SIGNIFICANT EVENTS IN THE DEVELOPMENT OF GEOTHERMAL DIRECT USE IN THE UNITED STATES

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INTRODUCTION

Since the founding of the Geo-Heat Center in 1975 a number of historic and significant geothermal direct utilization events have been described and documented in the Geo-Heat Center Bulletin and other references. These projects are listed chronologically below.

MILESTONES

10,000 Years Before Present - Use of hot springs throughout the U.S. by Indians as a place of refuge for rest and recuperation from warfare, old age and for cooking.

Hot springs were a revered and sacred place to the Indians. They believed this was the home of the Great Spirit. It was he who brought forth the rejuvenating warmth of mother earth. The vapors were his breath, breathing upon and warming the waters. This was neutral ground. Here a warrior, regardless of tribe or tongue, could lay aside his arms and bathe in peace.

Various deposits found at the hot springs were used by the Indians. At Hot Springs, Arkansas novaculite, a very hard, even textured flintstone, was mined and used for arrowpoints, spearheads, and tools. The hot water was used for cooking, and loosing the feathers and skin from game.

1500's to 1800's - White men learned of and used various warm springs throughout the U.S.

The westward migration of settlers brought them to the various hot springs of the Midwest and West. In most cases we do not know who first saw these misty locations of hot water, unchanged by centuries of Indian use. Folklore says that DeSoto visited Hot Springs Arkansas during his 1541 expedition. The early European visitors would stay at these springs for extended periods of time to rest, graze their stock, find food, and to recover salt from the ground.

Early scientists attributed the heat to slaked lime, electricity, volcanism, radioactivity, bending of the rocks, and buried molten rock. Some thought the water came from precipitation; others thought the water came from the interior of the earth.

Unfortunately, these early visitors as well as recent ones, have developed many of the springs so that pollution, depletion, and poor management often threaten what they wished to preserve.

1807 - Resort city of Hot Springs, Arkansas founded.

With the purchase of the Louisiana Territory by the US in 1803, exploration of the area accelerated. A government survey party visited the area in 1804, and the first residents arrived in 1807. Jean Emanuel Prudhomme, a prosperous Louisiana plantation owner, was the first European resident. He was led to the springs by Natchitoches Indians, who recommended that he bathe in the springs for his health. He was so delighted with the results that he stayed in the area. Crude canvas shacks and log cabins were the first bathing facilities. Excavations were made into rocks in which hot water flowed. By regulating the flow, the temperature was also regulated. The first bathhouse was opened by Asa Thompason in 1830, consisting of one wooden tub in which one could bathe three times for one dollar. By 1878 Hot Springs had a permanent population of more than 3,500 and visited by 50,000 annually. (Bedinger, 1974).

Figure 1. DeSoto's legendary visit in 1541 to the hot springs is depicted by this statue in the Fordyce Bathhouse. (Source: Bedinger, 1974)

1823 - Calistoga, California "aqua caliente" explored by Spanish.

In the early 1800s, the Spanish explorers visited the Calistoga area looking for a possible Mission site. Naturally, they referred to the site as "Aqua Caliente." These missionaries did not establish a mission here, but it is believed that they planted the first grape vines to be used for sacramental wines. The person who had the greatest influence on the geothermal development of the community was Samuel Brannan. He first saw the geothermal springs and marsh in 1852. He envisioned a resort and spa similar to Saratoga Hot

Springs of New York and the famous spas of Europe. The Name Calistoga resulted from Brannan's combination of California and Saratoga. Sam Brannan poured an estimated half a million dollars into his "resort", which included a Japanese tea garden, a mulberry orchard, a brandy distillery, the hotel, bathhouses and five-room cabins connected by wide circular avenues and an elaborate park, a reform school, a skating pavilion, a race track and stables.

In the summer of 1880, Robert Louis Stevenson and his bride moved to Calistoga for health reasons. In was during this time that he developed the story for the book, "The Silverado Squatters" and ideas for settings of "Treasure Island."

Around the turn of the century, over 30 resorts existed in the surrounding area. They were devoted to health and relaxation, much as they are today (Lund, 1976; GHC Bulletin Vol. 4, No. 3).

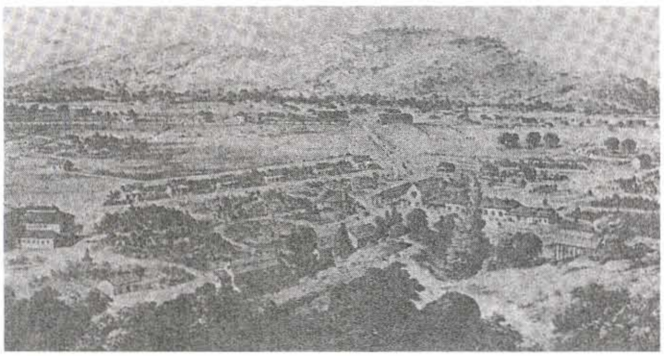

Figure 2. Calistoga as Stevenson saw it (1871).

