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Examples of United States geothermal district heating systems

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ABSTRACT

There are 18 geothermal district heating systems in the United States. These systems use geo-thermal fluids from 59 to 103°C, with peak flow rates from 5 to 250 L/s. Installed power varies from 0.2 to 31 MWt, and annual energy use from 0.6 to 22 GWh. Thus, the total installed power is almost 100 MWt and the annual energy use is 168 GWh. Both open and closed distribution systems are used--the later type using a secondary fluid to supply the heat to the customers. Approximately half of the systems use a central mechanical plant containing heat exchangers, circulating pumps, expansion tanks and controls. Both volume and energy metering systems for customer billing are used. A variety of geothermal fluid disposal systems are used, including injection and disposal in a nearby river or stream. The energy and environmental savings, as compared to fossil fuel, amount to nearly 135,000 barrels of oil equivalent annually (20,200 TOE), and a reduction of 58,000 metric tons of carbon (coal) or 12,000 metric tons **of** carbon (natural gas) per year. Three systems are described.

KEYWORDS

District heating, geothermal direct utilization, heating equipment, USA

Introduction

Geothermal districr heating is defined as the use of one or more production fields as sources of heat to supply thermal energy to a group of buildings. Services available from a district heating system are space heating, domestic water heating, space cooling, and industrial process heat. Depending on the temperature of geothermal fields, it may he advantageous to develop a hybrid system including, in addition to geothermal, a heat pump and/or conventional boiler for peaking purposes (Lund and Lienau 1997).

A geothermal district heating system comprises three major components.

The ***first part*** is ***heat production*** which includes the geothermal production and recharge fields, conventional fueled peaking station, and wellhead heat exchanger.

The ***second part*** is the ***transmission/distribution system,*** which delivers the geothermal fluid or geothermally heated water to the consumers.

The ***third part*** includes ***central pumping stations*** and ***in-building equipment.*** Geothermal fluids may be pumped to a central pumping station/heat exchanger or heat exchangers in each building. Thermal storage tanks may be used to meet variations in demand.

Advantages of geothermal district heating

Potential advantages of district heating include:

1. ***Reduced fossil fuel consumption.*** Geothermal district heating nearly eliminates the consumption of oil, coal, or natural gas traditionally used for space and domestic water heating. It may be advantageous to use conventional fuels for peak demand.

2. ***Reduced hearing costs.*** Through the use of geothermal energy and increased efficiency, district heating systems often can offer thermal energy at lower prices than conventional heating systems.

3. ***Improved air quality.*** By installing a closed system with injection wells, geothermal district heating systems eliminate noxious gases, greenhouse gases (such as CO_2) and particulates that occur in cities with conventional single-building heating systems.

4. ***Reducedfire hazard in buildings.*** The fire hazard in buildings is reduced because no combustion occurs within individual buildings.

5. ***Cogeneration.*** Cities located near high-temperature (>150°C) geothermal fields can jointly produce electric power and hot water for district heating at a greater efficiency than generating electric power alone.

Geothermal district heating systems are in operation in at least 12 countries, including: Iceland, France, Poland, Hungary, Turkey, Japan and the U.S. The Warm Springs Avenue project in Boise, Idaho, dating back to 1892 and originally heating more than 400 homes, is the earliest formal project in the U.S.

U.S. district heating systems

There are 18 geothermal district heating systems in the United States. (Table 1; Figure 1) These systems use geothermal fluids from 59 to 103°C, with peak flow rates from 5 to 250 L/s. Installed power varies from 0.2 to 31 MWt, and annual energy use from 0.6 to 22 GWh. Thus, the total installed power is almost 100 MWt and the annual energy use is 168 GWh. The oldest system in operation is the Warm Springs Water District in Boise, Idaho that began operation in 1892, with the system at Ketchum, Idaho in operation since 1929, on the Oregon Institute of Technology in operation since 1962, and Midland, South Dakota since 1964. The remaining systems have all been in operation for less than 20 years. Both open and closed distribution systems are used--the latter type using a secondary fluid to supply the heat to the customers. Approximately half of the systems use a central mechanical plant containing heat exchangers, circulating pumps, expansion tanks and controls. Both volume and energy metering systems for customer billing are used. Volume metering or flat rate changes are the most common in the U.S. A variety of geothermal fluid disposal systems are used, including injection and disposal in a nearby river or stream. The energy and environmental savings, as compared to fossil fuel, amount to nearly 135,000 barrels of oil equivalent annually (20,200 TOE), and a reduction of 58,000 metric tons of carbon (coal) or 12,000 metric tons of carbon (natural gas) per year (assume 75% efficiency of fossil fuel plants). Details of these systems can be found in Rafferty (1989a and 1990) and in ***Geo-Heat Center Quarterly Bulletin,*** Vol. 18, Nos. 3 and **4.** The Elko, Nevada project, a medium-sized system; and Oregon Institute of Technology, an institutional system are described here as examples.

