Geothermal district heating: A century of service

The operation of GDH systems displaces conventional fuels and eliminates production of greenhouse gases

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The use of geothermal and other renewable energy technologies is considered to be a relatively recent practice. However, there are examples of visionary individuals who developed alternate energy systems years, or even decades, before most of the HVAC community.

Geothermal district heating (GDH) is one example, with the first GDH system established in Boise, Idaho, in 1892. Such early use of this now widespread resource is surprising. More impressive is the fact that this system is still in operation, one century later.

Its success has spawned the development of 17 other GDH systems throughout the western United States and dozens more internationally. Interestingly, the pioneer developers of the Boise Warm Springs Water District (BWSWD) system encountered the same issues we address today in district systems: marketing, rate structure, metering and hardware problems.

History of the Boise GDH system

Boise was experiencing boom-town growth in the late 19th century because of the nearby gold discoveries and the city's location on the Oregon Trail. In 1890, two local companies were vying for the right to develop this growing city's domestic water system. One of these, the Boise Water Works, chose to "sweeten the pot" by delivering not just cold water but hot water as well.

To accomplish this, wells were drilled in an area of hot springs east of town. By March 1891, two 400 ft (120 m) wells had been completed that could sustain an artesian flow of 550 gpm (35 L/s) at 170 °F (77 °C).[1]

The quality of the water was sufficient that it could be offered to customers for both domestic and space heating purposes. This marketing strategy was successful, with the Boise Water Works absorbing its rival and then incorporating as the Artesian Hot and Cold Water Company in early 1891.[2]

Shortly thereafter, a wooden pipeline was installed to deliver the hot water to the newly constructed natatorium. These wood-stave lines were also extended along Boise's Warm Springs Avenue to the downtown area so that nearby homes and businesses could be served.

The "several miles" of pipe incurred a capital cost of $20,000.[2] With a calculated conventional fuel (wood and coal) savings in the area of $50,000, it appeared that the system was on the road to success.

However, marketing proved to be more difficult than expected. Local building owners were wary of the new heating source and some were certain that either the flow or temperature would soon decline.

To convince the public of the system's reliability, the homes of two prominent local citizens (who were also directors of the Artesian Company) were connected to the district in January 1892.[1] Numerous social functions were conducted during February and March in these homes and these events, along with the attractive rate of $2.00 per home per month (compared to coal at $7.00 per ton), soon began to attract new customers.[1]

Within a few years, the system consisted of 4-1/2 miles (7.2 km) of large-diameter distribution pipe and served 200 homes and 40 downtown businesses.[2]

Early equipment and materials

As with any geothermal project, the wells were the heart of the Artesian Hot and Cold Water Company's system. Originally, the system was operated with only the natural artesian head. However, it quickly became apparent that more flow would be required to serve the growing customer demand.

Additional wells were drilled, but apparently these did not increase the flow. At one time between 1900 and 1912, an air-lift pumping arrangement (similar to that now used for testing wells)

