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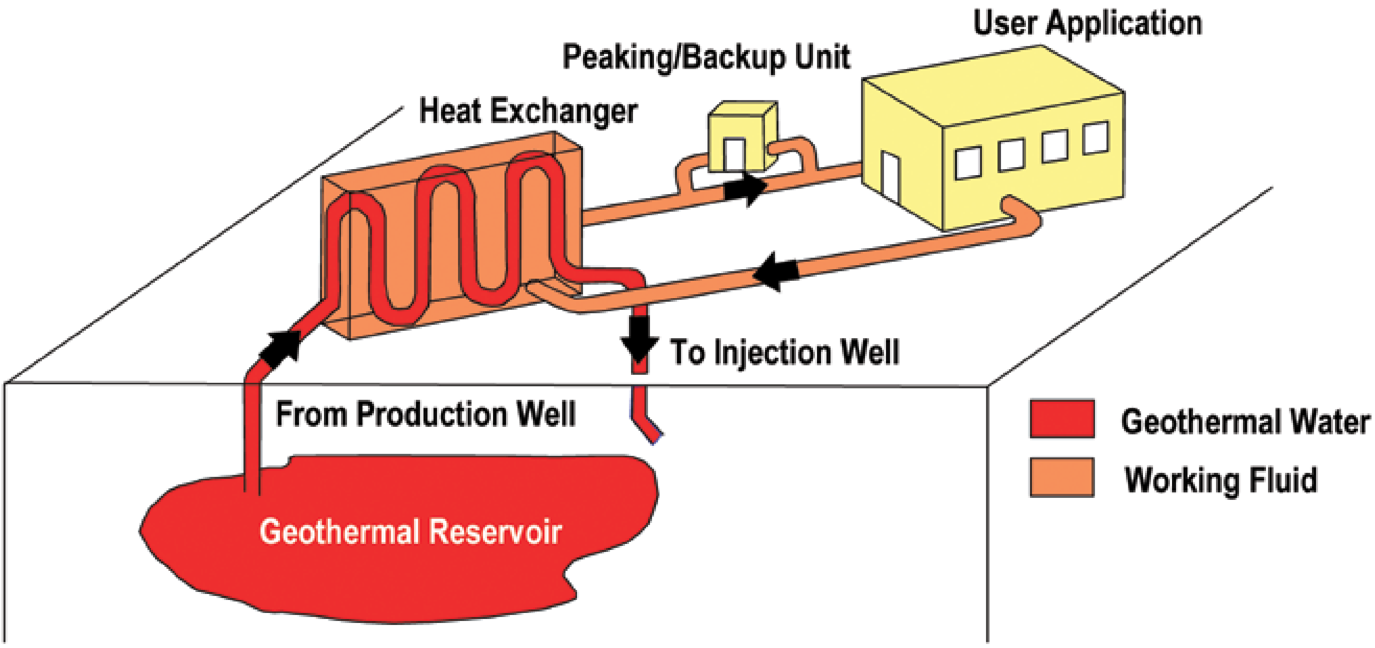
GEO-HEAT CENTER QUARTERLY BULLETIN

UTILIZING GEOTHERMAL



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

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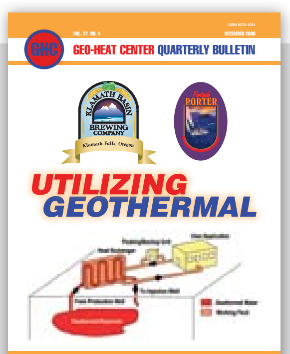

*Cover - Top Left: Logo of the Klamath Basin Brewing Co.**
*Right: Microbrew Label from Kl. Basin Brewing Co.**
Bottom: Typical geothermal direct-use equipment using a heat exchanger to isolate potentially corrosive or scaling geothermal fluid from the space heating equipment by using "clean" fluid in the second loop.
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FROM CREAMERY TO BREWERY WITH GEOTHERMAL ENERGY: KLAMATH BASIN BREWING COMPANY

Andrew Chiasson, Geo-Heat Center

INTRODUCTION

The Klamath Basin Brewing Company, located in Klamath Falls, Oregon, is the only known beer brewing company in the world that uses geothermal energy in their brewing process. The brewery opened in 2005 after renovating the historic Crater Lake Creamery Building, built in 1935. The building is now known as "The Creamery Brewpub and Grill". The brewery currently brews about 10 different beers.

THE GEOTHERMAL RESOURCE AND DISTRIBUTION SYSTEM

The City of Klamath Falls is located in a Known Geothermal Resource Area (KGRA) that has been used to heat homes, businesses, schools, and institutions since the early 1900s. The Creamery Brewpub and Grill is part of the Klamath Falls district geothermal heating system, which was originally constructed in 1981 to extend the benefits of geothermal heating to downtown Klamath Falls. This year (2006) marks the 25th anniversary of the district heating system, and after some difficult times in its development, the system now provides heat to 24 buildings totaling about 400,000 ft2 (37,200 m2), 150,000 ft2 (14,000 m2) of greenhouse space, 105,000 ft2 (9,750 m2) of sidewalk snow-melting area, and also provides process heat to the Klamath Falls wastewater treatment plant (WWTP).

The history and design of the Klamath Falls geothermal district heating system has been recently summarized by Brown (2006). The system is served by two geothermal production wells located about 1 mile (1.6 km) from the downtown area. Well #CW-1 is 367 ft (112 m) deep with a groundwater temperature of 226˚F (108˚C) and well #CW-2 is 900 ft (274 m) deep with a groundwater temperature of 216˚F (102˚C). Production well pumps, which are the vertical line shaft type each rated at 500 gpm (31.5 L/s) pumping capacity with a 50 hp (37 kW) motor, convey geothermal water through a transmission pipeline to a central heat exchange building. The transmission pipeline is 8-inch (203 mm) steel with polyurethane foam insulation protected by a fiber-wound FRP jacket. The pipeline is about 4,400 ft (1,340 m) long, with about one-third of the line being direct-buried and the remainder enclosed in a concrete tunnel.

At the heat exchange building, the geothermal water transfers heat to the closed downtown circulating heating loop via large stainless steel plate-type heat exchangers. The geothermal water is then injected back into the aquifer via a 1,200 ft (365 m) deep injection well adjacent to the heat exchange building. Hot water is provided to the downtown customers at approximately 180˚F (82˚C). Variable speed drives on well pumps and circulating pumps in the closed heating loop help the system to maintain the design supply temperature.

THE BREWERY GEOTHERMAL SYSTEM

The Creamery Brewpub and Grill uses geothermal energy from the Klamath Falls geothermal district heating system for all its heating purposes. Uses of geothermal energy include space heating of approximately 11,000 ft^2 (1,022 m^2) of restaurant/pub space, snow-melting of about 1,000 ft^2 (93 m^2) of sidewalks, and generation of hot water for the brewing process.

THE BREWING PROCESS

The brewing process is shown schematically in Figure 1. The process starts with malted barley stored in a silo outside