Table1 :Summary Data on U.S. Geothermal District Heating Systems

Name/Location	Years in Service	Temp. °C	Peak Flow L/S	Power MWt	Energy Use TJ/yr	GWh
Litchfield Correctional Center, CA	14	77	76	6.15	48.6	13.5
San Bernardino District Heating, CA	14	59	234	12.83	79.1	22.0
Susanville District Heating, CA	13	77	19	5.57	12.1	3.4
Pagosa Springs District Heating, CO	16	60	51	5.13	7.3	4.8
Boise City Geothermal District Heating, ID	15	79	253	31.15	69.8	19.4
Fort Boise Veteran's Hospital, ID	10	72	19	1.76	12.8	3.6
Idaho Capitol Mall, ID	16	76	47	3.31	67.2	18.7
Ketchum District Heating, ID	69	70	63	0.88	7.0	1.9
Warm Springs Water District, ID	106	80	100	3.6	31.6	8.8
New Mexico State University, NM	16	61	26	2.18	48.4	13.4
Elko County School District, NV	10	88	19	4.25	16.5	4.6
Elko District Heating System, NV	16	79	41	3.81	23.4	6.5
Warren Estates, Reno, NV	16	98	63	1.05	8.3	2.3
Warren Properties, Reno, NV	16	100	45	3.63	76.2	21.2
City of Klamath Falls District Heating, OR	15	103	45	4.39	29.9	8.3
Oregon Institute of Technology, OR	36	89	47	5.13	40.4	11.2
Midland District Heating, SD	34	67	5	0.2	2.1	0.6
Philip District Heating, SD	16	68	19	3.37	12.1	3.4
				98.39	602.8	167.8

District heating system in Elko, Nevada

Elko Heat Company has been operating a geothermal district heating system since December 1982 (Lattin and Hoppe 1983, and Lattin 1997). The system serves 17 customers, and conveys approximately 5 million Us of 81°C geothermal water annually. the customers are primarily using the geothermal water for space heating and domestic hot water heating. Two customers are utilizing their return water for winter-time snow and ice melting on walkways, and one is utilizing a heat pump system. Another customer, a commercial laundry, is softening geothermal water, and using it directly for wash and rinse water. The water has a total dissolved solid content of 605 ppm and is mainly a sodium-bicarbonate water with a pH of 6.6.

The system has one geothermal production well drilled to a depth of 265 m. The well is cased with 12-, 8- and 6-in. carbon steel casing. The production zone of the well is the last 20 m and is not cased (open-hole completion). The well flows approximately 27 L/s under artesian conditions at 81°C. The shut-in pressure of the well is 358 kPa. The well is equipped with a 11-kW lineshaft turbine pump. The pump is used during periods of high flow to boost the system pressure. The wellhead discharge piping is constructed of chedule **40** carbon steel pipe.

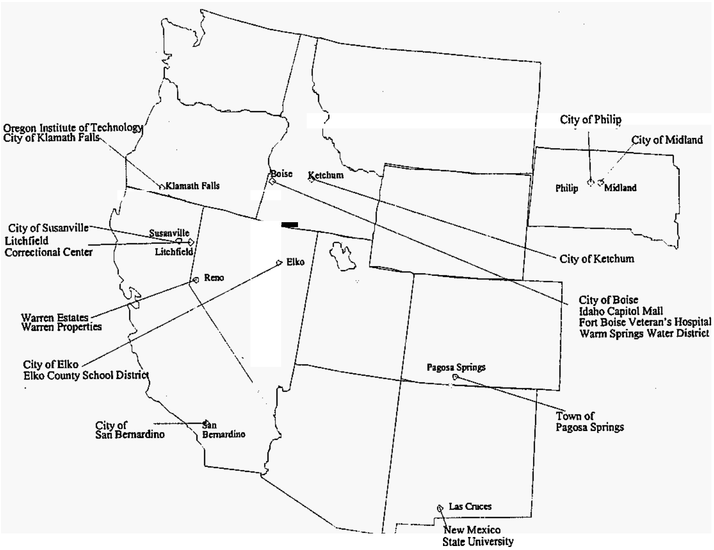

Figure 1: Locations of U.S. geothermal district heating system.

The piping system consist of a two-pipe system, an insulated supply pipe and an uninsulated return pipe in an open-loop distribution system where the spent geothermal fluid is disposed to a 0.6-ha cooling pond followed by discharge to wetlands area adjacent to the Humboldt River. Fortunately, the geothermal fluids are of a good quality and the only treatment required is cooling. Figure 2 shows the details of a portion of the distribution system. The majority of the piping is 200-mm diameter, with some 150-mm and 100-mm diameter pipe. Services to the individual customers are normally 50 mm, and in a few instances are 75 mm and 100 mm for the large customers. Service lines were initially constructed out of carbon steel and lasted two to four years before failing due to a combination of internal and external corrosion.

