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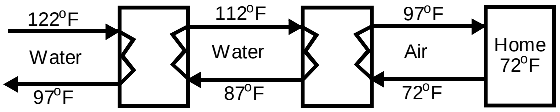

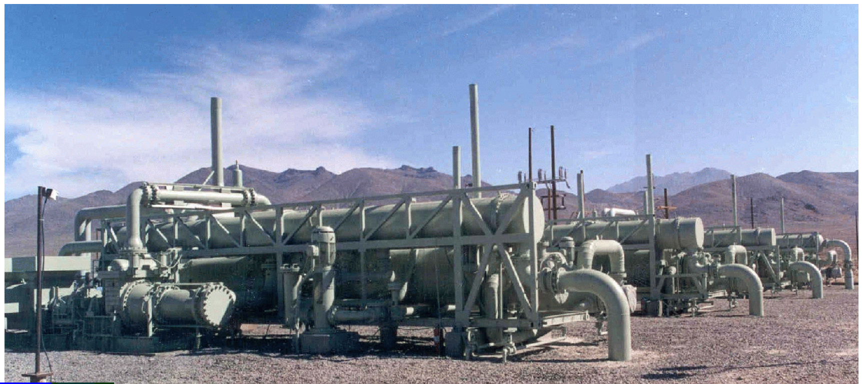

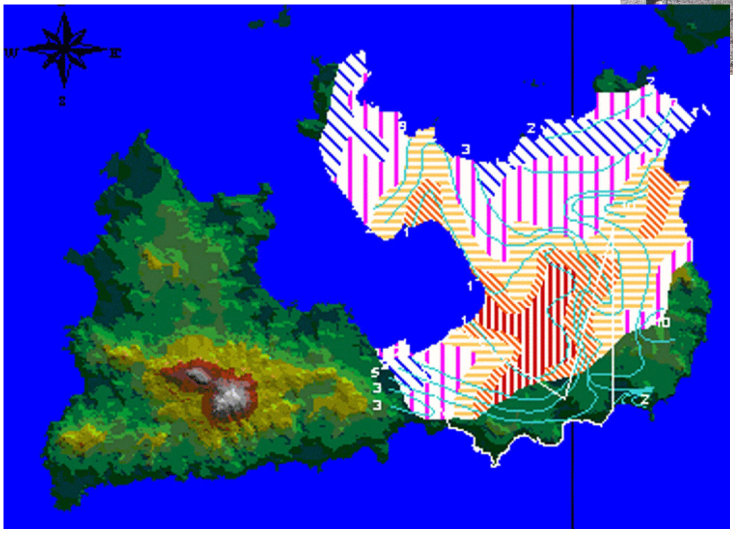

THE UTILIZATION OF GEOTHERMAL ENERGY

Vol. 25, No. 2 **June 2004**

GEO-HEAT CENTER QUARTERLY BULLETIN

ISSN 0276-1084

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

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World Geothermal Congress 2005

Cover Photographs: Upper left to lower right: 25/10/rule (Kevin Rafferty); Power generation at Empire, NV (John Lund); San Bartolo Spa (Susan Hodgson) and Resistivity map of Milos Island, Greece.

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DIRECT-USE TEMPERATURE REQUIREMENTS: A FEW RULES OF THUMB

Kevin Rafferty
Private Consultant
Klamath Falls, OR

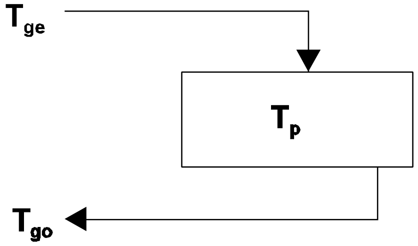
INTRODUCTION

Over the years, questions posed to Geo-Heat Center engineers have frequently taken the form: "What temperature do I need to do ___________;" or "I have a resource of ____ °F, can I feasible run a _____________." This article is intended to provide the reader with a few rules of thumb for the minimum temperature requirements of typical direct-use applications and equipment.

The design of mechanical systems involving heat transfer, such as direct-use geothermal systems, is heavily influenced by temperature. Temperature difference--what engineers refer to as Delta T (often written Δt)--is particularly important as it frequently governs feasibility, equipment selection and flow requirements for the system. Important though it is, the gruesome intricacies of heat transfer can be a yawner for even the most ardent engineer, but acquiring familiarity with a few key principles is relatively painless.

The flow of heat has close parallels to the flow of water--a phenomenon much more familiar to most people. Water naturally flows from a higher pressure to lower pressure. Causing water to flow from point A to point B requires that a higher pressure exist at A than at B. The higher the pressure difference between the two points, the greater the water flow will be. Pressure is the tool we use to cause the water to flow from A to B. In much the same way, temperature is the "pressure" that is used to cause heat (usually measured in Btus) to flow from Point A to point B. Heat naturally flows from a high temperature to a low temperature. That is, some temperature difference (or Δt) must exist to cause the heat to flow from one place to another. Just as in the case of water flow, the greater the temperature difference available, the greater the heat flow. In direct-use systems, the goal is to cause heat to flow out of the geothermal water and into a process--aquaculture, greenhouses, buildings, industrial processes, etc. To accomplish this, it is often necessary for the heat to flow through equipment (heat exchangers of various types) that constitutes a resistance to heat flow. To overcome this resistance, a temperature difference or Δt must be allowed for at each point where heat is transferred. Understanding the magnitude of the temperature differences required is key to the evaluation of a individual applications.

Two primary temperature differences govern feasibility, flow requirements and design of direct-use equipment. These are illustrated in a simplified way in Figure 1. The first is the difference between the geothermal temperature entering the system (Tge) and the process temperature (Tp). This difference determines whether of not the application will be feasible. For a direct-use project, the temperature of the geothermal entering the system must be above the temperature of the process in order to transfer heat out of the geothermal water and into the process (aquaculture pond, building, greenhouse, etc). Beyond that, it must be sufficiently above the process to allow the system to be constructed with reasonably sized heat transfer equipment. The greater the temperature difference between the geothermal resource and the process, the lower the cost of heat exchange equipment. The key question is how much above the process temperature does the geothermal need to be for a given application.



Delta T	Influence
$T_{ge} - T_p$	Feasibility, equipment cost
$T_{ge} - T_{go}$	Geothermal flow rate

Figure 1. Fundamental direct-use temperature differences.

The second temperature difference is the one between the geothermal entering the system and leaving the system (Tgo in Figure 1). This determines the geothermal flow rate necessary to meet the heat input requirement of the application. The greater the temperature difference between the entering and leaving temperatures, the lower the geothermal flow required. Obviously, the resource temperature is fixed. The process temperature plays a role as well since the leaving geothermal temperature cannot be lower than the process temperature to which it is providing heat. In addition, the specifics of the application and the heat transfer equipment associated with it also influence the temperature required. There are two broad groups of applications with similar characteristics in terms of heat transfer–aquaculture and pools, greenhouses and building space heating

AQUACULTURE AND POOL HEATING

Aquaculture pond heating, as illustrated in Figure 2 is among the simplest geothermal applications; since, it is often accomplished by allowing the available geothermal water to flow into the pond to provide the necessary heat input. In the example of Figure 2, geothermal water is available at a temperature of 125°F and the pond is maintained at a temperature of 85^{p}F. If the geothermal water is added directly to the pond, then the leaving geothermal temperature is the same as the pond temperature or 85°F. The amount of heat supplied to the pond by the geothermal can be calculated according to the formula Btu/hr = 500 x gpm x (Tge – Tgo). In this case, assuming that the pond required 100 gpm, the heat supplied would be: 500 x 100 x (125 – 85) = 2,000,000 Btu/hr. It is useful to examine what would happen to the geothermal flow requirement if a lower temperature resource was available. If only 105°F was available, the relationship would be: 2,000,000 / 500 x gpm x (105 -85) Solving for the gpm results in a value of 200 or twice the flow at the 125°F temperature. If only 90°F geothermal was available, the flow requirement would rise to 800 gpm. Obviously, as the available geothermal temperature decreases, the flow requirement to heat the pond rises very rapidly. For applications of this type, reasonable water flows generally require that the heat source water be delivered to the pond (or pool) at a temperature of at least 15°F above the desired pond temperature.

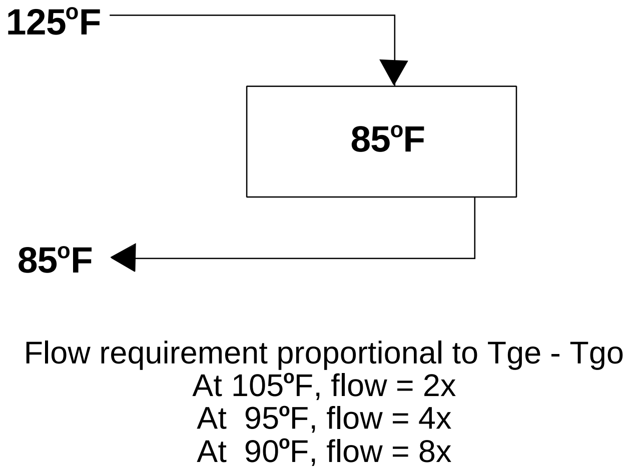


Figure 2. Direct pool/pond heating.

In many pool and aquaculture applications, the geothermal water cannot be used directly for heating purposes. In these situations, it is necessary to place a heat exchanger between the pool water and the geothermal water to accomplish the necessary heat transfer. The result is an arrangement such as that appearing in Figure 3. It remains necessary to adhere to the previous rule of delivering the heating water to the pool at a temperature of at least 15°F above the pool temperature. As shown in the figure, this would require a temperature of 100°F. Since the heat must first pass through the heat exchanger, an additional ^{a}t is required to accommodate this heat transfer. An effective rule of thumb is that the geothermal water on the "hot" side of the heat exchanger must be at least 10°F above the temperature of the water being heated on the "cold" side (pool side) of the heat exchanger. In the example, this would require that at least 110°F (100°F +10°F) geothermal water be available. The same Δt is also necessary on the return side of the heat exchanger. In this case, the water to be heated is returned from the pool at a temperature of 85°F. The geothermal water leaving the heat exchanger must be at least 95°F (85°F + 10°F) to meet the heat exchanger Δt requirement.

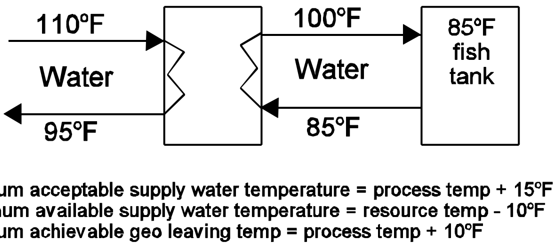


Figure 3. Pool/pond heating with heat exchanger.

