Examples of industrial uses of geothermal energy in theUnited States

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Abstract

Industrial uses of geothermal energy in the United States have included both industrial applications and agricultural drying. A zinc extraction plant has been completed in the Imperial Valley of California, which uses electricity from geothermal power plants for the recovery of the metal from geothermal brines. The plant will eventually extract 30,000 tonnes of zinc annually from the wastewater from ten power plants. Two large gold and silver ore heap-leaching projects are located in Nevada with an installed capacity of 15 MWt and use 250 TJ (69 GWh) annually. They are able to increase the extraction of ore by 17% and extend their operating season into the colder months, compared to conventional means. At present, these extraction operations have been suspended due to the low price of gold and silver, and in part due to the cost of Federal royalties for energy from wells on public lands. Geothermal milk pasteurization was in operation in Oregon for over 50 years, processing 225,000 kg of milk each month with 87°C fluid. Wastewater sludge digestion is assisted with geothermal heat in the city of San Bernardino, California using 58°C fluid transferring 6.4 GJ/hr through spiral plate heat exchangers to the sludge in four tanks. The agricultural drying operations consist of two large onion and garlic dehydration plants, also located in Nevada. They can process up to 280 tonnes of raw product per day producing almost 60 tonnes of dried product at 5% moisture. Other smaller uses, include a mushroom growing operation in Oregon, mineral water processing in California, an industrial park in Hawaii, and laundries in Oregon, Nevada, California and Montana.

Keywords: *zinc extraction, heap leaching, milk pasteurization, sludge digestion, agricultural drying.*

1 Introduction

Industrial applications and agricultural drying uses of geothermal energy are few in number in the United States. Several large operations dominate the scene, followed by a few minor projects. Some of these applications were initially reported in a paper presented in Iceland in 1992 at the meeting on “Industrial Uses of Geothermal Energy” by Gene Culver of the Geo-Heat Center (Culver, 1992). Since that time several operations have been suspended (heat leaching in Nevada) and a large one started (zinc extraction in California). This paper presents selected current industrial uses and also discusses those, which are of interest from the past. The present total installed capacity is about 70 MWt and the annual energy use about 1,500 TJ (415 GWh), the majority of which is due to the zinc extraction operation.

2 Industrial operations

2.1 Zinc extraction

The main industrial operation using geothermal energy in the United States is the CalEnergy Operating Corporation $200 million Mineral Recovery Project on the shores of the Salton Sea in southern California's Imperial Valley (Clutter, 2000). CalEnergy currently operates ten geothermal power plants with a capacity of 347 net MWe at the Salton Sea. Unit 5, the most recent unit, a 49-MWe facility that uses high-temperature waste brine from four of the existing plants, was constructed to fuel the minerals recovery project and produce electricity. The mineral recovery project will produce 30,000 tonnes of 99.99-percent pure zinc annually for Cominco Ltd. The facility, constructed in 1999 and placed in operation in late 2002 (Figure 1), will be the lowest cost producer of zinc in the world, and the first and only operation specifically designed to harvest mineral from high-temperature geothermal brine in the United States. Prior to the construction of the zinc extraction facility, the spent brine from eight geothermal power plants was being injected at 182°C, thus in an effort to capture more energy from the resource, a 49-MWe Unit 5 (triple flash) was constructed and brought on-line in conjunction with the zinc recovery facility. Unit 5 uses the spent brine from four other plants to produce electricity for the minerals recover operation, tapping about 20 MWe of the power plant's production (which is about 30 MWt of heat energy input assuming a 67% conversion factor). This also reduces the brine temperature to 116°C, which is the desired temperature for the zinc extraction process. It is estimated that 1,200 TJ of energy is used annually in this process, which includes the electrical energy thermal equivalent input along with some process steam provided to the plant.

