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Geothermics as an Option of Alternative Source of Energy in Baja California, México

Margarito Quintero Núñez*, Jesús García Molina* and Juan de Dios Ocampo Diaz**

*Instituto de Ingeniería **Facultad de Ingeniería Mexicali, UABC

Email maquinu@iing.mxl.uabc.mx

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ABSTRACT

México is one of the countries endowed with very important geothermal reserves (probable reserves 4,600 MW and posible reserves 6,000 MW). With 45 years of development in this field, México has made great progress in the exploitation of this resource in the generation of electric energy, and in a very incipient way, in industrial uses. These developments have been supported by a goverment policy to diversify its energy sources, in order to reduce the country's dependancy on hydrocarbons and at the same time, cope with the demands of the population of a developing country. The contribution of geothermal to the national energy scheme is less than 1 percent. Nevertheless, it has proved to be an excellent integrative energy source to use with other known resources; its development has therefore been encouraged, in particular during the oil crisis. The Comision Federal de Electricidad (CFE), (Federal Electricity Bureau), based on the Gerencia de Proyectos Geotermoelectricos (GPG), (Geothermoelectric Project Management), is responsible for exploration and exploitation activities in the mexican geothermal program. This institution has carried out an evaluation of geothermal characteristics of the country, identifying about 1300 thermal systems; they were grouped into 515 geothermal areas, 30 of which have been classified as having the greatest potential for exploitation. Cerro Prieto, Baja California; Los Azúfres, Michoacán; Los Humeros, Puebla; Tres Vírgenes, Baja California Sur; and La Primavera, Jalisco, are the most important geothermal fields in México under production or on the brink of exploitation. Cerro Prieto is the most important prospect in México. Some wells were drilled at the end of the 60s; however, it wasn't until April 1973 that two units, 37.5 MW each, started operating. At the moment, 720 MWe has been installed. This paper describes the actual use of geothermal energy in the state of Baja California, its development, its nature as a clean source of energy, its non electric potential, and its byproducts; a comparison is also made with other energy sources in the state, such as natural gas, its contribution to the reduction of green house gases and plans for the inmediate future are discussed.

1. INTRODUCTION

The knowledge of the existence of thermal areas, at least in the state of Baja California, began in the 16th century when the spanish Conquistadores explored the area and unveiled them to the world in their chronicles. The thermal areas were described by Pedro de Castaneda in his detailed reference to the expedition by Melchor Diaz (Ives, 1973) in 1540. Arriving at Cerro Prieto, in the Mexicali, "as they were walking, they came across some ardent ash banks that nobody walked on because they did not want to fall through and drown in the subsurface water. The land they found trembled as an iceberg and appeared as though there were several lakes beneath it. It seemed marvelous to see the ash (mud) boiling in some parts, that looked like an infernal substance.

In the same valley the relationship of geothermal phenomena and seismology was described in a chronicle taken from the diary of Lieutenant Sweeney, officer in the American army, stationed in military service at Fort Yuma. He describers an earthquake that ocurred at midday in november 1852, causing the land to open up in all directions. This small narrative fragment gives an indication of the thermal presence in the area of Cerro Prieto, although the indication of seismicity is not used as a general rule to indicate the geothermal potential of an area. The large number of thermal manifestions identified in the center of the country and in the extreme north of the Peninsula led to the start o research in the 1950s to investigate the geothermal potential for power generation. With very little experience but great optimism, the people involved in these first studies and drillings carried out at the end of the 50s were the pioneers in geothermal development at Ixtlan de los Hervores, Michoacán; Pathe, Hidalgo and Cerro Prieto, Baja California.

Progress in the utilization of alternative sources of energy made it possible for CFE, through La Comision Nacional de Energia Geotérmica (CNEG) (Geothermal Energy National Commission), to install the first geothermal power plant in Latin America in Pathe, Hidalgo on 24 January 1952, with 3.5 kW atmospheric discharge and a proved capacity of 600 W. This was a triumph in the utilization of this kind of energy, which was different from the conventional projects that the Mexican personnel new so well. This success proved their skills and paved the way for the integration and training of the scientists and technicians who would be responsible for the subsequent development of geothermal energy in Mexico.