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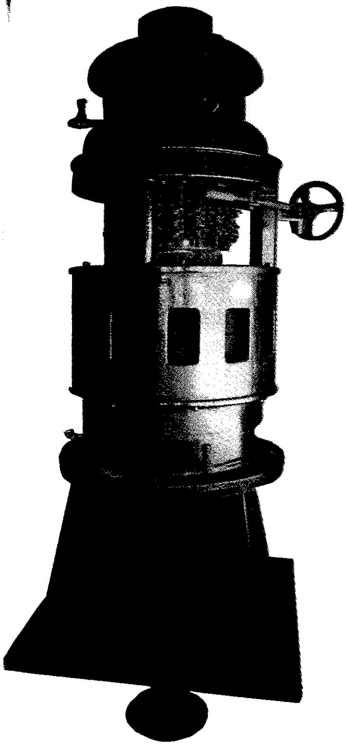
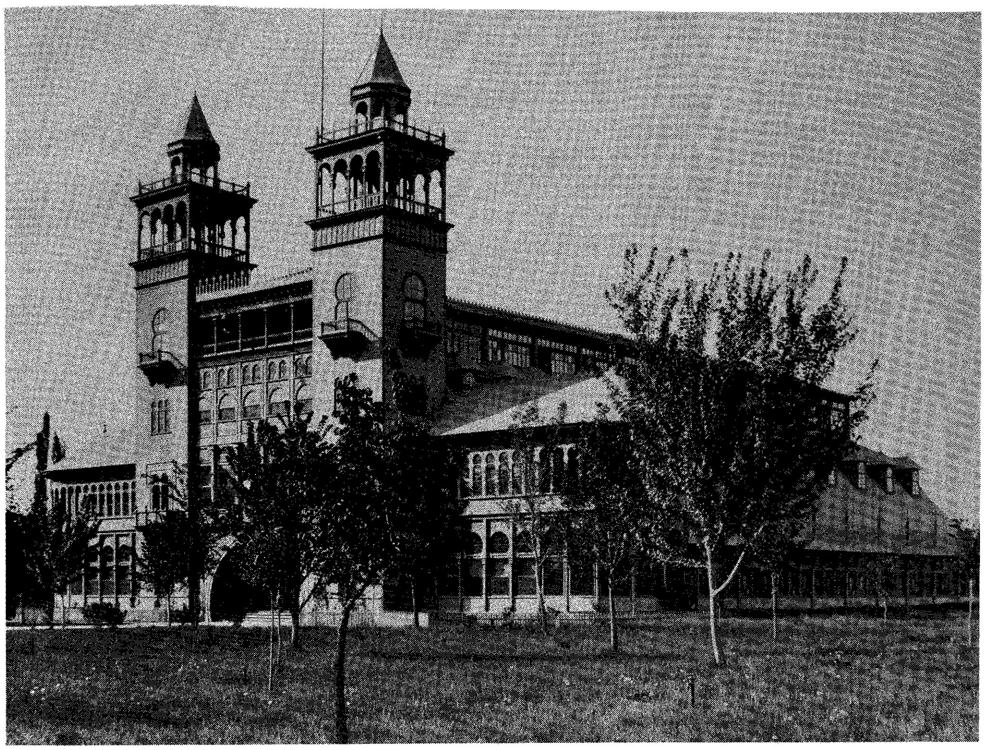
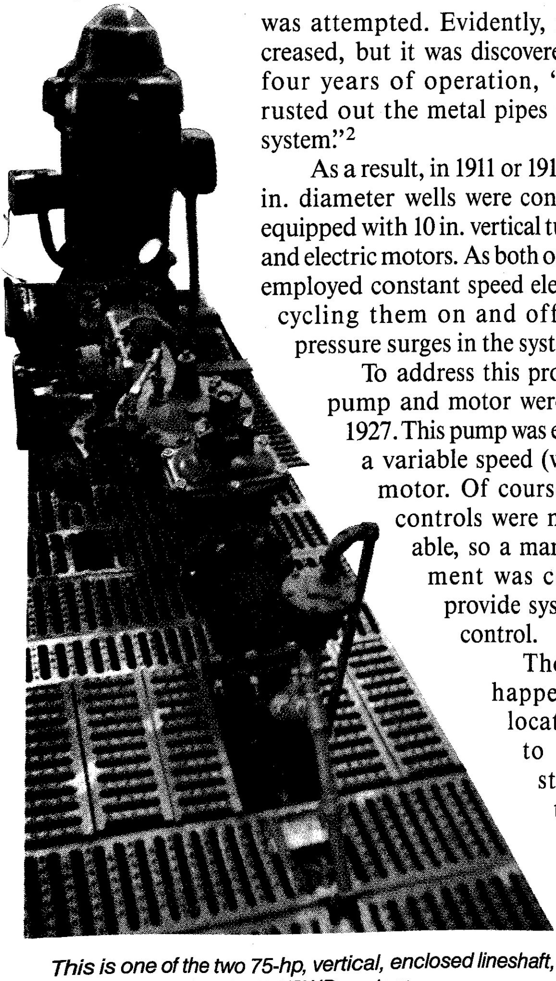




This 75-hp wound rotor motor (above left) was installed on the west well in 1927. The manually controlled, variable speed motor provided improved system pressure control. The Boise Natatorium (1892-1934) (above right) was among the first buildings connected to the geothermal district heating system.



This is one of the two 75-hp, vertical, enclosed lineshaft, turbine pumps currently serving the BWSWD system.

was attempted. Evidently, flow was increased, but it was discovered that, after four years of operation, "the air had rusted out the metal pipes of the entire system."[2]

As a result, in 1911 or 1912, two new 16 in. diameter wells were constructed and equipped with 10 in. vertical turbine pumps and electric motors. As both of these pumps employed constant speed electric motors, cycling them on and off resulted in pressure surges in the system.

To address this problem, a new pump and motor were installed in 1927. This pump was equipped with a variable speed (wound rotor) motor. Of course, automatic controls were not yet available, so a manual arrangement was concocted to provide system pressure control.

