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

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GEOTHERMAL PIPELINE

Progress and Development Update
Geothermal Progress Monitor

WASHINGTON

GOP Unveils Plan to Boost Alternative Energy Sources, Cut Oil Imports

Senate Republicans unveiled an energy policy bill that aims to offset foreign oil imports by as much as 50% by maximizing electricity production from alternative energy sources and boosting domestic oil production.

The legislative proposal also contains tax incentives for electricity produced from renewable energy sources, such as wind, solar and "biomass." It also promotes power produced by hydro-electric, nuclear and coal-fired plants.

Senate Majority Leader Trent Lott (R., Miss.) and Senate Energy Committee Chairman Frank Murkowski (R., Alaska) support the bill, which Lott said, "isn't just about increasing oil production, but about boosting energy production from coal, solar, wind and other sources.

Under the bill, a $2,000 residential solar energy tax credit would be created and the tax credit for electricity co-generated with steel and coke production would be extended.

Another tax provision in the bill excludes from electric utilities' gross income any contributions to capital fees paid by customers for connecting electric, natural gas or steam lines.

The Republican proposal would authorize $25 million for the Energy Department to establish an energy-efficiency research grants program, and would call for improving an existing U.S. home-weatherization program.

The measure would require U.S. agencies to inventory U.S.-owned hydropower facilities and develop a report on what upgrade would be necessary to increase power production.

It also calls for the Federal Energy Regulatory Commission to report within six months on measures it needs to expedite the licensing process for privately-owned hydropower plants. The Nuclear Regulatory Commission would be required to report within six months on steps that can be taken to boost output from nuclear-power plants. The bill also calls for the NRC to assess its relicensing procedures and make recommendations for improving and expediting the process.

Furthermore, the bill would create an Office of Spent Nuclear Fuel Research within the Energy Department to administer a grant program for research of "treatment, recycling and disposal" of spent fuel generated by nuclear power plants.

It calls for legislators to assess whether spent fuel destined for long-term storage in a proposed repository at Yucca Mountain, Nevada, should be subject to permanent burial or "considered an energy source that is needed to meet future energy requirements."

The bill notes that future nuclear-power uses may require construction of a second repository unless "improved spent-fuel strategies" are developed to increase the repository's capacity.

The Energy Department would be required to report within six months on the potential for increasing the output of U.S. coal-fired power plants "and any impediments to achieving such (an) increase."

The bill contains language promoting commercial application of clean-coal technologies, and in particular, calls for the Energy Department to provide grants to refine and demonstrate new technologies for the conversion of coal into liquid fuels.

Energy Committee Chairman Murkowski said he would hold hearings on the proposal within the next two weeks. The measure also will require action by the Senate Finance Committee, Murkowski noted. (Source: Dow Jones & Company, May 16, 2000).

ICELAND

Geothermal Powers Húsavík

The first geothermal power applications of the Kalina Cycle is on schedule for a June 2000 startup. The project is a 2-megawatt (net) binary geothermal power plant being built by the electric division of Húsavík, Iceland.

Once completed, this program will result in what will be one of the most geothermal energy efficient and diverse towns in the world. The 2-MW plant will provide up to 80 percent of the town's electric power demand. The heat source for the plant will come from geothermal wells located 20 km south of Húsavík.

The efficiency and overall economic advantage of the Kalina Cycle over other existing technologies was a prime consideration in the decision to install the Kalina Cycle. The distinguishing trait of the Kalina Cycle is its working fluid of ammonia-water. The efficiency gain is achieved by the ability of this working fluid to closely parallel the temperature of the heat source (in this case–hot geothermal brine) and the heat sink (cooling water). Cost effective energy recuperation within the cycle is also possible due to the unique characteristics of the ammonia-water mixture.

The efficient utilization of the geothermal energy doesn't stop at the power station. In parallel with the power plant, the hot water will be used by local industries for shrimp processing, drying of wool, process heat and drying of hardwood. (The hardwood comes from oak trees cut in Maine, USA, and after drying in Húsavík, is shipped to mainland Europe.) This geothermal energy is even being considered for pasteurizing, sterilizing and evaporating milk for the town's flourishing dairy industry.

The geothermal brine that exits the power station will also be used. After the generation of electric power, the geothermal brine will leave the power station at a cooled temperature of 80ºC (176ºF). This is just the right temperature for space heating and hot water use in all the homes and business in Húsavík. Other uses of this water include greenhouse heating, snow melting and heating of the town's swimming pool.

Finally, even the cold, clean mountain water used in the Kalina Cycle's condenser finds a secondary use. The cold water, initially at a temperature of 5ºC (41ºF), exits the condenser at 25ºC (80ºF). This warm water will be piped to a trout (fish) farm, where the higher temperature promotes optimal growth rate and health conditions for the fish.

The township of Húsavík expects to profit from this program in two ways. The efficient use of geothermal energy will maintain the high environmental standards of the area; while, the availability of inexpensive thermal and electrical energy will promote economic growth. The geothermal capacity potential for the town has been assessed at 75 to 100 megawatts of sustained power generation.

The Kalina Cycle technology was developed by Exergy, Inc., Hayward, California. The design and equipment procurement for this Húsavík plant was executed out of Exergy's Houston, Texas office. (Source: *GEA Washington Update*, May 2000)

JAPAN

Power Generation with Thermal Energy Conversion System Using Hot Springs

Introduction

Hot springs have been a part of Japanese culture since ancient times, and are important areas for tourism, therapy and general relaxation. On the other hand, with environmental and energy issues becoming even more prominent as we head into the new millennium, generating power using hot spring water is attracting considerable attention.

From an environmental and energy perspective: 1) hot spring water is a totally indeginerous energy in Japan, 2) it is a clean energy that does not discharge any CO_2, 3) it has a higher energy density than other forms of natural energy, 4) it has yet to be fully exploited as a source of energy, and 5) it is almost an unlimited source of energy.

The reason that it has not been fully exploited, is a combination of technological difficulties and low-economical efficiency.

Saga University has been involved in the development of OTEC (Ocean Thermal Energy Conversion), and have been pursuing research into its practical application. From this research, we invented a new cycle, which is called Uehara Cycle, and its application in various power generation systems has attracted substantial interest. Introducing this new cycle and other new technologies is expected to resolve a number of issues that have contributed to the under-exploitation of power generation using hot spring water, or other heat sources such as waste heat from factories/power plants, and heat from waste incineration.

In their research, they have established a 50-kW plant to conduct a verification test of hot spring water power generation using this new cycle, and in this article they explain the principles and current state of this test, and the future prospects for its practical application.

Principle of Hot Spring Water Power Generation

The basic principles of power generation using hot spring water, uses waste hot water and unused discharged hot water. It can be applied to binary cycle generation that uses geothermal energy directly from production wells, power generation using waste heat from factories and power plants, and heat from waste incineration.

While in principle this system is basically the same as thermal power generation, it can generate power without burning fossil fuel, using nothing more than the energy of hot spring water. In most cases, hot spring water hotter than 50ºC is cooled using groundwater. In this system, hot spring water of 50-90ºC is cooled after generation, so it is more readily usable. This has a potential to solve a serious problem of securing the supply of cooling water, such as groundwater.

Introducing New Technologies to Hot Spring Water Power Generation

To date, Freon gases have been used as the functioning medium when generating power from thermal energy of around 100ºC, such as hot spring water or waste heat. But, the use of specified Freon gases, which were the main medium, is now restricted because of the damage they cause to the ozone layer. At present, there is no suitable medium. However, natural mediums as a Freon substitute are attracting interest. Ammonia shows some promise, especially in refrigerators and air-conditioners. Ammonia has also been used in power generation with OTEC. With ammonia, though, pressure inside the pipes reaches roughly 50 atmospheres; so, equipment costs will be very high. At the same time, a new cycle using a mixture of ammonia and water has come to the forefront. Using this cycle in hot spring water power generation has the potential to generate electricity with much greater heat efficiency than the Rankin Cycle using a pure ammonia medium. Moreover, adjusting the water-ammonia mixture allows the pressure inside the pipes to be reduced to 20 atmospheres or lower.

Space does not allow them to go into any great detail, but the introduction of new technologies such as the new cycle, turbines, and heat exchangers is expected to result in a dramatic rise in both heat efficiency and economic efficiency.

Outlook of Hot Spring Water Power Generation

Their studies reveal that there are about 300 hot springs in Japan, where this system can be used. If they add to this power generation from waste heat at factories and power plants where a similar system can be used, the range and scale of use of this system is indeed immense.

Conclusion

Power generation using a low heat source of around 100ºC, such as hot spring water, was regarded as difficult technology in terms of heat efficiency and choice of the functioning medium. But this view is set to change with the invention of a new cycle using aqueous ammonia. There is still many technical issues that need to be addressed, but the practical use of power generated from hot spring water is expected to make a significant contribution to resolving today's energy and environmental problems. (Source: Haruo Uehara & Ysuguki Ikegami, Faculty of Science and Engineering, Saga University, Japan. *New Energy Plaza*, Vol. 15, No. 3 [2000] Tokyo)

PAVEMENT SNOW MELTING

John W. Lund
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ABSTRACT

The design of pavement snow melting systems is presented based on criteria established by ASHRAE. The heating requirements depends on rate of snow fall, air temperature, relative humidity and wind velocity. Piping materials are either metal or plastic, however, due to corrosion problems, cross-linked polyethylene pipe is now generally used instead of iron. Geothermal energy is supplied to systems through the use of heat pipes, directly from circulating pipes, through a heat exchanger or by allowing water to flow directly over the pavement. Examples of geothermal and other systems in New Jersey, Wyoming, Virginia, Japan, Argentina, Canada, Switzerland and Oregon are presented.

INTRODUCTION

Pavement snow melting using geothermal hot water and steam has been demonstrated in several countries, including Argentina, Japan and the United States. These installations include sidewalks, roadways and bridges. Most commonly it is done with a glycol solution, hot water or steam being circulated in pipes within or below the pavement, using either heat pipes or geothermal fluids, however, in one instances hot water has been sprinkled directly onto the pavement. This paper will attempt to present the general design requirement for a snow melting system and then give examples of those in operation using geothermal energy along with several other systems. The obvious benefits of these systems is that they eliminate the need for snow removal, provide greater safety for pedestrians and vehicles, and reduces the labor of slush removal.

GENERAL DESIGN CRITERIA

The heating requirement for snow melting depends on four atmospheric factors: (1) rate of snow fall, (2) air temperature, (3) relative humidity, and (4) wind velocity (ASHRAE Handbook, 1995).