If geothermal water was available above 110°F in this case, the additional temperature would allow reduced geothermal flow and reduced heat exchanger size. Maintaining the leaving geothermal temperature fixed (at higher available geothermal temperatures) would minimize flow requirements. Raising the geothermal leaving temperature would minimize heat exchanger cost.

In summary, the basic rules of thumb for pool and aquaculture heating are as follows:

- Minimum acceptable heating water temperature = pond temperature + 15°F
- Maximum available heating water temperature = geothermal temperature – 10°F
- Minimum achievable leaving geothermal temperature = pond temperature + 10°F

GREENHOUSE AND BUILDING SPACE HEATING

Heating of greenhouses and buildings often involves the transfer of heat to the air in the structure using some sort of water-to-air heat exchanger. Figure 4 indicates an example of the simplest version of this application. In this case, a home is to be heated and the air maintained at 72°F. To accomplish the heating of the home, it is necessary to deliver the heated air to the space at a temperature of at least 25°F above the space temperature. In the example, this would result in a supply air temperature of at least 72 + 25 = 97°F. There are two reasons for the 25°F Δt between the supply air and the space. The first is to limit the required quantity of air circulated to meet the heating requirements to reasonable levels. The closer the supply air temperature is to the space air temperature, the greater the air flow required to meet the heating needs. At less than the 25°F difference, fan and duct sizes become large and fan power consumption can be excessive. A second issue is occupant comfort. At supply air temperatures below about 95°F, the temperature of the air approaches human skin temperature. This can result in a "drafty" sensation for occupants, even if the desired air temperature is maintained.

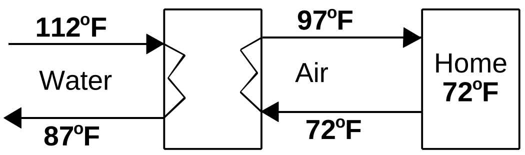


Figure 4. ***Space heating without isolation heat exchanger.***

A second issue is that the temperature of the geothermal water delivered to the air heating device (usually referred to as a "coil") must be at least 15°F above the temperature of the desired supply air. This requirement is a result of the need to limit the size of the coil. Although it is possible to design a coil capable of operating at less than the 15 Δt, its cost and resistance to air flow are such that this is not normally practical. The 15 Δt rule also applies to the return side of the air heating coil. If the air returning from the home to be heated is 72°F, then the geothermal water leaving the coil can be no less than 15°F above the return air temperature. In the example, this results in a leaving geothermal water temperature of 72 + 15 = 87°F. As a result of these considerations, to maintain the home at 72°F, a geothermal resource temperature of 72 + 25 + 15 = 112°F would be required. This assumes that the geothermal fluid is suitable for use directly in the coil. Often, this is not the case; since, coils normally have tubes constructed of copper and geothermal water often has hydrogen sulphide--a chemical that attacks copper.

In cases where the geothermal must be isolated from the heating system equipment, a plate heat exchanger is normally placed between the two circuits to protect the heating equipment. This arrangement is illustrated in Figure 5. The right side of the figure is simply a repeat of Figure 4 with the isolation heat exchanger added. All of the temperatures from the previous figure remain valid here. The difference is that with the isolation heat exchanger in place, an additional temperature difference is needed to accommodate the heat transfer through the heat exchanger. Just as in the case of the heat exchanger described for the aquaculture/pool application, the Δt required for this heat exchanger is 10°F. The geothermal resource now required to meet the needs of the system would be 10°F higher than in Figure 4 or 122°F. Again, the situation is reflected on the return side of the heat exchanger; where, the geothermal water can be cooled to only 97°F as a result of the intermediate loop return temperature of 87°F and the required 10°F Δt.

Figure 5 demonstrates the 25/15/10 rule for space heating and greenhouse heating applications:

- Minimum supply air temperature = space temperature + 25°F
- Minimum supply water temperature for air heating coil = supply air temperature + 15°F
- Minimum geothermal temperature entering isolation heat exchanger = coil supply water temperature + 10°F

The same temperature differences apply to the leaving side of the heat exchange equipment.

- Minimum air coil leaving water temperature = space + 15°F
- Minimum geothermal temperature leaving isolation heat exchanger = coil leaving temperature + 10°F

All of the rules of thumb discussed here are exactly that. It is possible in all cases to "bend the rules," and design systems and equipment for temperatures closer than the guidelines provided above. The values provided here are intended for initial evaluation of applications by those not in the practice of designing heating systems on a regular basis. The guidelines cited apply to new systems using commercially manufactured equipment. Homemade heat exchangers or existing equipment selected for water temperatures well above available geothermal temperature would require additional analysis.

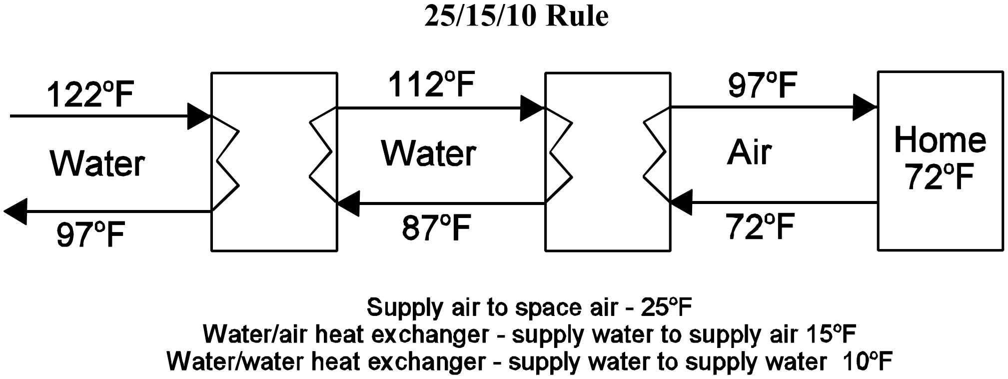


Figure 5. ***Space heating 25/15/10 Rule.***

- A BEAUTIFUL SPA -
THERMAL WATERS AT SAN BARTOLO AGUA CALIENTE, MEXICO

Susan Fox Hodgson
California Department of Conservation
Division of Oil, Gas, and Geothermal Resources

INTRODUCTION

In San Bartolo Agua Caliente, a small rural town in the Mexican Volcanic Belt, a spa operates today amidst ruins of a much larger, ancient complex that originally included an orphanage, hospital, and a hostelry for travelers. This was one of the first colonial spas in Mexico.

The spa was so well engineered that it remains virtually unchanged today from the time it was built at the very end of the 1700s. It uses the same outside and inside plumbing, and interior collection basins. The only change is the new pipeline that circumvents the original outside, hot-water collection tanks that remain in good working order and are interesting to look at. The locals still enjoy soaking in the spa's thermal waters flowing down from the same artesian spring that always has replenished the baths.

STORY OF THE SPA

A small, isolated town in the north-central part of the Mexican Volcanic Belt, San Bartolo Agua Caliente, lies about halfway between the cities of Celaya and Querétaro (Photo 1). Described over 100 years ago as a jewel in the midst of the brown hills surrounding it, San Bartolo became famous for mineral waters and baths. Today in rural Mexico, it is a tiny, out-of-the-way place with a dirt road winding at its heart and with the remains of a magnificent complex, announced by a sign at the entrance as the Antiguo Hospital de Baños Termales de San Bartolomé, or the *Ancient Hospital of Thermal Baths of Saint Bartholomew 1599-1802* (Photos 2 and 3).

Photo 1 . Location of San Bartolo Agua Caliente.

Photo 2. ***Welcome sign for the communal property owned and operated by an "ejido."***

Photo 3. ***Sign with key historical dates. The name has changed over the years.***

The complex, dedicated to St. Bartholomew, patron saint of nervous and neurological diseases, was built next to ancient waters famous for hydrotherapy and cures.

Several structures once stood here together—a church, a home for Catholic orphans and homeless, a hospital for the sick and traveling, and thermal baths for all (Photo 4). Today, most of the buildings are in ruins—except for the baths that remain open at this ancient, extraordinary spa.

For good reasons, the dates of the sketchy and mysterious story of the complex do not correspond exactly with the sign at the door reading 1599-1802, but they come close. In fact, the 203-year period noted on the sign in Photo 3 is critical to the history of the complex. This is what happened.

Photo 4. ***Church dome and arches decorated with paintings of the apostles.***

On July 4, 1602, Doña Beatríz de Tapia died and left money in her will for the project's construction. A lawsuit stalled the work until 1770—168 years later—and it was not until 31 years after this, in 1801, that the complex was finally finished. It is likely Doña Beatríz's project was blessed by the church a few years before she died, perhaps in 1599—the first date on the sign. It is also likely the complex was dedicated formally in 1802, a year after building ended and use had begun of one of the first colonial thermal spas in Mexico—the second date on the sign.

I don't know all the reasons for the ruins of today—earthquakes, war, neglect, or a combination—but this is what I learned of the spa's history. In 1844, 43 years after construction, the site of San Bartolomé was occupied by the Mexican General Antonio López de Santa Anna, who wanted to buy the property, and who was in and out of the presidency of the country at least eight times in the politically turbulent years between 1832 and 1855. He is best remembered in the United States for attacking the Alamo.

The Departmental Assembly of the State of Guanajuato, where San Bartolomé is located, "vainly protested the sale of the property to him," according to a history of Guanajuato written in 1860. Probably in 1846, the administration of General Maríano Paredes y Arrillaga annulled the sales contract, also in vain. General Santa Anna finalized the transaction in the year 1847. (From 1846-47, he was again President of Mexico.) Now, sadly predicted the historian, "This magnificent hospital will be ruined within a few years" (Noticias, 1860).

But parts remain. Of all the buildings in the complex, the spa was most unaffected by destruction through the years; probably because, it is a solidly built, single-story building–and it is gorgeous. The spa is a large building of carved stone blocks laid out along a large, open interior patio in the Spanish style (Photo 5). Private, two-room suites for thermal bathers lead off from the breeze way around the patio and a different saint's name is painted brightly over the doorway to each (Photo 6). This is important because anyone entering a suite, sick or well, would be under the patronage of this saint, who would receive the visitor's prayers and act as a custodian.