1830 - Resort of Warm Springs, Georgia founded.

Warm Springs, Georgia is famous for studying and treating the after effects of poliomyelitis. It was used by President F. Roosevelt from 1927 when he founded the Georgia Warms Springs Foundation. President Roosevelt died there in 1945. The springs are 88°F.

1832 - Hot Springs, Arkansas set aside as a government reservation.

In this year, Congress took the unprecedented step of establishing public ownership by setting aside four sections of land as a reservation. Unfortunately, no one adequately identified the exact boundaries of this reservation, so the mid-19th century was filled with conflicting claims and counterclaims to the springs and surrounding land.

By 1870 a system evolved that reserved the springs for the Federal Government and sold the developed land to the persons who had settled it. At the same time the government agreed to collect the 143°F geothermal spring water into a central distribution system which, cooled and carried it to private property establishments where baths were offered to the public.

By 1877 all primitive soaking "pits" along hot Springs Creek were eliminated when the creek was confined to a concrete channel, roofed over, and then paved to create what is now Central Avenue. (Loam & Gersh, 1992).

1864 - Hot Lake Hotel, Oregon established.

A large two-story hotel was built near La Grande, Oregon in 1864. It was also used as a hospital and a conference center. Heat for the building is provided by a well. A large spring discharging 400 gpm at 176°F water is located in front of the building. Fish can be caught in adjacent cold water, dragged through the hot springs, and reeled in cooked and ready to eat.

1892 - District heating system implemented in Boise, Idaho.

The use of geothermal and other renewable energy technologies is considered to be a relatively recent practice. There are examples, however, of visionary individuals developing alternate energy systems years of even decades ahead of most of the HVAC community. Geothermal district heating is one example with the first system established in Boise, ID, in 1892. Such early use of this widespread resource is surprising. More impressive is the fact that this system is still in operation -- a century later. It's success has spawned the development of 17 other geothermal district systems throughout the western U.S. and dozens more internationally. Interestingly, the pioneer developers of the Boise Warm Springs Water District system encountered the same issues we address today in district systems: marketing, rate structure, metering and hardware problems. (Rafferty, 1992; GHC Bulletin Vol. 14, No. 2)

1900 - Big Springs in Klamath Falls, Oregon.

Much of the geothermal history of Klamath Falls, Oregon, centers around Big Springs, the present site of Modoc Field, an athletic field for Klamath Union High School. The Indians recognized the value of the hot water long before the early settlers made use of it. As reported in the Oregon Sunday Journal, January 8, 1939, Lizzie Schonchin, wife of Peter Schonchin, an Indian survivor of the Modoc war, told of one use of the water, "Long time back, Indian hunt rabbit, porcupine, geese, ducks," she said. "He tie on string, let down in hole. Pull 'em up, skin come off easy. He boil meat, cook fish that way too." They placed great value on the healing powers of the hot water, by bringing the aged and crippled from long distances to be cured of their ailments. After the Butler Natatorium was built on the field in 1928, the Indians would still come to soak in the tub baths.

In 1911, a new and "grand" structure was completed in Klamath Falls about a quarter of a mile southwest of Big Springs. This was the four-story brick White Pelican Hotel. According the Klamath County Museum Curator "The White Pelican was to be one of the most pretentious enterprises in this part of the country and one of the finest hostelries on the Pacific Coast". Big Springs contributed an important function to the hotel, in that it provided the heat for the building, and water for a tile-lined swimming pool in the basement. During the early morning hours of October 16, 1926, fire started in the hotel, and by evening all that was left was a pile of rubble and one standing wall.

In 1927, the property was sold for new construction and by 1930, Balsiger Motor Company was in operation. Today, over 66,000 square feet of building is heated by the same geothermal waters, running through the same pipeline that was constructed for the White Pelican Hotel.