The snow melting system must first melt the snow and then evaporate the resulting water film. The rate of snowfall determines the heat required to warm the snow to 32°F and to melt it. The evaporation rate of the melted snow from the pavement is affected by the wind speed and by the difference in vapor pressure between the air and the melted snow. Since the vapor pressure is determined by the relative humidity and temperature of the air, and as the pavement surface temperature is usually fixed, the resulting evaporation rate varies with changes in air temperature, relative humidity, and wind speed. Convection and radiation loss from the melted snow depends on the film coefficient and the difference in temperature between the surface and air. The film coefficient is a function of wind speed alone, and since the pavement temperature is fixed, convection and radiation losses vary with changes in air temperature and wind speed (ASHRAE Handbook, 1995).

Chapman (1952) derives and explains equations for the heating requirement of a snow-melting system. Chapman and Katunich (1956) derive the general equation for the required pavement heat output (q_o) in Btu/h·ft^2:

$$q_o = q_s + q_m + A_r\,(q_e + q_h)$$

where

q_s = sensible heat transferred to the snow (Btu/h·ft^2),
q_m = heat of fusion (Btu/h·ft^2),
A_r = ratio of snow-free area to total area (dimensionless),
q_e = heat of evaporation (Btu/h·ft^2), and
q_h = heat transfer by convection and radiation (Btu/h·ft^2).

The sensible heat q_s to bring the snow to 32°F is:

$$q_s = s\, c_p\, ?\, (32 - t_a) / c_1$$

where

s = rate of snowfall (inches of water equivalent per hour),
c_p = specific heat of snow (0.5 Btu/lb·°F),
? = density of water equivalent of snow (62.4 lbs/ft^3),
t_a = air temperature (°F). and
c_1 = conversion factor (12 in./ft).

For hot water (hydronic) systems, the above reduces to:

$$q_s = 2.6\, s\, (32 - t_a)$$

The heat of fusion q_m to melt the snow is:

$$q_m = s\, h_f\, ? / c_1$$

where

h_f = enthalpy of fusion for water (143.5 Btu/lb).

For hot water (hydronic) systems, the above reduces to:

$$q_m = 746\, s$$

The heat of evaporation q_e (mass transfer) is (for hydronic):

$$q_e = h_{fg}\, (0.0201\, V + 0.055)\, (0.188 - p_{av})$$

where

h_{fg} = heat of evaporation at the film temperature (Btu/lb),

V = wind speed (mph), and

p_{av} = vapor pressure of moist air (inches of mercury).

the heat transfer q_h (convection and radiation) is (for hydronic):

$$q_h = 11.4\ (0.0201\ V + 0.055)\ (t_f - t_a)$$

where

t_f = water film temperature (°F), usually taken as 33°F.

The solution of the general equation for q_o for the required pavement heat output, requires the simultaneous consideration of all four climatic factors: wind speed, air temperature, relative humidity, and rate of snowfall. Annual averages or maximums for the climatic factors should not be used because they are most likely not to occur simultaneously. It is thus necessary to investigate the various combinations that might occur at a site, based on several year's worth of data, to determine the critical combination that is most likely to be experienced (ASHRAE Handbook, 1995). Some design weather data and required heat output for selected cities in the U.S. are given in chapter 46 of the 1995 ASHRAE Applications Handbook.

Chapman (1957) classifies snow melting installation according to type as Class I, II or III. These types are described as follows:

Class I (minimum): residential walks or driveways; interplant ways or paths.

Class II (moderate): commercial sidewalks and driveways; steps of hospitals.

Class III (maximum): toll plazas of highways and ridges; aprons and loading area of airports; hospital emergency entrances.

The 1995 ASHRAE Applications Handbook presents design output data for each of the three classes for selected cities in the U.S. As examples, the following four cities are given below:

	Design Output (Btu/h·ft^2)		
City	Class I System	Class II System	Class III System
New York City	121	298	342
Chicago	89	165	350
Reno, NV	98	154	155
Portland, OR	86	97	111

CANADIAN EXPERIENCE

Experimental work carried out by the Division of Building Research, National Research Council of Canada (Williams, 1976), validates the ASHRAE design method with some adjustments as detailed below. They experimented with an exposed site at Ottawa with heat transfer coefficients of 170 Btu/ft^2/hr (536 W/m^2). Their research conclusions are as follows:

1. The ASHRAE formulas for calculating design heat requirements for snow-melting systems are reasonably satisfactory, provided adjustments are made to take into account the size of the heated area, the exposure to wind, and the height at which wind speeds are measured.
2. The limiting condition controlling design heat requirements of snow-melting systems operating in cold climates is the maintenance of an ice-free surface immediately after snowstorms rather than the effective melting of snow during a storm. These heat requirements can be estimated by calculating the rate of surface heat loss from bare, wet pavements and by using weather data obtained from representative or design storms.
3. The use of insulation reduces edge and ground heat losses to insignificant amounts and eliminates the need to make allowances for such losses in design heat calculations of insulated snow-melting systems.

PIPING MATERIAL AND PAVEMENT INSTALLATIONS

Piping materials are either metal or plastic. Steel, iron and copper pipes have been used extensively in the past, and are still used abroad, however, steel and iron corrode rapidly if they are not protected by coatings and/or cathodic protection. The use of salts for deicing and the elevated temperature accelerate corrosion of these materials. NACA (1978) experience indicates that the corrosion rate approximately doubles for each 18°F rise in temperature. Corrosion failures of iron pipe caused the shut-down of a Klamath Falls geothermal snow melting system after almost 50 years of operation. The corrosion was due to the failure of the outside protective wrapping of the pipes (Lund, 1999).

Present practice in the U.S. is to use plastic pipe with iron for the header pipe. Typical plastic pipes are of a cross-linked polyethylene (PEX), that according to ASTM standard F 876, can handle 180°F water at 100 psi or 200°F water at 80 psi. This type of pipe is lightweight and easier to handle, can be bent around obstructions or for reverse bends with radii of as little as 12 inches, comes in long sections, do not require expansion loops, and use mechanical compression connections. It obviously does not corrode, thus it has a life of over 50 years.

Generally, an antifreeze solution (ethylene or propylene glycol) is used in the pipes, circulated in a closed system and heated by a heat exchanger. Antifreeze solutions are necessary, as most systems will not be operated continuously in cold weather, and thus the system must be protected from freeze damage.

Chapman (1952) derived the equations for the fluid temperature required to provide an output q_o (defined earlier). Using 3/4- to 1-inch diameter pipe placed approximately 2 inches below the pavement surface, the equation is:

$$t_m = 0.5\ q_o + t_f$$

where

t_m = the mean fluid (antifreeze solution) temperature in degrees F and t_f is generally taken as 33°F.

Portland cement concrete (PCC) or asphalt concrete (AC) may be used for snow-melting system. The thermal conductivity of AC is less than that of PCC, thus pipe spacing and temperatures are different. However, the main reason for not using AC pavements with pipes embedded in them, is that the hot asphalt may damage the pipes, as AC is usually placed at above 300°F in order to get adequate compaction. Also, the compaction process may deform and even break pipes and their connections.

With PCC pavements, the pipes can be attached to the reinforcing/expansion steel within the pavement (which may not always be used) , but should have at least 2 inches of concrete above and below the pipes. This then requires a pavement of at least 5 inches thick. In the case of sidewalks, the piping is usually place below the slab in a base or subbase, as these pavements are usually only 3 to 4 inches thick. In this latter case, the advantage of not placing the pipes in the concrete, is that future utility cuts or repairs can be made without damaging the pipes. In Klamath Falls, pipes under the sidewalks were covered with a weak fluid cement paste to hold them in place. Pipes should not cross expansion or contraction joints within highway pavement, as shrinkage during curing may be as much at 3/4-inch per 100 feet of slab, and long term expansions and contractions can be significant from hot to cold weather periods. All pavements must be protected from frost heave with proper drainage and adequate base or subbase thicknesses, as heaving may damage the pipes, especially where they are connected to a header along the edge of the pavement.

GEOTHERMAL HEAT SUPPLY AND EXAMPLE INSTALLATION

Geothermal energy can be supplied to the system by one of four methods: (1) through the use of heat pipes, (2) directly from a well to the circulating pipes, (3) through a heat exchanger at the well head, or (4) by allowing the water to flow directly over the pavement. All of these systems have been utilized to one degree or another throughout the world.

Heat Pipes

This type of configuration was first used in Trenton, New Jersey in 1969 (Nydahl, et al., 1984). This system circulated an ethylene glycol-water mixture between pipes embedded 2 inches below the pavement surface and a horizontal grid buried 3 to 13 feet below the pavement on 2-foot levels. The total length of the ground pipes was twice as long as the pipes in the pavement. The measured undisturbed ground temperature at 7 feet depth varied between 48 and 57°F during the winter and the antifreeze temperature ranged between 40 and 52°F during most of the snow storms. Typical measured snow melting rates were 1/4 and ½ inches per hour when the corresponding air temperature ranged between 20 and 35°F. The performance of this ground system proved to be superior to that of a companion 68 Btu/h/ft^2 electric pavement heating system while requiring only about 2% of the electrical power to operate the circulation pump. One of the draw-backs with the system was the expensive excavation required for placement of the ground pipes.

A second project, using the results of the Trenton experience, was to conduct research on a vertical ground heat exchanger or gravity-operated heat pipe (Nydahl, et al., 1984). The gravity-operated heat pipe consisted of a sealed tube which contained a fluid in the liquid-vapor state. Ammonia and Freon were utilized as the working fluid partly because they were not susceptible to the freezing problem that plagued water based system, and they are chemically inert with respect to most steels. Today Freon could not be used due to restrictions on the use of CFCs. The lower end of the pipe was the evaporator while the upper portion served as the condenser. When the evaporator is warmer than the condenser, a portion of the liquid vaporizes and travels to the condenser where its latent heat of vaporization is released upon condensing. The evaporation and condensation processes create the driving pressure potential that is required to transport the vapor upward, while the condensate returns due to gravity in the slightly slanted condenser to the vertical evaporator. Since the thermal energy is transported in the form of latent heat of vaporization, the heat pipe can transport large amounts of energy over a long distance (about 180 feet at two experimental installations) with a relatively small temperature difference. There are no mechanical moving parts in this system, and the heat pipe self activates anytime the ground around the evaporator is warmer than the pavement in which the condenser is embedded.