Photo 5. ***Interior patio with church dome in background.***

Photo 6. ***Entrance to a two-room suite–each painted with a different saint's name.***

Each suite is designed somewhat differently and some are larger than others. But all have two rooms, an anti-chamber for changing before entering the inner chamber with the thermal bath itself, everything built of solid stone—massive, shadowy, peaceful, and cool (Photo 7). All thermal-bath chambers have domed ceilings with cupolas whose tops are open, allowing light and air to enter and steam to escape. Propelled by gravity, the thermal waters pour through original plumbing into the large, hand-carved thermal basins cut in the floor.

The thermal waters, about 85EC, flow from an artesian spring on the side of a small hill above the spa to the south (Photo 8). A small stone chapel stands by the spring, and neighbors living next to the thermal waters plant corn and beans in the hot nearby ground, sometimes cooking their meals in the steam (Photo 9).

Photo 7. Chamber with a thermal bath.

Photo 8. Thermal water from a spring flows to the spa.

Hot waters from the spring pour down to the spa through an elegant, stone aqueduct (Photo 10). Once the thermal waters reach the spa, they are still too hot to use and must cool before entering the bathing chambers, a process that occurred originally in two stages. As water arrived, it flowed from the aqueduct into one of three stone troughs by slowly falling over a series of riffles, an air-cooling process that somewhat lowered the temperature (Photo 11). Next the thermal water moved to a fourth stone trough; where, it was mixed with cold water until a temperature was reached that bathers could enjoy. Today, a pipeline circumvents this cooling system; although, the troughs and riffles still are there to see.

The author of the 1860 history writes that the baths of San Bartolomé have very hot mineral waters, and that the waters issue abundantly from many hot springs. He writes that once the water is cooled, it is healthy to drink and good for fattening cattle.

Such multiple uses of mineralized hot spring waters are typical worldwide. No one will ever know all the ways thermal waters have been used at San Bartolo Agua Caliente or all the ways they are used there by the villagers today.

Photo 9. Vegetables grown in the warm ground.

Photo 10. The aqueduct.

Photo 11. Original water-collection troughs where the water is cooled.

ACKNOWLEDGMENTS

I would like to thank the Comisión Federal de Electricidad for its support and Ing. Arturo González Salazar, whose assistance with interviews and interest in what we saw made a big difference.

REFERENCE

Noticias para Formar la Historia y la Estadística del Obispado de Michoacán, 1860. El Gobierno del Estado de Guanajuato, p. 145.

ELKO HEAT COMPANY DISTRICT HEATING SYSTEM

- A CASE STUDY -

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LOCATION

The Elko Heat Company District Heating System is located in the city of Elko, Nevada, in the southwestern part of Elko County. Elko County is located within the Basin and Range Physiographic Province in the southwestern United States (Fenneman, 1931). The Elko Heat Company district heating system is one of two district heating systems in Elko, with the other being the publicly-owned system operated by the Elko School District. The system was initiated in 1978 when the United States Department of Energy, under its "Field Experiments for Direct-Uses of Geothermal Energy" Program Opportunity Notice (PON), granted financial assistance for the development of a district heating system to serve the core business area of downtown Elko.

Original plans were to serve three large commercial customers, including an office building, a laundry and a casino/hotel complex (Figure 1).

Stockman's Casino

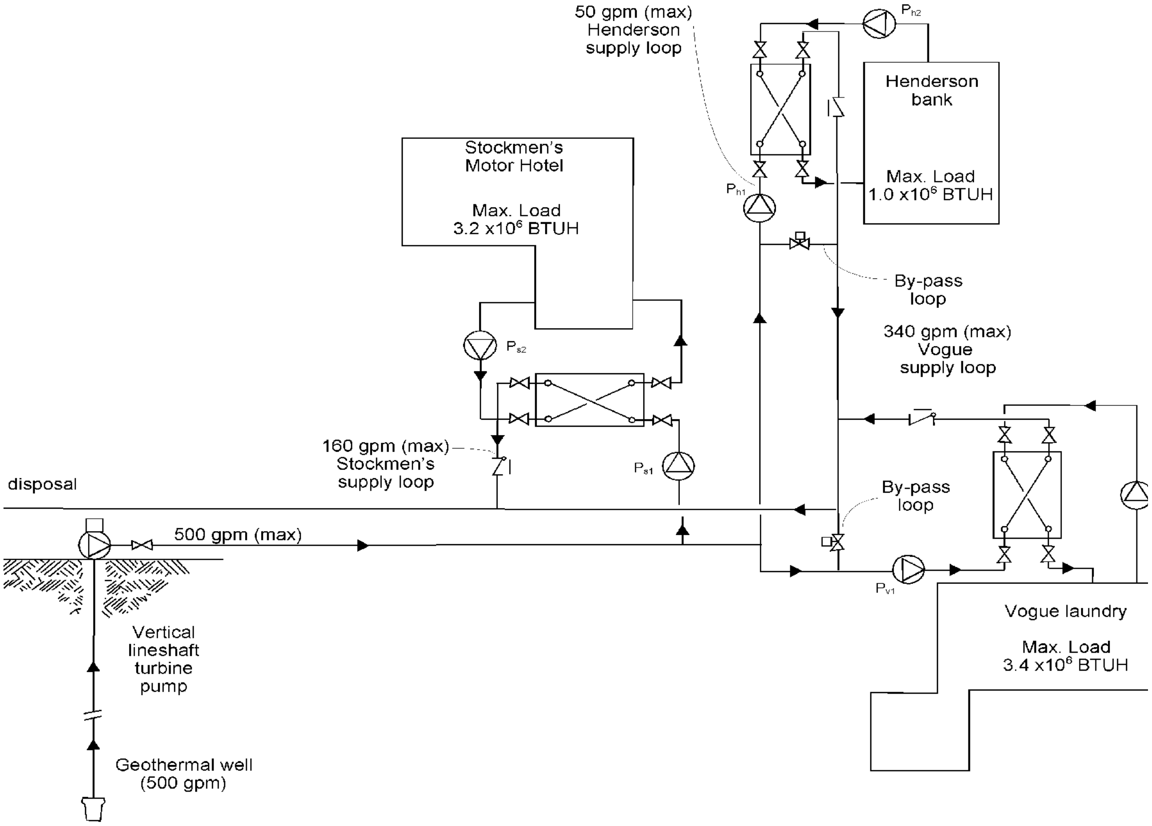

Figure 1.

Vogue Dry Cleaners

After completing resource assessment activities, a well was drilled in 1981 which was successfully completed to a depth of 869 ft (265 m). The well was found to be capable of producing approximately 1,000 gpm (63.09 L/s) of 177ºF (81ºC) water from the primary production zone that lies at a depth of 845-850 ft (258-259 m). The district heating system was completed and put online in 1982 at a total cost of $1,382,346 including $281,000 in customer retrofits. Of the total amount, $827,404 or 59.8% of the total was provided by the USDOE grant. Since coming online in late-1982, the system has grown appreciatively to include 19 consumers, and with gross revenues in 2001 of $184,267. The owners continue to attract new customers and the system appears to be capable of serving nearly double its existing load without the need for additional wells or central peaking. The only limitations on growth at the present time appear to be pumping capability and possible disposal issues.

RESOURCE

Elko County is located within the Basin and Range Physiographic Province. The distinctive features of this province are isolated, longitudinal fault-block mountain ranges separated by long, alluvial-filled basins. The city of Elko is located on the floor of one of these basins. The County's geothermal resources are located within the Battle Mountain Heat Flow High, as defined by Sass, et al. (1971). The area has been defined as a region of high heat flow; where, 194-302ºF (90-150ºC) resources are associated with deep fluid circulation along range front faults (Converse Consultants, 2002). The Elko area has a long history of geothermal water use and development, beginning with Native American use of the water at the "Hot Hole" in southwestern Elko. Continued use and reference to the Hot Hole and associated hot water springs were made by pioneers along the Oregon Trail in the 1840s. Development of the hot springs in the area provided for the old "Elko Home for the Aged" and subsequently, the Elko County Association for Retarded Children used the area's hot water into the late-1970s (Converse Consultants, 2002). Review of the geologic literature suggests that there may be an extension of a fault or fault zone from the Sulfur Springs hot springs southwest of the city, which travels northwest through the community and intersects the Hot Hole and its associated springs as well as the geothermal high in the area of the Elko Junior High School.

The Elko Heat Company well was drilled to a depth of 869 ft (265 m). Hot water at a temperature of 177ºF (81ºC) was encountered at approximately 705 ft (215 m) (Therma Source, 1982). The primary production zone, however, appears to be in the interval 845-850 ft. (258-259 m). The well has an artesian shut in pressure of 55 to 60 psi (379 to 414 kPa).

Other wells in the area include the Elko Junior High School well which was drilled in 1985 to a depth of 1,876 ft (572 m) and which encountered approximately 190ºF (88ºC) water at a flow rate of 300+ gpm (18.93+ L/s). The resource currently supplies the Elko County School District district heating system. Robinson and Pugsly (1981) reported surface temperature in the area ranging from 150-192ºF (66 to 89ºC) and geothermometers point to a resource temperature of from 176-237ºF (80 to 114ºC).

USE

The Elko Heat Company district heating system provides for the heating requirements of 19 customers including both public and private entities. Considering that the system was originally designed to serve only three primary customers, the success of the system in attracting new customers is noteworthy and highly commendable. The system now serves the Bank of America, Chilton Engineers (personal residence), City of Elko (STP), Elko County Detention, Elko County Court House (Meter #1), Wells Fargo Bank, Stockman's Casino and Hotel, Commercial Casino, Callagher Building, Thomas H. Gallagher (private residence), Henderson Investment Company, Ormaza Investor's, U.S. Post Office, Sierra Pacific Power, Vogue Laundry and Dry Cleaners, Western Folk Life Center, America High Votage, Ormaza Investor's Old Newmont Building and Elko Court House (Meter #2) (Elko Heat Company, 2003a). These customers are served via a 9,358-ft (2,852-m) distribution system of primarily asbestos concrete construction. Each customer is required by the Energy Connection and Service Agreement to provide his/her own backup heating system in order to provide energy service in the event that the geothermal system is shut down (Elko Heat Company, 1989). The distribution piping is insulated and jacketed. The return line is also of asbestos concrete construction; however, the return line is uninsulated. Piping runs from the distribution loop to individual consumers is 304 stainless steel using welded connections. Geothermal fluid at approximately 177ºF (81ºC) is circulated directly from the wellhead through the distribution system to each consumer. Each consumer, with the exception of the Vogue Laundry and Dry Cleaners, is connected to the system via a plate-and-frame heat exchanger of stainless steel construction. In the case of the Vogue Laundry and Dry Cleaner, the geothermal fluid (after softening) is used directly in the laundry. Geothermal fluid, after passing through the customer heat exchangers, enters the return line and is carried to the disposal facility. Disposal is via ponds used to cool the water and allow for some percolation. Some water, once cooled, is allowed to flow to the Humboldt River.