At the same time Balsiger's was being constructed, construction was also started on Klamath Union High School. A 6 inch cast iron pipeline was run about 1,000 feet from the artesian well to the new building. Thus even today, Big Springs still serves Klamath Falls. Three wells, two production and one injection, are located in Modoc Field. As reported in the 1939 newspaper article, "... the scalding 'River Styx' which flows beneath" is still doing its good work. (Lund, 1978; GHC Bulletin Vol. 3, No. 3)

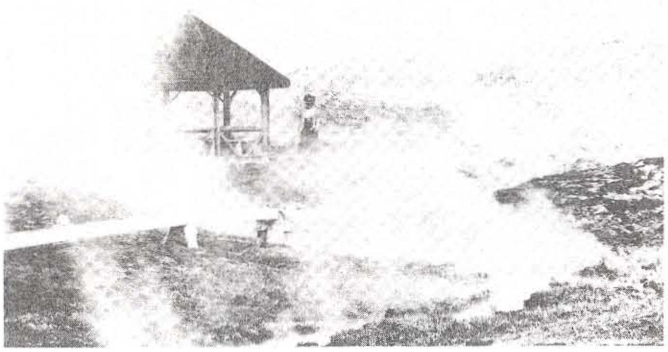

Figure 3. Big Springs, Klamath Falls, Oregon (source: Klamath County Museum)

1921 - Hot Springs National Park in Arkansas created.

In 1921 the Federal Reservation became Hot Springs National Park and the Park Service became the exclusive custodian of the springs and the contractual supplier of hot mineral water to the elaborate establishments on Bathhouse Row. The Park Service had the authority to approve rates, equipment, personnel and services related to the use of the water by the establishments.

Until 1949 each bathhouse needed to have its own evaporation tower in order to cool the incoming hot mineral water to usable temperature. In that year the Park Service installed air-cooled radiators and tap-water cooled heat exchanger to supply a centralized cooled water. As a result, consumers were provided water through two pipes; "hot" at 143°F and "cold" at 90°F.

During the last 40 years most of the historic buildings have been closed due to declining patronage. However, in recent years, resort hotels, motels and therapy centers in downtown Hot Springs have responded to increasing demands for thermal soaking, and some of the historic Bathhouse Row locations are being refurbished and reopened. Two of the hot springs in the park have been left uncovered, for visitor observation only. Users outside the park who receive geothermal waters via the distribution system, are under National Park regulation. (Loam and Gersh, 1992).

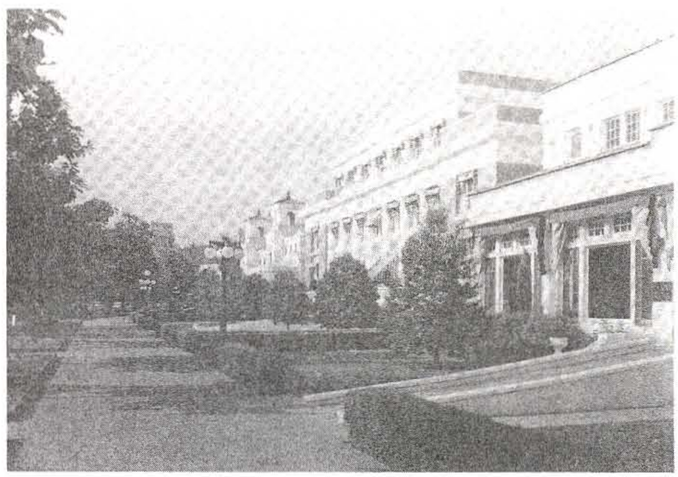

Figure 4. Hot Springs, Arkansas Bathhouse Row.

1930 - Edwards greenhouses in Boise are the first to use geothermal energy.

Edwards Greenhouses in Boise have the distinction of being the oldest commercially operated greenhouses in Idaho to heat with geothermal energy. The original alpine style greenhouse was built by Thomas F. Edwards in the 1930's and now a third Edwards generation is working in the greenhouses. Easter lilies, geraniums, bedding plants, poinsettia and over 150 perennial are grown in approximately 20,000 square feet of greenhouses under glass. An additional 30,000 square feet of space, including greenhouses, store and outbuildings, are covered by plastic.

A 1200 ft well, drilled in 1926, supplies 118°F water to heat the glass greenhouse, then the plastic covered buildings. (Street, 1985; GHC Bulletin Vol. 9, No. 2)

1930 - First downhole heat exchanger (DHE) used for home heating in Klamath Falls, Oregon.