The main problems anticipated with this system was to make sure all joints were sealed and that the pipes were protected against corrosion. Construction costs would increase for the pavement due the unusual characteristics of the system and for drilling and placing the vertical pipes. Full scale test projects were constructed on a highway ramp in Oak Hill, West Virginia and on two highway ramps near Cheyenne, Wyoming (Nydahl, et al., 1984). These latter two 7%-grade ramps utilized 177 field constructed heat pipes to warm 10,600 ft^2 of pavement. Each heat pipe had a 100-foot long evaporator attached to a manifolded condenser section with a total length of 120 feet. The ground temperature was 54°F, however the system performed to expectations. A more detailed section was constructed at Sybille Canyon (1976) and at Spring Creek Bridge (1980) in Laramie, Wyoming, which were extensively monitored. The latter installation included 60 large heat pipes, two header pipe vaults, four service vaults and 3 inches of polyurethane insulation on the underside of the heat portion of the deck. The evaporator pipes were made from 2-inch schedule 80 steel pipe with a spiral groove

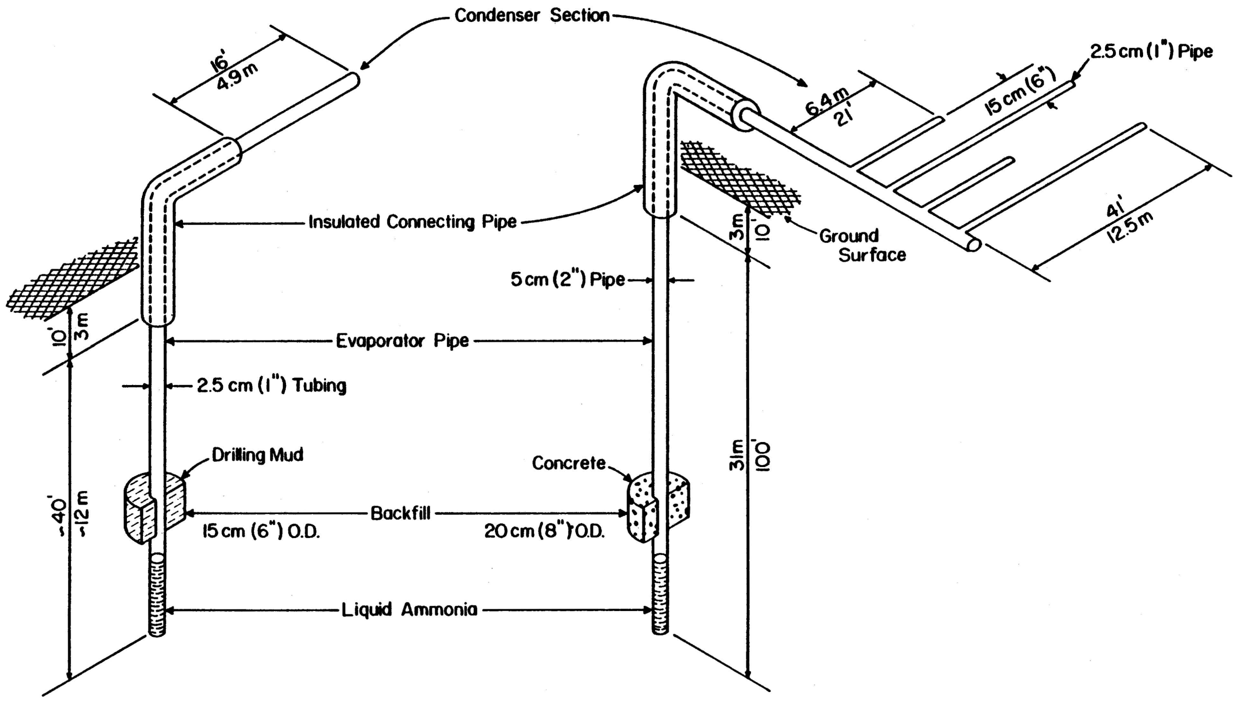

Figure 1. Schematic of Sybille and Spring Creek Heat Pipes (Nydahl, et al., 1984).

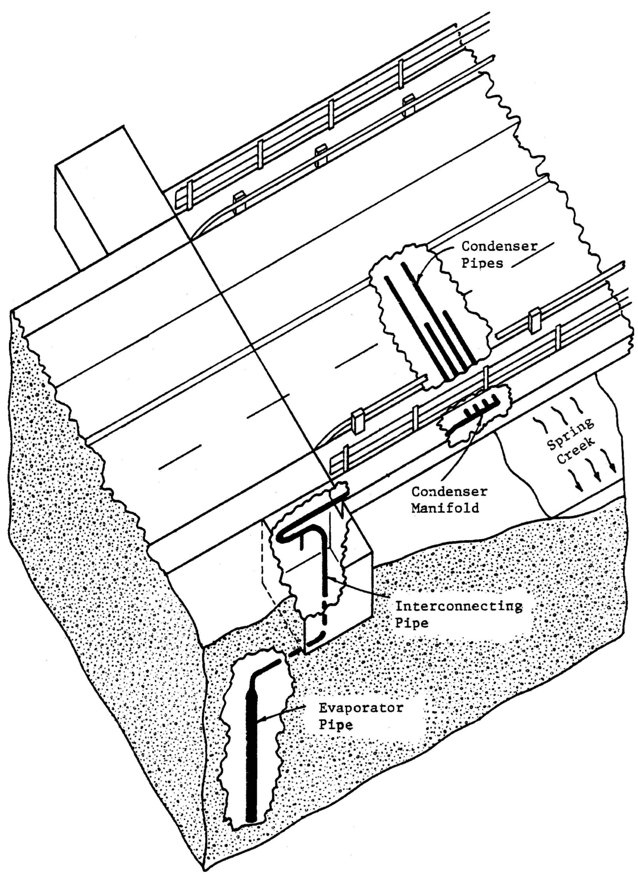

Figure 2. Schematic of the Spring Creek Heat Pipe System (Nydahl, et al., 1984).

machined on the internal surface to enhance the wetting of the wall by the returning condensate. The evaporator pipes were placed in 8-inch diameter holes and consisted of 15 pipes located on 10-foot center at each corner of the bridge. The connecting pipes and the condensers were all made from 1-inch schedule 40 pipe, and set on a minimum grade of 2% to ensure condensate drainage back to the evaporators. The pipes were charged with ammonia so that the liquid level at the bottom of each evaporator was about one foot high. The installation was monitored for two years and performed well in preventing freezing of the heated deck. Even though the ground temperature was only 47°F, the heated bridge surface was increased by as much as 27°F. The only serious design problem that became evident was that the pipe grades were insufficient to compensate for settling of the earth, thus producing liquid locks. It was recommended to increase the grades from 2 to 5% to overcome this problem.

Similar systems have been tested in Japan and by the Colorado Department of Highways near Glenwood Springs. In the later case, a water well was used to supply the heat rather than the ground.

Pavement Sprinkling

Sprinkling a roadway surface with warm water has been used in Fukui City of the Tohoku region of northern Japan (New Energy Plaza, 1997). This is a water cascaded snow melting system in which groundwater at 60°F flows through heat exchanger ducts buried in the sidewalk where the temperature is reduced to 45°F. After melting the snow on the sidewalk the water is sprinkled on the adjacent roadway. "Snowfall sensors" are used to automatically operate the snow-melting system. The sensors check whether snow has fallen and if snow is remaining on the surface, and whether the snow has melted thoroughly.

Geothermal Steam

In the Copahue-Caviahue Thermal Area of west-central Argentina on the slopes of the Andes, geothermal steam is used for heating streets and the access road to Villa Copahue, a ski resort (Pesce, 1998). The steam is produced from the 4,600-foot deep CO04 geothermal well, which produces 30 ton/h of steam. The steam is transported through an 8,500-foot long pipeline. Winter temperatures in the area are as low as 10°F; winds can reach 100 mph; and snow depths average 13 feet. Using the geothermal heat, the pavement temperature can kept between 54 and 61°F. The heating is done by radiant panels underneath the road surface, consisting of serpentine hot water distribution pipes, covering almost 24,000 ft^2 of road surface. The waste water is then discharged at the surface through a collector pipeline.

Geothermal Hot Water

Geothermal hot water has been used for pavement snow melting in Japan and the U.S. At Sapporo in Japan, water from the Jozankei Spa has been used for snow melting on roads since 1966 (Sato and Sekioka, 1979). The system covers 112,000 ft^2. Initial construction used steel pipes, but due to external corrosion, these were replaced with one-inch diameter polybutene pipes in 1973. Hot spring winter is circulated by three 10-hp pumps through three separate loops of pipe embedded three to five inches deep at one-foot spacings and then discharged to the Toyohira River at 77°F. The hot water flows in the three loops at between 40 to 50 gpm with inlet temperatures between 169 and 181°F, resulting in a total heat supply of 6.6 million Btu/hr or 1.92 MWt. Assuming lateral and downward heat loss of 20%, the effective heat supply to the road surface is 48 Btu/ft^2/hr, which was in good correlation with the calculated load of 49 Btu/ft^2/hr required for a continuous snowfall of 0.4 inches per hour according to ASHRAE.

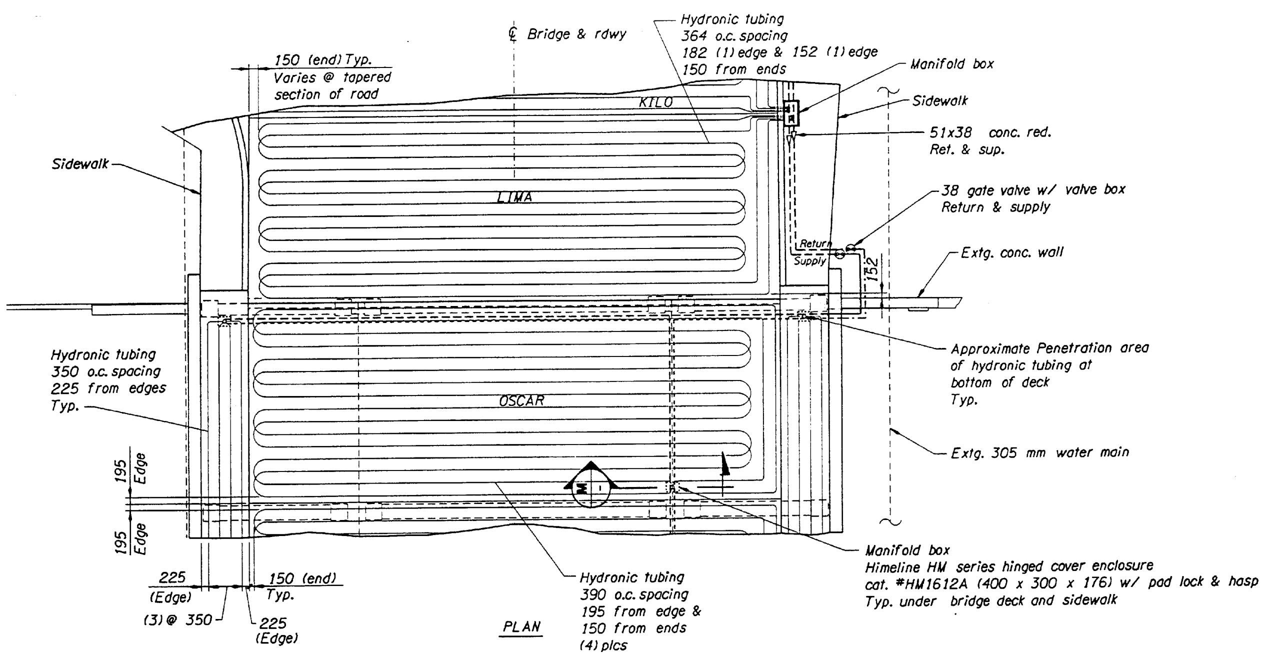

Figure 3. Detail of the loop system for the Klamath Falls Project (Lund, 1999).