Customers are billed on the basis of gallons used. Flow is measured via hot water, totalizing, multi-jet, turbine meters that are read each month. At present, the rate is $1.50/1,000 gal (3,785 L). Originally, the rate had been set at $1.15/1,000 gal (3,785 L). That rate was increased to $1.38/1,000 gal in 1992 (3,785 liters) and to $1.50 in 2001 (Elko Heat Company, 2003b). Two residential consumers (Mark Chilton and Thomas Gallagher) are charged a flat rate of $122.10 per month (Elko Heat Company, 2003b). Total gallonage for 2000 was 6,659,286 (25,208,140 L), for 2001 4,190,126 (15,861,352 L) and in 2002 it was 4,901,980 (18,556,013 L). The system is capable of providing approximately 400 gpm (25 L/s) under artesian conditions (i.e., to meet baseload requirements). Flow rates in excess of 400 gpm (25 L/s) require pumping to boost the pressure. Total system capacity is estimated at approximately 1,000 gpm (63.09 L/s) and with a 15-hp (11-kW) pump approximately 700 gpm (44.16 L/s) can be provided. Pumping is accomplished via 2-stage vertical turbine pump (lineshaft turbine) equipment with a 15-hp (11-kW), 1,800-rpm motor. Although the system was originally equipped with sensors that would activate the pumping when pressure fell below 35 psi (241 kPa), the automated controller was removed and pump activation is now manual. The system appears to be capable of meeting the needs of additional consumers even in its present configuration, and could meet the heating needs of additional consumers through addition of pumping to increase flow to a peak of approximately 1,000 gpm (63.09 L/s), drilling of additional wells or addition of a fossil fuel peaking unit. The addition of a fossil fuel peaking unit would, from the author's experience, appear to provide the greatest near term as well as future benefit; as, it would allow not only for expansion of the system to new customers but would also provide backup to the existing geothermal wells and thus, eliminate the need for in- building backup/peaking equipment.

OPERATING COSTS

The Elko Heat Company system was reportedly built at a cost of $1,101,346 (Elko Heat Company, 1989). The largest expenditures were $169,739 for resource assessment work, $166,314 for drilling the production well and $320,938 for construction of the distribution system. An additional $281,000 was spent for retrofitting the original three customers to the system. Maintenance of the system accounted for expenditures of $19,105; while, contract services and materials accounted for $22,135. Information relative to subsequent retrofits is not available. Of the total cost of $1,382,346 including the $281,000 for retrofits, $827,404 was provided by a grant from the United States Department of Energy under its program for "Field Experiments for Direct-Uses of Geothermal Energy."

Based on the latest figures available (Elko Heat Company, 2001), the operating revenue for 2001 was $184,267. Total operating expenses were $47,840 or an increase of $4,465 from the previous year. Maintenance of the system accounted for an expenditure of $19,105 while contract services and materials accounted for $22,135. (Elko Heat Company, 2003b).

No numbers are available for customer savings.

REGULATORY/ENVIRONMENTAL ISSUES

The project encountered only one significant regulatory/environmental hurdle. This was related to the issue of water rights. The project had initially secured a state permit for non-consumptive use of water. However, a non-consumptive use permit required that all geothermal fluids be returned to the same aquifer from which they had been pumped. After carefully evaluating a number of disposal options, the project developers finally decided upon surface disposal as the preferred alternative. This resulted in the Elko Heat Company having to go through the entire water rights permitting process a second time (Gordon, 1985).

It remains to be seen whether or not surface disposal will be allowed over the long term and if it will have a potential negative impact upon further expansion of the system and thus, increase requirements for disposal. The Elko School District System is already facing serious surface disposal issues, and surface disposal that results in any runoff into the Humboldt River will no longer be permitted.

PROBLEMS AND SOLUTIONS

The project has experienced ongoing problems associated with corrosion of various components of the distribution system. Initially, customer branch piping consisted of carbon steel lines running from the main asbestos concrete distribution lines. Several failures, including one inside the customer building, resulted in a requirement that all new customer branch lines be constructed using 304 stainless steel. There were also corrosion problems associated with carbon steel service saddle components. The current practice is to use stainless steel bands (Elko Heat Company, 2003c).

Other system components have also failed due to corrosion related issues and in 1997, the Elko Heat Company reported the need to replace several components due to corrosion failure, including ductile iron valves, fittings and steel bolt up hardware (Lattin, 1997). In 1999, Converse Consultants submitted a metallurgical report to Elko Heat Company that detailed a number of corrosion related issues, probable cause for corrosion and recommendations for further action (Converse Consultants, 1999).

Converse concluded that corrosion was probably caused by geothermal water leaking into or in contact with various metal components. The geothermal water contains about 17 ppm of chloride ions and 75 ppm of sulfate ions. Hydrolysis involving chloride and sulfate ions is expected to have increased acidity of water and resulted in a pH of around 4.0 or lower. Such acidified water in confined regions (e.g., in the annular region of flanges), under corrosive residues or in the soil encasing system components (e.g., valves) can chemically react with susceptible components and result in harmful corrosion. Converse further concluded that if water could not be kept away from susceptible components, then it would be necessary to install structural materials that can resist deterioration by corrosive waters better than Type 304L stainless steel. Recommended materials included 310L, Monel and Titanium. It was also noted that galvanic corrosion was also a factor with certain components and that cathodic protection should be provided.

The only other major problem occurred with the direct use of geothermal fluid through one customer's existing heating system (Elko Heat Company, 2003). That customer subsequently left the system.

The potential still exists for disposal related problems if all runoff to the Humboldt River is required to be terminated.

CONCLUSIONS

The Elko Heat Company geothermal district heating system has operated successfully since 1982 and has grown from three customers to nineteen. The system is economically viable, and maintenance and operating costs have been held to manageable levels. Rates have risen very slowly since system start up and still provide an economic incentive for new customers to hook up to the system. Corrosion-related problems have resulted in changing out several components, use of more corrosion resistant materials, use of cathodic protection and increased attention to workmanship. The system has the capacity to serve additional customers, but would require additional pumping and could possibly result in disposal problems. An alternative may be to look at the installation of a central peaking boiler, but increasing water temperature could have an adverse impact on return lines that are constructed of non-metallic material.

Because the system is based on the direct circulation of geothermal fluid to each customer on the distribution loop, it provides an interesting contrast to the Elko School District district heating system which is based on the circulation of non-geothermal fluids.

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EMPIRE ENERGY, LLC
- A CASE STUDY -

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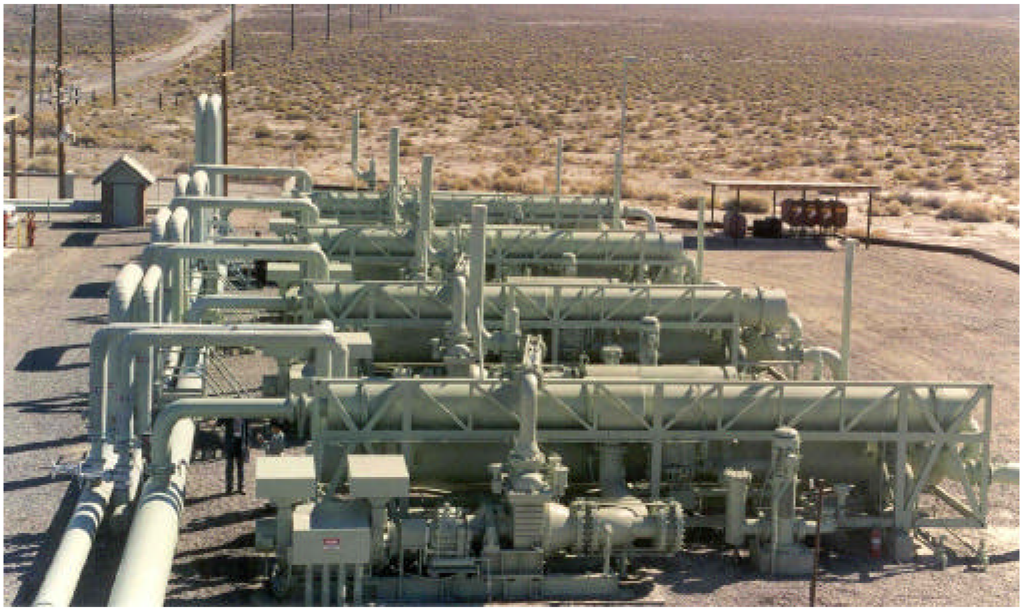

Empire Energy, LLC

LOCATION

Empire Energy, LLC is part of the Empire Group of companies including Empire Research and Empire Farms. Facilities owned by or to which Empire Energy supplies energy include an approximately 3.6-MWe net geothermal binary power plant and an onion/garlic dehydration plant operated by Empire Farms (Figure 1). Both facilities are located in the San Emidio Desert in northern Washoe County, Nevada. The site is located just south of Empire and Gerlach, and approximately 100 miles (161 km) north of Reno, Nevada. The power plant was constructed by ORMAT Energy Systems and went online in mid-1988. The plant consists of four 1.2- MWe ORMAT energy converters (OEC) designed to produce 3.6 MWe of net power at a design temperature of 285°F (141°C). The dehydration plant, originally built by Integrated Ingredients, was dedicated in May of 1994. The dehydration unit uses approximately 800-1200 gpm (50.47-75.71 L/s) of 298°F (148°C) geothermal water for the four-stage dryer. Present, capacity of the dehydration plant is 75,000 pounds (34,019 kg) of onions per day or 85,000 pounds (38,555 kg) of garlic (Stewart and Trexler, 2003).

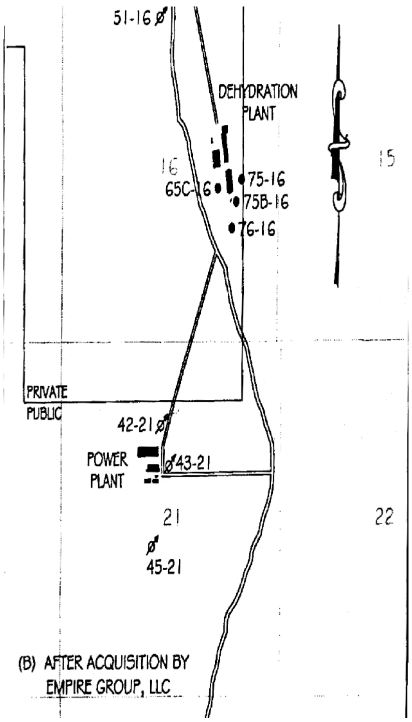

Figure 1. Location of wells, power plant and dehydration plant.