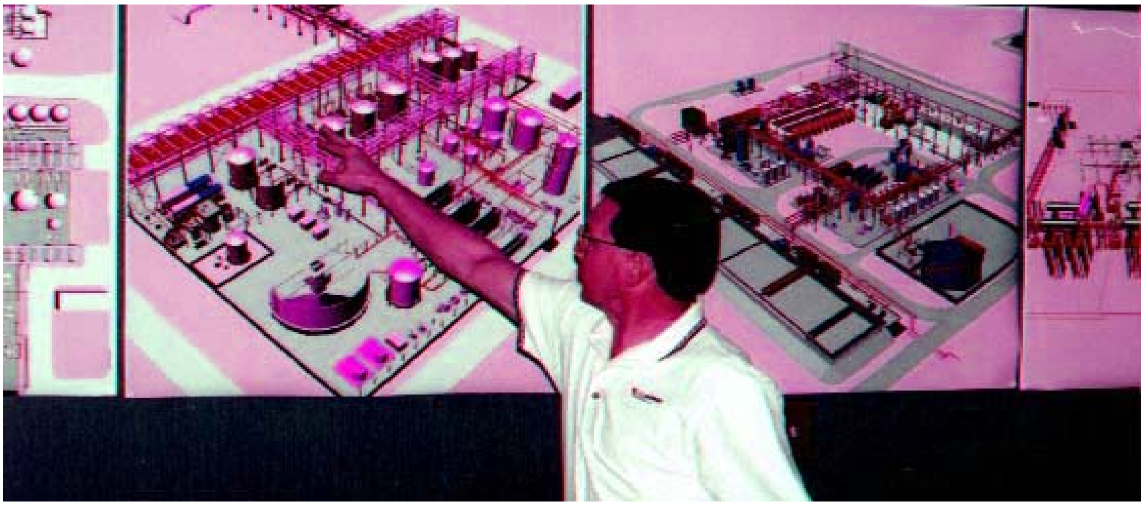

Figure 1: CalEnergy engineer pointing out the minerals recovery facility, with the ion exchange and solvent extraction plant on the right and the electrowinning facility on the left (Clutter, 2000).

The mineral recovery facility uses existing technology of ion exchange, but also employs solvent extraction and "electrowinning" to extract zinc from the spent brine. The brine at over 9,000 tonnes per hour, comes from all the power plants, and after the metal is extracted, the remaining brine is injected back into the geothermal reservoir. The process, as described by CalEnergy personnel is summarized as follows (Clutter, 2000). The brine first passes through an ion exchange resin similar to that used in water softening equipment - but modified with organic molecules that are very specific to zinc in the right conditions. After being pumped to a second facility, a solvent extraction process then transforms resultant zinc chloride into zinc sulfate, which is passed across electrowinning cells that separate sulfate molecules from zinc atoms. The result is nearly pure zinc deposited on large cathodes. The metals build up to more than six mm in thickness on the cathode in 24 hours when it is removed. The metal is then melted into approximately one tonne ingots for sale to Comico.

The brine contains 550 to 600 mg/L of zinc, and thus the project is estimated to recover 30,000 tonnes of zinc per year. In addition to zinc, CalEnergy is also investigating extracting high-grade silica and manganese in the future. The plant is presently only operating at 40 percent of capacity.

2.2 Heap leaching

Heap leaching for gold recovery is a simple process that eliminates many of the complicated steps required in conventional milling (Texler et al., 1990). The process consists of placing the crushed ore on an impervious pad and then sprinkling or dripping a dilute sodium cyanide solution over the heap. The solution trickles through the material, dissolving the gold in the rock. The pregnant (gold) solution drains from the heap and is collected in a large plastic-lined pond. The pregnant solution is then pumped through tanks containing activated charcoal, absorbing the gold. The gold bearing charcoal is chemically treated to release the gold, and the gold bearing strip solution is treated at the process plant to produce a doré, or bar of impure gold. The doré is then sold or shipped to a smelter for refining. The barren cyanide solution is then pumped to a holding basin, where lime and cyanide are added to repeat the leaching process. A similar process is followed for extracting silver from the crushed ore.

Cyanide leaching can recover over 95 percent of the gold ore. Using geothermal energy increases the gold recovery, as the heat allows year-round operation, and the gold and silver recovery can be enhanced by five to 17 percent by accelerating the chemical reaction. This year-round operation is important in Nevada, as winter weather allows under normal circumstances only mid-March through late October operation using a minimum outside production temperature of 4°C. The additional benefits are increased revenue to the mine operator, year-round employment for the labor force, and increased royalty payments for mineral leases to both federal and state governments.