The well house happened to be located adjacent to the Idaho state penitentiary. Prison trustees were stationed, 24 hours per day, in the well house to operate the wound rotor motor.

Employees of the Boise Water Corporation (a successor to the Artesian Company) monitored a pressure gauge connected to the system downtown. When the pressure deviated from acceptable limits, a call was placed to their supervisor. The supervisor then called the prison switchboard operator who, in turn, contacted the trustees in the well house and advised them which way to adjust the pump speed. Although cumbersome, this control strategy remained intact until the 1970s.[3]

New pumps were installed intermittently over the years (in 1935, 1943, 1954, 1962 and 1987). In some cases, this was as a result of pump failure from cavitation caused by declining water levels.[4] However, reliability has been very good because two wells were used throughout the system's history.

Distribution piping for the GDH system has been constructed of a wide variety of materials. As discussed, the first pipeline was of woodstave construction. However, this piping was found to be "dangerous and useless" as early as 1896.[2]

The early failure of the piping is curious as wooden piping in other geothermal systems has lasted for up to 70 years. The failure is most likely to have been related to corrosion of the iron bands rather than the wood pipe itself.

The wood material was replaced about 1910 with an iron alloy pipe that employed lead and oakum connections. Some of those lines were insulated by constructing redwood boxes around the pipe and filling them with sawdust. Some redwood boxes were found intact as late as the 1980s.[3] However, in many cases, the sawdust became saturated with water, causing rapid failure of the pipe from external corrosion.[5]

Many failures were also attributed to electrolysis that occurred when electric service was extended to the area in the early 1900s.[5] In 1937, most of the main distribution lines were replaced with cast iron piping that served until 1982, when the entire system was replaced with asbestos cement piping.

From the outset, the system has employed only a single line (supply only) distribution system. Waste water is disposed of in irrigation ditches, storm sewers and surface drains.

Several billing approaches have been used by the BWSWD. In the early days, a single flat rate of $2 to $3 per month was employed. Later, in an effort to get customers to conserve, water meters were installed. It is unlikely that hot water meters were available at that time and the cold water meters that were tried failed quickly.

For most of its history, billing has been based on the use of orifice plates. A small orifice is placed in each customer service line and a constant pressure maintained in the distribution system. Rates are based on the size of the orifice, with most homes using a 3/16-in. (5 mm) size.[3]

The names of the entities operating the system have varied over the last 100 years from the Boise Water Works to the Artesian Hot and Cold Water Company to the Boise Water Corporation to the present Boise Warm Springs Water District (BWSWD).

The customer base declined somewhat during the late 1950s and 1960s when natural gas became available but rebounded after the 1973 energy crisis. Currently, 266 mostly residential customers are served.[6]

Modern GDH systems

Although there were no large district systems installed for many years after the construction of BWSWD, individual building geothermal systems were widely used during the 1920s and 1930s throughout the western United States. Competition from fossil fuels in the 1950s and 1960s slowed development, but growth returned after 1973.

The success and high visibility of the BWSWD system served as a catalyst for developing numerous other GDH systems both here and abroad. As of 1991, there were 18 GDH systems in operation in the western United States (see *Figure 1*). With one exception in 1963, all of these were developed since 1979. *Table 1* summarizes information on these systems.

Modern GDH systems are characterized by two general designs: open distribution and closed distribution. In the open distribution approach, geothermal fluid is delivered directly to the customer where a heat exchanger isolates the building system from the geothermal fluid (see *Figure 2*).

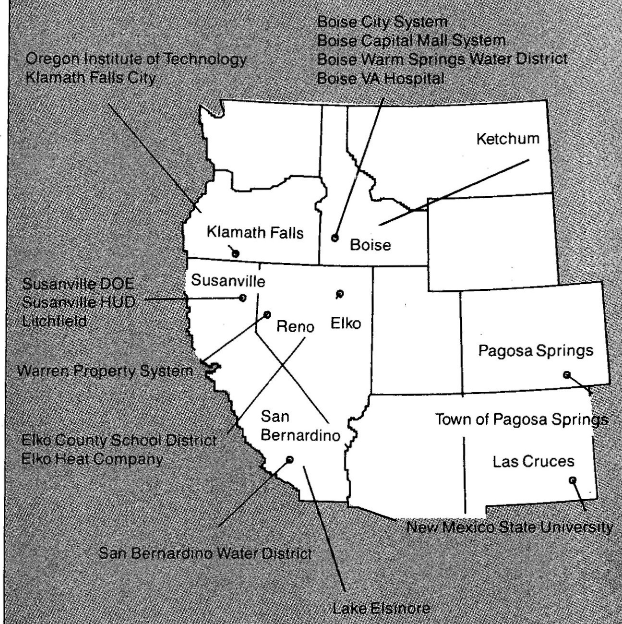


Figure 1. GDH systems in operation in the western United States.