The oldest geothermal pavement snow melting system was installed in Klamath Falls, Oregon in 1948 by the Oregon Highway Department (Lund, 1999). This is a 450-foot long section of Esplanade Street approaching a traffic signal on a 8% grade. The grid consisted of 3/4-inch diameter iron pipes placed three inches below the surface of the concrete pavement on 18-inch centers. The grid system was connected to a geothermal well with the heat transferred through a downhole heat exchanger to a 50-50 ethylene glycol-water solution that circulated at 50 gpm. The temperature drop in the grid was approximately 30 to 35ºF with the supply temperature varying from 100 to 130ºF, The system is estimated to supply a maximum of 3.5 x 10^5 Btu/hr at the original artesian flow of 20 gpm and 9.0 x 10^5 Btu/h at the pumped rate of 50 gpm. The latter energy rate could provide a relative snow free pavement at an outside temperature of -10ºF and a snowfall up to three inches per hour, at a heat requirement of 41 Btu/ft^2/hr. Due to a temperature drop in the well from 143 to 98ºF, the well was rehabilitated in 1992 (Thurston, et al., 1995).

By 1997, after almost 50 years of operation, the system had failed due leaks in the grid caused by external corrosion. In the fall of 1998, a contract was issued to reconstruct the bridge deck and highway pavement along with replacing the grid heating system. The top layer of concrete on the bridge deck was removed by hydroblasting and the roadway pavement was entirely removed, and new crushed rock base added. A 3/4-inch cross-linked polyethylene tubing (PEX) was then used for the grid section, placed in a double overlap pattern at from 14 to 16 inches on center. The PEX pipe was attached to the reinforcing steel within the concrete pavement providing a cover of about 3 inches over the pipe within the 7-inch pavement section. The header pipe, placed along the edge of the roadway consisted of 1.25- to 2.5-inch insulated black iron pipe, which in turn was connected to the downhole heat exchanger. The header pipe has brass manifolds placed at about 40-foot intervals in concrete boxes, to allow for four supply and return PEX pipes to be attached.

The entire cost of the reconstruction project was approximately $430,000 and the estimated annual maintenance cost will be $500 and the operating cost (for the circulating pump) $3,000. The heated bridge deck and pavement covers 22,000 ft^2 and is designed for a heat output of 50 Btu/ft^2/hr. The DHE supplies 100ºF glycol mixture to the grid with a temperature drop of 24ºF, estimated to increase to 30ºF once the ground and concrete temperatures reach equilibrium. This is suppose to keep the deck clear during heavy snowfall down to -10ºF. The renovated deicing system appears to be operating effectively, based on substantial snowfalls in January and February 1999.

NON-GEOTHERMAL HEATING SYSTEMS

VDOT's Hot Bridge

The Virginia Department of Transportation has built a heat bridge on Route 60 over the Buffalo River in Amherst Country. The site is in the eastern foothills of the Blue Ridge Mountains, where road conditions during winter storms often can be treacherous. The bridge is 117 feet long and 44 feet wide and was built at a cost of $663,937, including $181,500 for the heating system. The anti-icing heating system was designed and fabricated by SETA Corporation of Laramie, Wyoming. The project contains approximately two miles of steel piping, including 241 heat pipes embedded in the concrete deck and approach slabs. The pipes are one half inch in diameter, spaced at seven to nine inches apart in the transverse direction. They were originally filled with Freon HCFC 123, but the resulting heat output was inadequate. In January of 1999, the system was converted to ammonia service and presently appears to be performing satisfactorily. A propane gas-fired furnace heats a mixture of propylene glycol and water. This antifreeze mixture circulates through a separate piping loop to evaporators, heating the ammonia in the pipes. The bridge is tilted slightly so one end of the pipes is higher than the other. As the fluid boils, vapor rises in the heat pipes from the lower end to the higher, and warms the bridge deck. As the vapor cools, it condenses and trickles back to the evaporators where it is reheated.

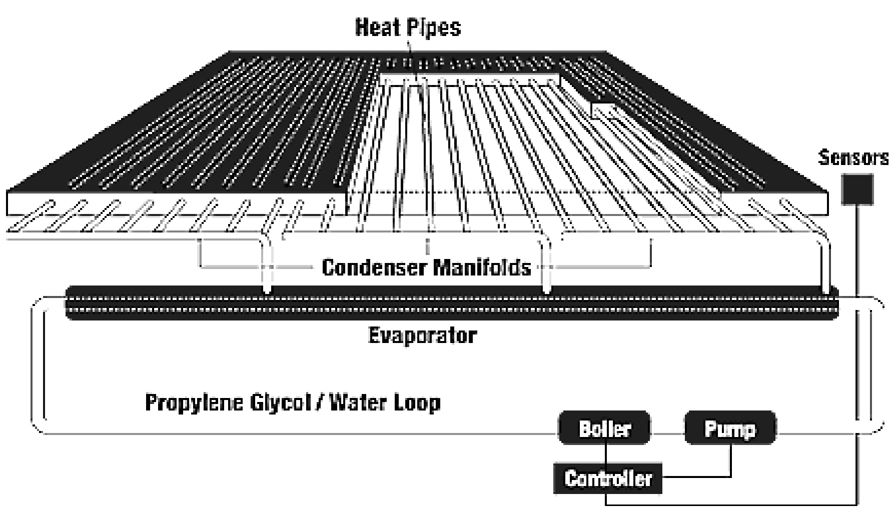

Figure 4. Schematic of the VDOT anti-icing system.

A computerized control system continuously receives information from various sensors and automatically activates the heating cycle when certain conditions are met.

Any of three conditions can activate the system:
- Deck surface sensor indicates snow or ice
- Precipitation sensor indicates precipitation and deck surface temperature is below 35º F
- Deck surface sensor indicates wet deck and surface temperature is below 35ºF

Either of two conditions will shut off the system:
- Deck surface sensor has indicated clear surface for more than 10 minutes
- Deck surface temperature is above 40ºF
- Additional details on this system can be found on the VDOT website: www.vdot.state.va.us/info/hotbridge.html.

Swiss Solar Energy Pilot Project

A solar energy pilot project (SERSO) has be installed on a bridge in the Swiss highway network on Road 8 at Därligen in Berne canton (Schlup and Schatzmann, undated; Rauber, 1995). The project was initiated by the Energy Office of the canton of Berne and carried out by Polydynamics Ltd., Zurich. The aim of the project was:

- To collect the heat of an asphalt bridge surface during the summer period, when roadbed temperatures of 140ºF and more are frequently reached
- To store the heat in an underground heat sink, and
- To utilize the heat during frost periods in winter to heat the bridge surface, thus preventing the formation of ice.

The essential components of the SERSO plant are:
- The heat exchange tube system embedded in the asphalt layer of the bridge, covering a surface of 14,000 square feet
- The underground heat sink, consists of 91 vertical bore hole heat exchangers, reaching a depth of 213 feet, thus forming a storage capacity of 1.94 million cubic feet of sandstone (area diameter of 98 feet)
- The hydraulic system, consists of the connecting pipework between bridge and heat sink, pumps, valves and mixing tanks.

During the summer period approximately 20% of the incident solar radiation on the activated road surface can be collected, corresponding to 150,000 kWh (512 million Btu). Losses amount to approximately 35% of this quantity, the remaining energy being available to keep the bridge surface free of ice during the winter period. The total cost of the SERSO pilot project amounted to 5 million Swiss francs (approx. $3 million), including preliminary studies, implementation, supervision and measurements. The system has been operational since the late spring of 1994. A follow-up system of similar dimensions would be expected to cost not more than about half this amount, since much of the preliminary research would not be necessary.

The heating coils are filled with a working fluid consisting of a glycol-water mixture. The 160 individual stainless steel coils, each 112 feet long, underlie a surface at a depth of 2.75 inches in the leveling course of the plastic/cement stabilized asphalt layer. The vertical heat exchangers in the rock are connected in groups to four closed loops, which are independently relayed to the service building.

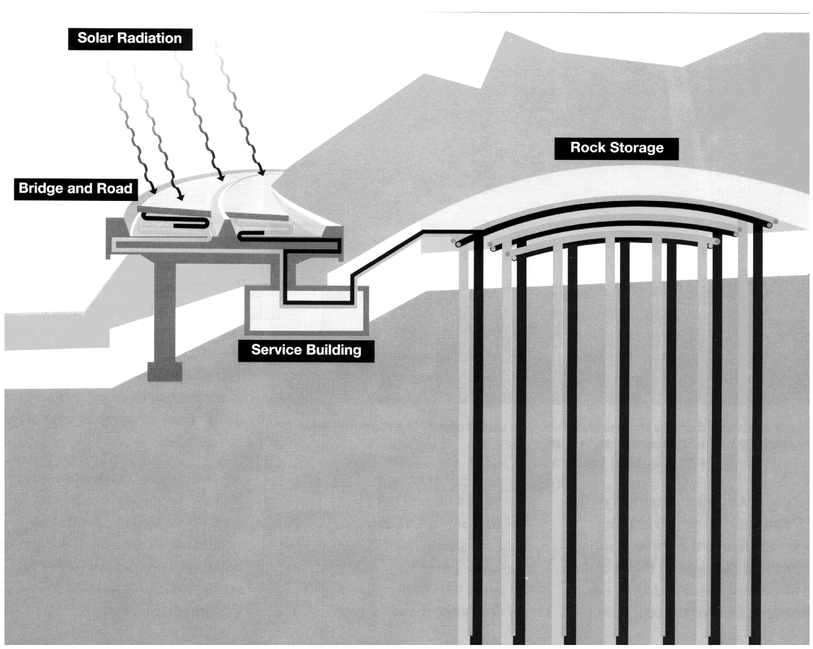

Figure 5. Swiss solar storage system (Rauber, 1995).

Airport Runway Snow Melting System

To the author's knowledge, there are no airport runway geothermal snow-melting systems in place in the United States. However, a theoretic study was performed by Senser (1982), which indicated that such a system was practical using heat pipes. A computer simulation, based on the response factor technique, was developed for use in the design of the pavement heat pipe heating system. The resulting algorithm was shown to be both computationally efficient and accurate. A simple snow-melting model that should be appropriate for heated roadways and runways studies was also developed.