Two mines in Nevada have used geothermal fluids in their heap leaching operations to extract gold and silver from crushed ore: Round Mountain Gold and the Florida Canyon Mine, located in the north-central part of the state.

Round Mountain mines an estimated 95,000 tonnes of ore per day containing approximately one gram/tonne of gold, and in 2001 extracted over 21,000 kg of gold. The mine used geothermal fluids from two shallow wells at 82°C and 69 l/s. Heat from the geothermal fluid is transferred to the cyanide leach solution through a plate heat exchanger (Figure 2). The average monthly heat production during the months of operation was approximately 42 TJ and the annual use was estimated at 208 TJ with an installed capacity of 14.1 MWt (Lund et al., 1985). At the Florida Canyon Mine, almost 13,000 tonnes of ore were produced daily (1990). The average gold content is about 0.7 g/tonne, and they produce almost ten kg of gold per day. The geothermal fluid is produced at 99°C and 23 l/s, and piped through a shell-and-tube heat exchanger where heat is transferred to the cyanide solution. It is estimated that 42 TJ of energy was used annually from the geothermal fluid with an installed capacity of 1.4 MWt (Lund et al., 1985). The University of Nevada carried out experimental work from 1988 to 1991 using geothermal energy with positive results (Trexler et al., 1991). Unfortunately, these two mines are presently shut down due to low prices for gold and silver, high operating costs, and the federal royalty charge for the use of the geothermal energy produced from wells on Bureau of Land Management land. The royalty cost is ten percent of the equivalent avoided competing fuel cost.

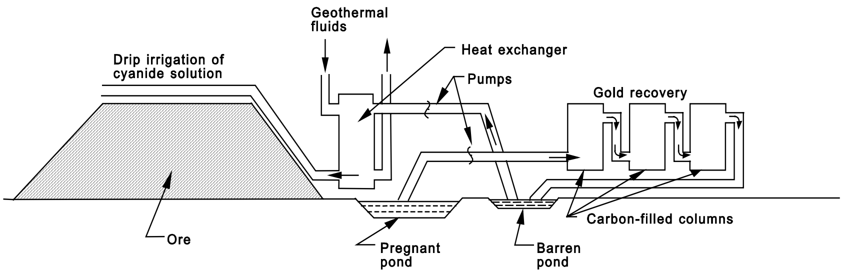

Figure 2: Idealized thermally enhanced heap leaching system (Trexler, et al., 1991).

2.3 Milk pasteurization

Medo-Bel Creamery, in Klamath Falls, Oregon used geothermal heat in its milk pasteurization process for about 50 years (Lund, 1997). A 233-m deep well provided 6.3 L/s of 87°C geothermal fluid to a three-section plate heat exchanger. The incoming cold milk at 3°C was preheated by milking coming from the homogenizer in one section of the heat exchanger. The milk was then passed to the second section of the heat exchanger where the geothermal fluid heated the milk to a minimum temperature of 78°C for 15 seconds in the short-time pasteurizer. If the milk temperature dropped below 74°C, the short-time pasteurizer automatically recirculated the milk until the required exposure was obtained. Once the milk was properly pasteurized, it was passed through the homogenizer and then pumped back through the other side of the first section of the heat exchanger where it was cooled to 12°C by the incoming cold milk. It was finally chilled back to 3°C by cold water in the third section of the plate heat exchanger, where the milk went into cartons (Figure 3). Milk was processed at a rate of 0.84 L/s, and a total of 225,000 kg were processed each month. Some steam was necessary in the process to operate equipment; thus,