Once the viability of the Pathe plant was established, an inventory was made of the potential resources of all Mexico. The most outstanding of all these were in the state of Baja California, in a zone beneath uncultivated land and swamps. It was frequented, especially in the winter, by people keen to watch natural steam emerge from the boiling swamps of water and mud in the area known as Laguna

Vulcano; the activity has decreased there because of the flooding of the nearby lagoon and its residual brine concentration. Exploration at Cerro Prieto indicated that the potential of the geothermal field was such as to justify the instalation of a large power plant; there were indeed more than 100 sites where optimistic results were expected from drilling. It appeared that several large–scale plants were going to be needed. A group of Mexican technicians were therefore sent over to Italy, to study developments in the geothermal field at Larderello, and to Wairakei in New Zealand (of particular interest because of its similarity to the geothermal phenomena in México). This group comprised of the pioneers of geothermal energy in Mexico: Jorge Guiza, Hector Alonso, Guillermo Fernández de la Garza, and last but not least Luis de Anda who, in the previous years had been the most outspoken promoter of geothermal resources as a source of energy.

The well tests and other studies carried out at Cerro Prieto in 1969, indicated that the field could feed a total capacity of more than 600 MWe. It was initially decided to install a plant with two separate 37.5 MWe units. The development program initiated at that time has now reached a total of 720 MWe, with the installation of four plants at Cerro Prieto; this makes it the most important field in Latin America and the fourth biggest (Huttrer, 2001).

An inventory of the thermal areas undertaken between 1961 and 1965 in the central part of the country resulted in the identification of Los Azufres Michoacán; La primavera, Jalisco and Los Humeros, Puebla. Although some studies were conducted in those areas in the 60s and early 70s, it was until 1975, with the experience gained at Cerro Prieto and other parts of the world, that systematic superficial exploration began at Los Azufres, and in 1978, at Los Humeros and La Primavera. The favorable results obtained at that time have indicated the existence of at least three gothermal fields in México, including Cerro Prieto, Baja California; and La Primavera, Jalisco. The latter has not been exploited because of ecological worries on the part of the neighbouring community. Years later, in 1990, exploration also began at Tres Vírgenes, Baja California Sur, which is now under exploitation .

2.ACTUAL GEOTHERMAL POTENTIAL

México can count on a proven capacity of 970 MWe (Mercado, 1985a; Quijano León and Gutierrez-Negrin, 2000) from its high and medium entalphy reservoirs (150-350°C) considering only the geothermal fields of Cerro Prieto, Baja California; Los Azufres, Michoacán; Los Humeros, Puebla; La Primavera, Jalisco; and Tres Vírgenes, Baja California Sur. Probable reserves of 4,600 MWe have been calculated to exist in geothermal zones investigated by geological, geophysical and/or geochemical studies to determine underground temperatures. Possible reserves of 6,000 MWe have been estimated from estudies of surface hidrotermal manifestations or geological surveys. The total high- and medium- enthalpy hydrothermal resources in the Mexican Republic is 10,500 MWe.

Other geothermal systems include low enthalpy systems (temperature lower than 150 °C), geopressurized systems (temperatures of 160 °C, high content of methane and high presure), Hot Dry Rock systems, melted rock (magma energy found in the active volcanoes of the neovolcanic axis), and marine systems. The low entalphy systems have been evaluated as having a potential of roughly 47,000 MWe. In the case of the geopressurized systems, evaluations have only been carried out (Grijalva, 1986) in the northwest area of the Sea of Cortez, a place known as the Wagner Fossa, resulting in a richer source of energy 1000 higher than the estimates for Cerro Prieto. In other words, exploitation of these energy resources could supply México with 20 times the current total energy requirements of the country. This prediction is based on the amount of helium isotope measured, which is detected when there is water at 600 °C or higher. At Punta Banda, Ensenada, Baja California, 100 m from the coast and at a depth of 25 m, several marine thermal manifestations have been detected. These manifestations are formed by discharges of hot water that escape through fissures associated with an important regional fault. The measured discharge temperatures are between 90 and 120 °C. The geothermal area could be accesible by installing platforms near the coast, similar to tose used in the oil industry in the Gulf of Mexico (Suárez-Bosche et al., 2000). Recently evidence was found (Beltrán, 1999) of a zone of low-enthalpy geothermal fluids at Punta Banda, Ensenada, Baja California. The other systems have not been evaluated but are also considered to have great potential, either for power generation or use in industry or agriculture.

2.1 Nonelectric Uses of Geothermal Resources

The diverse possible uses of geothermal resources, apart from power generation, have been amply demostrated throughout the world and are well summarized in the Lindal diagram (Lindal, 1983). In México they are classified by the temperature range of the geothermal fluid at each specific site and by the local industrial needs.

