), the annual energy cost for the conventional system would be $8,640 for electricity and $5,080 for natural gas, giving a total annual cost of $13,720. This is about 58% higher than the 2004 cost of $8,640 from the metered use, giving an estimated annual savings of about $5,080. Neglecting maintenance costs, this savings amounts to a simple payback period of 4.7 years.

Operating Experiences: Calpine reports that the drilling was more difficult than expected due to the presence of large cobbles and boulders underlying the site. This resulted in drilling costs in excess of original estimates.

The only operating difficulty to date is that not enough cooling was provided to the kitchen. This difficulty, however, is not attributable to the heat pump system, but to an oversight in the estimation of the kitchen cooling load.

Overall Summary:
Building Description:
Location: Middletown, California
Occupancy: Visitor Center
Gross Floor Area: 6,000 ft^2 (560 m^2)
Number of Floors: 1
Type of Construction: New
Completion Date: 2001

July Avg. High Temp.: 92°F (33.3°C)
Jan Avg. Low Temp.: 35°F (1.7°C)
Annual Heating Degree Days: 2800°F-day (1550°C-day)
Annual Cooling Degree Days: 800°F-day (444°C-day)
Interior System:
Total Installed Heat Pump Capacity: ~25 tons (88 kW)
No. of Heat Pump Units: 10
Heat Pump Capacities: 1 to 6 tons (3.5 to 21 kW)
Pumping System: Individual flow centers
Additional notes: Water-to-air heat pumps for space conditioning
Water-water heat pump for domestic water
Ground-Source System:
Geologic Materials: Alluvial sediments
Mean Ann. Ground Temp.: 62°F (16.7°C)
Type: Vertical closed loop, single U-tube
Configuration: 20 boreholes (4x5 grid pattern)
225 ft (69 m) deep,
20 ft (6.1 m) spacing
Borehole per ton: 180 ft/ton (15.6 m/kW)
Heat Transfer Fluid: Pure water
Economic Analysis:
Installed Geothermal HVAC Capital Cost:
\$78,000 ($\$13.00/\text{ft}^2$)($\$140/\text{m}^2$)
Estimated Conventional HVAC Capital Cost:
\$54,000 ($\$9.00/\text{ft}^2$)($\$97/\text{m}^2$)
Total Building Energy Use:
80,000 kWh
Simulated Conventional Building Electrical Use:
86,400 kWh
Simulated Conventional Building Gas Use:
598 million Btu (63 GJ)
Estimated Simple Payback Period:
<5 years

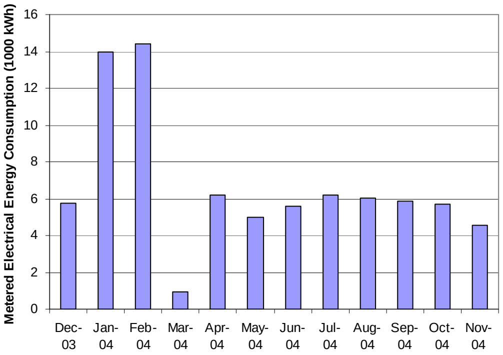


Figure 4. 2004 metered electrical energy consumption for the Calpine Visitor Center (note this is all electrical energy use for the building).

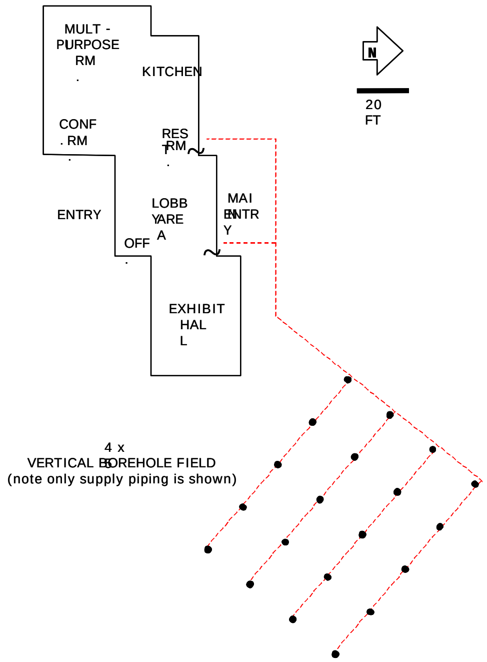


Figure 1. Calpine Visitor Center site sketch showing ground loop field.

Figure 3. Photograph of a 6-ton, water-air, vertical heat pump and flow center.

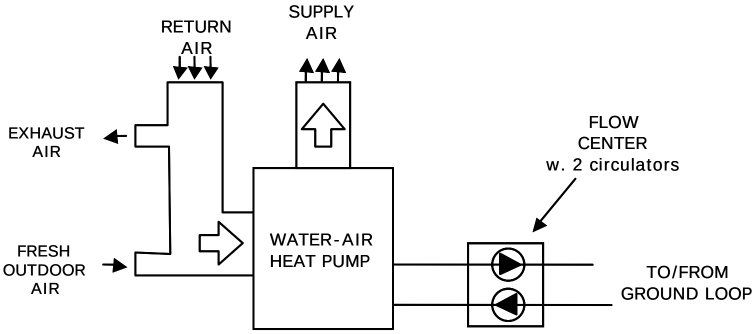


Figure 2. Schematic of a typical heat pump at the Calpine Visitor Center.

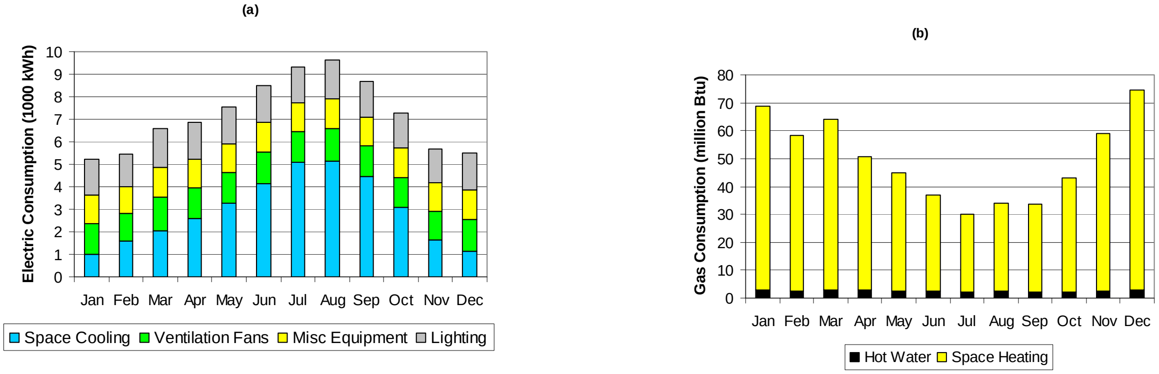


Figure 5. Simulated energy consumption of a conventional multi-zone rooftop unit with forced air natural gas heat and DX cooling: a) cooling with electricity, and b) heating with gas.

CANYON VIEW HIGH SCHOOL
CEDAR CITY, UTAH

Location & Background: The Canyon View High School is located in Cedar City, UT, about 90 miles (145 km) northeast of the point of intersection of Utah, Arizona, and Nevada. It is a two-story building with 233,199 ft^2 (21,665 m^2) of floor space, and construction was completed in 2001.

Average high temperatures in the region in July are about 93^oF (33.9^oC) and average low temperatures in January are about 15^oF (-9.4^oC). There are approximately 6100 (3390^oC-day) heating degree days and 700 (390^oC-day) cooling degree days per year [65 ^oF (18^oC) base].

The Canyon View ground-source heat pump system is considered the first “large” geoexchange system in the Central Rocky Mountain Region.

System Description

Ground Source System: The ground source system (Figure 1) is the vertical closed loop type consisting of 300 vertical boreholes, each 300 ft (91.4 m) deep, for a total length of 90,000 ft (27,432 m). The boreholes, installed under the school playing field, are placed in a 15 x 20 grid pattern with a 20-ft (6.1-m) borehole spacing and 25-ft (7.6-m) spacing between run-outs. A single u-tube heat exchanger is installed in each borehole, and the borehole field is piped in a reverse-return arrangement.

The mean annual ground temperature in this location is approximately 53^oF (11.7^oC). An in-situ thermal conductivity test revealed that the average thermal conductivity of the soil to a depth of 300 ft (91.4 m) is 1.19 Btu/hr-ft-^oF (2.06 W/m-^oC). The loop field was installed in basin-fill type sediments, consisting of coarse sand and gravel with clay stringers and trace volcanics.

Interior System: The total installed heat pump capacity at the Canyon View High School is approximately 550 tons (1953 kW). Space conditioning is accomplished by over 100 water-air heat pumps, which are installed in ceiling spaces to serve individual classrooms and other zones. Outdoor air is introduced through heat recovery ventilator (HRV) units. The original design called for total energy recovery (ERV) units, but HRV’s were installed due their to lower cost. There is little use of domestic hot water in the school, and thus it is generated partially by water-water heat pumps and natural-gas water heaters. The fluid distribution system consists of a central pumping system with a variable frequency drive.

A generalized schematic of the system is shown in Figure 2. Figure 3 is a photograph of the ground-loop headers in the mechanical room and Figure 4 is a photograph of a typical horizontal, ceiling-mounted water-air heat pump.