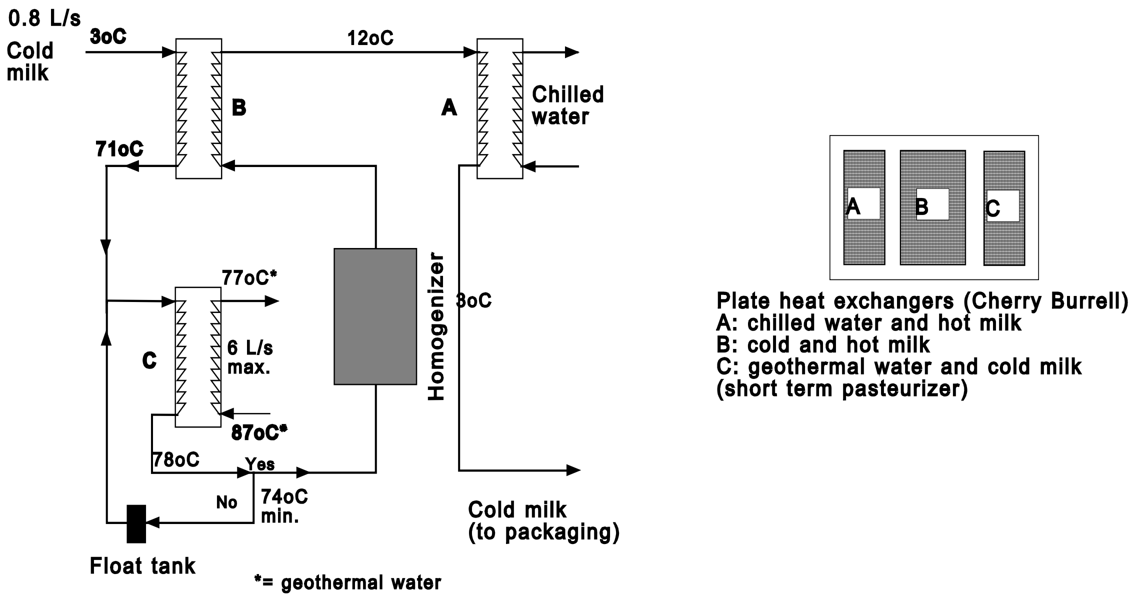

Figure 3: Medo-Bel milk pasteurization flow diagram (Lund, 1997).

geothermal water was heated by natural gas to obtain the required temperature. Geothermal hot water was also used for other types of cleaning, and for batch pasteurizing of ice cream. The heat was used to pasteurize the ice cream mix at 63°C for 30 minutes.

The annual operational cost of the system was negligible; just for a 5 kW pump costing $120 per month. Pipe corrosion from the 800 mg/l sulfate-sodium water was the only maintenance problem. However, the savings amounted to approximately US$1,000 per month as compared to conventional energy costs. Geothermal hot water was also used to heat the 2,800 m^3 buildings, which amounted to a substantial savings during the winter months. The estimated peak energy use was 1.0 GJ/hr (0.3 MWt) and the annual use was about 1.0 TJ.Sludge digestion

The City of San Bernardino, California installed a primary anaerobic sewerage digester in 1983 (San Bernardino Municipal Water District, undated). The process uses 58°C geothermal fluid that replaced methane that was burned to fuel the digester (Figure 4). At the time of the implementation of the geothermal conversion, the city wastewater treatment plant was processing an average of 80,000 m^3 per day of domestic and industrial wastewater. The process includes primary and secondary treatment of all wastewater, and tertiary treatment of 11,000 m^3 per day, which is reclaimed for process, washdown and irrigation purposes. The sludges and other solids collected throughout the treatment process are pumped from their various collection points to the thickeners, where they are concentrated through settling. This thickened sludge is then pumped to the digesters. Digestion is a biological process that uses living anaerobic (absence of free oxygen) microorganisms to feed on the organics. The process is aided by heating and mixing to break down the organic material into a digested sludge and methane gas. The methane gas is collected and used for fuel in various in-plant engines which drive pumps and compressors, while the well digested sludge is dried (Racine, et al., 1981).