RESOURCE

The San Emidio geothermal area is located within the Basin and Range Physiographic Province. The distinctive features of the province are isolated, longitudinal fault-block mountain ranges separated by long, alluvial-filled basins. It is adjacent to the northern end of the Lake Range. The geology is dominated by a thick sequence of Tertiary lava flows, ash flow tuffs and volcaniclastic sedimentary rocks that accumu-lated on an irregular surface of Mesozoic metamorphic base-ment (Stewart and Trexler, 2003). Within the San Emidio Desert, the Tertiary rocks are covered by a layer of lake beds. A discontinuous line of hydrothermally altered rocks marks the boundary of the desert on the east (Mackelprang, et al, 1980). The northern portions of this zone show intense silificants and calcium carbonate deposits which, to the south of the zone, is marked by fumaroles, acid leaching and some deposits of native sulfur (Mackelprang, et al., 1980). Mapping has identified four north-south striking faults and one southwest-northeast striking fault in the area of geothermal development. The faults appear to have between 1,000 and 2,000 ft (305-610 m) of vertical offset (Stewart and Trexler, 2003).

UTILIZATION

During the 1970s, several geothermal exploration companies conducted exploration in the San Emidio Desert and in addition to extensive geophysical work, more than 60 holes from 40 to 2000 ft (12-610 m), were drilled. In the mid-1970s, Chevron drilled two deep exploration wells that encountered temperatures up to 260°F (127°C). The first production well for the Empire geothermal power plant encountered 285°F (141°C) water at 500 ft (152 m) and in all 17 production, injection or observation wells were drilled as part of the power plant development project.

In 1992, the first wells were drilled to serve the planned dehydration plant, and the first production well was found to be capable of producing 200°F (93°C) geothermal water at a flow rate of 650 gpm (41.01 L/s). Two additional wells, drilled in 1994 and 1997, are capable of producing in excess of 3,000 gpm (189.27 L/s) of geothermal water at or above 306°F (152°C). The water is a sodium-chloride type with a total TDS of 4150 mg/L. These three wells are now used to supply both the dehydration plant and the power plant (Stewart and Trexler, 2003).

The original use of the geothermal water was supply of the Empire Power Plant. This 3.6-megawatt net power plant consisted of four 1.2-MWe ORMAT energy converters (OEC) and was constructed by ORMAT Energy Systems. The plant went online in 1988. The plant was originally designed to produce maximum net output with an input resource temperature of 285°F (141°C). Cooling water for the condenser was provided by spray cooling ponds. However, due to increasing interference with cooler injection fluids, the wellhead temperature had fallen to as low as 237°F (114°C) by 1996 and output had fallen to 0.92 MWe (Stewart and Trexler, 2003).

However, subsequent drilling beginning in 1992 in anticipation of developing the geothermal resource for the dehydration plant, and resource studies conducted in 1994 indicated that this much better resource was capable of providing geothermal energy to both the dehydration plant and the power plant. After fully acquiring the assets of the power plant, a fully insulated 1-mile (1.6-km) line was completed to the power plant. With the availability of hotter geothermal fluids, production was increased to 1.8 MWe. Additional wells drilled in 1997 increased output again. Unfortunately, output was still well below design due to the inefficiency of spray cooling ponds that resulted in temperatures as high as 80-85°F (27-29°C) during the summer. In 1997, a decision was made to construct a 3-cell, inline counter-flow cooling tower with makeup water supplied from a potable water well some 4.5 miles (7.2 km) to the northwest of the plant. The availability of better geothermal fluids and the increased cooling efficiency has boosted power plant net output to over 4.0 MWe in the winter and 3.6 MWe in the summer.

The dehydration plant operated by Empire Foods is capable of producing 75,000 pounds (34,000 kg) of dried onions or 85,000 lbs (38,600 kg) of dried garlic per day. The dehydration plant is supplied with from 800 to 1200 gpm (50 - 76 L/s) of geothermal fluid at a minimum temperature of 285°F (141°C). The dryer is a National 4-stage dryer. Delta T across the heat exchanger is approximately 60°F (16°C).

The spent geothermal fluid is being considered as the input for a planned 1-MWe binary power plant that will meet the power needs of the facility (Stewart and Trexler, 2003; Kutscher, 2001).

OPERATING COST

No capital cost relative to the project was available either in relation to the original 3.6-MWe net power plant project or the dehydration plant. Information concerning operation and maintenance costs was also unavailable. However, some information relative to the 1-MWe expansion has been accessible due to the fact that this is being done in partnership with National Renewable Energy Laboratory (NREL). Preliminary estimates place the cost of the project at approximately $2,585,000, of which NREL's share would be 80% (Kutscher, 2001). This cost does not include the drilling of any additional wells as the plant would be supplied from the spent geothermal fluid exiting the dehydration plant at a temperature of between 230-245°F (110-118°C). Annual O&M is estimated at $80/kW and cost of energy without cost share is 8.8 cents/kWh (Kutscher, 2001).

REGULATORY/ENVIRONMENTAL ISSUES

No major regulatory or environmental issues or obstacles have been identified. Permitting was under the jurisdiction of the Bureau of Land Management and Washoe County.

PROBLEMS AND SOLUTIONS

The only major problem was not specifically regulatory or environmental, but was related to the original restricted land position of the original power plant project that allowed for little offset between production and injection wells. The resulting interference from the low-temperature injection resulted in a rapid cooling of the reservoir and an approximately 75% reduction in power plant output. Through land acquisition, this problem was resolved and production and injection wells are now appropriately spaced so as to minimize future interference problems.

The other significant problem was with the use of the spray cooling ponds as a means to cool water for use in the condensers. The ponds were found to be very insufficient during the summer months and temperatures reached 80 to 85°F (27-29°C). The very warm water resulted in a significant decrease in power plant output during the summer months. In 1997 a decision was made to replace the spray ponds with a 3-cell, inline counter flow cooling tower of fiberglass construction with a wet bulb design temperature of 58°F (14°C). Makeup water for the cooling tower is supplied from a potable water well on Empire Farms, 4.5 miles (7.2 km) to the northwest.

The only other major concern relates to the use of lineshaft pumps and associated requirements for an oil-drip lubrication system. Empire Energy expressed a strong desire to be able to go to submersible pumps.

CONCLUSIONS

The Empire Group of companies has been very successful in optimizing the use of the geothermal resources available in the San Emidio Desert. The collocation of both electric generation and direct use projects demonstrates the economic viability of such arrangements. Should the planned 1-MWe binary power plant be constructed to use the spent geothermal fluid from the dehydration plant, it will serve as further evidence of the benefits of integrating electrical generation and direct-use applications.

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Power plant cooling tower.

Sorting onions before drying.

Dried onions coming off the belt drier.

ELKO COUNTY SCHOOL DISTRICT HEATING SYSTEMS ELKO, NEVADA

- A CASE STUDY -

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LOCATION

The Elko County School District

The district heating system is located in the city of Elko in the southwest portion of Elko County, Nevada. Elko County is located within the Basin and Range Physiographic Province in the southwestern United States (Fenneman, 1931). The Elko County School District system is one of two district heating systems in Elko, with the other being the privately-owned system operated by the Elko Heat Company. In 1985, the school district had originally planned to drill a well to tap low-temperature geothermal resources that could be used for a geothermal heat pump system for the junior high school. However, when the well, drilled to 1,876 ft (572 m) encountered significant flows of 190°F (88°C) geothermal water, a decision was made to serve all of the school district facilities in Elko as well as a number of additional public buildings, including the hospital and Convention Center, through the construction of a district heating system (Figure 1). The School District is at present in the process of determining the feasibility of expanding the system to serve a number of buildings on the Great Basin College Campus (CBC). Preliminary findings indicate that a number of significant changes would have to be made to the existing system in order to meet the heating load requirements of the CBC facilities.

RESOURCE

Elko County is located within the Basin and Range Physiographic Province. The distinctive features of this province are isolated, longitudinal fault-block mountain ranges separated by long, alluvial-filled basins. The city of Elko is located on the floor of one of these basins. The county's geothermal resources are located within the Battle Mountain Heat Flow High, as defined by Sass, et al. (1971).

The area has been defined as a region of high heat flow where 194 to 302°F (90 to 150°C) resources are associated with deep fluid circulation along range front faults (Converse Consultants, 2002). The Elko area has a long history of geothermal water use and development, beginning with Native American use of the water at the "Hot Hole" in

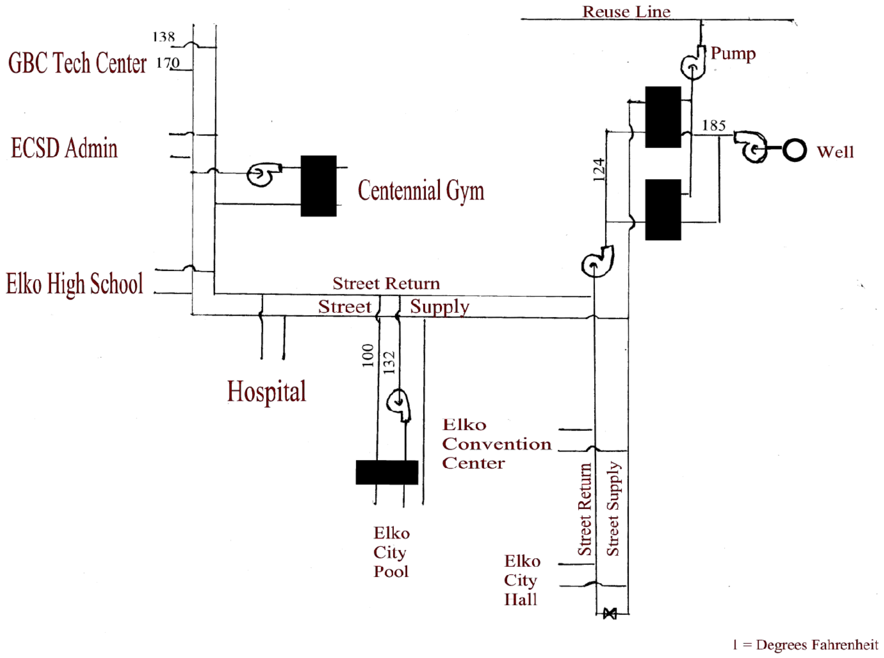

Figure 1. Geothermal system layout.