The closed distribution design employs central heat exchangers and a closed distribution loop of treated water to which customers can be directly connected (see *Figure 3*). It is likely that most future district systems will be of the open design as this reduces total capital cost for the developer.

The design of most American geothermal district heating systems can be divided into five or six subsystems. These subsystems include:

- Production facilities,
- Central plants (closed distribution systems only),
- Distribution network,
- Customer connections,

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Table 1. Information Summary on Selected U.S. Geothermal District Heating Systems*

System	Location	Years Operated	Resources Temperature	Peak Flow (gpm)	Feet of Pipe
Oregon Institute of Technology	Klamath Falls, OR	27	192°F	980	7,300
Klamath Falls City	Klamath Falls, OR	6	218°F	1,000	14,000
Susanville, DOE	Susanville, CA	6	174°F	700	19,000
Susanville, HUD	Susanville, CA	5	155°F	300	10,000
San Bernardino Water District	San Bernardino, CA	6	138°F	3,700	35,000
Pagosa Springs	Pagosa Springs, CO	7	140°F	600	15,000
New Mexico State University	Las Cruces, NM	7	142°F	230	N/A
Boise City	Boise, ID	6	170°F	4,000	37,000
Boise Warm Springs Water District	Boise, ID	100+	176°F	1,600	11,300
Boise Capital Mall	Boise, ID	7	169°F	750	6,000
Elko County School District	Elko, NV	3	190°F	290	11,300
Elko Heat Company	Elko, NV	7	170°F	650	15,500
Warren Property	Reno, NV	7	210°F	710	26,500

**Source: Rafferty, 1989*

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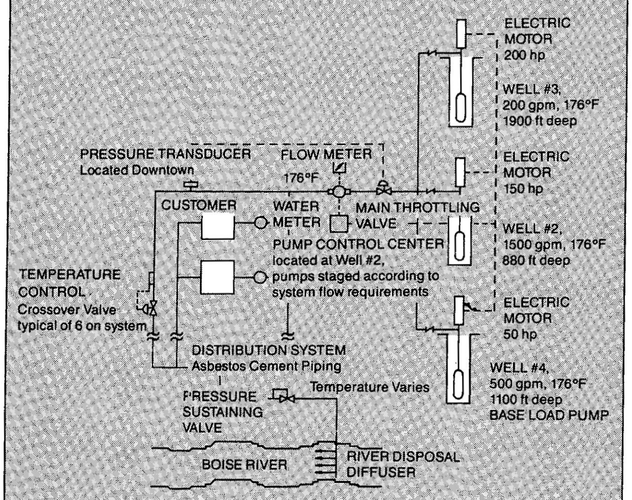

Figure 2. Open distribution GDH system.

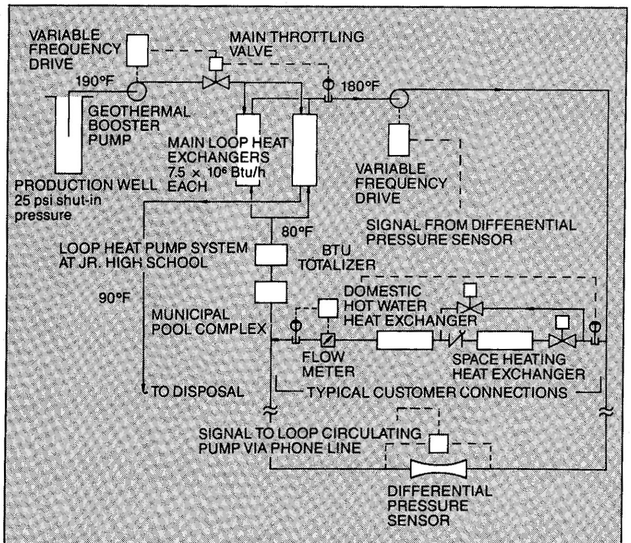

Figure 3. Closed distribution GDH system.

- Metering and
- Disposal.