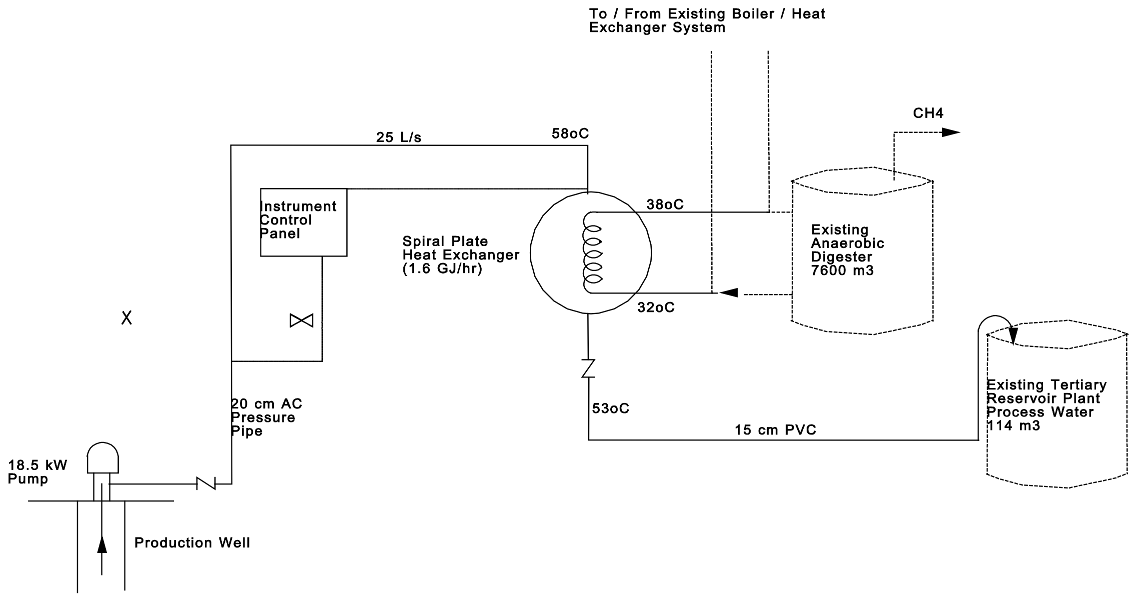

Figure 4: Diagram of geothermal heating of the anaerobic disgester (Racine et al., 1981).

The geothermal design required an 18.5 m^2 spiral plate heat exchanger designed to transfer 1.6 GJ/h of heat to the digester sludge in a tank 7,600 m^3 in volume. The total quantity of dissolved solids is 290 mg/l in the geothermal water, which is of better quality than the treated water from the boiler system. The geothermal water, at maximum flow of 25 l/s, enters the heat exchanger at 58°C and exits at 53°C. The annual cost saving (1983) for the single digester was estimated at almost US$30,000. The system has since been expanded to four digesters, with geothermal providing 6.4 GJ/h (1.8 MWt) of heat and an estimated annual load of 53 TJ. The resulting payback of investment is less than 10 years (San Bernardino Municipal Water District, undated). The city also has a geothermal district heating system that serves 14 major buildings for an installed capacity of 13 MWt.

3 Agricultural drying

Two large geothermal onion and garlic dehydrators are located in Nevada, in the northwestern part of the state: Integrated Ingredients near Empire and at Brady's Hot Springs. These two large units can process almost 12 tonnes of wet onions per hour and use 35 MJ of geothermal energy per kg of dry product to dry it from about 80 percent to 5 percent moisture content (Lund and Lienau, 1994). The daily use of energy for both facilities is about 1.37 TJ and the annual use, based on a 150 day working season, is about 208 TJ/year.

Onion and garlic dehydration at these Nevada locations involves the use of a continuous operation, belt conveyor using fairly low-temperature hot air from 40 to 105°C (Lund and Lienau, 1994a). A typical processing plant will handle 4,500 kg of raw product per hour (single line), reducing the moisture from around 80 percent to 5 percent in about six hours. The continuous belt drier, is a single-line unit 65 m long and 3.8 m wide, requiring 2,450 m^3 of air per minute and up to 42 GJ per hour. Due to the moisture removal, the air can in some cases only be used once, and thus is exhausted. Special silica gel – Bryair, desiccation units are usually required in the final stage. The drier normally consists of four sections, A through D, with each one requiring lower temperature air (96 to 74°C), but with increasing depth of product (from 5 cm to 2 m) (Figure 5)