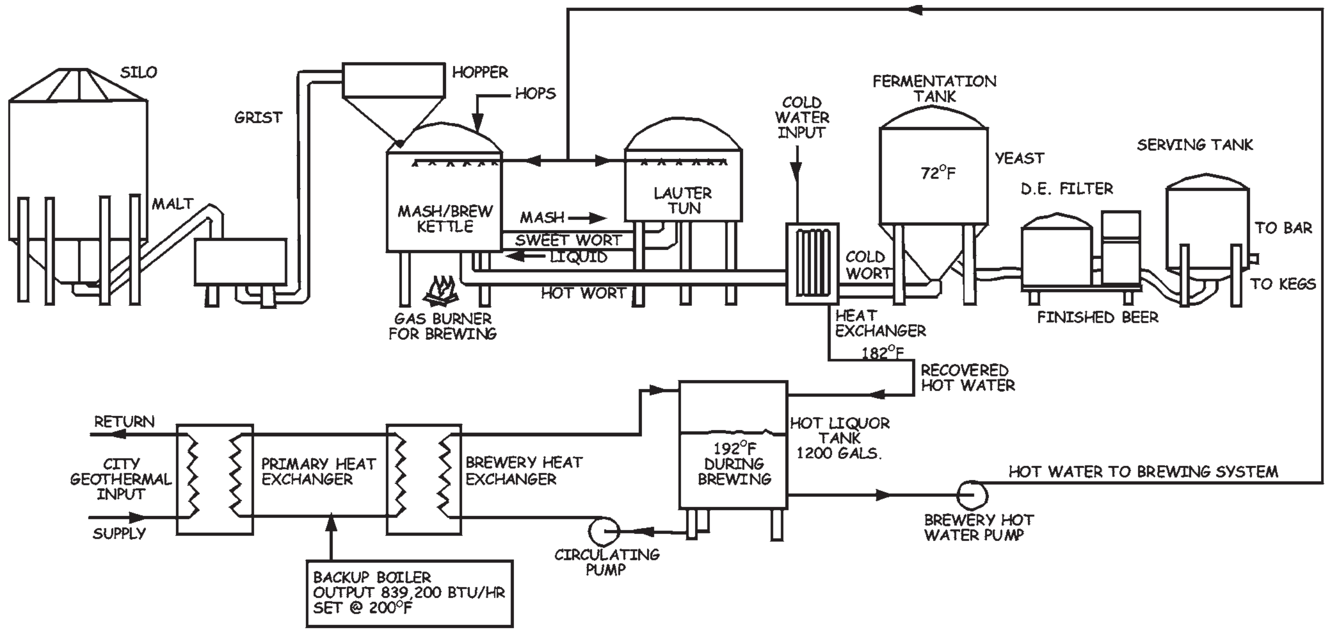

Figure 1. Brewing process schematic.

the building (Figure 2). The blend of malts required for a particular recipe is cracked in a roller mill. The milled malt or "grist" is transported by an auger to the grist hopper above the brewhouse.

The grist is mixed with hot water generated from the geothermal source in the mash tank (Figure 3), which starts the process of "mashing". As shown in Figure 3, the hot water provided by the City geothermal system exchanges heat with a heating loop, which includes a backup/supplemental boiler. The heat exchanger between the primary geothermal water and secondary heating loop is shown in Figure 4.

Figure 2. Photograph of the malted barley silo.

This secondary loop provides heat through another plate-type heat exchanger to the pure water stream used in the brewing process. The desirable temperature of the mash is about 154˚F (68˚C), and depending on the temperature of the grist (which enters the building near ambient outdoor temperatures) , hot water up to 192˚F (89˚C) must be supplied. After a few hours, mashing converts starches in the malt to sugars, and then the mash and the sweet liquid called "wort" are transferred to another tank called the "lauter tun".

Once the mash and wort are transferred to the "lauter tun", the wort is pumped back to the mash tank which now becomes the brew kettle. During this step, the "lautering" process is started, which is done by rinsing the mash with clean hot water at a temperature of about 172˚F (78˚C), generated from the geothermal source. The temperature of the water will shut down the conversion process of starch to sugar so that the wort will not become astringent tasting.

Once the brew kettle is full, the wort is brought to a boil for about two hours using a gas burner. Bittering hops are added at the beginning of the boil, while hops used for aroma and flavor are added toward the end. After the boiling process, the wort is "whirlpooled", where the centrifugal force separates the hops from the wort and helps clarify the wort.

The wort is then cooled as it passes through a heat exchanger on its way to temperature-controlled fermentation tanks kept at 72˚F (22˚C).

The initially cold water on the cold side of the heat exchanger is recovered at about 182˚F (83˚C) and is pumped to the hot liquor storage tank. During the transfer of the wort, yeast is added which ingests the sugars to produce alcohol and carbon dioxide. Many different strains of yeast are used to give many different flavors of the finished beer. Fermentation takes 3 to 4 days for ales and 1 to 2 months for lagers.

The Klamath Basin Brewing Company does not filter their beer, as it is believed that using "fines" to help clarify the

Figure 3. Photograph of the mash tank/brew kettle.

beer results in a more full-flavored beer. The finished beer is carbonated and stored in serving tanks in a walk-in cooler, where it is either kegged or served to customers.

ENERGY CONSUMPTION AND OPERATING COST

City metering of geothermal energy usage by the Creamery Brewpub and Grill has just begun in March 2006, so documented geothermal energy use history is limited. During March 2006 when a significant amount of space heating and snow-melting were required, the Creamery Brewpub and Grill used about 1,700 therms (179 GJ) of geothermal energy, which cost about $1,360. The avoided cost of natural gas at 80% efficiency and $1.20/therm would be about $2,550. Therefore, the Creamery Brewpub and Grill saved about $1,190 during the month of March 2006 with geothermal energy.

During the month of June 2006 when most of the geothermal energy would be used for beer brewing, the Creamery Brewpub and Grill used about 430 therms (45 GJ) of geothermal energy, which cost about $344. The avoided cost of natural gas at 80% efficiency and $1.20/therm would be about $645.

Figure 4. Photograph of the heat exchanger between the City geothermal district heating system and the brewery secondary heating loop.

Therefore, the Creamery Brewpub and Grill saved about $300 during the month of June 2006, with geothermal energy. It should be noted however, that the geothermal system was shut down sometime in June 2006, so these values may not be representative of a full month's energy useage.

ACKNOWLEDGEMENTS

The Geo-Heat Center wishes to thank the owners of the Klamath Basin Brewing Company, D. Azevedo & L. Clement, for providing the information for this case study, and D. Beach of Stanford University for the photographs.

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BONNEVILLE HOT SPRINGS RESORT, NORTH BONNEVILLE, WA

R. Gordon Bloomquist, Washington State University Energy Program, Olympia, WA

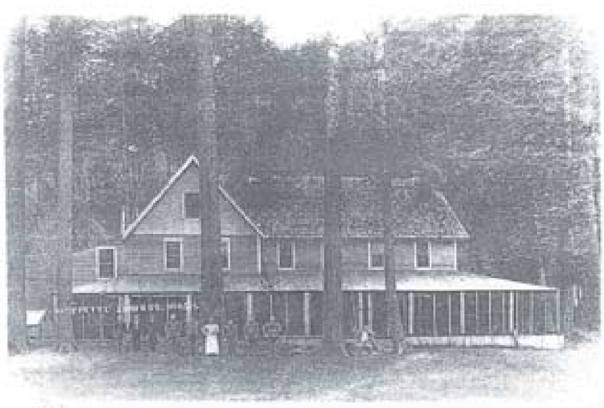
Bonneville Hot Springs Resort Main Lobby

LOCATION

The Bonneville Hot Springs Resort is located in North Bonneville, Washington some 72 km (45 miles) east of Vancouver, Washington and Portland, Oregon. The resort, located in Skamania County, is in the Columbia River Gorge National Scenic Area.

Historical records indicate the springs were first used by the Native American Indian tribes living in the area and that tribes such as the Rogue River, Chitcoe, Calapoi, Klamath and Makah would travel to this treasured spot, bringing their sick and aged to bathe in, and drink the waters.

Discovery of the spring by European settlers was in 1880 by an old miner, Mr. R. J. Snow. A local merchant, Mr. Thomas Moffett, who was keeping a store at the Cascades at the time, recognized the value of the springs and acquired an interest in the springs. In 1881, Mr. Moffett built the Cascade Springs Hotel and in 1885 began selling the bottled water for 10 cents per bottle.



Cascade Springs Hotel, 1920's

The bottled water was recommended to bar rooms, clubs, restaurants, hotels, etc. By 1890, Mr. Moffett had a thriving business based on chemical analysis performed by prominent Portland, Oregon physician Dr. Rex and subsequently by renown chemist J. H. Fisk and the US Chemical Assayers of Washington DC, who all agreed as to the mineral content and the potential good health qualities. The water was advertised as being helpful for kidney complaints, liver problems, dyspepsia, rheumatism, dropsy, and general debility.

From its early beginnings the spring changed ownership and even name when the town changed from Moffetts, Washington to North Bonneville in 1934. It also saw several episodes of growth including the building of a new hotel in 1932 to replace the original structure that had been destroyed by fire. Sub-sequent development included the addition of a dozen cabins and a 38-acre campground with 75 electrical hookups.

However, by the time the author first visited the site in the late 1970's, there was little remaining of the glory days of the 20's and 30's. Only a few cabins remained and the entire facility was in disrepair and the owners were being sited for health violations due to sewage problems. It seemed that Moffetts Hot Springs/Bonneville Hot Springs would become a historical footnote to the area.