Project Costs: The Canyon View High School is an example of a building where a ground-source heat pump system was cheaper to install than a conventional boiler chiller system. The project costs are summarized as follows:

- Conventional Mechanical System Bid:
    - \$17.00/ft^{2} (\$183.00/m^{2})
- Canyon View High School Ground Source System Bid:
    - Mechanical/Plumbing bid: \$2,457,000
    - Loop Field bid: \$778,000
    - Total Ground Source bid: \$3,235,000
    - Mechanical Cost/ft^{2} (m^{2}): \$13.87/ft^{2} (\$149.30/m^{2})
    - Cost Savings: \$3.13/ ft^{2} (\$33.69/m^{2}) = \$729,000

Additional cost savings may be realized if one considers architectural savings in the mechanical room floor space in the ground-source system over the conventional system. For the Canyon View High School, the mechanical room for the ground-source system is 2,680 ft^{2} (249 m^{2}), or 1.15% of the total floor space. Comparing this value to 3.80% of mechanical room floor space to total floor space for average schools, and assuming \$50/ft^{2} (\$538/m^{2}) cost of new construction, an additional savings of \$309,000 may be realized.

System Performance And Operating Cost: The system has performed as designed. Maximum ground loop temperatures observed in the summer are about 92^{o}F (33.3^{o}C) and minimum loop temperatures in the winter are 40-42^{o}F (4.4–5.5^{o}C). Annual utility costs for 2001-2002 are summarized as follows:

- Annual Utility Costs for Canyon View High School:
    - Electricity: \$135,886.54 (96%)
    - Natural Gas: \$5,446.87 (4%)
    - Total: \$141,333.41
    - Cost/ft^{2} (m^{2}): \$0.61/ft^{2} (\$6.57/m^{2})
- Utility Costs for a Comparable School:
    - Cost/ft^{2} (m^{2}): \$0.86/ft^{2} (\$9.26/m^{2})
      (77% electrical, 23% gas)
- Operating Cost Savings: \$0.25/ ft^{2} (\$2.69/m^{2})
  = \$58,300 (or 29%)/year

Operating Experiences: Although the geoexchange system at the Canyon View High School is performing well, it is a large system, and the designer admits that there are ways that the pumping system could have been designed to optimize energy consumption. For example, systems of similar size are being designed with primary/secondary pumping, multiple loop pumps to utilize only as much of the ground loop as necessary, and distributed pumping in the building.

Most heat pumps are installed in ceiling spaces, and access has been a bit tight. Dirt and sand was a problem in the system for about 6 months after start-up, which was attributed to a damaged header pipe, likely caused by landscaping work.

Acknowledgements: The Geo-Heat Center wishes to thank Cary Smith of Sound Geothermal for providing the data and information for this case study

Overall Summary:

Building Description:

Location: Cedar City, Utah
Occupancy: School
Gross Floor Area: 233,199 ft^2 (21,665 m^2)
Number of Floors: 2
Type of Construction: New
Completion Date: 2001
July Avg. High Temp.: 93°F (33.9°C)
Jan Avg. Low Temp.: 15°F (-9.9°C)
Annual Heating Degree Days: 6100°F-day (3390°C-day)
Annual Cooling Degree Days: 700°F-day (390°C-day)

Interior System:

Total Installed Heat Pump Capacity: ~550 tons (1,935 kW)
No. of Heat Pump Units: 100+
Pumping System: Central with VFD

Ground-Source System:

Geologic Materials: Basin-fill sediments
Mean Ann. Ground Temp.: 53°F (11.7°C)
Type: Vertical closed loop, single U-tube
Configuration: 300 boreholes (15x20 grid pattern)
300 ft (91.4 m) deep,
20 to 25 ft (6.1 to 7.6 m) spacing
Borehole per ton: ~164 ft/ton (14.2 m/kW)

Economic Analysis:

Installed Geothermal HVAC Capital Cost:
$3,235,000 ($13.87/ft^2)($149.30/m^2)
Conventional HVAC Capital Cost Bid:
$3,963,363 ($17.00/ft^2)($183.00/m^2)
Annual HVAC Energy Cost (2001-2002):
$141,333 ($0.61/ft^2)($6.57/m^2)
Annual HVAC Energy Cost of Comparable Conventional School:
$200,500 ($0.86/ft^2) ($9.26/m^2)
Annual HVAC Energy Savings:
29%
Estimated Simple Payback Period:
Immediate

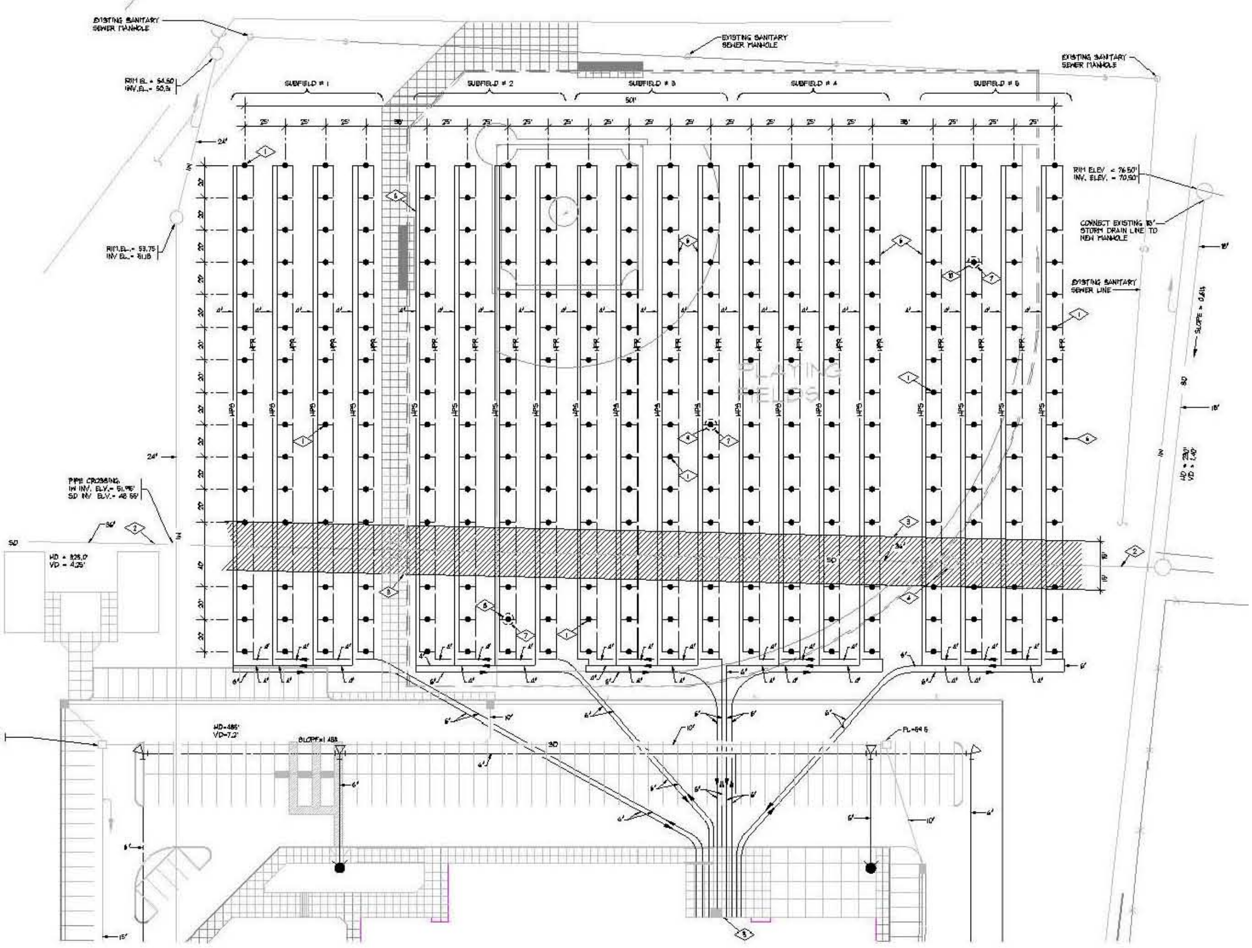


Figure 1. Canyon View High School ground loop field.

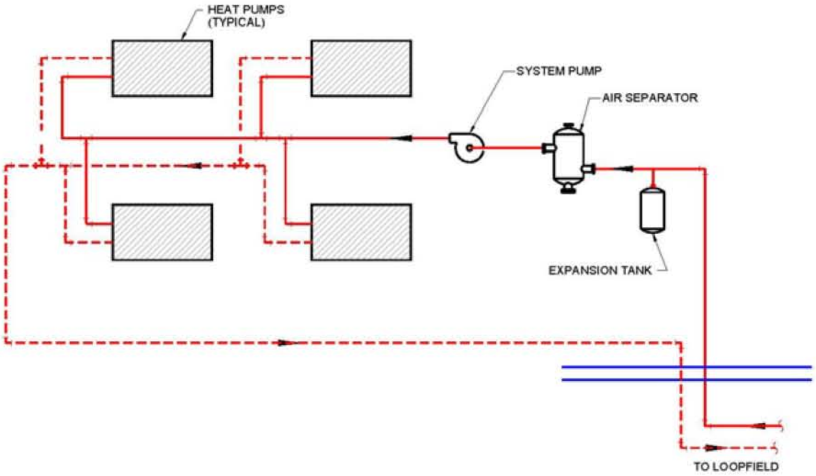


Figure 2. Schematic of the ground-source heat pump system at the Canyon View High School.

Figure 3. Photograph of the mechanical room at the Canyon View High School, showing the ground loop field supply and return headers.

Figure 4. Photograph of a typical horizontal, ceiling-mounted water-air heat pump.

MURRAY HIGH SCHOOL
SALT LAKE CITY, UTAH

Location & Background: The Murray High School is located in Murray, UT, which is part of the Salt Lake City metropolitan area. It is a two-story building with 267,256 ft^2 (24,829m^2) of floor space, and construction was completed in 2003.

Average high temperatures in the region in July are about 91°F (32.8°C) and average low temperatures in January are about 21°F (-6.1°C). There are approximately 5600 heating degree days (3110°C-day) and 1100 cooling degree days (610°C-day) per year [65 °F (18°C) base].