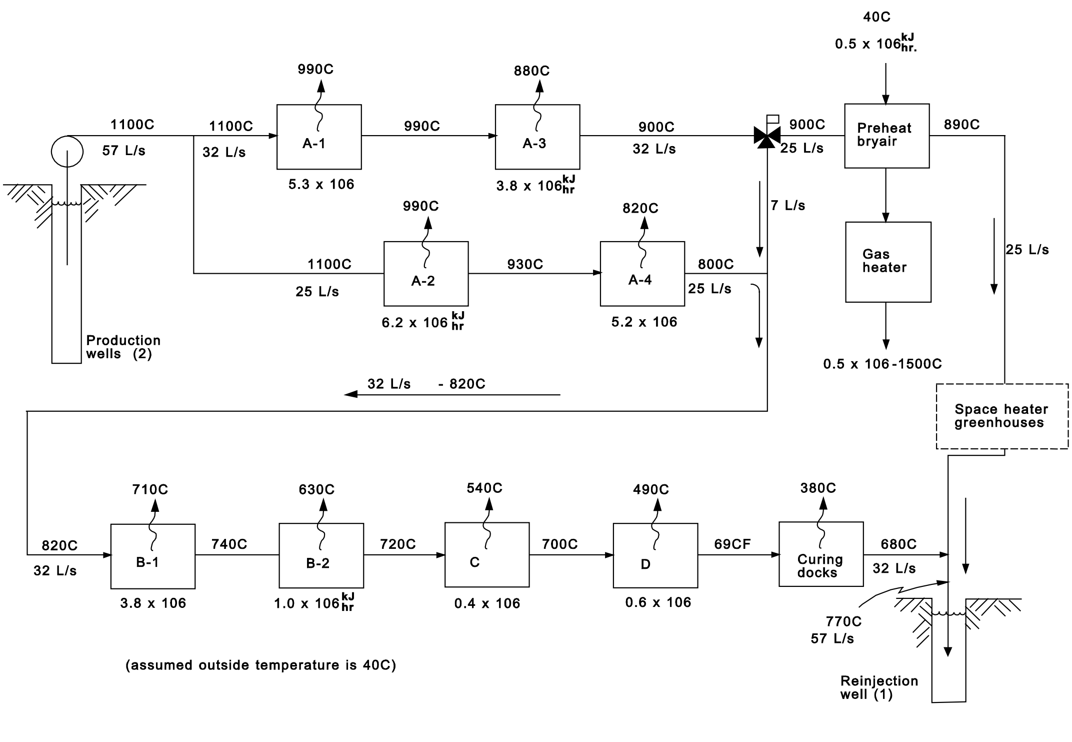

Figure 5: Temperature and energy requirements for each compartment of a single-line

The Integrated Ingredients plant uses a high temperature resource (146°C), which is also used by four ORMAT 1.5 MWe binary units (Lund and Lienau, 1994b). Up to 75 l/s are supplied to the plant at 130°C and finally discharged as low as 71°C. The plant thus used a maximum of 80 GJ/h (approximately 11 MJ/kg of wet product). The facility also has a cold storage warehouse which can store as much as 22,000 tonnes of product, which can provide year-round operation. Recent improvements at the plant allow the drier to handle 7,250 kg/h and produce 1,500 kg/h of dry product, and a second line is being considered. The Brady's Hot Spring plant has a similar operation using 132°C fluid. This was the first U.S. vegetable dehydration plant to utilize geothermal energy (Lund, 1994). This unit has only three stages (A through C). During the six-month operating season, almost 23 million wet kg of onions are processed. The 58-m long dehydrator uses from 88 to 49°C air in the various stages. The plant has also processes celery and carrots to extend the operating season.

4 Summary and conclusions

There are other smaller industrial uses of geothermal energy in the United States such as: 1) laundries in California, Nevada, Montana and Oregon; where in San Bernardino, California approximately 34,000 m^3/month of geothermal water is used with an annual savings of $354,000 (Fisher and Bailey, 1994); 2) mushroom growing in Oregon where 22.5 tonnes of white button mushrooms are produced annually (Culver, 1992); 3) mineral water processing in California using geyser water (Calistoga Water); and 4) an industrial park at the Puna geothermal facility, Hawaii with a variety of experimental uses of geothermal energy (Boyd, et al., 2002). Another potential use that has not been documented is enhanced petroleum recovery in northeastern Wyoming by injecting geothermal water into the reservoir. Unfortunately, the Geo-Heat Center has not been able to obtain any reliable information on this large operation, since it is privately run. The most successful operations in the United States are the onion dehydration plants in Nevada. The current installed capacity of all these industrial uses is approximately 70 MWt and the annual use 1,500 TJ (415 GWh), but has been as high as 100 MWt and 2,000 TJ (555 GWh) in the past. Additional information on industrial applications can be found in Lienau and Lund (1998).

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