Elko Junior High School

Elko Convention Center

southwestern Elko. Continued use and reference to the Hot Hole and associated hot water springs was made by pioneers along the Oregon Trail in the 1840s. Development of the hot springs in the area provided for the old "Elko Home for the Aged," and subsequently the Elko County Association for Retarded Children used the area's hot water into the late-1970s (Converse Consultants, 2002). Review of the geologic literature suggests that there may be an extension of a fault or fault zone from the Sulfur Springs hot springs southwest of the city, which travels northwest through the community and intersects the Hot Hole and its associated springs as well as the geothermal high in the area of the Elko Junior High School. A 1,876 ft (572 m) well drilled adjacent to the junior high school in 1985 encountered 300+gpm (18.92+ L/s) of 190ºF (88ºC) water in the bottom 20-30 ft (6-9 m) of the hole. This is the resource currently supplying the Elko County School District heating system.

Several other geothermal wells have been drilled in the Elko area including the Elko Heat Company well which was drilled in 1982 to a depth of 869 ft (265 m). Hot water at a temperature of 177ºF (81ºC) was encountered at approximately 705 ft (215 m) (Therma Source, Inc., 1982). Robinson and Pugsley (1981) reported surface temperatures in the area ranging from 150 - 192ºF (66 - 89ºC) and geothermometers point to a resource temperature of from 176 to 237ºF (80 to 114ºC).

UTILIZATION

The Elko Junior High School well provides heat to serve 16 public buildings through 11 interconnections. The buildings served include Elko Junior High, the Convention Center, City Hall, City Pools (pool heating), City Pools (space heating), the hospital, Elko High School Vocational, Elko High School (six buildings), and the Centennial Gymnasium (including central kitchen building) central office building (includes service and maintenance building and warehouse). The total building area is 348,680 sq ft (32,393 sq m) of which 304,971 sq ft (28,333 sq m) is heated geothermally. Estimated peak geothermal flow is 309 gpm (19.49 L/s) with a peak heating load of 10,708 kBtu/hr (3,136 kW_t). The average delta T is approximately 34.8ºF (1.6ºC) with a peak delta T of 43.5ºF (6.4ºC). Two of the connections are to the return loop, including the pool heating portion of the city pool's heating load, and Elko Junior High's heating load is also served from the return loop. The Elko Junior High domestic hot water heating load is served with geothermal fluid directly from the well side of the geothermal heat exchanger.

The geothermal fluid from the geothermal well is transferred to a secondary circulating loop at the junior high school via a plate and frame heat exchanger for space heating. Discharge from the system is 110-140ºF (43-60ºC) and goes to holding ponds and eventually to the Humboldt River. Disposal of the fluid has become a major issue and both EPA and the State of Nevada are requiring that there be no flow to the Humboldt River due to down river water quality problems. The circulating loop is welded steel pipe, insulated and jacketed. Each building is connected to the circulating loop via a plate and frame heat exchanger, and each consumer is required to provide their own backup/peaking capability.

Recently, a new building on the Great Basin College (CBC) campus was connected to the system and raised concerns as to whether or not the system was adequate to meet the needs of the new customer as well as additional buildings on the CBC campus. The expansion to the five existing buildings on the campus would result in an increase in the peak demand of approximately 2,440 kBtu/hr (715 kW_t) and an increase in peak flow of 122 gpm (7.70 L/s). Preliminary analysis done by the Washington State University Energy Program indicates that the system would be inadequate as it is now configured to meet this additional load without significant capital improvement. Several alternatives were identified, including increasing the diameter of some piping runs, installing a booster pump within the distribution loop or installing a peaking boiler. During a recent site visit, it was found that the old hospital has been converted to office space, and that there may be sufficient boiler capacity at that site to provide peaking and backup to the entire system. This would result in a more robust system, minimize the need for customer backup systems and also reduce peak flows and associated disposal issues. Further evaluation of this alternative will be carried out over the next several months.

OPERATING COSTS

No cost figures could be obtained relative to the construction of the original system or cost of individual entities connecting to the system. Cost of operating the system is covered by an annual $5,000 assessment to each of the four entities that receive service from the system. Individual entities, however, must cover any costs that may be required related to their equipment operation, maintenance, repair or replacement. Additional or special assessments may be levied to cover system costs in excess of the $20,000 or when possible, such costs may be covered by funds held in a reserve fund created for that purpose. Savings to the four entities are estimated to exceed $250,000 per year and in 2002 exceeded $285,000 (Elko School District, 2003).

REGULATORY/ENVIRONMENTAL ISSUES

The most serious environmental/regulatory issues are related to the disposal of geothermal fluids. The system does not have an injection well and at present all disposal is via surface means with some flows reaching the Humboldt River. Both EPA and the state of Nevada are requiring that no flows reach the Humboldt River. The main concern is associated with increasing temperature in the river. The school district is considering several alternatives to address the disposal issue, including diverting the flow to effluent ponds at the golf course or possibly using abandoned sand and gravel pits as percolation ponds. A more drastic solution would be to limit the amount of geothermal flow, requiring that consumers rely upon backup boilers during periods when heightened flows of geothermal would be required to meet peak demand. WSUEP has recommended that a central peaking plant could be a better alternative and existing boilers at the old hospital will be evaluated for this purpose.

PROBLEMS AND SOLUTIONS

The system has experienced few real problems since being put online in 1985, with the exception of one pipe break as a result of external corrosion--the piping system is not jacketed. This could also result in additional problems in the future. Although major problems have not plagued the system, there appears to be little overall system management or coordination, and various entities have essentially free rein to connect as they please. This has resulted in some minor but potentially major problems as with the pool system; when, booster pumps have been installed that actually tend to pressure the return line in a reverse direction.

A more pro-active management approach with better overall system management and control would seem to be critical to future successful operation. Recently, concerns over disposal have forced system operators to seriously look at either reducing peak geothermal usage or find alternative disposal options. Finally, the system is operating pretty much at maximum capacity and expansion to the GBC campus would severely stress the system and most likely result in an inability to meet peak demand if significant capital improvements are not initiated. Options appear to be replacement of some piping runs with larger diameter pipe, installation of booster pumps in the distribution line or provision of central peaking to allow for peak loads to be met through increasing temperature in the distribution loop as opposed to increasing flow, as is now the only alternative. The availability of presently under-utilized boilers at the old hospital only some tens of meters from the distribution loop would seem to provide an excellent opportunity to provide peaking; thereby, not only increase capacity to a level that could adequately meet the needs of expansion to the GBC campus but also minimize peak flows and thereby, disposal problems.

CONCLUSION

The Elko County School District district heating system has successfully provided for the heating requirements of the buildings connected to the system over the past 22 years. The system saves over $250,000 per year in energy costs to the four public entities receiving service from the system. The desire to extend service to the GBC campus as well as comply with increasingly restrictive requirements for fluid disposal could well be met through use of existing boilers at the old hospital to meet peak system demand. The closed loop system provides an interesting contrast to the Elko Heat Company system where geothermal fluids are circulated directly to each consumer.

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THE CURRENT GEOTHERMAL EXPORATION AND DEVELOPMENT OF THE GEOTHERMAL FIELD OF MILOS ISLAND IN GREECE

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[b] Milos, Company for Water Supply of Milos island, SA

INTRODUCTION

Milos island is located in the Aegean Volcanic Arc and is characterized by abundant geothermal resources of high temperature. Early geothermal exploration undertaken by the Institute of Geological and Mining Research of Greece, summarized in Fytikas (1977), includes temperature measurements in shallow wells drilled for this purpose and Schlumberger resistivity measurements of subsurface rocks. The results, which are shown in Figure 1, indicate that the eastern part of the island and especially the plain of Zefyria is the region with the highest temperature gradients and lowest apparent resistivities, hence the parts of the island most promising for high enthalpy geothermal potential. Later drilling exploration undertaken by the Public Power Co (PPC) of Greece, summarized in Mendrinos (1988), identified geothermal fluids of temperature 300-323 ºC at depths 800-1400 m below sea level in theZefyria plain. The results of the geochemical exploration financed by the PPC are shown in Figure 2. By examining Figure 2, we conclude that the region of the island most promising for exploitation of shallow, low enthalpy (<100 ºC) geothermal resources, is the one where deep fluids are present in shallow aquifers, namely the east half of the island.

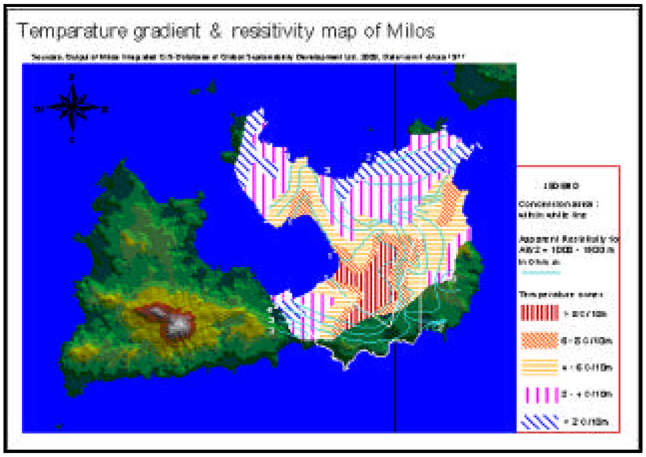

Figure 1.

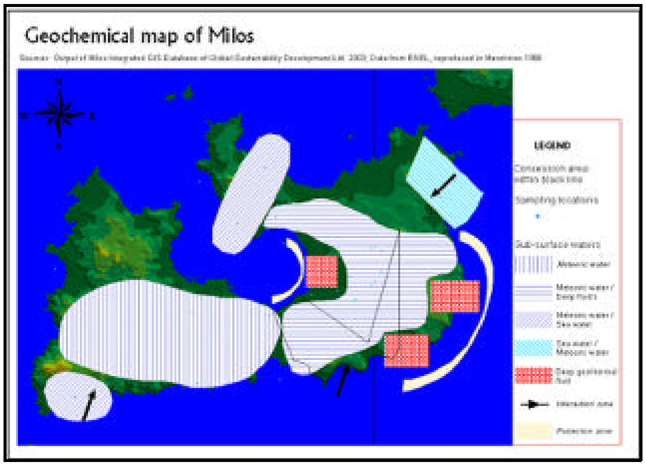

Figure 2.