With the exception of certain materials considerations, the areas of distribution, customer connections, metering and central plants in GDH systems are quite similar to their conventionally fueled counterparts. It is the production facilities and disposal subsystems that set geothermal district heating apart from district heating in general.

Materials selection is a major portion of the design of any GDH system. Because of their elevated temperatures, GDH fluids are able to maintain, in solution, various chemicals that can cause rapid failure of common construction materials. Chief among these chemicals are: hydrogen sulphide (copper and copper alloys), ammonia (copper and copper alloys), chlorides (stainless steels and ferrous alloys) and carbon dioxide (ferrous alloys). Details on materials selection and performance in GDH systems are contained in Knipe[7] and Rafferty.[4]

All operating systems tap low temperature resources (defined by the geothermal industry as less than 200 °F; 93 °C), and pumps are required to bring the water to the surface. Most systems employ lineshaft turbine pumps for this purpose. These pumps are similar to those used for irrigation.

Modifications for geothermal service generally include enclosed oil lubricated lineshaft and bearings, special alloy bearings in the pump section, stainless-steel fasteners and pump shafts. Depending on the application, lengthened impeller housings may be required to accommodate shaft expansion.

Electrical pumping costs for most systems are in the range of $0.10 to $0.35 per million Btu (0.034 to 0.12 cents/kWh).[8]

Capital costs for resource development (wells) are highly site-specific and influenced by local well depth requirements and drilling conditions. Well costs for some of the systems listed in *Table 1* range from $150 to $1,200 per gpm of capacity, with most around $500 per gpm.[6]

Disposal is one major issue that distinguishes GDH systems from their conventionally fueled counterparts. Because of their heat source, GDH systems are characterized by a large throughput of warm groundwater. Once the heat is extracted from the groundwater, it must be disposed of. In general, two methods are used for this: surface disposal and injection.

Surface disposal consists of discharging the water to some surface feature, such as rivers, lakes or percolation ponds. It is considerably less expensive than injection but, it can lead to problems if a large number of users on the same resource employ the method.

In two areas of the country where significant development has occurred (Boise, Idaho, and Klamath Falls, Oregon), extensive use of surface disposal has resulted in measurable declines in the geothermal aquifer. As a result of these events and in the interest of resource conservation, many jurisdictions now favor injection as the accepted disposal method. Both surface disposal and injection are regulated by EPA and state environmental agencies.

Injection is now practiced by 30% of the systems surveyed. Another 30% are in the construction or final planning stages of injection.[8] In all cases, those systems planning injection are doing so in reaction to aquifer declines, regulatory pressures or both.

The costs of injection wells are generally higher than for production wells on the same system. This arises from the increased geological and hydrological consulting services required. These services are typically employed in siting the well to help ensure that, once in operation, the injected fluid does not simply short-circuit to the production well.

In addition, drilling techniques for injection must be more precise to accurately identify the well's geology and to prevent damage to a potential receiving aquifer.

Future prospects for GDH

Geothermal seems to be the quiet renewable resource. One major impediment to its future development is simply a lack of awareness on the part of the public. A quote from the April 2, 1892, *Idaho Statesman* newspaper[2] is as true today as it was 100 years ago:

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It is probable that people do not fully realize the value of the hot water that flows in such abundance from the artesian wells. It is understood in a general way to be a nice idea to have houses heated by such an agency; but very few whose attention has not been called to the subject appreciate what the influence of this method of heating will be upon the future.

It remains true that the public is largely unaware of geothermal energy's contribution. Excluding heat pumps, there are approximately 300 sites in America where geothermal energy is currently used for such applications as district heating, absorption refrigeration, aquaculture, greenhouse heating, industrial processes, snow melting and enhanced oil recovery.

These projects currently supply 13.0 $\times 10^{12}$ Btu/yr (13.7 $\times 10^{12}$ kJ/yr).[9] In addition, geothermal electric power production now totals 2,912 MW in the United States.

Future prospects for developing GDH systems are quite encouraging. By nature, the operation of such systems displaces the use of conventional fuels and eliminates production of "greenhouse" gases such as carbon dioxide.

In addition, the geographical extent of geothermal resources is quite significant. One study identified a total of 373 western cities within 5 miles (8 km) of at least one hydrothermal site.[10] Research has recently begun to refine these data.

California currently leads the nation in developing new GDH systems. Using royalty funds from the operation of existing geothermal power plants, the state provides funding for feasibility studies and construction of new systems.

At present, the most likely areas for development are those states with known geothermal resources and a deregulated institutional setting for district heating development. This would include the states of Oregon, Washington and California.

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