System Description:

Ground Source System: The ground source system (Figure 1) is a "hybrid system", consisting of vertical, closed-loop ground heat exchangers and a supplementary fluid cooler to balance the annual ground loads (since summer occupancy of the school was expected). The ground loop is comprised of 316 vertical boreholes, each 300 ft (91.4 m) deep, for a total length of 94,800 ft (28,895 m). It is installed under the north parking lot of the school, and the boreholes are placed in a grid-like pattern consisting of 5 sub-fields for easier flushing and purging. A single u-tube heat exchanger is installed in each borehole, and the borehole sub-fields are piped in a reverse-return arrangement. A photograph of the supplementary fluid cooler is shown in Figure 2. The fluid cooler capacity is 125 tons (440 kW).

The mean annual ground temperature in this location is approximately 53°F (11.7°C). An in-situ thermal conductivity test revealed that the average thermal conductivity of the soil to a depth of 300 ft (91.4 m) is 1.13 Btu/(hr-ft-°F)(1.95 W/m-°C). The loop field was installed in basin-fill type sediments, consisting of clay, sand, and gravel with cobble stringers.

Interior System: The total installed heat pump capacity at the Murray High School is approximately 650 tons (2286 kW). Space conditioning is accomplished by over 100 water-air heat pumps, which are installed in ceiling spaces to serve individual classrooms and other zones. Outdoor air is introduced through heat recovery ventilator (HRV) units. The original design called for total energy recovery (ERV) units, but HRV's were installed due their to lower cost. There is little use of domestic hot water in the school, and thus it is generated partially by water-water heat pumps and natural-gas water heaters. The fluid distribution system consists of a central pumping system with a variable frequency drive. Figure 3 is a photograph of the ground-loop headers in the main mechanical room.

Project Costs: The Murray High School is an example of a building where a ground-source heat pump system was cheaper to install than a conventional boiler chiller system. The project costs are summarized as follows:

- Conventional Mechanical System:
    \$19.00/ft^2 (\$204.50/m^2)
- Murray High School Ground Source System Bid:
    Mechanical/Plumbing bid: \$3,065,161
    Loop Field bid: \$930,784
    Total Ground Source bid: \$3,995,945
    Mechanical Cost/ft^2 (m^2): \$14.95/ft^2 (\$160.92/m^2)
    Cost Savings: 4.05/ ft^2 (\$43.59/m^2) = \$1,082,387

Additional cost savings may be realized if one considers architectural savings in the mechanical room floor space in the ground-source system over the conventional system. For the Murray High School, the mechanical room for the ground-source system is 2,160 ft^2 (200.7 m^2), or 0.8% of the total floor space. Comparing this value to 3.80% of mechanical room floor space to total floor space for average schools, and assuming \$50/ft^2 (\$538.20/m^2) cost of new construction, an additional savings of \$405,000 may be realized

System Performance And Operating Cost: Maximum ground loop temperatures observed in the summer are about 92^{o}F (33.3^{o}C), and minimum loop temperatures in the winter are 40-42^{o}F (4.4-5.5^{o}C). According to the designers of the system, to their knowledge, the fluid cooler has not yet been needed. Annual utility costs for 2003-2004 are summarized as follows:

- Annual Utility Costs for Canyon View High School:
    Electricity: \$156,505 (96%)
    Natural Gas: \$6,521 (4%)
    Total: \$163,026
    Cost/ft^2 (m^2): \$0.61/ft^2 (\$6.57/m^2)
- Utility Costs for a Comparable School:
    Cost/ft^2 (m^2): \$0.86/ft^2 (\$9.26/m^2)
    (77% electrical, 23% gas)
- Operating Cost Savings:
    \$0.25/ ft^2 (\$2.69/m^2) = \$58,300 (or 29%)/year

Operating Experiences: Thus far, the system has operated well, with the only difficulties being those typical at start-up, such as trapped air and some mud in the ground loop.

Acknowledgements: The Geo-Heat Center wishes to thank Cary Smith of Sound Geothermal for providing the data and information for this case study.

Overall Summary:

Building Description:

Location: Salt Lake City, Utah
Occupancy: School
Gross Floor Area: 267,256 ft^2 (24,829 m^2)
Number of Floors: 2
Type of Construction: New
Completion Date: 2003
July Avg. High Temp.: 91°F (32.8°C)
Jan Avg. Low Temp.: 21°F (-6.1°C)
Annual Heating Degree Days: 5600°F-day (3110°C-day)
Annual Cooling Degree Days: 1100°F-day (610°C-day)

Interior System:

Total Installed Heat Pump Capacity: 650 tons (2,286 kW)
No. of Heat Pump Units: 100+
Pumping System: Central with VFD

Ground-Source System:

Geologic Materials: Basin-fill sediments
Mean Ann. Ground Temp.: 53°F (11.7°C)
Type: Hybrid, vertical closed loop, single U-tube
Configuration: 316 boreholes (grid-like pattern in 5 sub-fields), 300 ft (91.4 m) deep + fluid cooler
Borehole per ton: 146 ft/ton (12.6 m/kW)

Economic Analysis:

Installed Geothermal HVAC Capital Cost: (\$14.95/ft^2)(\$160.92/m^2)	\$3,995,945
Conventional HVAC Capital Cost Bid: (\$19.00/ft^2)(\$204.50/m^2)	\$5,077,864
Annual HVAC Energy Cost (2003-2004):	\$163,026 (\$0.61/ft^2)
Annual HVAC Energy Cost of Comparable Conventional School:	\$229,840 (\$0.86/ft^2) (\$9.26/m^2)
Annual HVAC Energy Savings:	29%
Estimated Simple Payback Period:	Immediate

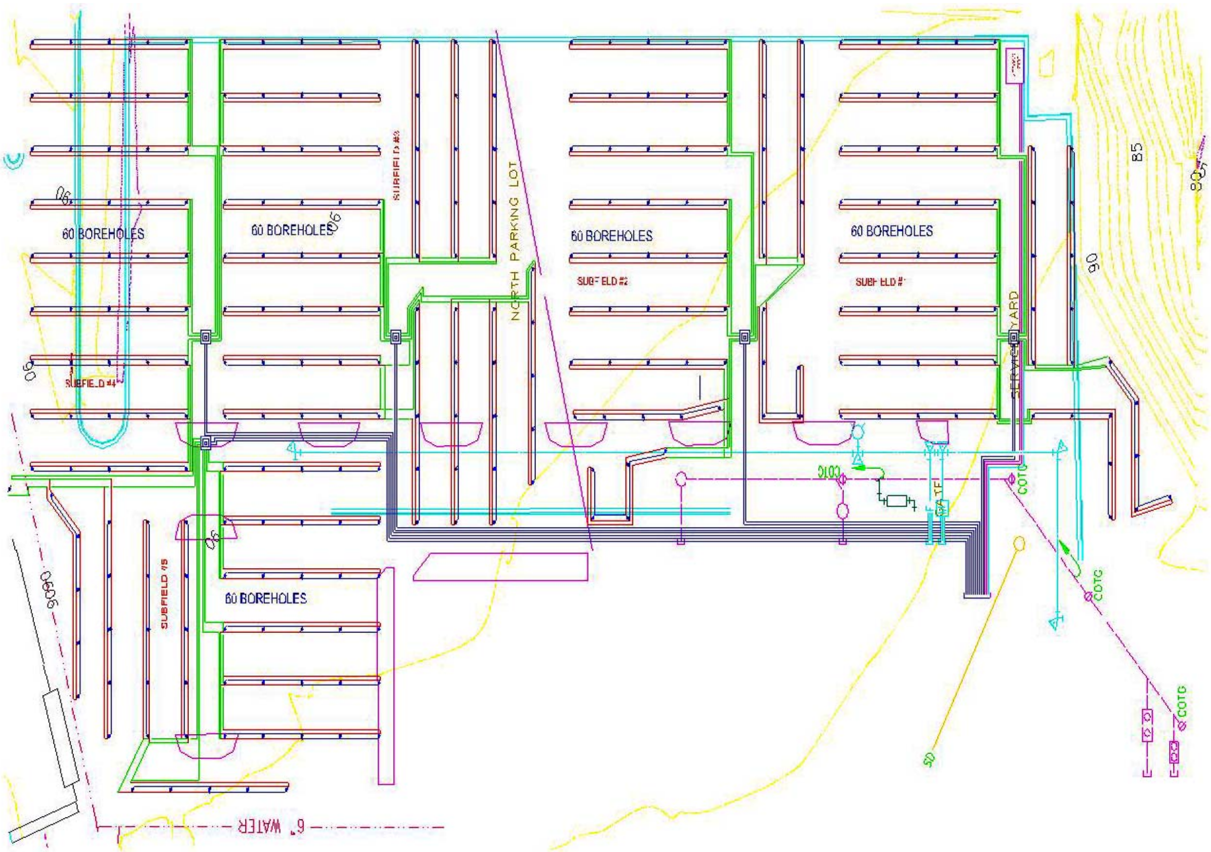


Figure 1. Murray High School ground loop field.

Figure 2. Photograph of the fluid cooler at the Murray High School.

Figure 3. Photograph of the main mechanical room at the Murray High School, showing the ground loop field supply and return headers.

CHILOQUIN COMMUNITY CENTER
CHILOQUIN, OREGON

Location & Background: The Chiloquin Community Center is located in Chiloquin, Oregon, which is in southern Oregon, about 30 miles (48 km) north of Klamath Falls, and about 250 miles (402 km) south of Portland. It is a single-level, 13,000 ft^2 (1,210 m^2) structure that provides space for the Chiloquin Public Library, the Two Rivers Art Gallery, public arts and crafts work-rooms, a large public meeting room with full kitchen, and also leases offices to the local Sheriff's Department. Portions of the building are in use 7 days per week, year round. A sketch of the building footprint and borefield are shown in Figure 1.