The first use of a downhole heat exchanger (DHE) in Klamath Falls was for a geothermal home (519 Pacific Terrace) heating system, designed by Charlie Leib some 63 years ago. The design was created for a friend who had a well but didn't know how to use it for heating his home. The DHE lasted 25 years and "would probably have lasted another 20 years", boasts Charlie, but unfortunately, the well caved in first. Early wells were cased about 15 to 30 ft or just enough to prevent the top soil from falling in. As a result, many wells collapsed prematurely. Charlie was instrumental in getting well owners to fully case their wells. In 1945, the first perforations were installed in a well under Charlie's supervision to promote circulation in the undersized casing in a borehole. The circulation is down the center of the casing exiting through lower perforations, mixing with the hot aquifer water, then up the annulus and through the upper perforations to complete the circuit. When that worked, the idea became increasingly popular. Today there are over 500 DHE systems in use, the largest (1.2 MW_t) provides heat to 92,000 square ft Ponderosa Junior High School. (Fornes, 1981, GHC Bulletin Vol. 6, No. 1)

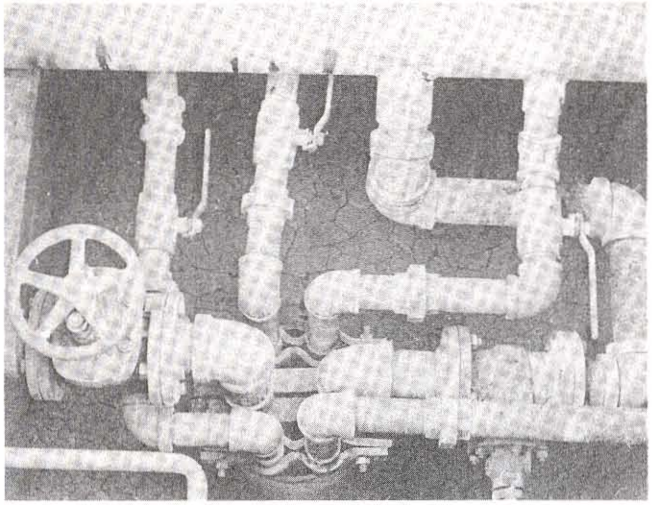

Figure 5. Ponderosa Jr. High School DHE.

1940s - Residential space heating at Moana area, Reno, Nevada.

In the Moana areas of Reno, there are approximately 300 DHE wells serving mostly single-family residences, and a few churches and small apartment houses. Use is steadily increasing with 2 to 3 new wells drilled per month over at least the last seven years. (Culver, 1990)

1945 - First geothermal milk pasteurizing at Klamath Falls, Oregon.

Geothermal hot water has been used to pasteurize milk at Lost River Dairy (later Medo-Bel Creamery) in Klamath Falls. Geothermal fluids were also used to heat the 30,000 square foot building, which amounted to a substantial savings during the winter months. The pasteurization process involved pumping up to 50 gpm at 189°F to the plate heat exchanger. The milk was heated to a minimum temperature of 171°F for 15 seconds and then quickly chilled to 38°F to retain its flavor. Milk was processed at a rate of 600 gallons per hour, and a total of 500,000 pounds were processed each month. The dairy closed in 1983. (Lund, 1976; GHC Bulletin Vol. 2, No. 2)

1947 - First large tonnage groundwater heat pump system in Portland, Oregon.

The large tonnage groundwater heat pump system was pioneered in the U.S. primarily by J.D. Kroeker, an engineer

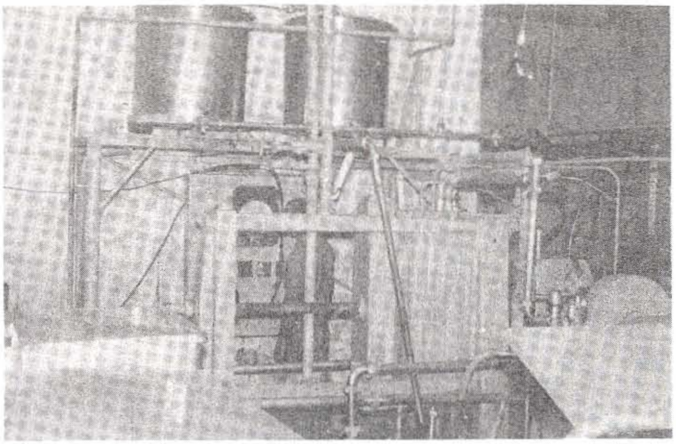

Figure 6. Plate heat exchanger used for milk pasteurization.

in Portland, Oregon in 1947. The best known of these is the Commonwealth Building (formerly known as the Equitable Building) in downtown Portland. This building is designated a National Engineering Landmark.

After a year of operation it became clear that a severe corrosion problem was occurring as a result of the direct use of the groundwater in the piping system. This problem was initially addressed through the use of various treatment chemicals with only limited success. In the late 1950's, a decision was made to employ isolation heat exchangers. (Rafferty, 1988; Vol. 11, No. 1)

1948 - First residential ground source heat pump (GSHP).