The possibility of exploiting geothermal fluids for direct uses is well documented in the heat processing literature. This function, however, is not included in the legislation of CFE (Alonso, 1988). In México, it is the duty of private industry and governmental agencies to promote exploitation of this resource, with the permission of CFE and Secretaria de Agricultura y Pesca (Agriculture and Fisheries Secretary).

At Cerro Prieto the geothermal water (717 t/hr in 1999), which is reinjected (Quijano and Gutierrez-Negrin, 2000) after several stages of flashing to produce vapor, contains dissolved salts; among these is potassium chloride, which is used as a fertilizer (Alonso, 1988). Once it was shown that it could be economically and technically exploited, it was decided in 1980 to comercially produce this product, with a goal of 80,000 tons of the product per year, starting in 1983. The process developed by the Instituto de Investigaciones Electricas (IIE) (Electrical Research Institute) was initially modified by Fertilizantes Mexicanos (Ferti-Mex), a government-owned company. The process consists of the modification and crystalization of the brine in solar ponds, which is then sent to a plant for fractioned crystallization, where the sodium chloride and calcium chloride are separated as subproducts. Due to economic restraints, Fertimex was unable to complete the project so that only the concentration pond has been constructed. Since then, in different periods, some private companies have shown interest in the project but none has come to fruition.

Apart from exploiting the salts dissolved in the geothermal brine, a feasibility study has been made of applying agricultural techniques such as hydroponics to food production, utilizing the water condensate from the power plant. Low-pressure vapor was going to be available to create macroclimates and heat barns, to increase the productivity of crops and milk, respectively.

Aquaculture has also been considered, again using the condensate from geothermal vapor to exploit high contents of nutrients. It is planned to utilize the various geothermal residual fluids from Cerro Prieto power plants in several applications. Nineteen years ago, the goverment of Baja California, in a joint adventure with Agroacuiva (private company) and Nacional Financiera S.A. (NaFinSA), (a goverment-owned banking institution) (National Financing Company), set up a company to contruct what could be called "The Geothermopolis of Baja California"; the Geothermopolis would bring together various geothermal enterprises: agriculture, aviculture, aquaculture, cattle rearing and industrial installations, of all which would use low enthalpy fluids that would otherwise be dispose of at Cerro Prieto; they could also use fluids from other low-temperature geothermal fields such as Tulecheck, Airport and Laguna Salada, which are located in the periphery of the Mexicali city.

At that time, several pilot installations had been already constructed (Mercado and Bermejo, 1985b) for fish and shellfish farming, animal breeding, and incubators heating. There was also an experimental absorption refrigeration system (Best et al, 1987) that utilized geothermal vapor as a source of heat with a 10.5 kW capacity. This refrigeration system was operated by research staff from IIE (Cuernavaca, Morelos and Cerro Prieto Baja California). It would appear it has been abandoned.

3-POWER GENERATION UPDATE (2004)

CFE is an institution of the federal goverment created to generate and distribute electric energy in México (Constitución Política de los Estados Unidos Mexicanos, 1988). In 1982 CFE created La Gerencia de Proyectos Geotermolectricos (GPG) (Management of Geothermoelectrical Projects) with the specific function of coordinating all geothermal-related activities in Mexico. CFE was thus responsible for Mexico becoming the third larger producer worldwide 959.50 MWe installed (CFE, 2004), after United States (2228 MWe), and Philippines (1909

MWe). The following is a brief resume of the geothermal field under current exploitation in México for the generation of electricity, in the valley of Mexicali, Baja California. Cerro Prieto (Baja California) is the most important development in México; it is located on the alluvial surface of the Mexicali Valley (115.16 longitud West and 32.25 latitude North); tectonically it is located at the boundary of the Pacific and American tectonic plates and near the San Andreas Fault. The plain is a delta and the geological section is made up of unconsolidated clays, sand , and gravel, which rest on sedimentary rocks of sandsdone, lutites and limonites.