The building is constructed of insulated concrete form (ICF) walls and a conventional wood frame roof. As a consequence of using ICF with fixed windows, the building is extremely well insulated and air-tight. The entire slab is insulated using 1-inch polystyrene board to reduce downward heat loss in winter.

The building was constructed in 2003-2004, and formally opened in the Spring of 2004. The ground-source heat pump system installation began prior to the commencement of the main building with the drilling of the network of vertical bores comprising the earth heat exchanger for the facility.

Average high temperatures in the area in July are about 85^{o}F (29.4^{o}C) and average low temperatures in January are about 22^{o}F (-5.6^{o}C). There are approximately 7000 (3890^{o}C-day) heating degree days and 200 (110^{o}C-day) cooling degree days per year (65 ^{o}F (18^{o}C) base).

System Description:

Ground Source System: The ground source system (shown in Figure 1) is a vertical network of 16 bores, each 6-inch (152-mm) diameter and 320 ft (98 m) deep, and arranged in a rectangular grid with a bore-to-bore spacing of 20 ft (6.1 m). The u-tube assemblies were fabricated using 1" (25.4 mm) diameter high-density polyethylene pipe (HDPE). Following insertion of the u-tubes, a bentonite/silica sand grout was pumped into the bores to achieve a nominal grout thermal conductivity of 1.0 Btu/hr-ft-^{o}F (1.7 W/m-^{o}C).

To aid in the design of the borefield, an in-situ thermal conductivity analysis was performed on a test bore. The resulting test data were used to determine that the average thermal conductivity of the earth surrounding the bore is approximately 0.62 Btu/hr-ft-°F (1.07 W/m-°C). The mean earth temperature was measured at 56°F (13.3°C).

The geology at the site, based on the drilling logs, consists of sands and gravels to a depth of approximately 16 ft (4.9 m), with the remainder of the bore depths consisting of gray clay deposits interspersed with occasional sandstone layers. The drilling was accomplished using air-rotary methods (Figure 2).

Interior System: A highly unusual integrated system design was conceived for the project that addressed the energy efficiency goals of the building owners, and built on the very high thermal integrity of the shell. A crucial initial step in this process was agreement on design criteria that allowed for a wider range of indoor air temperatures than is typical for a building of this type. This determination facilitated the choice to use radiant floor heating as the primary means of thermal distribution, and this concept was then extended to include radiant floor cooling.

The building's 15 control zones are connected by a hydronic piping system to a central plant that has only one heat pump. The heat pump is a water-to-water unit (Figure 3) with a nominal rating of 15 tons (53 kW), and is equipped with a single compressor and refrigerant circuit. To prevent short-cycling, a thermal energy storage tank (Figure 4) is employed on the building side of the heat pump a significant buffer volume and de-coupling the control of building water distribution from the operation of the heat pump.

Because the building has no operable windows, all ventilation air is provided by mechanical means. A heat-wheel type air handling unit with a nominal capacity of 4000 cubic feet per minute (cfm) (6,800 m^3/hr) is installed in the attic space, together with ducting to distribute the air to each zone. At the zonal level, occupancy sensors operate a damper in the ventilation duct to minimizing the air handled by the fan system. These occupancy sensors also control lighting in the individual zones. The fan speed is modulated by means of variable frequency drives.

The building's hydronic circulation pumps are in-line centrifugal types, with variable frequency drives that are controlled based on pressure in the supply pipe. At the heat pump, the ground loop pump is also controlled with a variable frequency drive. The tank circulation pump between heat pump and thermal storage tank is constant speed.

To allow the programming of desired control sequences, a direct-digital control (DDC) system was installed. The system uses ASHRAE's BACnet communications protocol set over TCP/IP. It is therefore possible to use conventional internet browser software to access and interact with the control system, and a dedicated server is located in the building to accomplish this task.

Project Costs: The installed cost of the interior HVAC system was \$189,400 or \$14.57/ft^2 (156.83/m^2) and the cost of the ground loop was approximately \$48,000 or \$9.38/ft (\$30.77/m) of vertical borehole. Thus, the total installed cost of the entire ground-source heat pump system was \$237,400 or \$18.26/ft^2 (196.55/m^2).

PacifiCorp provided incentives to the owners, underwriting the costs of pre-design analysis and construction. Additional efficiency incentives were provided through the State of Oregon's Business Energy Tax Credit (BETC) program. Together these incentives totaled approximately $80,000.

System Performance And Operating Cost: The first full year of operation has just completed, and the building has proven itself to be even more efficient than anticipated. Average energy use index is 19,800 Btu/ft^2/yr or 5.8 kWh/ft^2/yr (62.4 kWh/m^2/yr), which is especially impressive because the building operates with no night setback due to the dynamics of the radiant slab.

Sub-metering of the building zones allows the HVAC energy costs to be broken out and tracked. From utility bills, the operating cost of the HVAC system for the first year was about $5,350 or $0.41/ft^2 ($4.41/m^2).

Operating Experiences: Chiloquin Visions in Progress (CVIP), a non-profit organization who raised funds to construct the building, report that they are very happy with the low energy use and operating cost of the building. Low operating costs are an especially attractive feature for non-profit organizations.

As anticipated, the building design does not provide for rapid adjustment to load changes with its radiant slab heating/cooling systems. This might be perceived as a drawback, but the building has no morning warm-up or cool-down time since it is operated without night setback of thermostatic controls. As designed, it seems to work reasonably well with the normal functional requirements of the building.

One rapid load change scenario that has been somewhat difficult to deal with is the occasional large public gathering in the meeting hall room. To best provide for the sudden cooling load, it has been necessary to anticipate the event by overcooling the room, and then keeping the supply water temperature lower than would normally be called for at the central thermal storage tank. In addition, decorative ceiling fans have been proposed in the meeting hall room to increase air circulation as well as to give occupants a visual perception of air movement.

Acknowledgements: The Geo-Heat Center wishes to thank Gene Johnson of Solarc Architecture and Engineering, Inc. for providing the data and information for this case study, and Chuck Wells and Jim Walthers of CVIP for providing the drilling and utility cost information.

Overall Summary:
Building Description:
Location: Chiloquin, Oregon
Occupancy: Community Center with continuous occupancy is some zones
Gross Floor Area: 13,000 ft^2 (1,210 m^2)
Number of Floors: 1
Type of Construction: New
Completion Date: 2003
July Avg. High Temp.: 85^{o}F (29.4^{o}C)
Jan Avg. Low Temp.: 22^{o}F (-5.6^{o}C)
Annual Heating Degree Days: 7000^{o}F-day (3890^{o}C-day)

Annual Cooling Degree Days: 200^{o}F-day (110^{o}C-day)

Interior System:

Total Installed Heat Pump Capacity: 15 tons (53 kW)
No. of Heat Pump Units: 1
Pumping System: Central pumping, variable speed control
Additional notes: Radiant floor heating and cooling

Ground-Source System:

Geologic Materials: Sediments
Mean Ann. Ground Temp.: 56^{o}F (13.3^{o}C)
Type: Vertical closed loop, single U-tube
Configuration: 16 boreholes (4x4 grid pattern)
300 ft (98 m) deep, 20 (6.1 m) ft spacing
Borehole per ton: 342 ft/ton (29.6 m/kW)
Heat Transfer Fluid: Methanol/water solution

Economic Analysis:

Installed Geothermal HVAC Capital Cost: \$237,400 (\$18.26/ft^{2}) (196.55/m^{2})
Estimated Conventional HVAC Capital Cost: \$130,000 (\$10.00/ft^{2}) (107.64/m^{2})
Annual HVAC Energy Use: 19,800 Btu/ft^{2} (62.4 kWh/m^{2})
Annual HVAC Energy Cost: \$5,350 (\$0.41/ft^{2}) (\$4.41/m^{2})

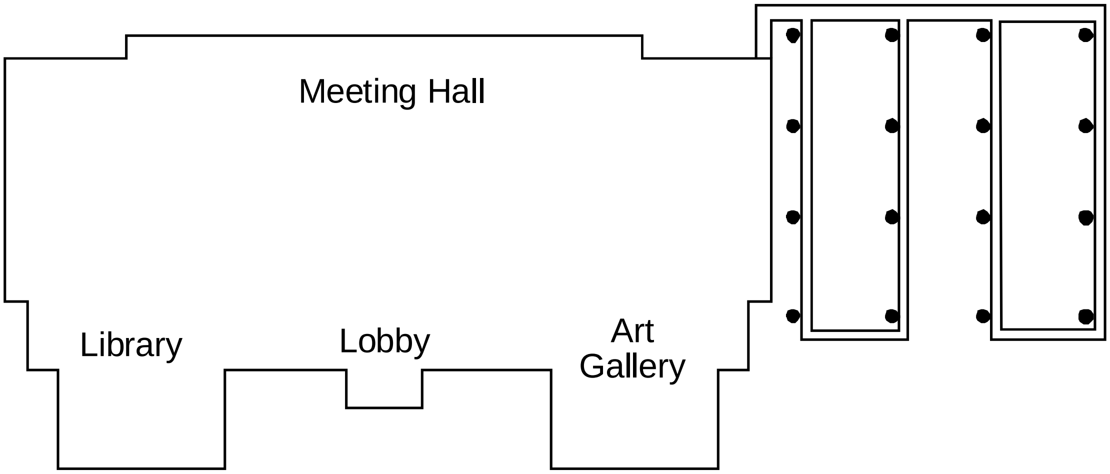


Figure 1. Chiloquin Community Center site sketch showing ground loop field.

Figure 2. Photograph of drilling activities

*Figure 3.	Photograph of the 15 ton water-water heat pump serving the entire building. Note the storage tank on the right.*

Figure 4. Photograph of the mechanical room, showing the distribution piping and storage tank.