Carl Nielsen, a professor at Ohio State University, has one of the oldest continuously operating ground source heat pumps on record. Since no commercial units were available in 1948, Nielsen devised his own one-ton unit, using standard refrigeration plant parts, except for the heat exchanger. "For that, I took two lengths of pipe-a one-inch o.d. piece and a 5/8-inch o.d. piece-pushed one inside the other, then coiled them up. Worked fine."

The water source temperature was 44°F, from a 80 ft well in the backyard, with the outflow to a pond alongside the house. The annual heating/cooling costs were about 25% less than an air-source heat pump in 1978 when electricity cost $0.03/kWh. (Gannon, 1978)

1948 - First highway deicing project constructed in Klamath Falls, Oregon.

A major truck route leading from the Klamath Falls urban area has a steep grade approaching a traffic light heated by geothermal water. Since the approach and stop at the intersection causes difficulty with traffic stopped on an eight percent adverse grade, geothermal deicing was incorporated in the design as an experiment in 1948. It was estimated that the pavement would be sufficiently clear of snow and ice to provide free travel at a temperature of -10°F, and under conditions of a 3 in. per hour snow fall. A 419 ft deep well was drilled at the bottom of the hill, near the original natural artesian hot water "Big Springs". A downhole heat exchanger, closed loop, was placed into the well consisting of two 2 in. diameter black iron pipes in parallel to the heating grid. Each grid system consists of ten loops of 3/4 in. diameter steel pipe placed 3 in. below the pavement surface on 18 in. center-to-center spacing. The temperature drop in the grids is approximately 30 to 35°F, which is estimated to supply 3.5 X 10^5 Btu/hr to the grid. A separate pump (added several years later) discharged approximately 10 gpm to the storm sewer for increased heat flow. (Lund, 1976; GHC Bulletin Vol. 1, No. 2)

In 1992, the well was deepened to 975 ft with a bottom hole temperature of 162°F, perforated at 400 and 975 ft, and installed with a DHE for the purpose of eliminating the pumping to the storm sewer.

Figure 7. State highway snow melt system heated by a downhole heat exchanger (DHE).

1960s - Thermal Enhanced Oil Recovery (TEOR) using geothermal fluids.

The basic principle of the TEOR method is that the lower the viscosity of the oil the better it flows into the producing well; and, by increasing the temperature of the oil reservoirs, the viscosity of the oil and the residual oil saturation can be lowered. Hot water flooding consists of continuously injecting hot water into a central well to reduce the oil viscosity and drive the oil, gases, and water to surrounding production wells. Hot water TEOR projects using thermal fluid supplies from the Madison and others formations have been successful in North Dakota, Montana, and Wyoming. In most cases thermal water from the oil reservoirs are used for TEOR (Jane Negus-de Wys, private communication). Currently, North Dakota actually reports the greatest occurrence of the use of hot reservoir waters. The oil gravities are relatively high (30 to 35°API). Temperatures range from 230°F at the Medora Field, to 240°F at the Fryburg Field. Flow rates are from 450 to 10,000 bpd. A 10 to 15% increase in overall production is attributed to using this method. Produced water is approximately two to one over production, perhaps 200,000 bpd over the entire state. (Negus-de Wys, 1991)

1970 - Geothermal Steam Act (Public Law 91-58) passed and signed by President Richard Nixon on Christmas Eve. Known Geothermal Resource Area (KGRA) defined.

1973 - Fish Breeders of Idaho started raising channel catfish at Buhl, Idaho with geothermal water.

Fish Breeders of Idaho, Inc. have been raising channel catfish in high density concrete raceways for 19 years. The geothermal water (90°F) is supplied by artesian wells with a total flow of 6,000 gpm. Cold water from springs and streams is used to cool the hot water to 80 to 85°F, the ideal production temperature.

The fish farm is located on a hill. Approximately 80 ft of elevation is used in the farm. This is very important in aerating and reusing water. The production facilities are concrete raceways, 24 ft by 10 ft and 4 ft deep. The raceways are arranged four in a series with a 2 ft drop between each section. The water passes through four sets of raceways, each raceway having four sections (16 section total), from the top to bottom of the hill. The upper end of the farm is used for catfish production and the lower end for Tilapia production.