The computer simulation indicated that the potential for a runway pavement heating systems at Chicago using low-grade water sources is high. A practical heating system with a conductance of 50 W/m^2 ^{o}C (8.81 Btu/hr/ft^2 ^{o}F) and a water source temperature of 10^{o}C (50^{o}F) was predicted to melt the snow as rapidly as it falls approximately 40% of the time. Melting at the snow/pavement interface would occur 87% of the time that there was some snow cover. Therefore, only 13% of the time with runway snow cover would the runway clearing operation be faced with the complicated situation of a frozen interface.

CONCLUSIONS

There are two main geothermal systems that can be used to heat a pavement for snow and ice melting: heat pipes and the direct use of geothermal hot water. The later case is less common due to the limited number of places in the U.S. where geothermal fluids above 100^{o}F are available. On the other hand, heat pipes can be used with normal ground temperatures that are typical of the entire U.S. or by using other heating mechanisms. Heat pipes may not be as efficient as using geothermal waters directly, due to the lower temperature of the circulating fluid. Geothermal systems can be installed for around \$20/ft^2, plus the cost of the well and pumping system. Heat pipe systems will run \$35/ft^2 for typical highway bridge deck systems. Total cost for the deck and heating system will run \$100 to \$150/ft^2. It may not be practical to heat an extended section of a highway or an entire runway with this system. However, heating critical areas such as bridge deck (exposed to the elements from top and bottom) and airport hard stands, refueling area, baggage handling areas, and passenger walkways may be more beneficial from a safety and economic standpoint.

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KLAMATH FALLS GEOTHERMAL DISTRICT HEATING SYSTEM FLOW AND ENERGY METERING

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INTRODUCTION

The city of Klamath Falls (Oregon) geothermal district heating system currently supplies about 20 commercial building service connections, 12 residential connections, and more than 40 snowmelt connections. The total system load is about 13 million Btu/hr (3.8 MWt). Only three services are currently metered, but the plan is to eventually meter all the commercial connections. Additional details on the Klamath Falls district heating system can be found in Brown (1999).

BACKGROUND

When the system was constructed in 1981, the original buildings were all metered, and the charge for service was based on the metered energy use. The metering consisted of a turbine flow meter with an electronic energy integrator and totalizer. Within a few years, the original meters all failed. Initially, the policy was to send the failed meters back to the factory for repair, and reinstall them. However, the repairs were expensive and the measured energy use didn't change much from year to year. Eventually, the policy became to use the metered energy use for billing until the meters failed, then bill based on historical usage.

When the city began a marketing effort in 1992 to add more customers to the system (Rafferty, 1993), the marketing decision was made to not include meters in the new installations. Instead, customers were offered a long-term (typically 10 years) flat-rate contract based on a study of historical heating energy cost. The city will install meters as those contracts expire, and the buildings will be switched to metered service.

Currently, the standard offer for new connections is the standard-metered service rate, with one year of free service to help defray the additional cost of connecting to the geothermal system.

GEOTHERMAL SERVICE RATES

The proposed standard-metered service rate includes charges for both energy and flow. The flow charge was implemented to encourage efficient flow control, which is required to maintain a high system delta-T. At an average delta-T of 40ºF, the total of the energy and flow charges is 90% of the price of natural gas. At the current natural gas price, the geothermal charge is $0.474 per therm ($10^5$ Btu) ($0.0162/kWht). Since geothermal heating is more efficient than combustion of natural gas, the cost of heating with geothermal energy will be 50 to 80% of natural gas, depending on the efficiency of the gas appliance.

Snowmelt systems that are supplied off a metered-building heating system are covered by the building charge. Unmetered snowmelt systems are billed at an annual flat rate of $0.25 per sq ft.

Residential connections on the Michigan Street, a low-income housing area, geothermal system are currently billed at 75% of the calculated cost of natural gas based on building size and calculated energy use.

METERS

The Klamath County Library and the Klamath County Government Center buildings are both metered with Emco magnetic flow meters. These meters offer excellent turn-down capability and reliability, and are easily connected to the building energy management system. The meter at the library was installed in 1996 and has offered no problems. The disadvantage of the magnetic flow meters for general system-wide application is the high cost and the requirement for utility power.

The Klamath County Courthouse is metered by a Hersey/Aaliant turbine flow meter. These turbine meters are somewhat less accurate than the magnetic flow meters and are harder to interface with a building energy management system. However, the meters offer adequate accuracy, are available in a battery-powered configuration, and are considerably less expensive than magnetic flow meters. The meters at the courthouse has operated for one season, without any problems. We expect that with the magnetic coupling drive on the Aaliant meters, that they will be more reliable than the original turbine flow meters.

The intent at this time is to standardize on the Aaliant flow meters for service connections. Two or more installations are scheduled for this summer.

Magnetic flow meters are planned for the heat exchanger building to measure total geothermal production and closed loop circulation.

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Original turbine meter (no longer functional).

Klamath County Library.

Magnetic flow meter in Library.

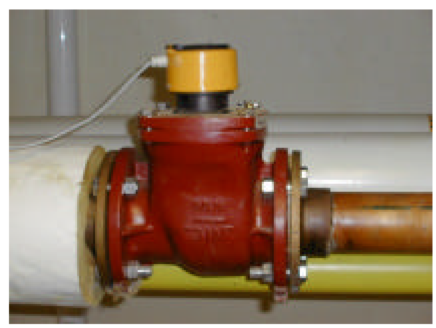
Klamath County Government Center.

Energy and flow totalizer in Government Center.

Magnetic flow meter in Government Center.

Klamath County Courthouse.

Energy and flow totalizer in Courthouse.



Turbine flow meter in Courthouse.

FLAT-RATE vs. BTU METERS
WARREN ESTATES AND MANZANITA ESTATES
RESIDENTIAL GEOTHERMAL DISTRICT
SPACE HEATING
RENO, NEVADA

Thomas Flynn
Mankato Enterprises
Reno, NV

INTRODUCTION

Warren Estates and the adjoining Manzanita Estates, located in southwest Reno, Nevada, (Figure 1) comprise the largest residential geothermal space heating district in Nevada. Nevada Geothermal Utility Company (NGUC), a privately-owned utility, has operated the district since 1983 when it served only 10 homes. Today, the NGUC 130-acre service area includes approximately 160 residences; about 100 of those are currently under contract for geothermal space and water heating, and other related applications.

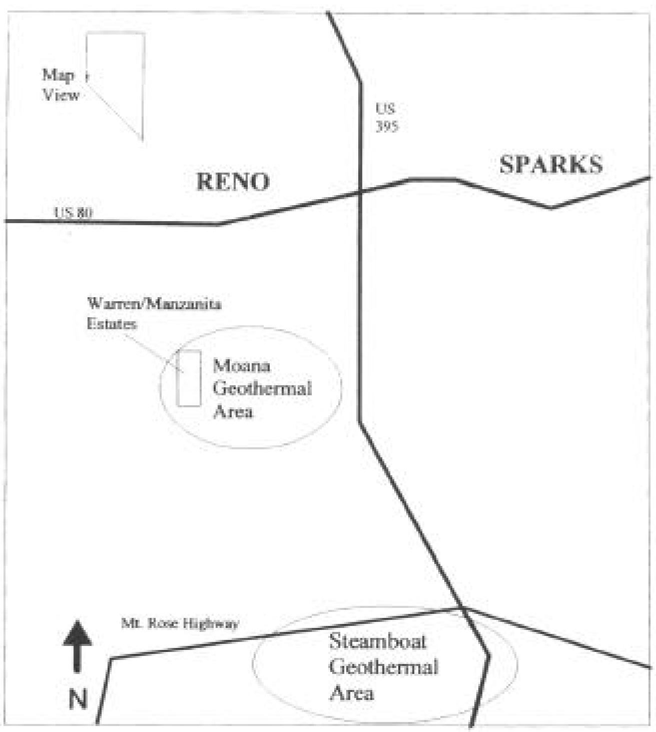


Figure 1. Sketch map of Reno, Nevada, showing approximate location of Warren and Manzanita Estates, and Moana Geothermal Area (not to scale).

The source of heat is the well-documented Moana geothermal reservoir. Production well depths range from 700 to 800 ft with temperatures in excess of 200ºF; high permeability is associated with northeast-trending fault-zone intersections. Geothermal water is pumped at a rate of 250-350 gpm from one of two production wells to flat-plate heat exchangers at the surface. Hot water (180ºF) is circulated from the heat exchangers to the subdivisions via underground pipes. All geothermal water is injected back into the reservoir through a well located on the premises. In addition to Public Utility Commission (PUC) regulations, NGUC is in compliance with permits and regulations of the Nevada Division of Water Resources and Division of Environmental Protection.

The district has operated relatively smoothly, but with a negative cash flow, for years largely due to uncertain billing practices. The average size of a single-family home in these modern, relatively affluent subdivisions is 3,500 sq ft, but many are in excess of 5,000 sq ft. After more than ten years of unreliable results from Btu meters, a flat-rate billing procedure was proposed to the customers and Public Utilities Commission. This paper describes the factors that lead to the decision to implement flat-rate billing, the reception by consumers, PUC stipulated tests, the results of those tests, and final recommendations for flat-rate billing.

BACKGROUND

On March 11, 1983, the Public Service Commission of Nevada issued Geothermal Operating Permit (GOP-001) to the Nevada Geothermal Utility Company (NGUC) for space heating 10 homes in the Moana Geothermal Area, in southwest Reno. NGUC presently provides hot water to about 100 private homes in the Warren and Manzanita Estates. The Moana area has been the site of small-scale, but widespread, geothermal direct-use applications. Bateman and Scheibach (1975) reported 35 individual geothermal wells were used to heat homes in the Moana area. Well depths range from 100 to 500 ft and the highest temperatures (210ºF) are associated with a series of north-trending fault zones. Additional information on the geology and geothermal resources of this and other areas is described in Garside and Schilling (1979), and Flynn and Ghusn (1984).

At the Warren Estates, hot water is pumped (250 to 400 gpm) from a single production well to surface, flat-plate heat exchangers. Heat is transferred to a second fluid circulating loop and delivered to the subdivisions. All pumped fluids are injected back into the geothermal reservoir through an injection well. The original application contained a description of the geothermal production well drilled to a depth of 800 ft with a downhole temperature of 210ºF. Since the wells have been completed, there has been no significant hydrologic drawdown nor temperature decrease in produced fluids.