SOUTH CARIBOO RECREATION CENTRE
100 MILE HOUSE, BRITISH COLUMBIA, CANADA

South Caribou Recreation Centre, 100 Mile House, BC
Interior BC Community eliminates greenhouse gas emissions and reduces energy costs in new recreation centre

Introduction: The recreation centre is the centre of activities in communities across Canada, and the hockey arena is the heart of most facilities. Rising energy prices over the last decade, however, has forced communities to look for energy efficient alternatives to industrial refrigeration plants that have been the norm for the last century.

At the turn of the century the community of 100 Mile House in the centre of British Columbia made a decision to replace their aging hockey arena that had served them for the last 50 years. The community began researching other new facilities that had been built recently. Two new facilities they visited in Chase and Kamloops, BC caught their attention. Both facilities had installed an integrated geothermal refrigeration, heating, ventilating and air conditioning (R/HVAC) system. The simplicity of operating the systems, low energy costs and low operating and maintenance costs, attracted their attention. The elimination of fossil fuels for heating the facilities also appealed to the growing concern for reducing greenhouse gas emissions.

The Building: Since the community is built around the forestry industry, it's only natural that wood is used for much of the structure. The building is well insulated (R20 walls, R30 ceiling). The ice arena is approximately 28,600 square feet (2,660 square meters), with approximately 700 spectator seats. The ice rink area and the concrete bleacher seating area is heated with a radiant floor heating system. The ice area is maintained at a comfortable 50°F (10°C). The ceiling is covered with wood for aesthetics. The wood surface on the ceiling, however, creates a much greater radiant heat load on the ice surface than a ceiling covered with a "low-emissivity" material.

There are six change rooms alongside the ice area, under the bleachers. The change rooms are maintained at approximately 70°F (21°C) with a radiant floor heat system. One and a half inches (39 mm) of high-density foam insulation was placed under the floor to prevent heat loss to the ground. The change rooms are well ventilated with a heat recovery ventilation system that exhausts air from the change rooms. Fresh, preheated air from the heat recovery system is ducted to the ice arena and then brought back to the change rooms through transfer grills from the ice area. The change rooms and mechanical rooms cover an area of approximately 8,200 square feet (760 square meters)

The lobby and viewing area overlooking the ice rink is approximately 5,900 square feet (550 square meters). Adjacent to the lobby is an office area of approximately 2,100 square feet (195 square meters). These areas are heated and cooled with several ground source heat pumps connected to the horizontal ground loop in the field behind the building.

The refrigeration system of the existing curling rink adjacent to the new arena has been connected to the geothermal system. The heating system of the lobby and lounge of the curling rink, however, has not been connected because of cost. There are plans to convert the heating system in the near future.

The Refrigeration System: A hockey arena is typically the most expensive building to operate (energy cost and operating and maintenance costs) in most small communities. The electrical costs associated with operating the compressors and pumps of the refrigeration system are high. The majority of the hockey arenas throughout Canada and much of the United States use ammonia as the primary refrigerant. Ammonia is a very efficient refrigerant, but the large refrigerant charge (1,000 to 1,200 pounds or 450 to 500 kg) requires constant monitoring and stringent safety procedures, including airlock entries to the refrigeration room, high capacity ventilation systems, eyewash stations and oxygen masks. Because of the potential danger, most jurisdictions require highly trained operators and the system operating pressures must be monitored regularly.

Ammonia does not transport oil through the system. It collects in the evaporator, or chiller barrel, and must be drained regularly, and treated as a hazardous waste product. Fresh oil must be added to the refrigerant system to ensure lubrication of the compressors. An average rink will drain and replace close to a barrel of oil annually, depending on how heavily the rink is used. This adds approximately $500 to $1,000 to the operating cost every year.

In this arena, eight large water to water heat pumps were used in place of a traditional ice plant (Figure 1). The heat pumps are designed to operate at source temperatures as low as 0°F (-18°C). They are designed to produce water to temperatures as high as 125°F (51°C). Each of the heat pumps contains approximately 12 pounds (5.5 kg) of HFC refrigerant R404A. The entire refrigeration system of eight units contains approximately 10% of the refrigerant of a traditional refrigeration system, and it is contained in eight independent units. Since this is a non-toxic refrigerant, there is no need for the same level of safety considerations.

The eight separate heat pumps are piped as four pairs. Each pair of heat pumps is piped with two pumps connected to the chilled fluid side and two pumps to the hot fluid side. The chilled fluid can be circulated either to the ice surface piping, the thermal storage buffer or the earth loop to pick up heat. The heated fluid can be circulated either to the building heating system or the earth loop, based on the temperatures in the building. This arrangement provides a high degree of redundancy

Humidity And Temperature Control In The Ice Area: Humidity control is important in an ice arena, especially if the ice surface will be used in warm weather. Condensation will form on the ice surface if the humidity is too high, creating a significant load on the refrigeration equipment. Each pound of water that condenses on the ice surface absorbs over 1,100 Btu (0.33 kW) of energy. Steel at the ceiling above the ice area radiates heat to the cold ice below it. Warm air at the ceiling will condense on the cold steel, eventually causing rusting and structural damage. It can also collect and drip onto the ice, creating bumps on the ice.

A heat pump designed specifically to provide dehumidification is installed in the ice area (Figure 2). The heat pump is designed to cool the air enough to condense the moisture from the air. Heat from the cooling process plus compressor heat reheats the air to provide warmer, drier air. The heat pump is also connected to the earth loop through a fluid to refrigerant heat exchanger. If the air temperature in the ice area is satisfied, the heat can be rejected to the earth loop, and the unit is used to provide approximately 16 tons (56 kW) of air conditioning. It can also be used when the facility is used for other activities, such as inline hockey or lacrosse during the summer.

The heat pump can also be used to extract heat from the earth loop if additional heat is needed in the ice rink area. It will provide approximately 200,000 to 250,000 Btu/h (59 to 73 kW), depending on the earth loop temperature.

The spectator stands are heated with radiant floor heat piping embedded in the precast concrete bleachers (Figure 3). The warmed seats provide heat where it is most needed. If snow is tracked into the seats, or a drink is spilled in the stands, it is melted and evaporates quickly, reducing cleanup time and potential liability from someone slipping on wet concrete.

Building Heating And Cooling: The ice surface and the Thermal Storage Buffer[1] are the primary heat source for the low temperature water to water heat pumps. Only when both the ice and the buffer temperatures are satisfied, and the building still needs heat, do the heat pumps extract heat from the earth loop. The building radiant floor heat system, the domestic hot water and snow melt are the primary heat sink for the heat pumps. Only when the building temperature is satisfied do the heat pumps reject heat to the earth loop. Conventional ground source heat pumps are connected to the earth loop to provide heating and air conditioning to the office areas (Figure 4).

A large site allowed the construction of a horizontal earth loop. The loop is a secondary heat source and secondary heat sink for the main heat pump system, storing excess heat that can’t be used. It is the primary heat source/heat sink for the conventional forced air heat pumps, domestic hot water heat pump and the dehumidification unit.

Domestic hot water is preheated using a double wall heat exchanger. When hot water is used in the building in showers or flooding the ice, make-up water is preheated to about 75 to 85°F (25-30°C). A water to water heat pump operating directly from the earth loop heats the water to 120°F (50°C) (Figure 5).

---

[1] US Patent #6,170,278, Canadian Patent #2,273,760

Heat removed from the ice is either used directly to provide space heating or domestic hot water, or is stored in the earth loop. This type of facility is very cooling dominant, and the earth loop becomes saturated with heat when the ice is used in summer. A fluid cooler is used to prevent the earth loop from becoming overheated.

Air from the change rooms is continuously exhausted using a heat recovery ventilation (HRV) system. Fresh air from the HRV is introduced to the ice area. Air from the ice area is drawn into the change rooms through intake grills from the ice area.

Thermal Storage: The patented rink floor design provides thermal cold storage directly beneath the ice surface. It provides several advantages over a conventional thin rink floor design:

- The large mass maintains a more consistent ice temperature than a floor with little storage. This is especially noticeable when the ice is being heavily used and resurfaced often.
- The large mass of the floor is “sub-cooled” several degrees lower than the ice surface when the ice is not being used. This is the heat source used for the heat pumps to heat the building, while simultaneously providing a significant amount of refrigeration for the ice when it is being heavily used.
- the refrigeration during peak use. Both the refrigeration capacity and the fluid circulation pumps required to maintain the ice surface during peak use can be reduced. A conventional system would require a 20 to 30-hp circulation pump for the ice surface and a 7.5 to 10-hp circulation pump for the curling rink. Four 3-hp circulation pumps provide the flow for both the ice surface and the curling rink. This reduces the refrigeration load created by friction losses in the rink
- surface pipe by 57 to 70% compared to a facility with a conventional thin floor.
- In the event of a power failure, the mass of the rink floor will maintain the ice for up to 3 days.

Integrating Systems With An Earth Loop: The integration of the entire system revolves around the earth loop. The facility is built on a large site that allows space for a horizontal earth loop (Figure 6). An area was excavated behind for the installation of the earth loop. All heat pumps in the system are connected to the earth loop. The large water-to-water refrigeration units use the earth loop as a secondary heat source when the ice temperature is satisfied, and a secondary heat sink when the building temperature is satisfied. The forced air heat pumps in the office spaces, the water-to-water heat pump that produces hot water for showers and flooding the ice, and the dehumidification/heating/air conditioning unit are all connected directly to the earth loop, and either pull heat from it, or reject heat into it as needed.

The primary benefit of integrating all the systems into a common earth loop takes advantage of the thermal storage capacity of the earth. In a building such as the South Caribou Recreation Centre, the water-to-water heat pumps used to make the ice either reject heat directly to the building radiant floor heat system, or to the earth loop. Since only a portion of the heat taken from the ice can be used in the building directly, even during a cold winter day, the earth loop is constantly being recharged by “waste heat” taken from the ice.