Small diameter service piping 100mm or less was replaced with Type 304L stainless steel, with welded or flanged joints. Stainless steel piping was quite expensive and thus, was then only used on the supply line. High Density Polyethylene (HDPE) pipe was used for the return service line piping since it was determined that the HDPE pipe was suitable for used in the relatively low pressure and temperatures encountered in the retum piping. HDPE piping is a plastic pipe with thermally fused joints and is relatively inexpensive. This type of pipe is not susceptible to internal and external corrosion; but, its use is limited to temperatures less than 60°C and 345 kPa (lower pressures will allow higher temperatures). Valves used on services were stainless steel butterfly valves with gear-type operators and 50-mm operating nuts for buried valves. Each customer's service has a shut-off valve on the supply and return line in close proximity to the customer's building.

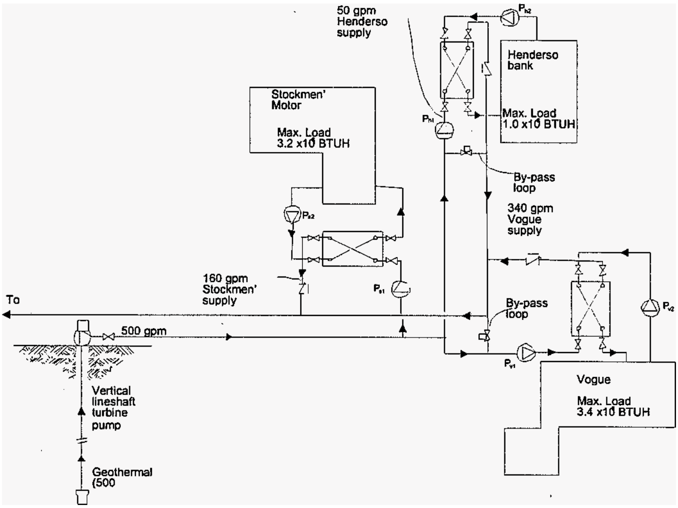

Figure 2 : Elko open-loop distribution system schematic.

The main distribution system was installed in city streets along with other utilities, water, sewer, natural gas, telephone, television and electrical. The main problem encountered involved working in the streets with traffic and expense of replacing pavement. Other buried utilities were not a problem. Consideration should be given to locating pipelines in alleys to avoid this problem (see Rafferty 1996).

The main distribution piping is asbestos-cement (transite) pipe, epoxy-lined with polyurethane insulation and an asbestos-cementpipe outer jacket. Rubber end seals prevent moisture entry into the insulation. The return line is also asbestos-cement with bell-and-spigot joints and EPDM gaskets. This was the most cost effective pipe material at the time, and is immune to corrosion; however, the pipe is no longer manufactured due to environmental concerns. Alternates today would include: steel (both carbon and stainless), fiberglass and ductile iron (see Rafferty 1989b, **for** detailed discussion on this subject).

The total design and construction cost of the system, designed by Chilton Engineering, was about $1.4 million with $827,000 provided by a USDOE PON cost shared grant. The customer's geothermal service is charged by the 1000s gallons (3.8 m^3) of supply water. Elko Heat Company initially started charging $1.25/1000 gallons ($0.33/1000 m^3) and in 1992, increased the rates to $1.38/1000 gallons ($0.36/1000 m^3). It is estimated that this rate for geothermal energy equates to approximately 30% of the equivalent rate for natural gas. Flow meters are installed inside the customer's facility and read monthly. **As** an incentive for customers to retrofit to geothermal, the company charged only 50% of the normal rate for the first three years of the contract, free geothermal use for two years and/or Elko Heat Company paying for retrofit and the customers pay the rate they were paying for conventional fuel for the next five years. Each of the customer requirements were unique and required special consideration. **An** existing hydronic system was a relatively easy and inexpensive retrofit; whereas, gas-tired air handlers required more complexity and expense. **A** new building could he designed to utilize geothermal energy at a relatively small additional cost.

In approximate numbers, the system generates $110.00 in revenue, with system operational cost approximately $45,000 per year (management, maintenance, legal and accounting, and permits for licenses). The peak heat use is 2.2 MW based on a 17°C temperature drop.

Finally, in order for geothermal energy to he cost effective, a potential customer has to he in close proximity to the distribution system and he a relatively large customer. Individual residences were too small to he cost effective; but, commercial and office complexes exceeding 930 m^2 were good candidates for retrofitting (see Rafferty 1996 for additional discussion on this subject). The Elko Heat Company system has operated successfully for 15 years with few interruptions in service and no major system failures--there is no backup or peaking source of energy!