But, in 1990, as has happened so may times before, a new owner – this time an entrepreneurial Russian by the name of Pete Cam – was about to change all of that and Bonneville Hot Springs Resort is once again one of the jewels of the Columbia Gorge.

RESOURCE

North Bonneville Hot Springs Resort is located in the central part of the Columbia River Gorge, near the town of North Bonneville, in the Cascade Range Geologic Province. Only Cenozoic stratigraphy is exposed and is entirely volcanic in origin, except for alluvial and landslide deposits. Small intrusives in the form of volcanic necks and dikes are located nearby as well as a small Quaternary volcanic center and associated deposits (Wise, 1970).

Structure in the area is represented by gentle folds and limited definable faulting. Minor topographic lineations, however, are fairly common and are presumed to represent major tectonic points or faults with minimal displacement.

Moffetts Hot Spring (Bonneville Hot Springs) and St. Martin's Hot Spring to the east near the town of Carson have temperatures of 32°C (89.6°F) and 49° C (120.2°F) respectively. These hot springs are structurally controlled and are probably located at the intersection of more than one fracture trend (Nielson and Moran, 1980). Recent drilling (2003) near Carson and to the east of the Wind River encountered the highest yet recorded geothermal waters in Washington 81°C (178°F) at 610 meters (2000 plus ft.). The Ohanapeosh Formation underlies the area and is considered to be an aquaclude due to post depositional formations of zeolites and clays.

The only definable fault mapped in the general area of Moffett Hot Springs is located on the south flank of Table Mountain and displaces Grande Ronde Basalts about 15.25m (50 ft.) down to the north on a vertical plane. The trend of the fault, N 70 E, is representative of structural trends to the east in the Klickatat River and from the Wind River to the Klickatat River.

A strong linear correlation exists from the alignment of the saddle in Table Mountain, the 244 m (800 ft.) scarp in the Eagle Creek Formation exposed in Red Bluffs, the position of Grays Hot Springs, and a small saddle above Carson Creek to the east. A parallel trend can be observed by constructing a line from Moffetts Hot Springs through St. Martin's Hot Springs.

Moffetts Hot Springs is located about 3 km (2 miles) northeast of North Bonneville and has a surface temperature of 32°C (89.6°F) with a predicted reservoir temperature of less than 80°C (176°F) (Schuster et al., 1978).

A temperature gradient hole drilled about 3 km (2 miles) to the southwest of North Bonneville at the mouth of McCord Creek on the south shore of the Columbia had a calculated gradient of about 50° C/kilometer (145°F/mile) consistent with the gradient of the region (Nielson and Moran, 1980).

USE

The Bonneville Hot Springs Resort, Spa and Conference Center was completed in 2002. The 1,115 square meter (12,000 sq. ft.) facility is located on the site of the original

Bonneville Hot Springs Resort Balcony Hot Tub

Bonneville Hot Springs Resort

Moffetts Hotel and Bottling Works. The resort has conference facilities, cocktail lounge, and restaurant, and is accented by a three-story fireplace in the lobby.

There are 74 deluxe rooms and four spacious suites. Sixteen of the rooms have private hot tubs filled with the natural hot spring waters.

There were originally four wells drilled at the site from 24.5 meters to 49 meters (80-160 ft.) deep. The wells flowed artesian until there was a major natural gas explosion caused by a rupture of a nearby major gas transmission line. The present owner drilled two new wells 183 meters (600 ft.) and 335 meters (1,100 ft.) in the late 1990's and early 2000's and retained one of the four original wells. They now pump 6.3-9.5 L/s (100-150 gpm) of 36°C (97°F) geothermal water using line shaft pumps.

The geothermal water is used directly in some of the soaking tubs and the large pools. As needed, the temperature is boosted using geothermal heat pumps. Heating for the facility is also provided through the use of geothermal heat pumps with heat being distributed through a forced-air system.

Resort Indoor Lap and Soaking Pools

OPERATING COSTS

No cost figures could be obtained as the facility was originally designed and constructed to maximize the use of the geothermal resource. No comparison costs were developed.

REGULATORY/ENVIRONMENTAL ISSUES

The main regulatory/environmental issues were related to obtaining water rights and water disposal. Application for water rights were made in 1995 and it wasn't until the late 1990's that water right issues were finally resolved. Water disposal was also an issue. Waters that are not used for swimming or bathing are returned to a nearby stream at ambient temperature; other waters have to be treated. Health concerns have also been a major issue for development of geothermal spas in Washington State and except for those facilities where the water is not for "public use" or there is sufficient flow through, the Department of Health generally requires chlorination. This is true at Bonneville where chlorination of waters used in "public" areas is employed.

PROBLEMS AND SOLUTIONS

The resort has experienced few real problems since opening to the pubic in 2002. One major problem did occur prior to opening when in the process of drilling they were forced to cement the hole and reduce the diameter of the hole from an originally planned 30 cm (12 inch) casing to 15 cm (6 inch) final completion. This of course had an impact on potential flow and pump selection.

Other problems have occurred relative to one of the line shaft pumps. The problem was overcome and pumps no longer seem to be a problem area.

Copper tubing was tried but was not suitable considering the chemistry of the geothermal fluids and now the geothermal is isolated through the use of stainless steel heat exchangers.

CONCLUSION

The rebuilding of the Bonneville Hot Springs Resort on the site of the original 1881 Moffett Hot Springs Hotel continues over a century of geothermal use in this scenic area of the Columbia River Gorge. When the author first met the present owner, almost 14 years ago, it seemed like he was about to try to do the impossible. Now his enthusiastic spirit and commitment to excellence have created one of the jewels of the Columbia River Gorge.

The geothermal hot springs provide for most of the energy needs of the facility, and numerous spa treatments also use the natural hot spring mineral water.

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OURAY HOT SPRING MOTELS, LODGES AND SPAS, OURAY, CO

R. Gordon Bloomquist, Washington State University of Energy Program, Olympia, WA

LOCATION

Ouray, Colorado lies in a natural amphitheatre in the upper Uncompahgre Valley in the northern portion of the San Juan Mountains at an elevation of 2,380 meters (7,800 ft.), Uncompahgre being a Ute Indian word for "hot water".

The town was incorporated in 1876 only a year after mining began in the area. Mining activity has been erratic and depends upon market conditions for gold, silver, copper, lead, and zinc, the primary minerals found in the area.

The city's large hot spring pool (see Geo-Heat Center, 2003) as well as the pools and spa facilities at a number of the city motels and lodges has made Ouray one of the most attractive vacation spots in Colorado. Ouray has also become the winter "ice climbing capital", with climbers coming from throughout the United States and abroad to challenge the numerous frozen water falls in the area.

Three of the major lodging establishments in the town—the Wiesbaden Hot Spring Spa and Lodgings, the Best Western Twin Peak Motel, and the Box Canyon Lodge and Hot Springs—have each capitalized on the natural hot springs in the area. Although all three have hot spring pools, use of the geothermal water for heating has met with mixed success.

RESOURCE

Ouray is located in a region of high heat flow, about 170 mW/m^2 (Zacharakis, 1981). Active faulting and a moderate to high level of seismic activity also characterize the region that lies in the northern portion of the San Juan Mountains, among the youngest mountains in Colorado. The San Juans are composed primarily of Tertiary volcanic rocks that were deposited upon an already varied topography of horst and graben, basin, and dome (McCarthy, 1981). Post volcanic caldera collapse and resurgence produced ring faults and radial fractures that provide an avenue for hydrothermal solutions and base metal precipitation (Burbank, 1941). The Ouray Graben is an east-west trending feature bordered by the Sneffels Horst to the south, and the Uncompahgre Uplift to the north-northwest (Baars and See, 1968). Ouray is bounded by the Ouray Fault to the south which is associated with the hot springs at Box Canyon. The Ouray Fault is one of several faults of NNW to ENE trend that make up the complex 5 km (3 miles) wide fault zone (Meyer *et al*, 1982).