Heat pumps operate more efficiently and have higher heating capacity when the source temperature is higher. The heat pumps used for space heating and heating water typically operate with an earth loop of 55-70°F (13°C), and operate at a COP between 4.4 and 5.4.

In spring and fall when less heat is needed in the building, the earth loop temperature typically climbs to 80-90°F (27-32°C). To prevent the earth loop temperature from climbing even higher, an evaporative fluid cooler was installed. During peak use of the ice the fluid cooler works in parallel with the earth loop to reduce the load on the loop. More importantly, at night when the building is not being used, the fluid from the earth loop is circulated through the fluid cooler to take advantage of cooler night time temperatures to drop the loop temperature. This allows the loop to absorb heat more readily during peak use the following day.

System Economics: The cost of installing a geothermal system is typically higher than the cost of installing a conventional system. This holds true with an integrated geothermal ice rink application as well. The building qualified for a Commercial Building Incentive Program (CBIP) from Natural Resources Canada (NRCan) of $60,000. The capital cost of the integrated system is compared to the estimated cost of installing a conventional refrigeration plant and heating system in Table 1. As is often the case, the difference in cost of the two systems is typically the approximate cost of the installation of the earth loop.

The additional cost of installing the integrated system is offset by lower energy costs as well as lower operating and maintenance costs. The energy costs of the facility are shown in Figure 7, along with a comparison of the energy costs of a typical conventional system. Annual energy cost savings are estimated at approximately $48,000 annually.

Operating and maintenance costs for a conventional refrigeration plant are typically much higher than the cost of maintaining other mechanical equipment. Ice rink owners and operators typically budget approximately $14,000 to $17,000 annually for maintenance costs.

Table 1.

	Integrated System	Conventional System*
Refrigeration heat pumps, circulation pumps, rink floor	$575,000	$525,000
Horizontal loop	$105,000	---
Building heating, cooling, ventilation	$112,000	$96,000
Incentives (NRCan / CBIP)	($60,000)	---
Connecting Curling Arena Refrigeration	$30,000	---
Dehumidification	$72,000	$110,000
Domestic hot water	$34,000	$18,000
Total	**$868,000**	**$749,000**

** estimated cost of conventional system*

Some of the costs of operating a conventional ammonia ice plant include:

- Oil to lubricate the compressor (ammonia vapor does not transport oil from the evaporator (chiller barrel) back to the compressor – it must be drained regularly and replaced. Typical cost is approximately $500-1,200 annually. The waste oil must then be disposed of appropriately.

- Compressor rebuilds. A conventional reciprocating ammonia compressor must be rebuilt after approximately 6,000 to 8,000 hours of runtime, at a typical cost of $6,000 to $12,000. With the schedule of this facility, one compressor would typically be rebuilt every year.
- In most jurisdictions it is required that an industrial refrigeration plant must be monitored regularly. Typically a rink operator must check the operating pressures and flows of the system 4-6 times per day (1.5-3 hours per day) This time is taken away from other needs in the facility.
- Special circumstances. The integrated geothermal system is designed with a high level of system redundancy. The design includes eight independent water-to-water heat pumps designed to operate with four sets of circulation pumps. If a heat pump or circulation pump fails, the other heat pumps and circulation pumps simply carry on to maintain the ice. If the single circulation pump, or one of two or three large compressors fails, the system must be repaired immediately, often at emergency service rates.

The water-to-water heat pumps do not require compressor rebuilds. Oil does not have to be drained from the system regularly. The size of the compressors of the water-to-water heat pumps and built in redundancy of the system eliminates the much of the daily operating cost of the system and reduces the cost of service. Similar ice rink facilities report operating and maintenance costs of $4,000 to $5,000 annually after several years of operation.

The simple payback of the system installed in 100 Mile House is estimated at approximately two years if the NRCan / CBIP incentive is included, and approximately three years if no incentive is considered.

OVERALL SUMMARY:

Building Description:

- Occupancy: Hockey arena, curling arena, office space
- Location: 100 Mile House, BC
- Gross Floor Area: 56,400 square feet (5,241 square meters)
    - Arena: 28,600 square feet (2,498 square meters)
    - Offices, change rooms, lobby: 15,400 square feet (1,430 square meters)
    - Curling Arena: 9,000 square feet (836 square meters)
    - Curling Lobby & Lounge: 3,600 square feet (335 square meters)
- Construction
    - Hockey Arena: new construction, well insulated
    - Curling Arena: retrofit
- Completion Date: 2002
- Heating Degree Days (below 64.4°F / 18°C): 9,076 / 5,042

System Description:

- Refrigeration heat pumps (hockey and curling combined): 88 tons (310 kW)
- Hockey Arena climate control
    - Humidity control: 15 tons (52.8 kW)
    - Cooling: 15 tons (52.8 kW)
    - Heating: 230,000 Btu/h (68.6 kW)
- Heating / cooling (offices, change rooms, lobby etc.): 24 tons (84 kW)
- Fluid: Methanol 30%, & water
- Circulation pumps
    - Refrigeration heat pumps (Hockey and Curling Arenas)

        - 4 3-hp circulation pumps building heating system / earth loop
        - 4 3-hp circulation pumps for ice floor circulation / earth loop
    - Heating / cooling heat pumps
        - 1 3-hp circulation pump
- Earth Loop: Horizontal earth loop, buried to 8 feet (2.4 meters), 50 circuits of 1” (25 mm) HDPE SDR11 pipe, 1,000 feet (300 m) length

Special Features:

- Thermal storage buffer floor (patented) design to minimize peak refrigeration demand and maintain constant ice temperature
- Optimized rink pipe layout to reduce pumping power requirements
- Earth loop to store excess heat and provide additional heat as needed
-

Figure 1. ***Eight low temperature water-to-water heat pumps provide approximately 84 tons of refrigeration at ice rink temperatures. The heat pumps reject heat either directly to a radiant floor heat system or to a horizontal earth loop.***

Figure 2. ***Dehumidification, air conditioning and heating are provided by a 20-ton heat pump in the ice area. The unit can cool and reheat 40-50°F (5-10°C) air. It can also cool or heat the arena by either rejecting or drawing heat from the horizontal earth loop.***

Figure 3. Much of the building, including the spectator seating, is heated with a radiant floor heat system. The warm floor dries snow that is tracked from outside into the building and reduces the opportunity for mildew growth in the change rooms.

Figure 5. A 10-ton water-to-water heat pump draws heat from the earth loop to produce service hot water (showers and ice flooding) at 120°F (50°C)

Figure 6 This photo shows the installation of the horizontal earth loop at 100 Mile House, BC. 50,000 feet (15,200 m) of 1 inch (25 mm) pipe was installed to a depth of 8 feet (2.4 m).

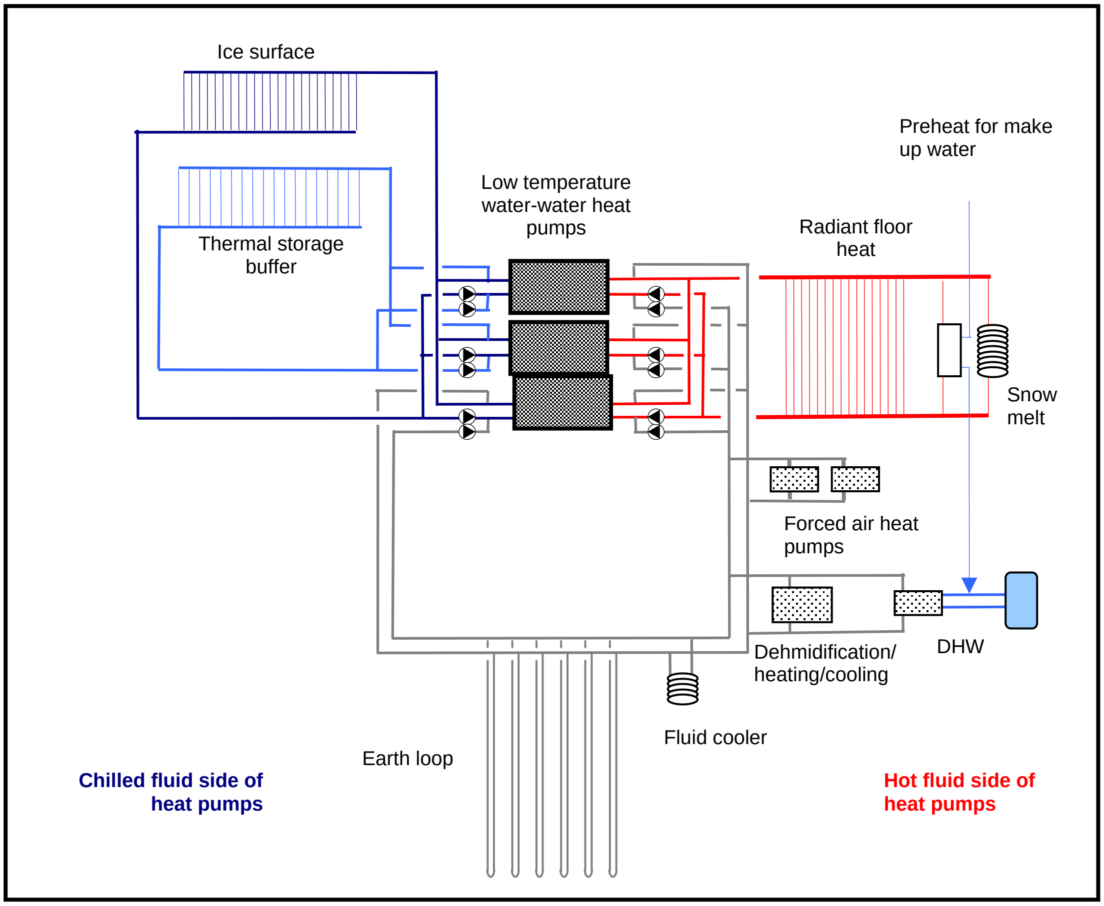


Figure 4.