The quality of channel catfish produced in the clean water is far superior to any other catfish on the market. A fish is like a sponge; it tastes like the water in which it is raised. The geothermal water produces a quality that has allowed Fish Breeders to introduce catfish into the gourmet markets and obtain high prices for catfish. (Ray, 1979)

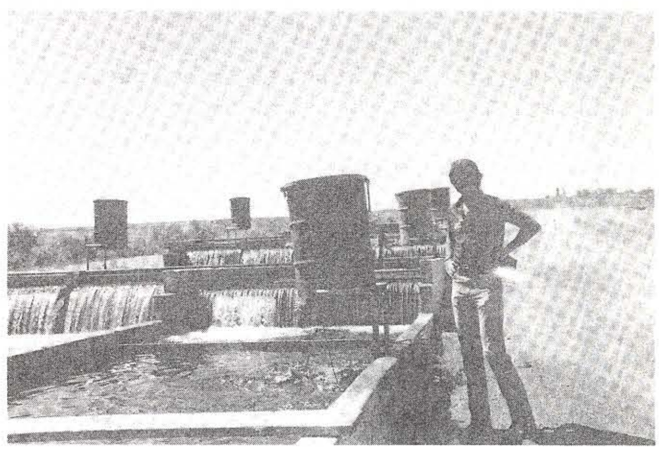

Figure 8. Fish Breeders of Idaho, Inc. on the Snake River Canyon.

1974 - First symposium on Direct Utilization of Geothermal Energy held on the Oregon Institute of Technology campus.

The conference, "International Conference on Geothermal Energy for Industrial, Agricultural and Commercial-Residential Uses" was held at Oregon Institute of Technology October 7-9, 1974. It was organized to review the direct use of geothermal energy in Hungary, Iceland, New Zealand, the United States and the USSR. The program chairman, Mr. R. G. Bowen called upon experts in the field to present papers based on experience gained from actual working installations rather than on theoretical models. Field trips were taken through the City of Klamath Falls where over 400 geothermal wells, at that time, were used for space heating and a few industrial applications. (Lienau, 1974)

Figure 9. Conference speakers.

1975 - Geo-Heat Center started at Oregon Institute of Technology.

As a result of the conference in 1974 and the increased interest in direct heat applications of geothermal energy, the Geo-Heat Utilization Center (later the name was changed to Geo-Heat Center) was established on the campus. Funding for the establishment of the Center was approved by the Pacific Northwest Regional Commission of Vancouver, Washington. The Center's objective was to disseminate information to potential users and conduct applied research on using low-to moderate-temperature geothermal resources. A quarterly Bulletin on the progress and development of geothermal energy is published. Since 1978, the Geo-Heat Center has been supported by DOE. (Lienau, 1975; Vol. 1, No. 1)

1975 - USGS released first national geothermal resource estimate and inventory.

1977 - Honey Lake Farms hydroponic greenhouse project started.

The Geoproducts Corp. Honey Lake Farms project near Wendel, California consisted of 30 units of geothermal hydroponic greenhouses to produce European cucumbers and tomatoes. Hydroponics is the growing of plants in nutrient solutions with or without an inert medium to provide support to the plants and their root systems. Each greenhouse at Honey Lake was 30 ft x 124 ft of quonset design covered with a double poly layer of film separated by an air space.

An old Magma Power Company well, drilled in the early sixties to depth of 627 ft, was used as the source of heating. Surface temperature of the thermal water produced by a submersible pump was 206°F with a capacity of 300 gpm. The heat removed from the geothermal fluids was distributed through a series of poly convection tubes, a main 24 in. heating tube attached to the heater and five smaller 9 in. tubes positioned between rows of plants at plant level.

Cucumber production in 20 houses averaged approximately 1,500 lbs. per unit per week and tomatoes produce an average of 850 lbs. per unit per week. The Honey Lake greenhouses stopped operating in about 1985. (Boren, 1978; GHC Bulletin Vol. 4, No.1)

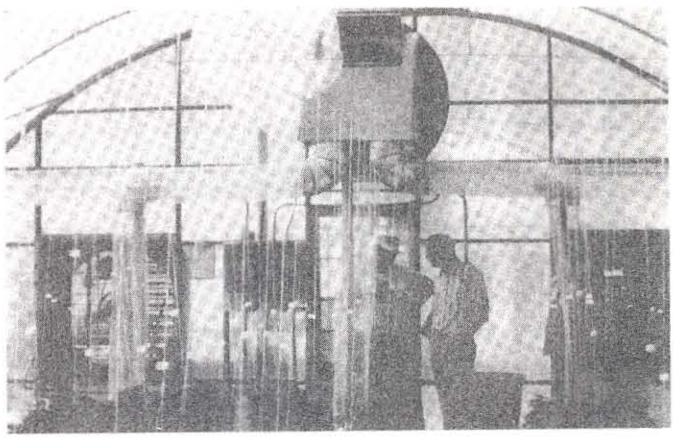

Figure 10. Hydroponic greenhouses at Honey Lake.