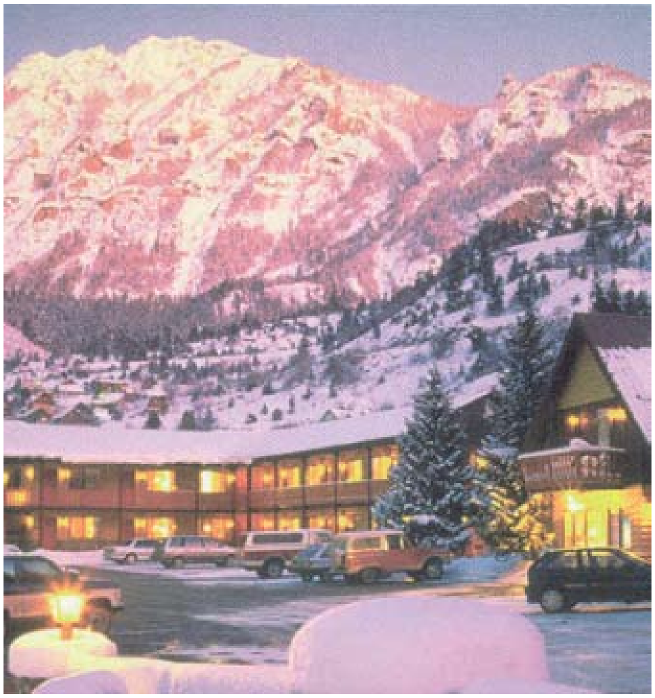
The geothermal springs are believed to be the result of deep circulation of meteoric waters in fractured permeable sedimentary rocks of the Ouray Graben. Recharge is most likely from the San Juan Mountains along the south flank of the graben (Meyer et al, 1982).

A number of springs occur in the area, the three primary ones include one at the mouth of Box Canyon, one at the Wiesbaden Lodge, and a third at the pool area. Total discharge from the spring is estimated to be up to 12.7 L/s (200+ gpm). Temperatures range from approximately 26.7°C to 66.7°C (80°F - 152°F), (Barrett & Pearl, 1976). McCarthy (1981) estimated that 238 x 10^9 MJ (2256 x 101^1 BTUs) of geothermal energy was available in the area. During the 1980's a number of wells were drilled in anticipation of building a geothermal district heating system. Although plans for district heating were never realized, one of the wells (Well OV-2) 8.5 L/s (134 gpm) at 51°C (124°F)) is used to provide water for the Ouray Hot Spring Pool (Geo-Heat Center, 2003).

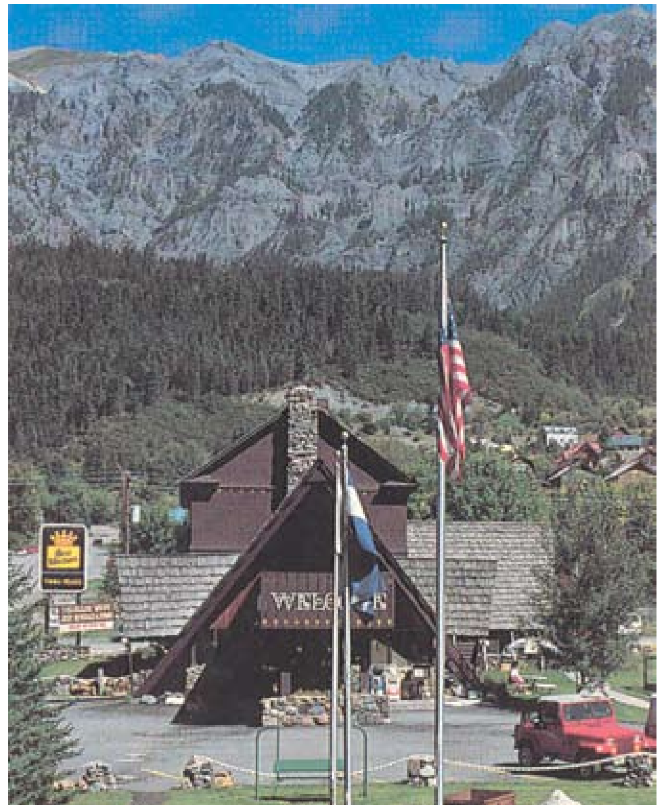
USE

The Box Canyon Lodge and Hot Spring is one of Ouray's most popular inns. The lodge is situated near the mouth of Box

Canyon. Several 57°C to 65.5°C (135° to 150°F) springs surface on the property and provide geothermal waters for several soaking pools.



Box Canyon Lodge



Best Western Twin Peaks

Although at one time the rooms were heated with the geothermal energy, use was discontinued due to major problems associated with pumps and piping. Scaling was a major problem. The geothermal water continues to be used to heat domestic hot water. The hot water is heated through use of coils of piping placed into a large pool. Piping from the springs to the pool is plastic.

The Best Western Twin Peaks Motel is located next door to the Box Canyon Lodge and utilizes the same spring system as does the Box Canyon.

The owner, Michael Bazin, indicated that the main spring is 66.7°C (152°F). The geothermal water supplies a number of hot spring pools, soaking pools, and a whirlpool. The water is also used to heat water for the main swimming pool and for domestic hot water. Domestic and hot water are heated in a heat exchanger made up of coils of copper tubing in a shell heat exchanger.

Maintenance of the system is a major issue according to Mr. Bazin. There have been continuous problems with both pumps and piping. Plastic piping is used but scale has to be broken out at least every six months and more often when problems arise. Pumps appear to be an even greater cause for concern and generally have to be rebuilt on the average every 60 days.

The Historic Wiesbaden Hot Spring Spa and Lodgings had its beginning in 1879. The soaking facilities and mini pool are fed by the naturally flowing springs that range in temperature from 25.5°C to 53°C (78°F to 128°F). Temperatures of the main pool range from 37°C to 39°C (99 to 102°F). One of the interesting features is the vapor cave that is located in and under the Wiesbaden's main lodge area. In the main vapor cave, the hot spring water is captured in an eighteen inch deep soaking pool ranging in temperature from 42°C to 43°C (107°F to109°F).

The Wiesbaden does use the geothermal water to provide space heating as well as domestic hot water. Although they originally used steel pipe, they have found that plastic pipe is preferable from a maintenance standpoint. The major maintenance issue is scale buildup in the pipes requiring that sediment be removed on a weekly basis.

OPERATING COSTS

None of the three facilities could supply operating costs. In truth, only minor pumping is required at two of the facilities. Maintenance costs had not been quantified and were considered to be just a necessary element of general maintenance duties. Although rebuilding or replacement of pumps was an ongoing problem, no detailed records as to cost incurred were available.

REGULATORY/ENVIRONMENTAL ISSUES

All of the facilities were established prior to the adoption of rules and regulations relative to water withdrawal or disposal.

The Twin Peaks Motel does use chlorinated city water in its main pool and in some of the soaking and whirlpools. The other facilities are flow-through and have adequate flow to

Wiesbaden Hot Spring Spa

avoid the need for chlorination. Water from the Twin Peaks is discharged to the city but does not go to the sewage treatment plant. Waters from the other facilities are discharged to local streams that ultimately flow into the Uncompahgre River.

Wiesbaden main vapor cave

The only serious regulatory issue that arose was in regard to a loss of flow from the spring at the Wiesbaden that resulted from the drilling of the city well that now supplies the municipal pool. The owner of the Wiesbaden, Lynda Minter, has been in litigation with the city over the loss of approximately 2 L/s (30 gpm) since 1987. At the time the facility was visited (late 2003) the issue had not been resolved although the city was proposing remedial measures.

PROBLEMS AND SOLUTIONS

The primary problems appear to be related to scaling. The waters are a calcium sulfate type and have a TDS from a low of 695 mg/l in one of the springs at the Wiesbaden to a high of 1,840 mg/l also from another spring at the Wiesbaden. The springs at the mouth of Box Canyon have a TDS of 1,650 mg/l.

Scaling has caused pump failure, requiring replacement or rebuilding on a regular basis—sometimes every two months. Scaling in the piping system requires removal every few months and at the Wiesbaden they indicated that they removed sediment from the piping weekly.

The scaling problem resulted in discontinuing the use of the geothermal water at the Box Canyon Lodge and the Twin Peaks Motel for heating, and causes ongoing maintenance problems at the Wiesbaden.