Oregon Institute of Technology

At the other end of the geothermal heating spectrum is the mini-district heating system for the Oregon Institute of Technology campus in Klamath Falls, Oregon (Rafferty and Lienau, undated; Boyd 1999). The 11-building campus has been heated by geothermal hot water since 1962; where, three hot water wells supply all of the heating needs for the 62,000 m^2 of floor space. The combined capacity of the well pump is 62 *Us* of 89°C water with the average heat utilization rate over 0.53 MWt and the peak at 5.6 MWt. **All** are equipped with variable-speed drives to modulate flow to campus needs. In addition to heating, a portion of the campus is also cooled using the geothermal resource. This is accomplished through the **use** of an absorption chiller. The chiller requires a flow of 38 Us and produces 541 kW of cooling capacity with 23 *Us* of chilled water at 7°C. The hot water distribution system consists of pre-insulated fiberglass piping installed in underground concrete tunnels. Plate heat exchangers have been installed in **all** buildings to isolate the building systems from exposure to the geothermal fluids. The waste water is delivered to an injection well on the other end of the campus. A simplified diagram of the system is shown in Figure 3. The total dissolved solids in the fluid is 795 **mgll** with sulfate (330 mg/l) and sodium (205 mg/l) being the highest constituents. Silica is 48 mg/l and hydrogen sulfide 1.5 **mgll.** The latter caused problems with copper in the mechanical system.

OIT has recently installed four sections of walkways and stairs which utilize the geothermal heat for snow melting. Two sections are the stairs leading to the upper level of the campus, a third is the wheelchair ramp in front of South Hall, and most recently, the ramp leading to the Residence Hall. All of the systems utilize 16-mm diameter cross-linked polyethylene tubing (PEX good for 82°C at 690 kPa or 93°C at 550 kPa).

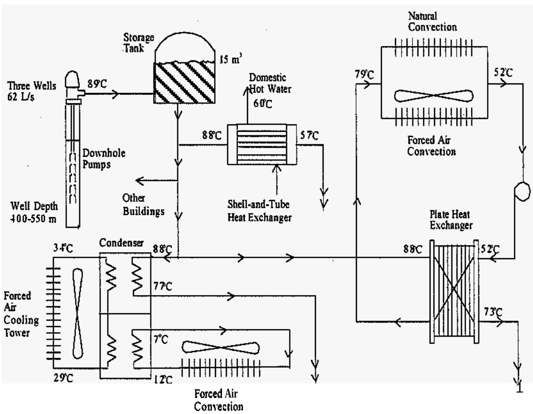

Figure 3 : Oregon Institute of Technology heating and cooling system.

The stairs each have three loops and the ramps four loops with tubing spacing of 250 mm. Each system uses a brazed-plate heat exchanger to isolate the glycol-filled snow melt loops (Boyd 1998).

The OIT system saves approximately 1650 tonnes of oil or $225,000 each year. The operating and maintenance cost are about $25,000 per year.

Conclusion

No new geothermal district heating system has been constructed in the United States for over 10 years. This is mainly due to the low cost of competing natural gas as the alternative fuel source and the high initial investment necessary for geothermal systems. In addition, communities, utilities and commercial firms are reluctant to explore for suitable geothermal resources, as the risk is often high, and lending institutions do not wish to finance these risky investments.

However, existing geothermal systems are still expanding and adding customers. This is true for Klamath Falls, that has almost doubled the number of customers on the system since it was initially constructed 15 years ago. The city has also added a snow melting system under downtown sidewalks. The Boise City system bas recently drilled an injection well in order to expand its system. Oregon Institute of Technology has added one new buildings to the system in the last 10 years and provided snow melting systems under sidewalks and stairs. In all these cases, the resource is fairly well known, and the high capital investment in wells and pipelines has been amortized.

There is one new ambitious project that is in the planning stages. **A** geothermal district heating project at the south end of Reno, Nevada, near Steamboat Springs is being investigated. This massive project could supply up to **3** million square meters with 116°C water from wells in the Steamboat Springs area and with waste water from the existing geothermal power plants. It is expected that the peak power will be 264 MWt and will provide both heating and air-conditioning demands. Initially, a large industrial park on 480 ha, which is in close proximity to the geothermal power plant, will be developed over the next five years. **A** high school, university branch campus, and casino will be future customers (Kanoglu et al. 1996).

Finally, one possible bright light on the horizon, is that the USDOE has provided some risk reduction money for exploration and reservoir confirmation for direct-use geothermal systems. In FY99, they awarded a total of $700,000 to three projects; one of which is a proposed district heating system at Canby, California.

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