Mendrinos (1988) performed evaluation of exploration data, well test analysis, resource assessment and computer simulation of the Milos geothermal system and indicated that the deep geothermal fluids correspond to boiled seawater of 80,000 ppm salinity. Mendrinos (1988) also calculated that by cooling the upper 2 km of the hot rocks below Zefyria, Vounalia and Adamas by 90 ºC would release 5 x 10^{18} J of heat (or 141 million TOE), which justifies the commissioning of 260 MWe geothermal power plant. In parallel, the evaluation showed that the minimum heat flow from deeper rocks cannot be less than 87.8 MWth. This value is slightly higher than the natural conductive heat flow towards the surface of the island, which has been estimated as 77 MWth (Mendrinos 1991) due to the convective heat flow component.

The figure of 87.8 MWth was based on small amount of natural convection through the geothermal system, due to the low permeability measured in the deep geothermal wells. Recent drilling in Vounalia, however, performed as part of the MIDES project, showed very high permeability and seawater infiltration to shallow rocks, as described above. This indicates that heat flow from deeper layers should be considerably higher.

THE LOW ENTHALPY GEOTHERMAL UTILIZATION PROJECT FOR ELECTRICITY GENERATION AND SEAWATER DESALINATION

The main objective of our ongoing project is to construct and operate a low enthalpy geothermal energy driven water desalination unit producing 75 to 80 m^3/h drinking water and an ORC power generator unit of installed capacity of 470 kWe on Milos island. The only source of energy is geothermal heat and the unit is anticipated to be entirely self sufficient in thermal energy and to have the potential to become self sufficient in electricity as well. Local community will benefit from the production of clear desalinated water, which will be produced at a very low cost (. 1.5 EURO per m^3) and from the utilization of a sustainable and environmentally friendly energy source, which is low-enthalpy geothermal energy. The amount of water produced will cover completely the needs for drinking water of the island. The project will use geothermal water from the Vounalia concession of Milos SA (Figures 1, 2 and 3) and will have the flow chart shown in Figures 4 and 5.

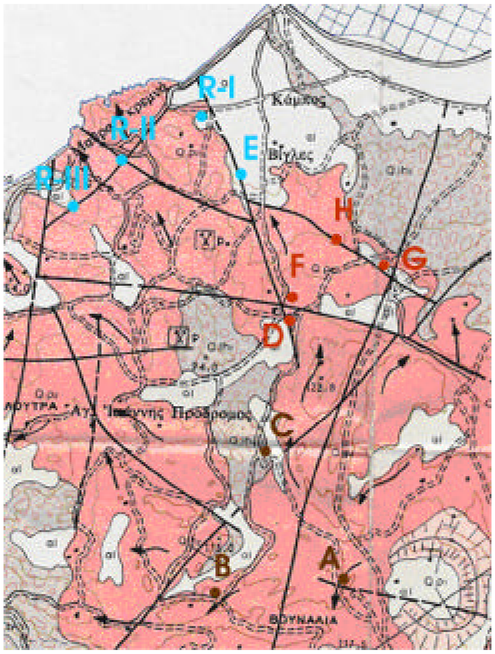

Figure 3.

"Gerling Sustainable Development Project GmbH – GSDP" is the project coordinator. Other project partners are "Milos Company for the exploitation of Renewable Energy Sources and Sustainable Development - Milos SA," the "Municipality of Milos", the "National Centre for Social Research – NCSR," the "Aristotelian University of Thessaloniki - AUTH" and the "Centre for Renewable Energy Sources - CRES." The overall project budget is 4,375,000 Euros, and the project as been partially financed by the European Commission (less than 10% financing through contract NNE5-1999-00041 MIDES project – "Energie" Programme).

GEOTHERMAL EXPLORATION RESULTS

MILOS S.A. a local subsidiary of GERLING SDP has allocated the drilling works to its subcontractor GEOEREVNA; a local contractor specialized in geothermal exploration and exploitation drilling. Well locations were decided in technical meetings between GSDP (Mr. G. Radoglou), AUTH (Prof. Dr. M. Fytikas) and CRES (Dr. C. Karytsas and Mr. D. Mendrinos).

Planning and supervision of drilling works and production testing was implemented by AUTH with the expert advice and assistance of CRES. The GIS database developed by GSDP proved a very effective tool for planning the drilling works. The GIS database includes all existing and documented information about the geology and geothermal potential of Milos. All data is digitalized and the frame is a topographic data package with an analysis of 4-meter height lines density combined with an evaluation of satellite images.

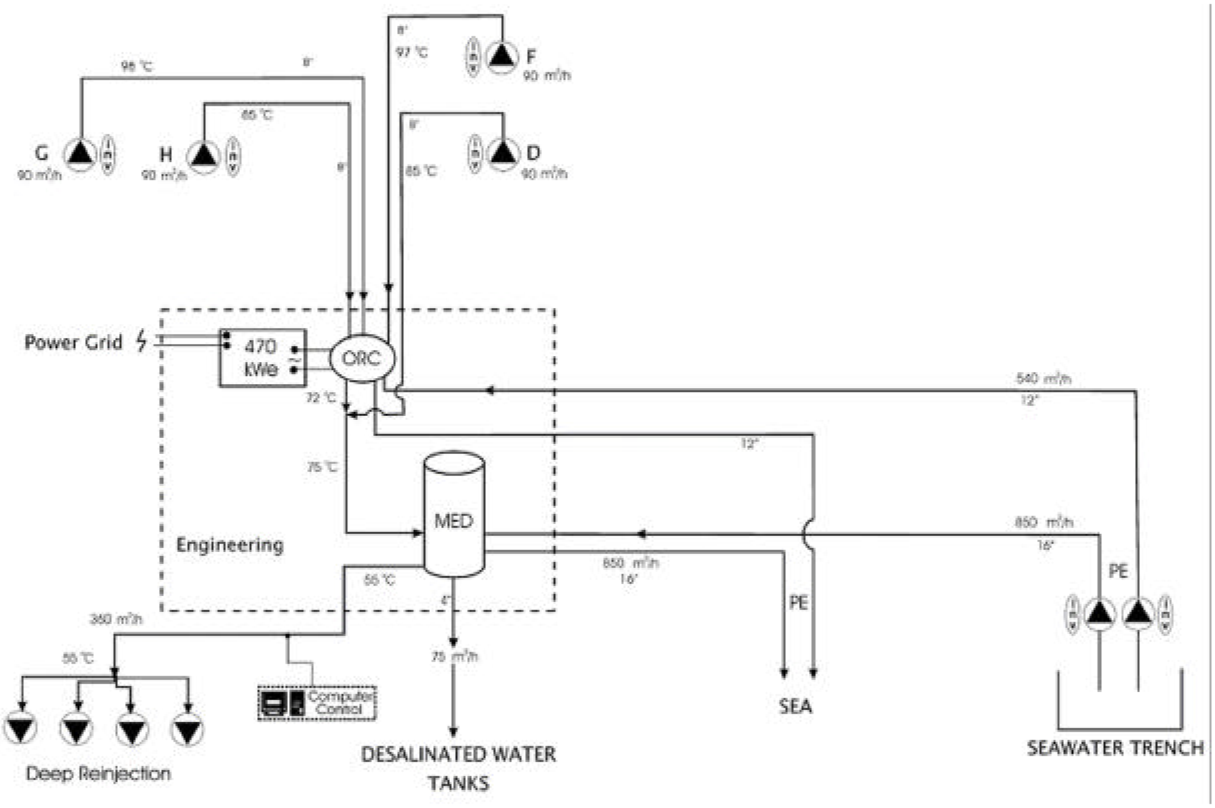

Figure 4.

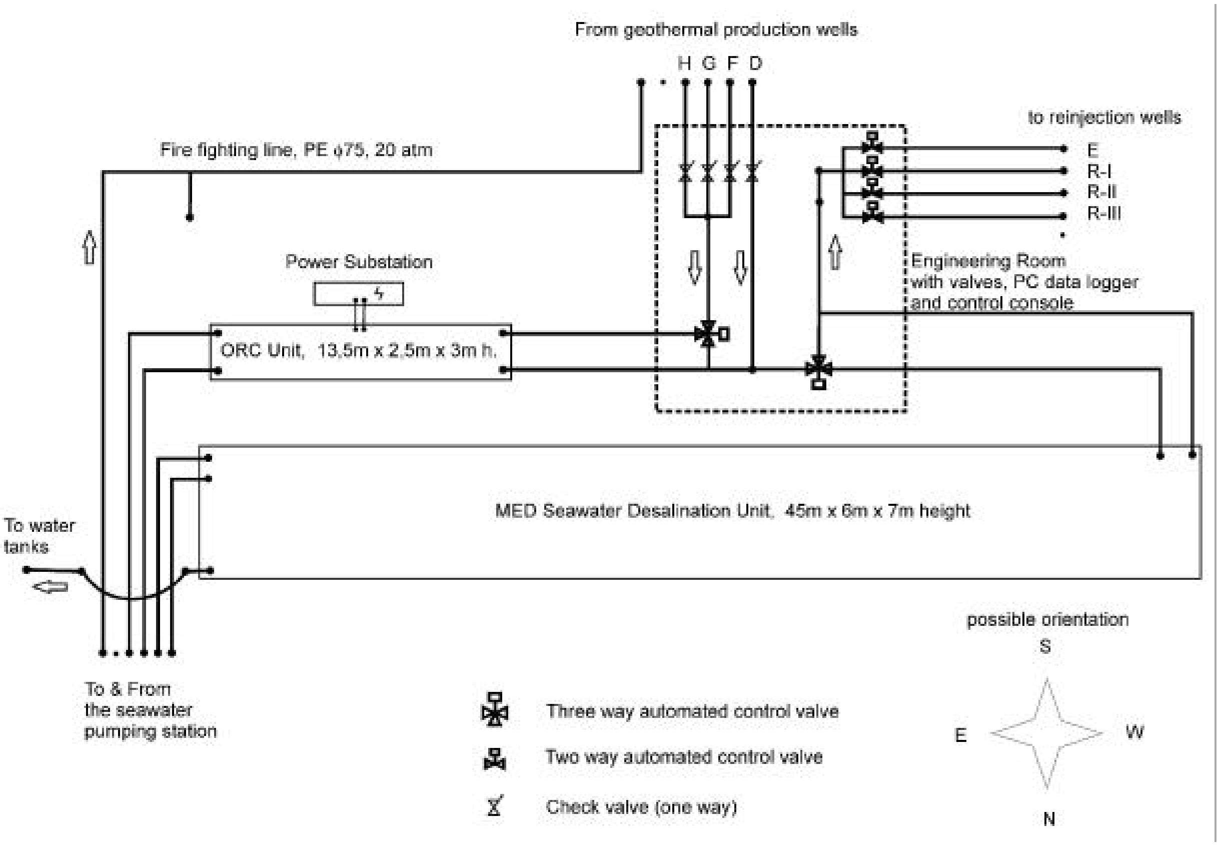

Figure 5.