Many of the problems associated with providing space heat could be easily overcome by separating the geothermal water from the internal heat distribution system with a heat exchanger. Material as well as equipment selection would also seem to be areas that need further study.

In talking with the owners or operators of the three facilities, none were familiar with geothermal technical support that is available through, for example, the Geo-Heat Center at Oregon Institute of Technology.

Issues surrounding the loss of flow at the Wiesbaden due to the drilling of the pool water well are much more difficult to resolve. The city does appear to be prepared to replace the lost flow from another source.

CONCLUSIONS

The three facilities visited have all capitalized on the hot springs to establish thriving businesses. Unfortunately, through a lack of understanding and technical expertise in geothermal direct use applications, use of the geothermal waters to supply much of the energy needed for the three facilities for heating is not being realized and ongoing maintenance problems with existing facilities require a great deal of maintenance, repair, and replacement of system components.

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THE VETERANS ADMINISTRATION HOSPITAL DISTRICT HEATING SYSTEM, BOISE, ID

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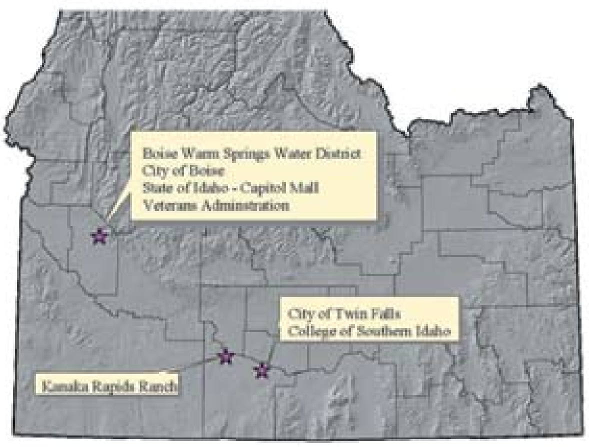


Boise Warm Springs Water District

LOCATION

The Veterans Administration Hospital District Heating System is located on the northeast side of Boise, Idaho, in Ada County of southwestern Idaho.

The hospital is within the borders of an administration district called the Boise Front Low Temperature Geothermal Resource Ground Water Management Area (GWMA). It is located in an area along the Boise Foothills known as the Boise Front. Boise is located along the northern margin of the northwest trending topographic depression known as the Western Snake River Plain. Wells in the area have water temperature ranging from about 27°C to 77°C (80°F to 170°F).

Development of geothermal water began in the Boise area in about 1890 when the Boise Water Works Company drilled an exploration well for hot water in an area about 4 km (2.5 miles) east of Boise at the location of some existing springs (Neely, 1996). In 1891 the first geothermal well was drilled near the site of the present Warm Springs Water District well house.

The first well encountered warm water at 24 meters (80 ft.) and the water became progressively hotter and the flow increased with depth. A flow of 9.5 L/s (150 gpm) of 68°C (154°F) water was encountered at a depth of 94 meters (308 ft.) Waag and Wood, 1987, quotes from the *Idaho Statesman* 1/30/1891. A second well drilled 15 meters (50 ft.) from the first was equally successful and the two wells reportedly provided an artesian flow in excess of 3,028,000 liters per day, 35 L/s (800,000 gallons per day, 555 gpm) of 77°C (170°F). This discovery resulted in the development of the Artesian Hot and Cold Water Company in 1892, later known as the Boise Warm Spring Water District.

After a period of nearly 80 years where there was no significant new geothermal development of the Boise geothermal resource, interest in further development began in 1970, and in 1977 the State Health Laboratory was converted to geothermal space heating.

In 1981 the Capitol Mall wells # 1 and 2 were completed. In 1982 nine buildings in the Capitol Mall complex were being heated by a geothermal district heating system. Boise Geothermal Limited also completed four production wells in the early 1980's in anticipation of constructing a district heating system to serve commercial and institutional buildings in the downtown area (Neely, 1996).

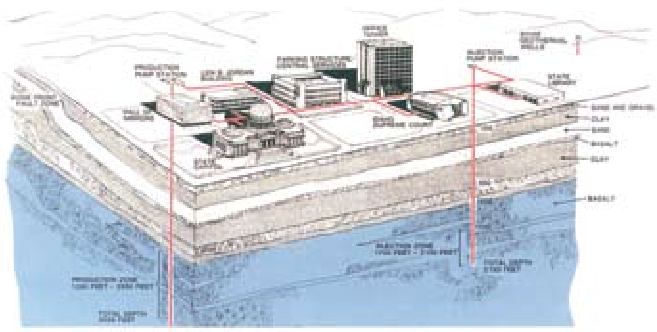
RESOURCE

The lower Boise River sub-basin is located along the northern margin of the northwest-trending topographic depression known as the Western Snake River Plain. The Western Snake River Plain has the appearance of a northwest-trending graben associated with continental rifting (Mabey, 1982; Woods and Anderson, 1981).

The Boise Front geothermal aquifers reside in a seemingly complex series of igneous rocks and interbedded sediments underlying the "cold water" sedimentary aquifers. Depending on location, geothermal water is found in Cretaceous-aged granite of the Idaho Batholith, Tertiary rhyolite, and associated sediments, and/or Tertiary basalts and basaltic tuffs (Petrich, 2003).

Warm Springs wellhouse

Geothermal water is thought to be associated with fractures along the northwest trending fault zone that marks the northeastern boundary of the Snake River Plain. Faults, fractures, and joint systems within the volcanic units serve as conduits for horizontal as well as vertical geothermal water movement.



The Capitol Mall geothermal system

There appears to be consensus among researchers that the geothermal flow system is largely dominated by the basin margin fault-fracture zone (Petrich, 2003).

Development of successful wells located away from exposed faults along the Front including the Capitol Mall well, city injection and Veterans wells, and documented hydraulic connections between these wells, demonstrates that the aquifer is continuous to the southwest (transverse to the main fault) for some kilometers/miles (Petrich, 2003).

Although the area is in an area of high heat flow the origin of the thermal waters is not well understood. Mayo, et al., 1984, states that "most researchers agree that radiogenic decay in the granitic rocks of the Idaho Batholiths is the principal source of heat" in the geothermal system.

USE

The Veterans Administration Hospital was established in 1929. The hospital complex consists of 30 buildings and has a staff of 640. The facility has units for extended care, substance abuse, in and out patient medical care, and intensive care.

The Veterans Administration began looking at the potential to develop a geothermal system in the early 1980 following the Capitol Mall and Boise Geothermal Limited successful geothermal drilling projects.

The Veterans Administration drilled a production well in 1983 that proved capable of producing up to 78.5 L/s (1245 gpm) during a pump test. Temperature of the production well was 71.7°C (161°F). An injection well was drilled in 1987 and the system was brought online in 1988 (Petrich, 2003; Pat Flanagan, 2003).

Six of the 30 buildings are connected directly to the geothermal water while the remaining 24 are connected via a central loop.

Maximum required flow is about 70 L/s (1,100 gpm) while average consumption is approximately 38 L/s (600 gpm). Summer use, which is primarily for heating domestic hot water, averages 12.6 L/s (200 gpm).

The facility was originally served by a steam plant and all the buildings were converted to hot water. They do have a 2940 kWt (300 hp) hot water boiler to meet peak demand and provide some backup should the geothermal system fail. They also have backup generators and the well pumps are connected to the backup power supply. In total the system supplies 40,506 square meters of building space (436,000 sq. ft.) with an average of 16 air changes per hour.

The production well has a 37 kW (50 hp) pump and the injection well is equipped with a 56 kW (75 hp) pump. Distribution is via asbestos concrete pipe.

OPERATING COST

The Veterans Administration could not provide detailed cost information relative to capital cost incurred or operational cost savings. Data available, however, indicated that although the original estimate was for an 8 year payback, the payback was actually achieved in 5 years.

In 2002 the system won an energy star award from the Environmental Protection Agency, competing against 40 other federal projects of which 17 were VA hospitals (Flanagan, 2003).

REGULATORY/ENVIRONMENTAL ISSUES

Although no major regulatory or environmental issues were raised relative to the drilling of the wells or construction of the system, a serious drawdown of production wells in the area resulted in a moratorium on further development being issued in 1985 (Johnson, 2003). This had no real impact on the Veterans Administration Hospital as it was reinjecting all of the fluids withdrawn from the aquifer.