Initially, each home was equipped with a Btu meter that measures flow rate and temperature drop, and computes heat energy consumption in therms (100,000 British thermal units-Btus). The system operator, Nevada Geothermal Utility Company (NGUC), reported significant problems, malfunctions and failures with the Btu meters due to their placement in subsurface utility boxes. For more than 10 years, NGUC tried several Btu meters with similar, disappointing results. Problems include water saturation of the meter box from lawn sprinkler runoff, failure of flow meters, and general failure of electronic components from steam condensation. With only 8 to 10 months of service life, replacement rates and maintenance costs were very high. As a remedy, NGUC proposed removing all Btu meters and provide unlimited hot water to all residences on a monthly, flat rate.

BILLING HISTORY

Billing data from 97 residences were reviewed in spreadsheet format covering the period March 1992 through February 1997; summary results are given below.

Table 1. Billing Categories

Category	Heating Requirements	Range of Monthly Bill
1	Space and domestic water	$0 to $74
2	Category 1 plus pool/spa	$27 to $105
3	Category 2 plus ice-melt	$181 to $232

These data were compared with expected heating costs using natural gas to underscore the fact that Btu meters were not performing, resulting in a depressed cash flow. The original PUC operating permit included the following provision:

> *In the event that meters are not available at reasonable cost or do not reliably reflect energy consumption, an equivalent rate will be developed on a flat-rate basis determined by home heat loss average for this area, and other average consumptive data for other uses such as, but not limited to, domestic water heating, swimming pools and spas.*

CALCULATION OF AVERAGE ENERGY CONSUMPTION

Three estimates were used to determine the flat-rate billing scheduled for geothermal heat: natural gas utilization, an estimate of natural gas use by the local utility company, and an estimate by the USDOE based on degree days. The following table lists the results of the preliminary energy calculations.

Table 2. Preliminary Energy Calculations

Item	Sq Ft	Therms	Annual Cost	$/ft^2	Therms/ft^2
Homeowner	2,250	969	$547	$0.24	0.43
SPPC 1993	1,800	596	$337	$0.19	0.33
USDOE	1,800	600	$339	$0.19	0.33
Average				$0.21	0.363

The Washoe County Assessor's Office has a computer database of all commercial and residential buildings in the county. The listing provided a reliable source for the amount of living space, in sq ft, for each home in the Warren and Manzanita Estates. On the basis of the PSNC regulations, the existing service contract, comparative evaluations with natural gas heating, and the historical record for the Warren and Manzanita Estates, the following new rate schedule was proposed.

Table 3. 1998 Proposed Billing Provisions

Item	Rate
Monthly service charge	$3.25 per household
Space and domestic water heating	$0.016 per sq ft (75% of natural gas)
Swimming pool	$30.00 per month
Spa/jacuzzi	$10.00 per month
Driveway deicing	$50.00 per month

PSCN staff suggested that NGUC provide customers with the opportunity to evaluate and comment on the proposed new rate schedule before it is implemented. Staff also suggested a letter be drafted to the commission that clearly states the intention of the utility and provides evidence (photos of the Btu meters, receipts for replacement, labor costs, etc.) for the proposed change. A public hearing was held in May of 1998, and comments were incorporated into the docket.

On June 26, 1998, the Public Utility Commission of Nevada (PUC) issued a Compliance Order (Docket No. 98-1022) allowing Nevada Geothermal Utility Company (NGUC) to implement a program of flat-rate billing for geothermal customers at Warren/Manzanita Estates. The Compliance Order contained a set of stipulations, including one requiring installation and monitoring of five new Btu/flow meters.

> *...Nevada Geothermal will install within thirty (30) days of the issuance of a Commission Order, at its expense, up to five (5) new Btu/flow meters at locations aboveground and within the perimeters of the residences. That selection of the meters be made by a committee composed of one representative each from the Applicant, the Commission staff, and the homeowners, and that the meters be monitored monthly for a period of one (1) year. That within thirty (30) days of the expiration of the one (1) year period, the Committee shall file a report with the Commission and copies*

mailed to all customers of the Applicant. Such report shall describe the accuracy and dependability of the meters, based on the five-meter trial. That sixty (60) days after the filing of the report with the Commission, Nevada Geothermal will submit a report and proposal to the Commission as to what, if any, changes in billing method and rates should be implemented.

The ad hoc committee sought five volunteers based on the following criteria:

1. An accessible mechanical room;
2. The hot water supply and return enter and leave the mechanical room; and
3. An agreeable, year-round tenant.

EQUIPMENT SPECIFICATIONS

Btu meters were obtained from the following manufacturers:

Hersey Measurement Co. 150 Venture Avenue PO Box 4585 Spartanburg, SC 29305	Model No. 7431 B Btu Meter, battery operated, includes two RTD sensors: two wire, Pt-500 (3 5/16 in. length), and turbine flow meter Model No. 413, hot (1 ½ in. diameter)
ONICON Inc. Sales & Manufacturing 2161 Logan Street Clearwater, FL 33765	System-1 Btu meter, includes temperature sensors, 115 vac. F110 single turbine flow meter with frequency output

INSTALLATION

As of February 10, 1999, all Btu meters were installed in five residences serviced by NGUC. The table below lists information related to the volunteers; all homes were plumbed for space heat and hot water.

The five meters were read on a monthly basis. The ONICON meters recorded only total Btu; while, the Hersey meters recorded Btu, water flow, temperature in and out, and battery life. Readings were taken by phone, fax and by site visits.

Table 4. Btu Meter Installation Specifications

Name	Sq Ft Meter	Installed		Circ. Pump	Other
SP	4,252	Hersey	11/9/98	Yes	No
MC	2,600	Onicon	12/8/98	Yes	No
NB	4,647	Hersey	1/11/99	Yes	No
PG	2,176	Onicon	1/18/99	No	No
SM	3,600	Hersey	2/10/99	Yes	Pool

SPECIFIC METER NOTES

All meters operated as specified for the duration of the test. There were no problems or adjustments required for the NB, MC or SP meters. The monthly data for the PG meter were not used in this calculation. The readings were consistently low all year. The meter was reinspected and found to be working properly. The reason for the low meter readings has been attributed to the fact that there is no water circulation pump in this heating system. The heating system worked, but the heat consumption did not register on the meter, due to low flow.

The data for the SM meter included swimming pool energy consumption during the summer months (May - September). These data were adjusted by using a multiplier of 0.786 of the NB meter readings, an empirically derived number. In addition, the ratio between the sq ft of these homes is 0.777. The resulting adjustment shows the pool and house as separate energy items, and provides a method to evaluate the pool heating requirements.

RESULTS

Figure 2 shows the results of the monthly monitoring program in therms for the five participants. The shape is indicative of the seasonal heating curve, shown in Figure 3 as the Degree Day Curve for the Reno area. Data for this curve were obtained from the Desert Research Institute, NOAA Climate Website (http://nimbo.wrh.noaa.gov/Reno/).

Natural gas utilization by residents in Warren and Manzanita Estates are shown in Figure 4. These data were requested from the 39 homeowners who used natural gas in the Warren/Manzanita Estates. Of the 39 contacted, 12 responded, only 6 provided useful data.

ENERGY CONSUMPTION CALCULATIONS

Space and Water Heating

Figure 5 shows the relationship between energy use and sq ft of living space. The flat-rate billing model currently used by Nevada Geothermal Utility Company (based on sq ft of living space) is depicted as the thin, solid black line. The present pricing model for space and water heating is $0.15/ft^2 for the first 3,500 ft^2 and $0.04 for additional space. These data are converted to therms (1 natural gas therm costs $0.565, slope is .2654).

The annual therms for the four geothermal Btu meters, plotted as solid circles, provide an average measured geothermal energy consumption equal to 0.40 therms/ft^2, or about $0.22/ft^2 annually at present natural gas prices. The annual therms for the six natural gas meters, plotted as solid diamonds, provide an average measured natural gas use equal to 0.46 therms/ft^2, or about $0.26/ft^2 annually. The pricing model includes a discount for sq ft of living space in excess of 3,500 sq ft. Both the Btu meter and natural gas data show a constant linear relationship for energy consumption in excess of 3,500 ft^2. There appears to be no indication that a price break at 3,500 ft^2 supported by these data. Table 5 lists the comparative costs for space and water heating for a typical 3,500 sq ft house. The cost is derived by multiplying therms by $0.565.

Swimming Pool

As described above, the heat budget for the SM swimming pool was extracted from the overall SM monthly

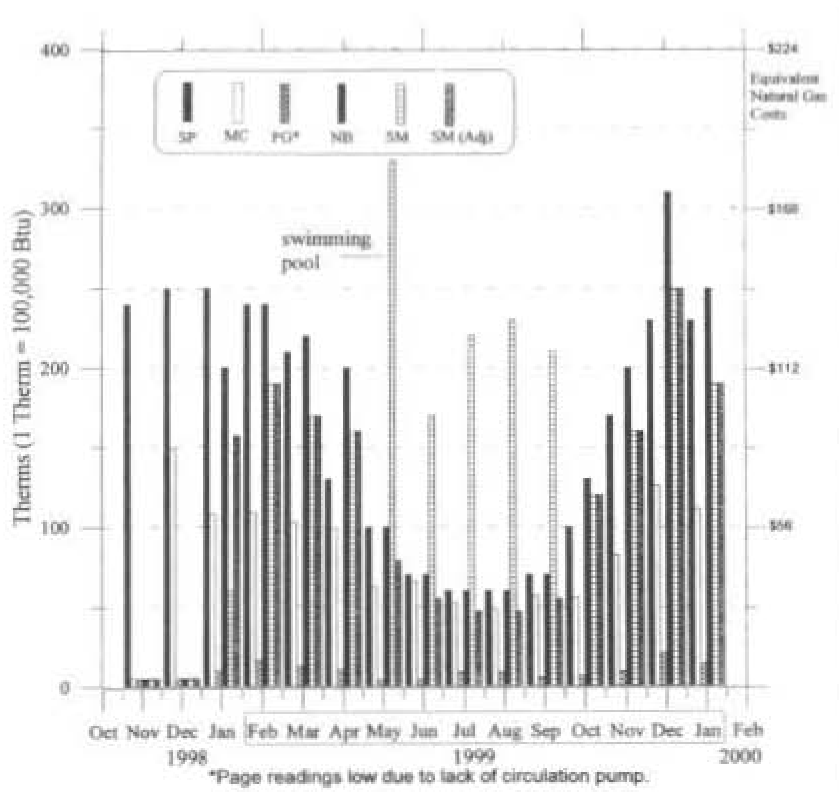


Figure 2. Results of the Btu meter test program as mandated by the Nevada PUC, 1998-2000.