1978 - First geothermal food processing (mainly onion dehydration) at Brady Hot Springs, Nevada.

In 1978, Geothermal Food Processors, Inc., of Reno, Nevada, started construction of a geothermal food dehydration plant. Funding for the plant was made available in part by means of a $3.5 million provision of the Geothermal Loan Guarantee Program.

A well located 1,300 ft from the plant supplies about 270°F fluid at a rate of 750 gpm under 190 psig pressure to the plant. The system is pressurized to almost three times the vapor pressure to make sure that the geothermal fluid is always in its liquid state. Operating the plant at elevated pressure prevents serious formation of scale inside the hot water coils and pipeline. An insulated pipeline supplies the super heated geothermal water used to heat air circulated through a large Proctor & Schwartz model SCF 3-stage dehydrator.

The plant can process 10,000 lbs. of wet onions per hour producing 1,500 to 1,800 lbs. of dry product. The geothermal energy replaces about 116 million ft^3 of natural gas annually. Apparently, because there are no products of combustion in the air stream resulting in no contamination or discoloration of the product; thus, a superior product can be produced using geothermal energy. (Lund, 1982; GHC Bulletin Vol. 7, No. 2)

1979 - USGS release updated national geothermal resource estimates and inventory showing a potential 233,023 quads of energy.

1979 - DOE starts funding of direct-use demonstration projects.

The U.S. Department of Energy (DOE), Division of Geothermal Technology, as part of the national geothermal program plan, which had the goal of encouraging the private and municipal development of geothermal resources for direct use, issued two solicitations requesting proposals to cost-share field experiment projects. The Program Opportunity Notices (PON) enabled the government to cost-share a significant portion of the high front-end financial risk with private and municipal developers in a variety of applications. Twenty-two projects resulted and were started in 1979. Sixteen of these projects became operational, six for institutional building heating, six for district heating, and four agribusiness, the remainder were discontinued for a variety of reasons. (Lienau, 1991)

Figure 11. PON projects location map.

1980 - TAD's Enterprises first to use geothermal energy for alcohol fuels plant.

TAD's Enterprises, Inc. ethanol plant of Wabuska, Nevada utilized geothermal energy in the cooking, distilling, and drying processes associated with alcohol fuels production. The plant had a capacity of 400,000 gal per year or 50 gallon per hour and operated 24 hours per day seven days per week. Corn was the main feedstock, however both molasses and Jerusalem artichokes were tried. The production rate was 2.5 gallon of ethanol and 15 lbs of distillers dried grain per bushel of corn. The distillers dried grain was sold as a by-product. The corn was delivered to the plant for $3.60 per bushel and the ethanol sold for $1.60 per gallon and the by-product sold for $140 per ton.

The geothermal fluid came from a well drilled by Magma Power as an exploratory well in the 1960s and provided 220°F at approximately 400 gpm. At the time, Alexander Dawson, Inc. raised catfish and Malaysian prawns in aquaculture ponds adjacent to the ethanol plant. (Fornes,1982; Vol. 7, No.2)

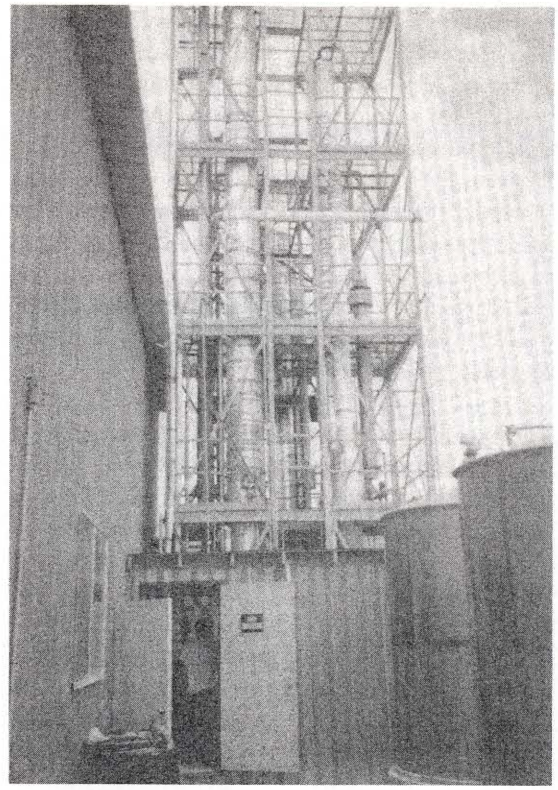

Figure 12. TAD's Enterprises, Inc. alcohol fuels plant.