The exploration area is in Vounalia, within the concession of Milos SA. Production wells, and the topography of the exploration area are shown in Figure 3. All production wells A to H have been completed. Tests performed included air lift, pumping at 3-5 flow rate steps, as well as continuous pumping at high flow rate for at least 48 h. Measurements included temperature profiles versus depth, static water level measurements, as well as water temperature, flow rate and water level during pumping tests.

In parallel, CRES implemented the optimal design study and integrated the engineering study which has led to detailed technical specifications of the entire application and of all necessary equipment.

The results of the production tests are summarised in Table 1, together with the energy potential of each well. Wells A and C are characterized by low flow rates, higher elevation, deep water level, low rock permeability, and temperature 84-100ºC. Wells D, E, F, G and H are characterized by high flow rates, lower elevation, shallower water level and very high rock permeability. In fact, the maximum flow rate they can yield is limited by the horsepower of the pump and the pressure losses of the piping rather than the permeability of the production layers. Production temperature varies from 55ºC (well E), to 99ºC (Well G).

All wells are relatively shallow, with well bottom at 70-185m, and stand with a water level approximately at sea level. With the sole exception of Well E, due to temperature close to the boiling point of water, which resulted in the presence of water vapor on top of the liquid surface due to evaporation, water level measurements were difficult and of questionable accuracy. This can be attributed to the condensation of water vapour directly on the water level sensor. Water samples were also taken and the results of their chemical analysis is shown in Table 2. The chloride content of the water varies between 11,200 and 25,000 ppm, indicating diluted to boiled seawater.

GEOTHERMAL EXPLORATION SCHEME

The geothermal power and desalination plant of the project will comprise the following components (based on CRES's engineering study please also refer to the plant flow chart in Figure 4):

- Geothermal production wells: Production will be derived from the wells located closer to the sea, due to their high energy yield and the corresponding hot water transmission costs. Wells F, D, G and H will produce 300 m^3/h of geothermal water 55-99ºC. Wells A and C will not be used due to their low energy output, their distance from the sea and their elevation, factors that raise considerably the capital costs and electricity needed for the production and transport of the geothermal water.
- Geothermal submersible pumps and inverters installed at the production wells.
- Piping network conveying the geothermal water to the main Plant. Buried steel or fiberglass piping will be used. Closed, pressurized at 10 bars maximum.

Table 1. Summary of Geothermal Well Data in Vounalia, Milos

Well	Well Bottom m	Casing Shoe m	Water Level m	Maximum Flow Rate m^3/h	Water Production Temperature °C	Thermal Power MWth (T_{base} = 25°C)
A	150	149	74	20	98	1.70
B	71	67	-	0	-	0.00
C	184	183	86	25	84	1.71
D	158	152	65	100	85	6.97
E	125	122	19	125	55	4.35
F	89	82	54	100	97	8.36
G*	85	82.5	57	100	99	8.59
H*	106	86	35	75	85	5.25
R-I*	102	98	18	85	60	3.45
R-II*	63	61	24	125	50	3.63
R-III*, **	100**	98*	20**	125**		

* Final casing 10", otherwise 8"

** Proposed R-III reinjection well

Table 2. Chemistry of the Produced Geothermal Waters from the Vounalia Geothermal Boreholes

WELL	A	C	D	E	F	R-I
Temperature (°C)	97	89	85	55	97	60
pH (at 25°C)	6.86	6.36	6.69	7.75	7.20	7.50
Conductivity (25°C, mS/cm)	55.1	43.9	25.2	32.8	57.1	69.0
Total hardness (mg $CaCO_3$)	4,800	3,900	1,700	2,510	5,230	5,940
Non-carbonate hardness (mg $CaCO_3$)	4,650	3,850	1,520	2,440	5,160	5,785
Total dissolved solids (g L^{-1})	42.3	33.2	19.0	25.2	43.6	54.1
Density (kg/L, at 15°C)	1.0288	1.0217	1.0114	1.0160	1.0300	1.0330
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	
Na^4	12,200	9,400	5,280	7,600	12,600	15,100
K^4	2,620	1,800	1,150	1,370	2,700	3,780
Ca^{2+}	1,515	1,350	725	850	1,520	2,120
Mg^{2+}	192	120	85	94	348	1,560
Fe^{2+}	0.4	30	0.7	0.6	1.1	0.4
Mn^{2+}	19	12	6	6.9	12.9	26.5
Sr^{2+}	23	18	10	14	23	32
Li^4	30	24	14	15	23	33
Zn^{2+}	0.5	5.2	1.2	0.4	3.3	0.3
Cu^{2+}	0.1	0.5	1.2	-	-	-
Pb^{2+}	0.01	0.02	0.07	0.04	0.04	0.04
Cd^{2+}	-	-	-	0.002	0.001	0.002
Ni^{2+}	0	0.015	-	-	-	-
Cr	0	-	-	-	-	-
NH_4^+	6.4	3.1	8.8	4.3	6.2	11

Cl^-	25,125	19,900	11,200	13,700	23,900	30,300
F^-	1.3	0.5	0.9	0.6	0.8	0.5
HCO_3^-	56	59	82	85	90	86
HS^-	-	-	-	-	-	-
SO_4^{2-}	310	275	170	1,350	2,180	850
NO_3^-	0.8	1.3	3.1	1	1.2	0.8
NO_2^-	0.04	0.4	0.01	0.5	0.7	0.01
PO_4^{3-}	-	-	-	-	-	0
SiO_2	158	202	162	104	138	142
As	0.12	0.03	-	0.02	0.03	0.05
B	28.0	25.1	11.4	14.0	25.6	30.3

- Power and data transmission lines from the main plant to the wells.
- ORC unit, transforming approximately 7% of geothermal energy to electricity designed to generate approximately 470 kWe.
- MED-TVC seawater desalination unit providing 75-80 m^3/h desalinated water.
- Main heat exchanger, transferring the energy from the hot geothermal water exiting the ORC unit to the MED-TVC desalination unit.
- Reinjection wells (RE I and II) located at the margin of the geothermal field, close to the coast, downstream and at lower elevation of the main Plant, in order to minimize water transmission costs and avoid disturbing the hot part of the geothermal aquifer, well E will also operate as a reinjection well, due to its low well-head temperature (only 55 °C).
- Geothermal water transmission lines from the main heat exchanger to the reinjection wells: buried steel or fiberglass piping, closed pressurized system at 10 bars maximum, no extra pumping.
- Seawater transmission lines conveying 1000 m^3/h cooling seawater to the MED-TVC unit plus 200-575 m^3/h cooling water for the ORC unit: Buried polyethylene piping, seawater intake and disposal from a trench close to the sea line, pumping station close to the intake point.
- Desalinated water transmission line from the plant to the water tanks near the town of Adamas: Buried polyethylene piping.
- Power substation for power provision or delivery to the local power net: 500 kWe.
- Main computer monitoring and control system for real time data logging and automation control.

Until now, drilling of production and reinjection wells has been completed. Construction works for the piping networks, the ORC power plant, the desalination plant and the electro-mechanical equipment, are expected to commence shortly.

CONCLUSIONS

The ongoing Milos low enthalpy geothermal energy utilization project, demonstrates that through the innovative and sustainable utilization of low enthalpy geothermal energy for electricity generation and seawater desalination in Milos, it can substantially contribute to the local water needs. It is sustainable, as it will use only a minimal fraction of the available geothermal potential. It can cover local water demand, as production wells drilled in Vounalia can provide the necessary energy quantity for the seawater desalination plant.

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GRC 2004 ANNUAL MEETING

The Geothermal Resources Council (GRC) invites you to attend the GRC 2004 Annual Meeting–scheduled for August 29 - September 1 at the Hyatt Grand Champions Resort & Spa at Indian Wells (near Palm Springs), California.

This year's Annual Meeting theme is *Geothermal Energy - The Reliable Renewable*. With co-sponsorship by the U.S. Department of Energy and contributions by GRC Corporate and Individual Members, the GRC 2004 Annual Meeting also provides an ideal opportunity for developers, suppliers and support organizations to exhibit their equipment and services at the (U.S.) Geothermal Energy Association Trade Show.

The 2004 Annual Meeting will feature distinguished international keynote speakers at its Opening Session, Technical and Poster Sessions on a broad range of timely geothermal topics. Workshops, Field Trips to nearby geothermal fields and features, an exciting Guest Program and the GRC Annual Banquet. And our 2004 event will once again feature the GRC Annual Golf Tournament!

The Hyatt Grand Champions Resort & Spa is one of the finest facilities in the Palm Springs area, with beautiful accommodations and a new Convention Center. Through a special arrangement with the resort, GRC 2004 Annual Meeting participants will pay only $109 for rooms, plus applicable fees and taxes. Complete guest information will be included in our *GRC 2004 Annual Meeting Registration Brochure*, which will be available on the Internet at: www.geothermal.org and mailed worldwide in June.

WORLD GEOTHERMAL CONGRESS 2005

Antalya, Turkey, 24-29 April 2005

"Geothermal Energy - The Domestic, Renewable, Green Option"

INVITATION

The International Geothermal Association and the Turkish Geothermal Association cordially invite members of the international energy community to the World Geothermal Congress 2005. The Congress aims to emulate the successful congresses held in Italy (1995) and in Japan (2000). As Organizing Committee composed of internationally respected geothermalists, has been formed and is proceeding with organization of the World Geothermal Congress 2005. A website is being setup to facilitate provision of up-to-date information (www.wgc2005.org).

LOCATION

The Congress will be held in the Glass Pyramid Sabanci Congress & Exhibition Centre in the city of Antalya, the chief city on the southern (Mediterranean) coast of Turkey. Antalya has a population of 500,000, and is a major tourist resort with numerous hotels and a wide range of visitor facilities. Antalya can be easily reached by regular scheduled air services (currently eight flights each day; 1.5 hours, non-stop) or by comfortable air-conditioned long-distance bus (725 km; 12 hours) from Istanbul, which is the major entry port to Turkey. Flights are also available from some major cities in Europe directly to Antalya. At the time of the Congress, the climate in Antalya will be mild (15-25°C) and with low rainfall.