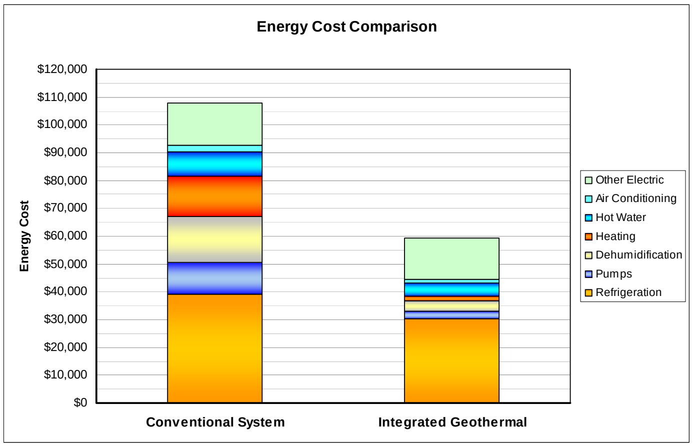


Figure 7. ***The actual energy cost of the facility in 2004 was slightly over $60,000. Energy consumption was 1,195,000 kWh, with a peak electrical demand of 257 kW. The total energy consumption of a comparable rink with a conventional refrigeration plant and gas fired heating system is estimated at approximately $107,000 annually. Heating, service hot water and dehumidification would typically be done with gas equipment. Gas costs for a conventional system in this building are estimated at approximately $40,000 annually.***

SUNDOWN M RANCH
YAKIMA, WASHINGTON

Photo credit: http://www.sundown.org/

Building Characteristics: The Sundown M Ranch, located just northwest of Yakima, Washington, is a drug and alcohol rehabilitation center for both youths and adults. The 134,880 ft^2 (12,531 m^2) complex was built in several phases beginning in 1985 with the adult facility totaling 77,300 ft^2 (7,181 m^2), followed by a family annex of 20,650 ft^2 (1,918 m^2) in 1990, a 39,730 ft^2 (3,961 m^2) youth facility in 1992, and the 7,200 ft^2 (669 m^2) administration building in 1995. The facility also provides laundry and food services for the patients. The buildings are stick-built wood frame, low-rise residential style. The buildings are well insulated and use primarily fluorescent lighting.

The residences are occupied 24 hours per day, while other facilities are normally occupied during normal office hours except for the gym that has an intermittent occupation pattern.

Geothermal Heat Pump System Characteristics: A process schematic is shown in Figure 1.

Geothermal Source Description: The complex is served by two production wells at ca 57ºF (13.9°C) and one injection well. The main well is approximately 200 ft (61 m) deep, and provides 360 gpm (22.7 L/s) via a 15-hp (11 kW) submersible pump. The second well is 187 ft (57 m) deep and supplies 260 gpm (16.4 L/s). It has a 15-hp (11 kW) submersible pump. After passing through the heat pump, the water is injected or used for irrigation during the summer months. The well pumps are run 24-hours per day at constant speed. Flow is controlled through the use of throttling valves. There are also two domestic water wells on the property. In addition to use for heating and cooling and domestic purposes, the wells together can supply a maximum of 1,100 gpm (69.4 L/s) for fire protection.

Heating, Ventilation, and Air Conditioning (HVAC) System Description: The various facilities are served by a combination of heat pumps and heat pump unit ventilators (Figure 2). Water is circulated in an open loop to each building. Circulating pumps serves to boost the flow through the various buildings. A total of 297 heat pumps supply the complex comprised of 257 1-ton (3.5 kW) heat pump unit ventilators, 12 3-ton (10.5 kW) units, and 28 5-ton (17.6 kW) units for a total of 433 tons (1,523 kW). In addition, there are four 5-ton (17.6 kW) water-to-water heat pumps in the adult building for hot water and two 5-ton (17.6 kW) units with back-up electric water heaters serving the youth facility (Figure 3). There is a 1,000 gallon (3785 L) hot water storage tank in the adult facility.

Selection Of The Geothermal Heat Pump System: The geothermal heat pump system was selected upon the recommendation of the serving utility, Pacific Power and Light; the availability of adequate supplies of reliable warm water; a desire for energy efficiency; and a guaranteed reduction in electrical rates by the serving utility if the heat pump system was installed. They were also very interested in having the ability to provide individual room control.

Operating History: The system has been built-out over 14 years, with additional buildings added every few years. The system has performed as expected, and has experienced few operating problems. The fact that for each subsequent phase of the build-out, the decision has been to continue with geothermal heat pumps is a good indication of the system's excellent operational performance.

Operation And Maintenance Issues: The system is operated and maintained by in-house staff. Since the well pumps are not equipped with variable speed drives, the pumps must be operated 24 hours per day. Flow is controlled by use of a throttling valve. In summer use, the water coming out of the loop is used for irrigation purposes and in certain cases this can reduce the water available to the loop to the extent that the system does experience some high head problems on the heat pumps.

Each heat pump has a valve that opens or closes depending on whether the heat pump is on. The heat pumps and unit ventilation have outdoor air access and are controlled by thermostats.

The one on-going operational problem has been associated with the injection well. The well tends to plug up and will not accept the return flow. This in turn causes a pressure build up in the injection system and often results in broken PVC pipes. Because of this, the well is now cleaned every six months by reversing the flow. Chlorine is also added to kill organic material that is the source of the plugging.

Since going into operation in 1985, compressors have been replaced on 11 unit ventilators and 3 heat pumps. Three fan motors have also been replaced. Once a month they change filters and back flush the coils on each heat pump, and check the screens going into each unit ventilator.

Every six months, they do a thorough inspection of all heat pumps and unit ventilators including coils, fans and motors, water flow, and operation. Once a year, they do a thorough cleaning of the heat pumps and coils.

Annual maintenance costs are running \$0.12 to \$0.15 ft^2 (\$1.29-\$1.61/m^2).

System Economics: Because of the phased build-out of the system over the past 14 years, there are no records available in relation to overall system costs. The owners, however, feel that the system has been very economic to operate, and the annual maintenance costs of \$0.12 to \$0.15/ft^2 (\$1.29 to \$1.61/m^2) is very acceptable.

Satisfaction With The System: The owners and operators of the complex seem to be very satisfied with the system. It has been economic to operate, requires only normal maintenance and a very few units have required repair or replacement. Operational staff indicated that there was less than 100 percent satisfaction on the part of some patients due to the fact that the units do not provide instantaneous heat. They get on the average of one complaint per month.

OVERALL SUMMARY:

Building Description:
Location: Yakima, WA
Occupancy: Drug rehabilitation
Gross Floor Area: 134,880 ft^2 (12,531 m^2), multiple buildings
Type of Construction: New
Completion Date: 1985-1995
July Avg. High Temp.: 87°F (30.6°C)
Jan Avg. Low Temp.: 21°F (-6.1°C)
Annual Heating Degree Days: 6012°F-day (3340°C-day)
Annual Cooling Degree Days: 465°F-day (258°C-day)
Interior System:
Total Installed Heat Pump Capacity: 433 tons (1523 kW)
No. of Heat Pump Units: 297 water-to-air, 5 water-to-water
Heat Pump Capacities: 1, 3 and 8.5 ton (3.5, 10.5 and 17.5 kW) water-to-air; 5 tons (17.5 kW) water-to-water
Ground-Source System:
Type: Open loop
Mean Groundwater Temp.: 57°F (13.9°C)
Configuration: 2 production wells, 1 injection well
Well Depths: 187-200 ft (57-61 m)
Pumping Rates: 620 gpm total (39 L/s)
Economic Analysis:
Installed Geothermal HVAC Capital Cost:
unavailable
Total Annual Building Energy Use:
20.07 kWh/ft^2 (216 kWh/m^2)
Annual Maintenance Costs:
\$0.12-\$0.15/ft^2 (\$1.29-\$1.61/m^2)

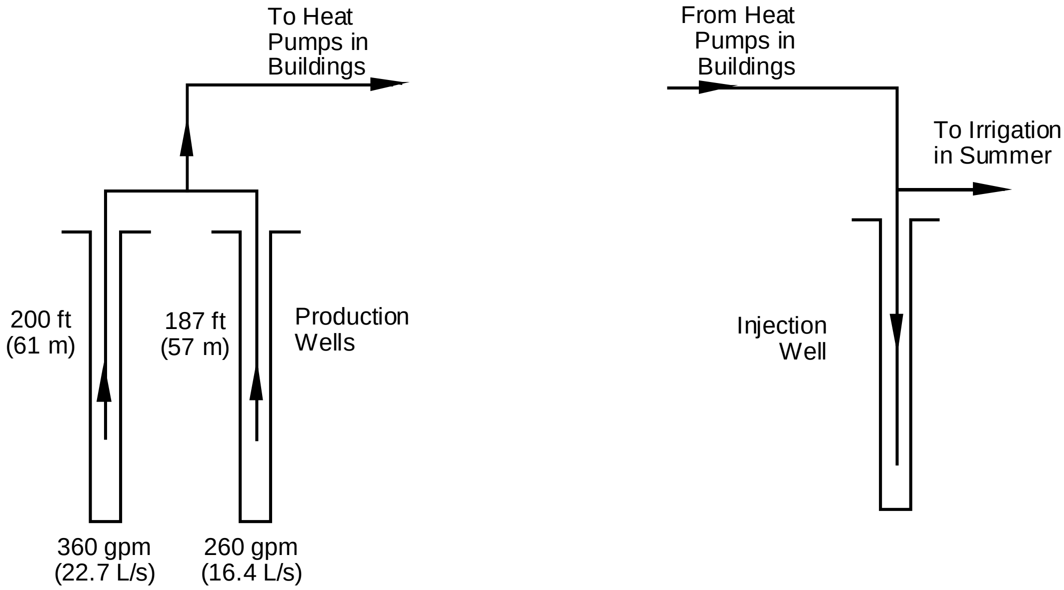


Figure 1. Process schematic of Sundown M Ranch.