The moratorium has remained in place and in fact on December 2, 2003, the Department of Water Resources ordered a five-year extension of the moratorium that bans new development or additional use of the Boise Front geothermal aquifer (Johnson, 2003). No other problems were reported.

CONCLUSION

The Veterans Administration Hospital has enjoyed the benefits of geothermal district heating since 1988. The system exceeded its anticipated payback of 8 years by 3 years and has operated nearly trouble-free for over 15 years. In 2002 it won an Energy Star Award from the Environmental Protection Agency (Pat Flanagan, 2003).

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MICRO-GEOTHERMAL DEVICES FOR LOW-ENERGY AIR CONDITIONING IN DESERT CLIMATES

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INTRODUCTION

In the developing world, particularly in hot, desert climates, there is a great need to provide effective, low-cost cooling methods for residences and small commercial buildings. In many situations, the building heat load is very high, and conventional technologies are prohibitively expensive. Low-cost conditioning through evaporative cooling may reduce temperature levels, particularly in dry climates, but the corresponding increase in humidity creates an uncomfortable environment. On the other hand, less effective and less costly cooling means may be capable of reducing temperatures so that residences and buildings can be tolerably occupied during the hottest portions of the day. This article describes the application of an inexpensive micro-geothermal air-cooling device. The effect of this cooling method is assessed and the energy savings evaluated.

During March, 2005, a faculty-led student research team from the University of St. Thomas (St. Paul, MN) traveled to Mali, Africa to implement the cooling modality described in the foregoing. The research trip lasted ten days; five days involved on-sight testing and concept evaluation. Mali, located at the westernmost edge of the Sahara desert, is one of the poorest nations in the world. Its location and development status makes it a prime candidate for implementation of inexpensive cooling solution that, if successful, can be expanded to include other nations in the region and around the world.

The research project focused on cooling of Community Learning and Information Centers (CLICs) which are small, single-room buildings which house 5-10 personal computers. A photograph of a typical CLIC is presented in Figure 1. Computers outfitted with internet capability are used by local residents to access websites and CD-ROM information related to health, education, economics, growth, and democracy. Continuous operation of computers and other heat-generating devices and heat dissipated by inhabitants pose additional thermal problems. First, the energy dissipated by the equipment and people must be accommodated by the cooling solution. Second, the sensitivity of the electronics to dust requires that doors and windows to the structure remain closed, especially during the hottest and driest months of the year. This period usually lasts from six to seven months and coincided with the current research project.

In the absence of natural ventilation through doors and windows, cooling means such as traditional compressor-based air conditioning or water evaporation may be considered. These alternatives, however, require continuous electrical power and/or water supply. This requirement, along with the associated electrical cost, poses a severe challenge for buildings on an unreliable power grid.

Figure 1. A typical building used in geothermal cooling experiment

The chosen alternative to active, expensive cooling seeks to fulfill the cooling goals by using the thermal inertia of the ground to pre-cool air prior to its introduction into the building. The technique used here is to be contrasted with the standard geothermal heat pump, the prospects of which have been growing substantially in recent years (Lund and Freeston, 2001; Fridleifsson, 2000). Most installed heat pumps use liquid as the working fluid and extend to depths far greater than those proposed here (Hepbasli, et al., 2001). Even small-scale systems are far more extensive than that which could be utilized in the present study (DiPippo, 1999; Allen and Milenic, 2003). The corresponding energy recovery for liquid-based systems are expected to be greater than with an air-cooling system however the initial installation costs and the long-term operating costs are prohibitive for the present application. The device described in this article bears resemblance to other applications which rely on the thermal inertia concept to effect cooling. Some applications used above-ground inertia storage containers (Rainbow, 2004) which are manufactured from contained rock piles or water tanks. While effective in lowering the temperature of air, these external storage containers exceed the cost limitations for the present application.

GEOTHERMAL COOLING

As mentioned in the foregoing, typical geothermal heat pumps utilize boreholes that extend deeply into the ground (Lund and Freeston, 2001; Teklemariam et. al, 2000). These pipes are usually installed during the building construction and are designed to provide continual cooling/heating which is predicated by the local ground temperature. For deeply laid pipes, the ground temperature is remarkably constant in time, varying only slightly through daily and yearly cycles.

Deep installation of piping was not possible due to the hardness of the ground and the lack of digging machinery. Instead, a shallow, shortened underground pipe was designed.

This pipe, approximately 65 ft (20 m) long was installed horizontally, 20 inches (50 cm) beneath the earth's surface. The underground duct was constructed of 7.9 inch (20 cm) diameter round PVC pipe. The choice of diameter was motivated by the need to provide adequate flow with a minimal pressure drop. The air was drawn through the pipe by low-power axial fans that function effectively in low-pressure piping system. The desired volumetric flow rate of 200 cfm (5.7m^3/min) was designed to provide between two and three air changes per hour for the structure.

A priori calculations to predict the required length of underground piping are difficult to make because the temperature of the underground pipe is generally not known with certainty. In fact, the presence of underground piping with associated air flow disturbs the ground temperatures in the near-pipe region. Of particular concern is the possibility of thermal exhaustion. Thermal exhaustion refers to a situation where hot air flowing through underground ducting heats the ground and limits future use of geothermal air cooling. Experiments investigating the ground temperature variations and the potential for thermal exhaustion were carried out during the experimental phase of this work.

GROUND TEMPERATURE MEASUREMENTS

The potential cooling effect of the underground ductwork was studied by ground temperature measurements that were made during the five-day testing period. Five thermocouples were installed at depths of 33, 27, 21, 16, and 10 inches (85, 70, 55, 40, and 25 cm).

Surprisingly, noticeable timewise and spatial temperature variations were observed. The temperature measurements for a complete daylight cycle are presented in Figure 2, with the legend indicating the depth at which corresponding temperatures were measured. The uncertainty in ground temperature measurements, based on calibration experiments involving the thermocouple wire and datalogger is +/- 0.5˚F (0.3˚C). Also shown in the figure are air temperature measurements which were recorded in the shade. As seen from the figure, the ground temperatures reach a minimum at approximately 2 pm while air temperatures peak at approximately 4 pm, indicating that the air and ground temperatures are almost completely out of phase.

The cyclical temperature variation, which was repeated for a three-day duration, is obvious from the figure. As expected, a phase shift exists between the air temperatures and the ground temperatures. In fact, the ground temperatures peak during the nighttime and decrease to a minimal value during the day. This behavior enables daytime cooling to occur when the ground temperatures are at a minimum.

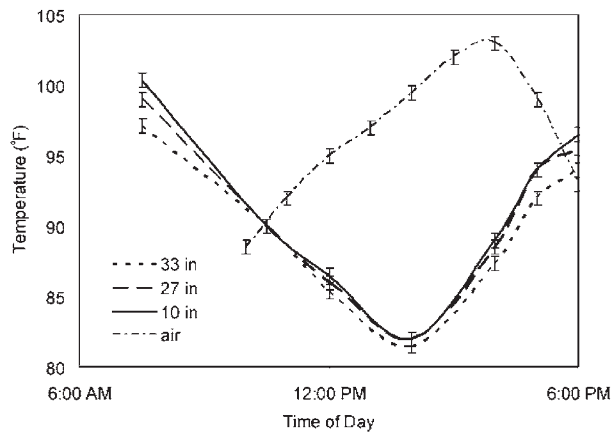

Figure 2. Timewise temperature variation of ground at depths of 10, 27, and 33 inches (25, 70 and 85 cm) and air temperatures during daylight hours

MEASUREMENTS OF THE DUCT AIR TEMPERATURES AND FLOW RATES

Upon completion of the duct construction and installation of ground thermocouples, the ductwork was connected to an axial fan which operated in the suction mode. Air temperature measurements were made at the inlet and exit of the air duct. The resulting data is presented in Figure 3. The temperature decrease of the air flowing through the underground duct is indicated in the figure. The temperature decrease is a direct measure of the cooling effect of the geothermal device. During the early afternoon, when cooling is most critical, the temperature decrease of the air is approximately 11˚F (6˚C). As the day progresses into evening, the cooling effect diminishes as evident by the convergence of the inlet and exit air temperatures. During the night time, the air flowing through the duct is actually warmed. This warming effect is visible by the morning data of Figure 4, where the air outlet temperature is higher than the air inlet temperature and, as a consequence, the ground is actually heating the air.