1980 - First geothermal absorption chiller went into use at Oregon Institute of Technology, Klamath Falls, Oregon.

During the summer of 1980, OIT installed a 154-ton absorption chiller for air-conditioning five campus buildings (277,300 ft^2). The chiller operates on the simple principle that under low absolute pressure (vacuum), water takes up heat and boils at a low temperature. Heat supplied in the generator section is added to a solution of Li Br/H_20. This heat causes the refrigerant, in this case water, to be boiled out of the solution in a distillation process. The water vapor that results passes into the condenser section where a cooling medium is used to condense the vapor back to a liquid state. The water then flows down to the evaporator section where it passes over tubes containing the fluid to be cooled. By maintaining a very low pressure in the absorber-evaporator shell, the water boils at a very low temperature. This boiling causes the water to absorb heat from the medium to be cooled, thus, lowering its temperature. Evaporated water then passes into the absorber section where it is mixed with a Li Br/H_20 solution that is very low in water content. This strong solution (strong in Li Br) tends to absorb the vapor from the evaporator section to form a weaker solution. This is the absorption process that gives the cycle its name. The weak solution is then pumped to the generator section to repeat the cycle.(Rafferty, 1983; GHC Bulletin Vol. 8, No. 1)

1982 - USGS completed the first quantitative national assessment of low-temperature (<90°C) geothermal resources of the United States.

1984 - Oregon Trails Mushroom project started at Vale, Oregon.

In 1984, the Oregon Trail Mushroom Company of Vale, Oregon secured a $6.5 million loan, guaranteed by DOE, for construction of a semi-automated mushroom growing plant using geothermal energy for heating and cooling. The geothermal well produces 235°F thermal fluids. A computer controls even the carbon dioxide levels in the plant's 40 growing rooms. Temperatures vary from 64 to 140°F in the growing rooms, depending on the stage of the process. The mushrooms are grown in eight-week "batches", with the crop from five of the growing rooms harvested each week. The plant produces 5 million pounds of the edible fungi annually. (GHC Bulletin Vol. 10, No. 1)

1987 - First geothermal enhanced heap leaching project for gold recovery in U.S. near Round Mountain, Nevada.

Round Mountain Gold in 1990 mined 40,000 tons of ore per day. Estimated gold reserves are 42 million tons of Type I ore at a grade of 0.043 oz/ton and 111 million tons of Type II ore at 0.038 oz/ton. In 1989, 286,200 ounces of gold were produced.

Geothermal fluids are produced from two shallow wells (approximately 1000 ft depth) which produce fluid at a temperature of 180°F and an average flow rate of 1100 gpm. Heat from the geothermal fluids is transferred to the cyanide leach solution via a counter flow plate heat exchanger. Geothermal fluids enter the heat exchanger at 180°F and exit at 80°F and are injected into a 1,055 ft well located 4,000 ft north-northwest of the production wells. Geothermal fluids are also used for processing ore at the Florida Canyon Mine located in the Ryepatch KGRA. (Trexler, 1990; GHC Bulletin Vol. 12, No. 4)

1989 - Geothermal Direct Use Engineering and Design Guidebook published.

The first edition of the "Geothermal Direct Use Engineering and Design Guidebook" was designed to be a comprehensive, thoroughly practical reference guide for engineers and designers of direct heat projects. The authors intent was that the Guidebook would be useful to a wide circle of persons interested in topics ranging from: geology, exploration, well drilling, reservoir engineering, mechanical engineering, engineering cost analysis to regulatory codes, and environmental aspects. Special attention was paid to unification of expert knowledge drawn from years of experience in order to ensure an integrated view of direct uses of geothermal energy. Since the Guidebook was first issued in 1989, a second edition was published in 1991. (Lienau, 1989; Vol. 11, No. 3)

1992 - DOE geothermal low-temperature reservoir assessment and heat pump evaluation program.

In Fiscal Year 1991, Congress appropriated money for the Department of Energy to begin a new program in the evaluation and use of low-to moderate-temperature geothermal resources. The program will consist of several components, including: (1) an update and compilation of all available information on resource location and characteristics, with emphasis on resources located within 5 miles of population centers; (2) development and testing of techniques to discover and evaluate these resources; (3) technical assistance to potential developers; and (4) evaluation of the use of geothermal heat pumps in domestic and commercial applications. Program participants include the University of Utah Research Institute, Idaho Water Resources Research Institute, the Geo-Heat Center and eight agencies of state governments in western states. (Wright, 1992; GHC Bulletin Vol. 14, No. 2)

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