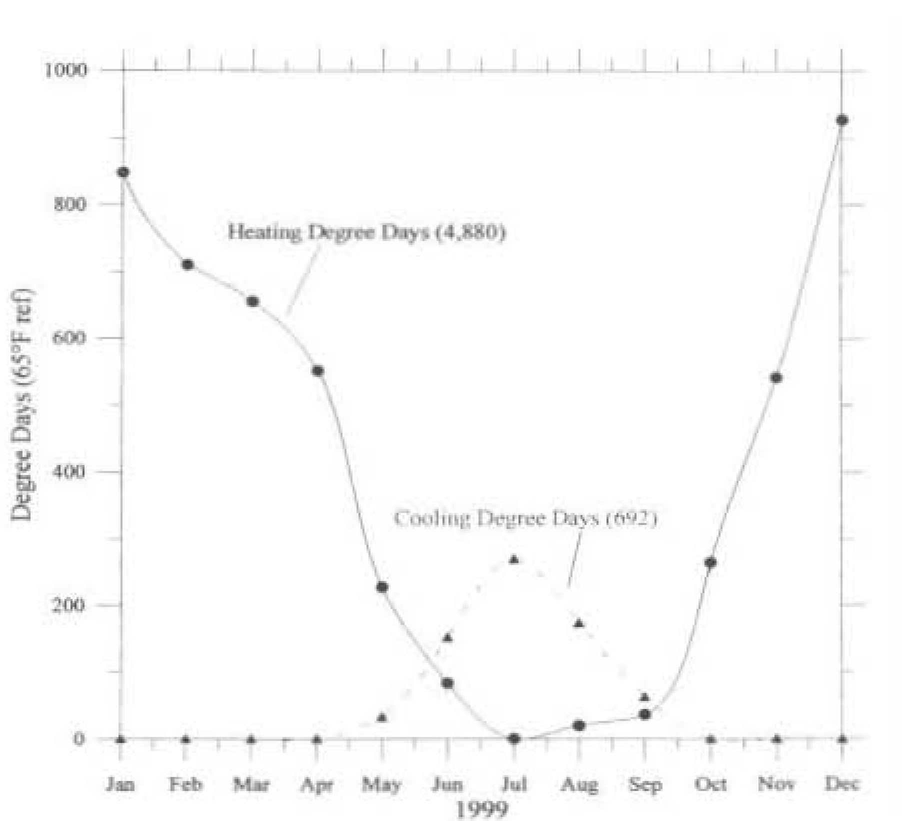


Figure 3. Degree day data, heating and cooling for Reno. Reference temperature is 65ºF (data from DRI).

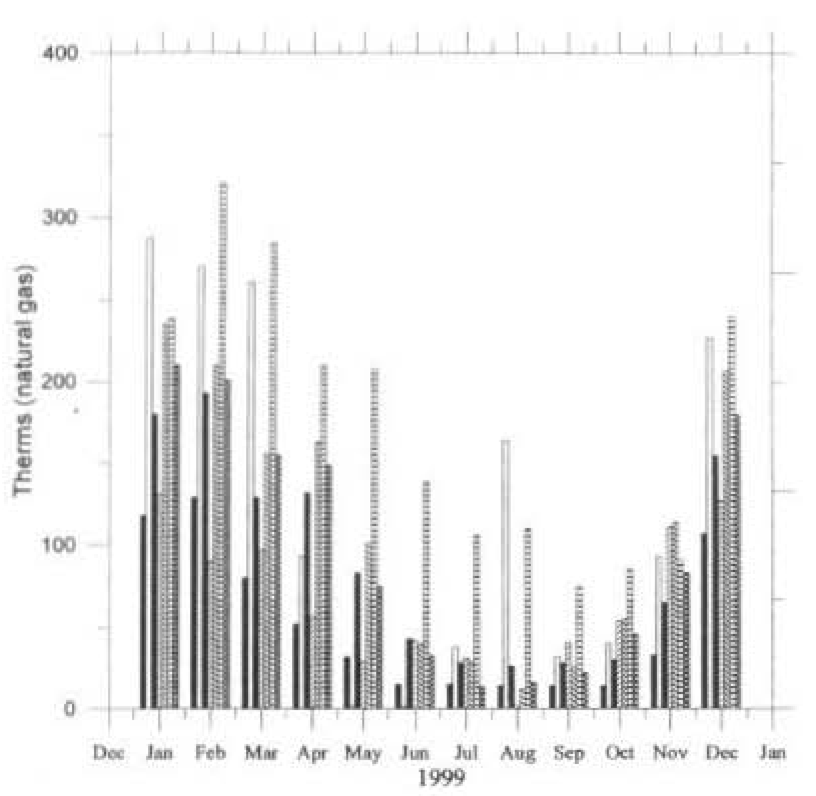


Figure 4. Energy consumption in natural gas-heated homes in Warren and Manzanita Estates, 1999 data.

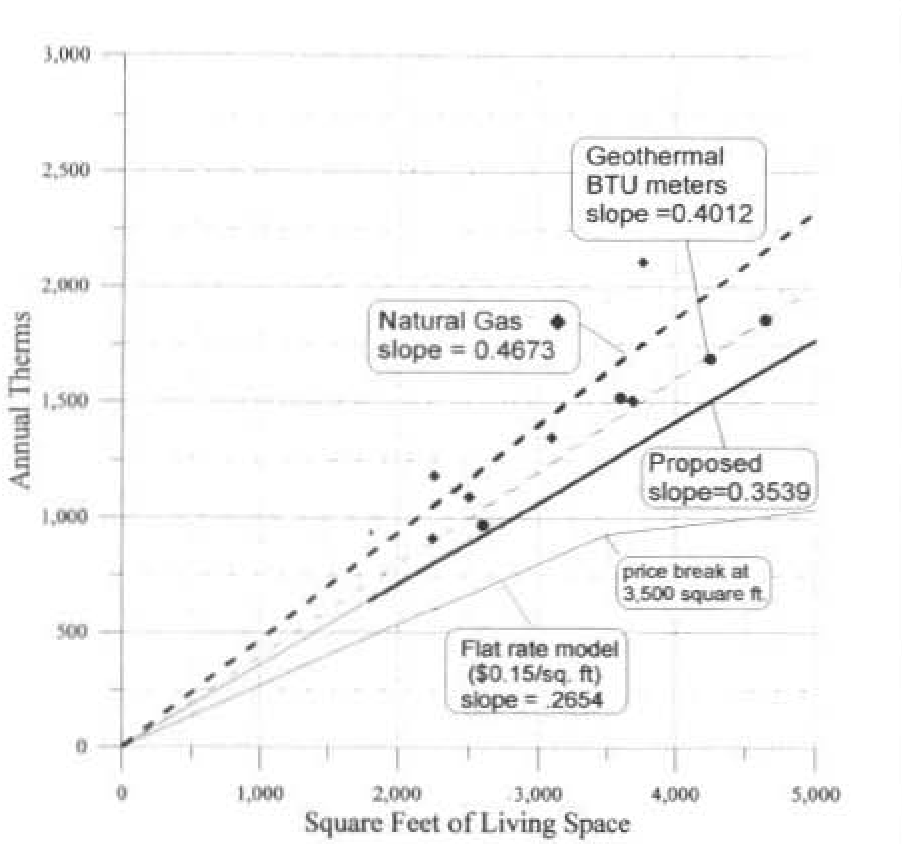


Figure 5. Relationship between sq ft of living space and annual therms used for space and water heating. The proposed rate of 0.3539 is equivalent to approximately 20 cents per sq ft at present natural gas prices.

Table 5. Comparison of Heating Costs

Item	Slope*	Times Ft^2	Equal Therms	Cost
Natural gas meter	.4614	X 3,500	1615	$912
Geothermal Btu meter	.4012	X 3,500	1404	$793
Flat-Rate billing	.2654	X 3,500	929	$525

* From Figure 5

energy budget by subtracting the equivalent of 0.786 of the NB monthly consumption. The results of this calculation is an estimate of the stand-alone energy budget for the SM swimming pool. The swimming pool operated for five months and consumed a total of 877 therms, or about 175 therms per month. At the present cost of natural gas, that is equivalent to about $98/month for five months, $495 per year, or about $41/month for 12 months. Presently, the flat-rate charge is $13/month.

RECOMMENDATIONS

Geothermal energy is an effective, clean, and efficient method to supply heat energy to residences in Warren and Manzanita Estates. It is renewable, non-polluting, but it is not free; appropriate fees must be established that satisfy both the developer and consumer. The developer is responsible for initial exploration, drilling, design and construction of the district heating system, as well as its long-term operation, regulatory permitting, accounting and maintenance. The consumer must install specialized heat exchange equipment in order to take advantage of the above listed benefits. There are no longer any federal or state programs that reward the risk of either development or use of geothermal energy. The financial burden is borne by both the developer and the consumer. The benefit of using non-polluting, renewable energy is, however, shared with society as a whole.

The present price model for geothermal heating offered by Nevada Geothermal Utility Company is fixed by the PUC until July 2001. On the basis of the data collected during this study, justifiable changes in the flat-rate billing model will be presented to the PUC (Table 6).

Table 6. 2001 Proposed Billing Provisions

Item	Rate	Example Monthly Costs
Monthly service charge	$3.25 per household	$03.25
Space/domestic water heating	0.3539 therms/ft^2/year	$58.32
Space heating only	0.3067 therms/ft^2/year	$50.54
Swimming pool	140 therms/mo (June-Sept)	$79.10
Spa/jacuzzi	20 therms/mo	$11.30
Driveway deicing	100 therms/mo (Nov-Apr)	$56.50

Those changes are also based on the following observations:

1. Geothermal Btu meters installed in a weatherproof and waterproof environment, provide the best method of energy accounting for individual homes.

2. Installation of Btu meters within homes in the Warren and Manzanita Estates should be considered on a site-by-site basis. For example, many of the newer homes can be retrofit with Btu meters relatively quickly. The costs would be about $1,200 for the meter and $500 to $1000 for installation. The existing plumbing in some of the older homes may be cost prohibitive if the retrofit includes digging up existing landscaping, sidewalks and driveways. Both the Hersey and Onicon meters work effectively, but the Hersey meter provides much more information.

3. The flat-rate billing that is presently based on cost per sq ft should be based on therms per sq ft of living space to maintain a consistent accounting system as the price of natural gas varies over time.

4. Billing should be monthly, based on the price of natural gas for that month.

5. The flat rate should be linear for homes of all sizes. This eliminates the price break at 3,500 ft, which is not supported by the data collected in this study.

6. Swimming pools will be billed at an estimated 140 therms per month for the five months from May through September (data based on a single pool).

7. The billing for spas and sidewalks deicing systems were slightly increased when they were converted to estimated therms.

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MINING ECONOMIC BENEFITS FROM GEOTHERMAL BRINE

CalEnergy Mineral Recovery Project Creates Jobs and Increases Revenues from Geothermal Power Operations in California's Imperial Valley

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On January 31, 1999, CalEnergy Operating Corp. (CalEnergy) unveiled a $400 million expansion of their geothermal power complex on the shores of the Salton Sea in southern California's Imperial Valley. The new construction includes nearly 60 megawatts (MW) of new geothermal electrical capacity, and a unique project to "mine" commercial-grade zinc from geothermal brine produced for power generation. CalEnergy is a subsidiary of Mid-American Energy Holdings Co. (Des Moines, IA).