Figure 2. Console heat pump.

Figure 3. Water to water heat pump.

INN OF THE SEVENTH MOUNTAIN
BEND, OREGON

Building Characteristics: The Inn of the Seventh Mountain is a hotel/condominium complex located approximately seven miles (11 km) from Bend, Oregon, on the road to the Mt. Batchelor ski area, about 175 miles (280 km) south of Portland. The Inn was first built in 1972, and consists of 22 individual condo buildings containing 350 units for a total of 248,800 ft^2 (23,115 m^2). The complex contains restaurants, a conference center, ice rink, spa, and other amenities common to a first-class destination resort. The complex is of wood construction. Heat was originally provided with resistance electric ceiling heat. Most of the lodging units are three stories. The buildings were built to meet the energy codes of the early 1970s, and according to operation staff under insulated. Windows are all double-paned.

Geothermal Heat Pump System Characteristics: A process schematic is shown in Figure 1.

Geothermal Source Description: The geothermal source is provided by one well located close to the central heat pump plant. Water flow is 1,150 gpm (72.5 L/s) at 50ºF (10ºC). The production well is 400 ft (122 m) deep. Pumping is provided by a 225-hp (168 kW) variable speed pump. After passing through heat exchangers (Figure 2), the water is disposed of through an injection well located near the edge of the property.

Heating, Ventilation, and Air Condition (HVAC) System Description: The central heat pump system consists of two 250-ton (879-kW) screw compressor heat pump/chillers (Figure 3). Originally, when the retrofit to heat pumps took place in 1992, one 300-ton (1053 kW) centrifugal unit was installed but, because it was oversized, it continued to surge and would not stay on-line. The two 250-ton (879-kW) screw compressors have proven to be much more satisfactory. The heat pump/chillers are separated from the geothermal source through the use of two plate and frame heat exchangers. Distribution of hot [ca 115ºF (46ºC)] or chilled [50ºF (10ºC)] water is via a four-pipe distribution system. The distribution system is centrally controlled for optimum temperature balance and energy use. The four-pipe system supplies fan coil units distributed throughout the condo units and other buildings. Hot water from the distribution system also preheats the domestic hot water supply to buildings. The swimming pool, spa tubs, and the bath house are also heated by the heating loop. The chilled water loop serves as the condenser water for the ice ring.

Selection Of The Geothermal Heat Pump System: By the late 1980s, the 1972 complex was beginning to experience problems with the ceiling electric resistance heating units, and there was an increasing need to be able to provide air conditioning during the summer months. The owners first looked at replacing the system with gas heating and gas absorption cooling. The servicing electric utility, however, recommended the geothermal heat pump option as a means to meet both heating and air conditioning requirements and provided incentives to the owners. The conversion was made at an investment of ca $3 million. The conversion project resulted in a 49 percent savings in metered energy, but only a 3 percent savings in energy costs. However, it must be remembered that the system now also provides air conditioning that was not provided by the system replacement.

Operating History: When the conversion from electric ceiling resistance units to a central geothermal heat pump system was made, the decision was made to go with one 300-ton (1053 kW) centrifugal heat pump/chiller. This, however, proved to be a poor choice, and during light loads, the unit was considerably oversized and continued to surge and would not stay on-line. After only a short period of time, it was decided to replace the 300-ton (1053 kW) centrifugal unit with two 250-ton (879 kW) screw compressor units. These units also suffered some initial problems due to faulty thrust bearings, and both motor assemblies had to be replaced within the first year. However, after these initial design and equipment problems, the system has operated as expected and with minimal operational or maintenance problems.

The only short coming of the system is that there is no central control over thermostats in individual condo units, thus when units are not occupied, there is no way to monitor or control temperature levels. This has resulted in many unoccupied units being heated or cooled needlessly and, of course, with a substantial waste of energy and with a significant cost penalty.

Operation And Maintenance: The system has operated extremely well since initial problems associated with the centrifugal heat pump/chiller and motor thrust bearings were solved. In neither case was the problem a result of or caused by the geothermal source. Maintenance and operation are both taken care of by an experienced and very competent in-house staff.

System Economics: The $3 million retrofit to geothermal heat pumps resulted in a 49 percent reduction in metered electrical energy consumption, and a 3 percent reduction in overall energy cost, while at the same time providing air conditioning. The total energy consumption for the facility is 24.47 kWh/ft^2/yr (263.4 kWh/m^2/yr), while the heat pump plant uses 10.14 kWh/ft^2/yr (109.1 kWh/m^2/yr). Annual maintenance cost for the past several years have averaged approximately $0.18/ft^2 ($1.94/m^2). The annual energy usage as well as the maintenance cost is somewhat of an over estimate, as the system also provides heating to two swimming pools and the spa pools, and the chilled water. loop serves as the condenser water for the ice ring.

Satisfaction With The Geothermal Heat Pump System: Operation and maintenance staff are both extremely happy with how the system has operated and the lack of maintenance problems that have occurred. The system seems to provide a high level of comfort to guests. It would appear that even greater energy and cost savings would be possible if the system were set up so that individual units could be monitored and thermostats adjusted when the units were unoccupied for any extended length of time.

Acknowledgement: The author wishes to thank Jon Menzic, the director of facilities for the Inn of the Seventh Mountain and Clark Satrae of Pacific Power and Light for their assistance in obtaining data.

Overall Summary:
Building Description:
Location: Bend, OR
Occupancy: Hotel/condominium resort
Gross Floor Area: 248,800 ft^2 (23,115 m^2), 22 buildings
Type of Construction: Retrofit
Completion Date: Buildings in 1972, heat pump retrofit in 1992
July Avg. High Temp.: 81.7°F (27.2°C)
Jan Avg. Low Temp.: 23°F (-5.0°C)
Annual Heating Degree Days: 4490°F-day (2494°C-day)
Annual Cooling Degree Days: 12°F-day (7°C-day)
Interior System:
Total Installed Heat Pump Capacity: 500 tons (1758 kW)
No. of Heat Pump Units: 2 water-to-water
Heat Pump Capacities: 250 tons (879 kW)
Ground-Source System:
Type: Open loop
Mean Groundwater Temp.: 50°F (10°C)
Configuration: 1 production well, 1 injection well
Well Depths: 400 ft (122 m)
Pumping Rates: 1,150 gpm (72.5 L/s)
Economic Analysis:
Installed Geothermal HVAC Capital Cost:
$3 million
Total Annual HVAC Energy Use:
10.14 kWh/ft^2 (109.1 kWh/m^2)
Total Annual HVAC Energy Savings:
49% plus the additional benefit of cooling
Annual Maintenance Costs:
$0.18/ft^2 ($1.94/m^2)

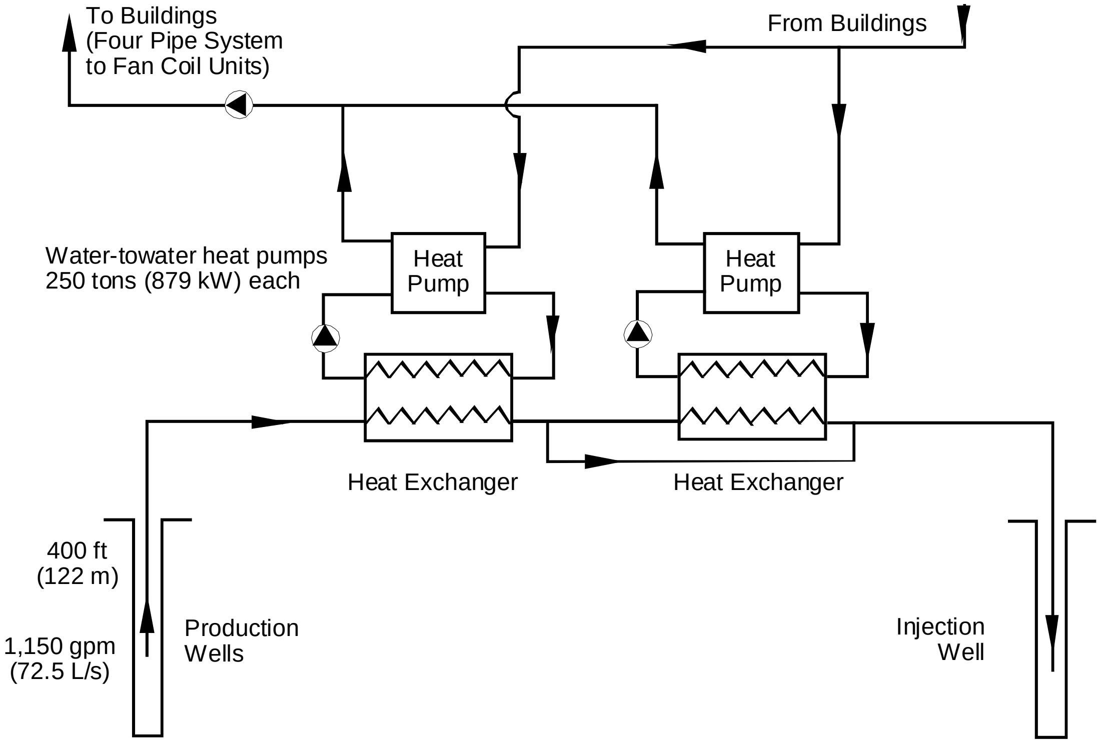


Figure 1. The process schematic for the Inn of the Seventh Mountain.

Figure 2. Photograph of one plate and frame heat exchanger at the Inn of the Seventh Mountain.

Figure 3. Photograph of one of the water-to-water heat pumps at the Inn of the Seventh Mountain.