It may be noticed that the peak inlet air temperature of Figure 3 exceeds that of Figure 2. This is due to the fact that the inlet to the underground duct was unsheltered and exposed to direct sunlight, leading to slightly elevated inlet temperatures.

From the results presented in Figure 3, it is seen that during the majority of the day, the air exiting the duct is notably cooler than the entering air. On the other hand, during times when the ground is hot and the air is cool (the early morning), it is seen that the ground actually heats the air. This behavior makes possible the regeneration of the ground during the night time by a continual air flow, thereby reducing the possible thermal exhaustion of the ground.

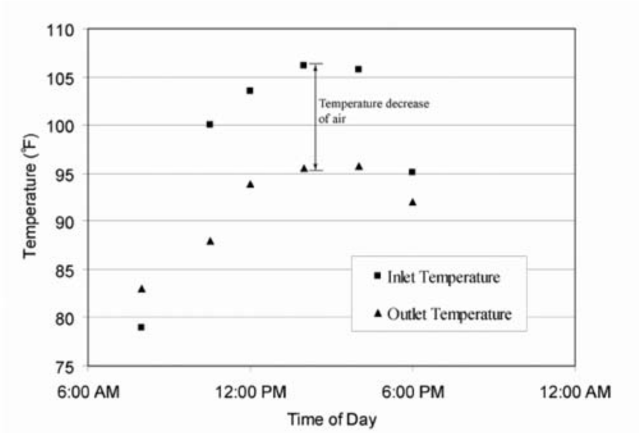

Figure 3. Inlet and outlet temperatures for air flowing through micro-geothermal air-cooling duct

During the present experiments, this approach was taken and airflow through the duct was provided 24 hours a day, for three days. Throughout this duration, no noticeable thermal exhaustion occurred, raising the possibility of long-time use of the micro-scale geothermal air-cooling system without deleterious exhaustion effects.

ENERGY SAVINGS FROM GEOTHERMAL COOLING

Air flow rate measurements in the duct were made frequently during the experimental investigation. The flowrate was generally steady in time and varied between 164 and 191 cfm (4.6 – 5.4m^3/min), slightly lower than the desired flowrate of 200 cfm (5.7 m^3/min).

The economic viability of the proposed cooling methodology was evaluated by determining the energy savings due to the conditioning effect compared to the expenditures of the flow-powering device. At any moment in time, the energy extracted from the air is calculated from the first law of thermodynamics for a flowing fluid. During the peak usage (between 10 am and 5 pm), the micro-geothermal duct extracts energy from the air at a rate.

$$\dot{W}_{cooling} = \dot{m}c_p\left(T_{inlet} - T_{exit}\right) = 14\frac{\text{lbm}}{\text{min}}\cdot 0.24\frac{\text{Btu}}{\text{lbm}-{}^{o}\text{F}}\cdot 11^{o}\,\text{F} = 37\frac{\text{Btu}}{\text{min}} = 650\text{watts}$$

where 11˚F (6˚C) is the average temperature decrease of the air flow through the duct during this eight-hour period. The energy extraction of 650 watts from the air had an appreciable effect on the comfort level in the building.

This result or Eq. (1) is to be compared to the energy investment of the required fan power of 114 watts. The total energy savings can be compared with published data on typical large-scale geothermal devices which typically range from a few kW to over a hundred kW (Lund and Freeston, 2001). The net energy savings represented by the geothermal cooling system is

$$\dot{W}_{net} = \dot{W}_{cooling} - \dot{W}_{required} = \dot{W}_{required}\left(COP_{geothermal} - 1\right) = 536\,\text{watts}$$

For the duration of the dry period, it is expected that approximately 680 – 790 kW-hours of power would by saved by the continuous operation of the geothermal air-cooling device.

CONCLUDING REMARKS

The development, implementation, and evaluation of a micro-geothermal air-cooling system for the conditioning of buildings in desert climates has been described. In contrast to typical geothermal cooling systems which extend far beneath the earth's surface, the present system was situated 20 inches (0.5 meters) deep. At this shallow location, the underground duct was subjected to timewise temperature variations throughout the day. An axial fan was used to provide a volumetric airflow that varied between 164 and 191 cfm (4.6 – 5.4m^3/min). During the hottest portion of the day (10am-6pm), the ducting system cooled the air approximately 11˚F (6˚C), resulting in a cooling effect equivalent to 650 watts and a net energy savings of 536 watts during its operation.

This project has demonstrated the capability providing low-cost cooling in hot climates through the use in small, shallow geothermal cooling systems. It is believed that the techniques described here can be applied worldwide in similar hot, dry climate for the conditioning comfort in residential and small commercial buildings.

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GEOTHERMAL PROJECTS PROPOSED FOR THE OREGON INSTITUTE OF TECHNOLOGY

LOW-TEMPERATURE POWER GENERATION

Oregon Institute of Technology (OIT) proposes to install a geothermal power plant using a low-temperature resource on the campus. Technical support would be provided by the Geo-Heat Center. The power plant would be a binary or organic Rankine cycle (ORC) type in the 200 kW generating capacity range. This plant would use the existing geothermal water that is presently supplied from wells for heating the campus. The process would take approximately 15˚F (8˚C) off the top of our 192˚F (89˚C) geothermal water, and the remaining 177˚F (81˚C) is then sufficient to heat the campus by "cascading" the water after being run through the power plant for space heating. The plant would be housed in the existing heat exchange building on the south east corner of campus near the geothermal production wells. Cooling water would be supplied from the nearby cold water wells to a cooling tower. The plant would provide approximately 20% of the electricity demand on campus saving approximately $100,000 annually. This would be the first geothermal power plant in Oregon, the first on a campus, and would serve as a demonstration site and as an educational training facility.

HIGH-TEMPERATURE POWER GENERATION

OIT also proposes to install a high-temperature geothermal power plant on campus. Technical support would be provided by the Geo-Heat Center. The power plant would be approximately one megawatt (MW) in generating capacity and most likely be a flash steam type. This plant would use high-temperature geothermal water/steam from a proposed 5,000 to 6,000 foot-deep (1500 – 1800m) geothermal well to be drilled into the fault along the east side of campus. The plant would be housed adjacent to the existing heat exchange building on the south east corner of campus near the geothermal production wells. Cooling water would be supplied from the nearby cold water wells to a cooling tower. The plant would provide 100% of the electricity demand on campus saving approximately $500,000 annually, with any excess electricity sold into the grid through a net metering system. This would be the first flash steam geothermal power plant in Oregon and would serve as a demonstration site and as an educational training facility. If sufficient temperature and flows were obtained from the deep well, not only could energy be generated from a flash power plant, but the "waste" water could also be run through a low-temperature binary power plant in what is called a "bottoming cycle" to produce additional energy. And, finally this "waste" water would be used for space heating on campus or sold for a fee to adjacent land owners, as the flow would supplement our existing wells used for space heating.

GREENHOUSE FACILITY

OIT with technical support from the Geo-Heat Center proposes to construct two geothermally heated greenhouses on campus. These greenhouses would each be 100 feet long and 60 feet wide (6,000 square feet) (31m x 18m = 560m2).

Different heating and cooling systems would be provided to each greenhouse as a research and demonstration project. Benchtop heating system would also be provided for soil heating of potted plants. All heating and cooling in the greenhouses would be monitored and controlled by computer.

The greenhouses would be utilized in conjunction with the Klamath-Lake County Economic Development Association as an incubator facility for interested investors/developers to test the feasibility of growing their crop in a controlled environment utilizing geothermal energy. This could result in spin-off full size commercial development that would contribute to the employment and economy of the region, similar to the development on the New Mexico State University campus (see GHC Quarterly Bulletin, Vol. 23 No. 4 – December, 2002).