CalEnergy currently operates eight geothermal power plants with a capacity of 288 net MW at the Salton Sea. Construction underway for completion by late-July includes Unit 5, a 49-MW facility that will utilize high-temperature waste brine from four of the company's existing power plants to fuel the minerals recovery project and produce electricity. In addition, a 10-MW turbine will be on-line by mid-March to upgrade power production at CalEnergy's Del Ranch and Vulcan power plants. Construction companies heading up the projects include Stone & Webster Engineering Corp. (Denver, CO) and Kvaener U.S., Inc. (San Ramon, CA), which are subcontracting work to local firms.

Funded entirely by CalEnergy, the $200-million mineral recovery project will produce 30,000 metric tonnes of 99.99-percent pure zinc annually for Cominco Ltd. under a contract signed last September. The facility will be the lowest cost producer of zinc in the world, and the first and only operation specifically designed to harvest minerals from high-temperature geothermal brine. "The minerals recovery project will make the geothermal energy we produce more cost effective and tap valuable minerals from the brine we bring to the surface for power production," says CalEnergy Vice-President of Operations Jim Turner.

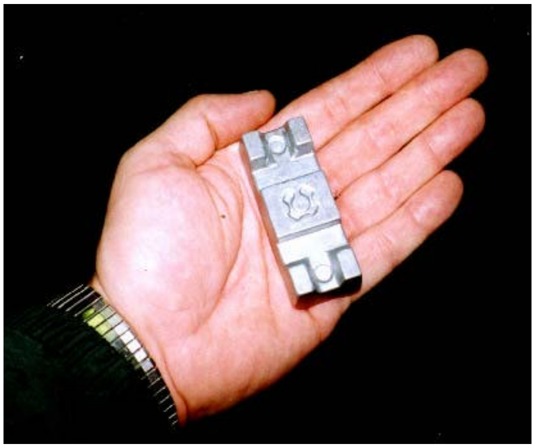
Thought a number of companies have sought to recover valuable minerals from Salton Sea geothermal brines over the years, it wasn't until 1997 that CalEnergy put its ideas to work. For a 10-month period extending into 1998, CalEnergy proved those concepts with a small demonstration plant at its Elmore power plant that successfully produced 41,000 lbs. of high-grade zinc. Under the leadership of Turner and CalEnergy Chief Technical Officer John Featherstone, company engineers scaled up the process to the full-sized facility now under construction.

Unlike CalEnergy's other power plants at the Salton Sea, Units 1, 2, 3 and 4 apply a pH modification process to the 500ºF (260ºC) geothermal brine rising to the wellhead from the geothermal reservoir. By increasing the brine's acidity by about half of a pH unit (to a value between 5.0 and 4.5), the process prevents silica precipitation and scaling during power production, but leaves behind spent fluid for injection at a temperature of 360ºF (182ºC). "We were basically leaving Btus on the table," says Turner. In addition, he explains, "The brine temperature from Units 1, 2, 3 and 4 is too high after power production for our zinc extraction ion exchange process."

From left to right: CalEnergy Vice President of Operations Jim Turner, Mid-American Vice President of Legislative and Regulatory Affairs Jonathan Weisgall, California Energy Commission Vice Chairman David Rohy, and CalEnergy Chief Technical Officer John Featherstone discuss the company's $400-million expansion project, which includes the 49-megawatt Unit 5 geothermal power plant under construction in the background.

The solution was to build the $150-million, 49-MW Unit 5, scheduled to come on-line concurrently with CalEnergy's zinc recovery facility. Unit 5 will use spent brine from Salton Sea Units 1, 2, 3 and 4 to produce electricity for the minerals recovery operation, which will tap about 20 MW of the power plant's production. Excess power from Unit 5 will be sold into the California deregulated electricity market.

"To tap the remaining energy potential of brine from Units 1, 2, 3 and 4, the new power plant will use low-pressure technology that employs multiple turbine inlets," Turner explains. After electricity is produced, brine temperature for use in the zinc recovery ion exchange facility falls to the desired temperature of less than 240ºF (116ºC). "We get the last squeal out of the pig for power production from our other power plants, and create brine that is ready for mineral extraction at the same time," says Turner.



A miniature zinc ingot from the CalEnergy minerals recovery process using Salton Sea geothermal brine. Ingots of the same shape weighing 2,400 lbs. will be shipped to Cominco Ltd. under a contract with CalEnergy signed last September.

The minerals recovery facility uses a combination of already existing technologies that were modified for the task. Besides ion exchange, the facility will employ solvent extraction and "electrowinning" to extract zinc from the spent brine from all of CalEnergy's Salton Sea geothermal power plants, supplied at a flow rate of 20 million lbs/hr. After the metal is extracted, the remaining brine will be injected back into the geothermal reservoir underlying the area.

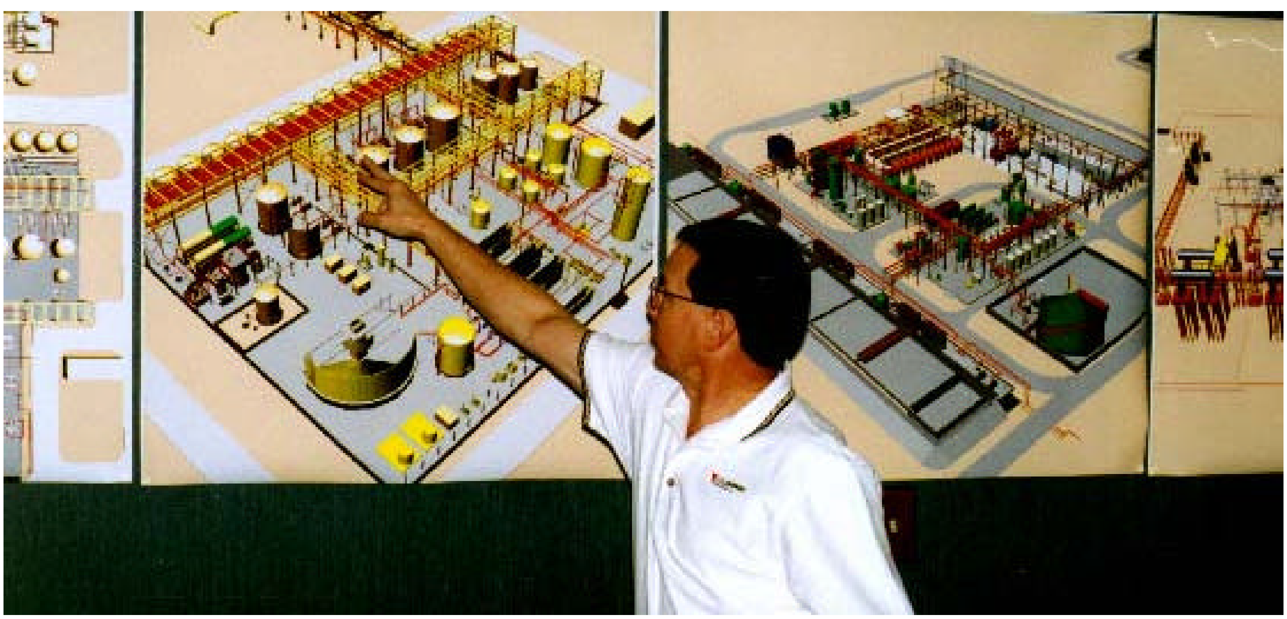
"The brine first passes through an ion exchange resin similar to that used in water softening equipment–but modified with organic molecules that are very specific to zinc under the right conditions," Turner explains. After being pumped to a second facility, a solvent extraction process then transforms 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 metal builds up to more than 1/4" in thickness on the cathodes in 24 hours, when it is removed. The metal will then be melted into 2,400 lb. ingots for sale to Cominco. "The end product is SHG, or special high-grade zinc, better than 99.99-percent pure and ready for manufacturing with no further processing necessary," Turner continues.

Even with the success of their minerals recovery project, CalEnergy continues to seek other potentially profitable products from its geothermal brine at the Salton Sea. These include manganese, lithium, boron, and small amounts of precious metals. But the most voluminous mineral contained in the brine is silica, which is produced by the company's Elmore, Del Ranch, Leathers and Vulcan power plants (without pH modification technology) at a rate of 100 tons per year.

In a new research project, the company is seeking economical methods of transforming precipitated silica from its power operations into a saleable product, and removal of manganese from brine already processed for zinc. "Once you have the zinc out of the way, it is much easier to get at the manganese," says Turner. "We're looking at several ways to do it, including ion exchange (with different organic ingredients than those used to extract zinc), solvent extraction, or a combination of the two methods like we use for zinc."

To assist CalEnergy develop methods to recover manganese, purify waste silica into a saleable product, and build a pilot facility, the California Energy Commission (CEC) awarded the company a $904,340-matching grant last summer from the agency's Geothermal Resources Development Account. If successful, the CEC-supported pilot



CalEnergy Vice President of Operations Jim Turner describes the company's minerals recovery facilities, which include an ion exchange and solvent extraction plant (right), and an electrowinning facility (left).

project will help reduce waste, conserve landfill space, and reduce operation and maintenance costs while extracting additional products for market.

"By perfecting ways to extract valuable minerals in the geothermal process, we help to bring down the cost of geothermal power and make it more attractive," said CEC Vice Chairman David Rohy at a press conference held at CalEnergy's Salton Sea project on January 31, 1999. "As the Energy Commission celebrates its 25th anniversary, we are proud to continue our long history of support for the geothermal industry."

That support is appreciated by CalEnergy. "Without the involvement of the CEC, and the positive signal it provides from the State of California, this kind of project would be much more difficult to accomplish," said Mid-American Vice President for Legislative and Regulatory Affairs Jonathan Weigall. "The dollars are important, but even more important is that the state promotes renewable energy production and its benefits for the economies of California and Imperial County."

Indeed, CalEnergy's Salton Sea expansion has created an average 700 construction jobs over the life of the project, and will provide 48 full-time jobs, bringing the company's total number of employees to about 220. For its part, the California Employment Training Panel (ETP) granted CalEnergy a $167,580 contract in January for hiring and training 28 new employees, and to retain 24 current employees for the zinc recovery facility,

Imperial County officials hope that CalEnergy's expansion activities could mean even more jobs–and business development–for the area. If Turner has his way, they won't be disappointed. "We've got a great team here, and I have every confidence that when they are finally perfected, our silica and manganese extraction methods will add another 50 to 60 full-time jobs to the Imperial Valley economy."