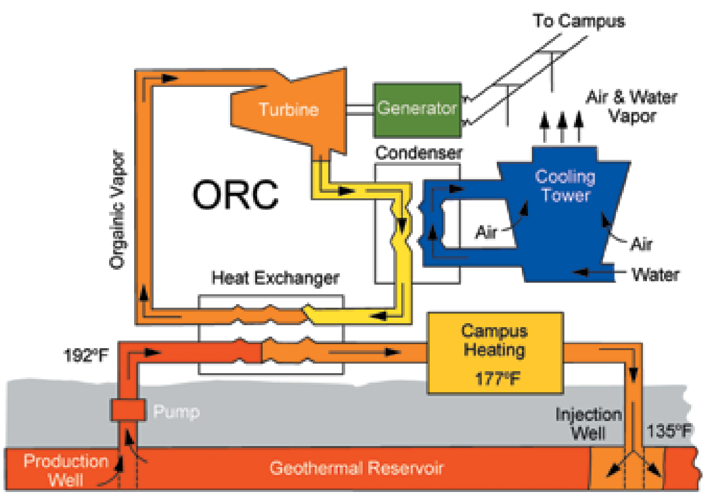
AQUACULTURE FACILITY

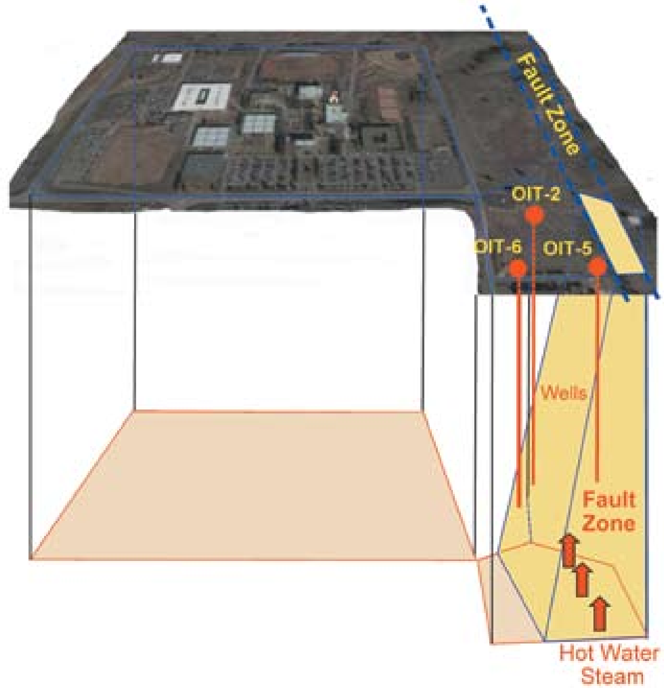
OIT with technical support from the Geo-Heat Center proposes to construct two geothermally heated outdoor aquaculture ponds and a covered grow-out tank facility on campus. The outdoor ponds would each be 100 feet long and 30 feet wide (3,000 square feet) (31m x 9m = 280m^2) and the indoor covered facility would be of greenhouse construction 100 by 60 feet (6,000 square feet) (31m x 18m = 560m^2). Different heating systems would be provided to each pond as a research and demonstration project. The covered facility would consist of a series of fiberglass tanks, heated by the geothermal water and supplement with overall space heating. All heating systems would be monitored and controlled by computer. Various fish species, hard-shell aquatic species and even various algae could be grown and tested.

The aquaculture facility would be utilized in conjunction with the Klamath-Lake County Economic Development Association as an incubator facility for interested investors/developers to test the feasibility of growing their specie in a controlled environment utilizing geothermal energy. This could result in spin-off full size commercial development that would contribute to the employment and economy of the region, again similar to the New Mexico State University campus facility.

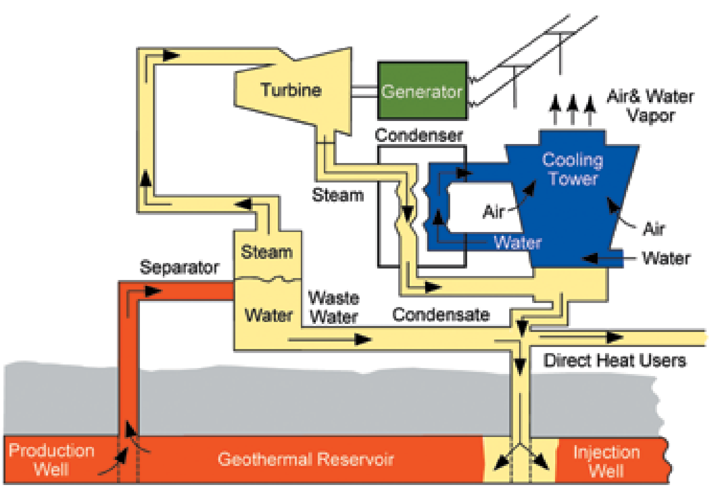
The greenhouse and aquaculture facilities would also provide research and demonstration projects for students in mechanical, electrical and computer engineering on campus. Agricultural students from the Klamath Community College could be involved in testing various crops and aquatic species for commercial production in the area. The local Oregon State University Extension office could also utilize the facility in cooperation with the local high schools. - *The Editor*

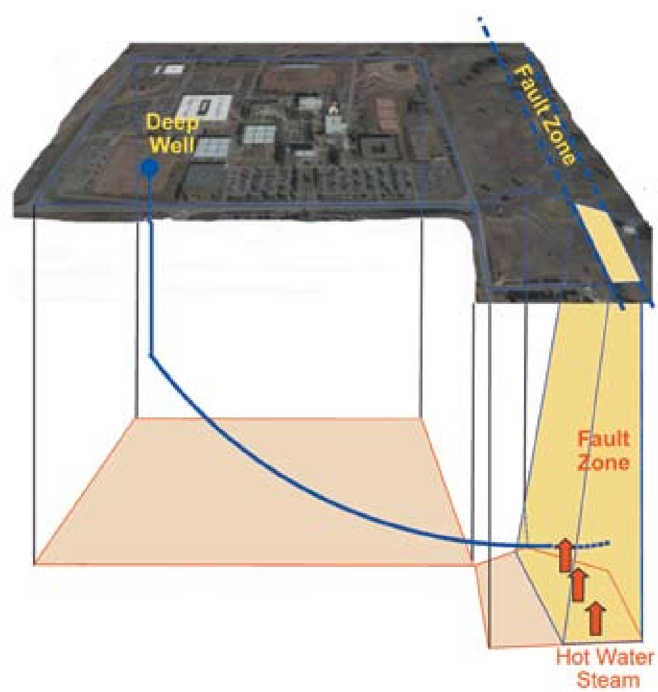
LOW-TEMPERATURE POWER PLANT





HIGH-TEMPERATURE POWER PLANT





CHENA HOT SPRINGS RECEIVES TWO AWARDS

Chena Hot Springs recently won two awards for their low temperature geothermal power plant installed at the resort, this past July (see GHC Quarterly Bulletin, Vol. 27 No. 3 – Sept. 2006). The 200 kW unit replaces diesel generators at this remote interior Alaska site using geothermal fluids at 165oF (74˚C) and cooling water at 40˚F (4˚C) – the lowest temperature use in the world – known as the "Chena Chiller". The unit now displaces around 100,000 gallons (380m2) of diesel fuel per year.

At a November 27 ceremony in Orlando, Florida, Power Engineering Magazine named the geothermal unit "Project of the Year" for renewable energy projects. The unit beat out hundreds of competitors from around the world. The second award came from the U.S. Department of Energy and Environmental Protection Agency. It was given on December 4 at the Annual Green Power Leadership award ceremony held in conjunction with the Renewable Energy Marketing Conference in San Francisco. The "On-Site Generation Award" goes annually to an exceptional alternative energy project in the United Sates. (Eric Lidji, Fairbanks Daily News-Miner, December 6, 2006).

32ND STANFORD GEOTHERMAL WORKSHOP

The Geothermal Reservoir Engineering workshop will be held from January 22-24, 2007 in the Frances C. Arrillaga Alumni Center on the Stanford University Campus, California. The workshop will bring together engineers, scientists and managers involved in geothermal reservoir studies and developments; provide a form for the exchange of ideas on the exploration, development and use of geothermal resources; and enable prompt and open report of progress.

Papers will be presented on: case studies; engineering techniques; field management; exploration; drilling and well bore flows; low enthalpy systems; and geosciences. Registration information can be found on their website at: http://ekofisk.stanford.edu/geoth/workshop2007.htm, or by phoning Laura Garner at Stanford, phone: (650) 725-2716.

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