Some of the wells in the field were drilled at the end of the 60s; however, it wasn't until April 1973 that the two 37.5 MWe units, started operating. There are now, 720 MWe capacity installed, distributed over four plants: Cerro Prieto I-IV, of 180, 220, 220 and 100 Mwe, respectively. The first section has four generetors, 37.5 MWe each, which operate on a single- flash system (1-flash), and one of 30 MWe, which operates on medium-and low-presure steam (dual-flash) obtained from the residual water after single- flash; Cerro oprieto II and III have four turbogenerators, 110 MWe each, and operate on médium-and-high presure steam (dual-flash). Cerro Prieto IV is a 100 MWe plant with four turbogenerators, 25 MWe each, and operate on high pressure steam (1-flash). From a total of 268 wells drilled (total of 596,380 m) at Cerro Prieto, there are 126 under production that were operated in 1999; their depths vary from 600 (in the shallow wells) down to 3,500 m (the deepest). Out of these wells , 31 were operated by the Latina S.A., a private company, which provided 30% of the steam utilized. This company financed the drilling of 12 out of 42 wells drilled in the period between 1995-1999. According to Alonso (1988) the Cerro Prieto geothermal reservoir has an estimated capacity of 1,200 MWe, with 840 MWe of proven capacity. Other geothermal fields such as Los Azufres (90 MWe), Los Humeros (42 MWe), Tres Vírgenes (10 MWe) y La Primavera (no explotation), can be studied in the literature (Hiriart and Gutiérrez, 1997; Cadena and De la Torre, 1998; Huttrer, 2001).

Table 1. Energy Balance in Mexico (2001)

Energy Source	Production (petajoules)	% total
Coal	239.1	2.4
Hydrocarbons	8,700.9	89.4
Crude oil	6,811.7	70.0
Condensate	137.7	1.4
Non associated gas	430.2	4.4
Associated gas	1,321.3	13.6
Electricity	445.7	4.6
Nuclear energy	96.7	1.0
Hydroenergy	291.8	3.0
Geoenergy	57.1	0.6
Eolic energy	0.1	n.s.*
Biomass	348.8	3.6
Sugar cane bagasse	93.0	1.0
Fire-wood	255.8	2.6
Total	9,734.5	100.00

* Not significant

4.COMPARISON OF GEOTHERMAL WITH OTHER SOURCES OF ENERGY

So far geothermal energy, along with other alternative sources of energy such as solar, wind, marine, biomass, etc. has contributed only marginally, to the energy balance of Mexico, as can be observed in Table 1, which shows the national energy balance for 2001 (Sener, 2004). At a state level (CFE, 1999) the generation of electricity from geothermal resources represented 65% of the total energy produced in Baja California, equivalent of 9.6 millions barrels of oil in a conventional power plant. This figure increased to 76% with the expansion of the Cerro Prieto geothermoelectric power plant in 2000, through a private contract of the construction, lease and transfer type.

The Secretary of Energy (SEner, 1999) encouraged the Comisión Nacional de Ahorro de Energía (CONAE) (National Energy Savings Commision) to promote the development of renewable energies in Mexico in order to reduce its dependency on hydrocarbons. In 1966, CONAE, together with La Asociación Nacional de Energía Solar (ANES), (Solar Energy National Association) organized an forum to discuss the actions needed to promote these sources of energy, which resulted in the creation of El Consejo Consultivo para el Fomento de las Energias Renovables (COFER) (Advisory Council for the Promotion of the Renewable Energies). The latter is a collegiate forum integrated by representatives from the industry, commerce, academy, government and the development banks. The aim of COFER is to promote the use of renewable sources of energy in Mexico within the market framework. It also functions as a consultant body for the identification of projects and the design and development of programs and policy related to explotation of these resources, including small hydro, solar, biomass, and geothermal. Sener (1998) estimates that by 2008 around 559 MWe will be installed in such systems, producing approximately 1,836 GWh.

5.CONCLUSIONS

Geothermal energy has been gaining increasing importance in the world, and in Mexico and Baja California in particular, both as regards electricity generation, which is very evident already, and non-electric applications, which seems to have a rosy future. The following observations can be made:

1. The resources in Mexico are used mainly for the generation of electricity. Direct uses are confined for the most part to theraupeutic bathing, also known as crenotherapy. The most important of these applications are in Los Azufres and Ixtlan de los Hervores (Michoacan), Ixtapan de la Sal (Estado de México) and Los Humeros (Puebla), among others. At Cerro Prieto, thermal baths were adopted by the local indigenous population and by some foreigners. This practiced ended after the power plant began operations. For that reason, exploitation of geothermal resources in direct uses should be based on the accumulated experience of other countries, as well as on technology developed locally.

2. Explotation of the geothermal fluid in direct uses should be implemented on a sustainable basis. For example, th residual brine at Cerro Prieto could be utilized through binary cycle systems; for the extraction of potasium chloride; for silica recovery; recent developments in the use of heat pumps open up a new dimension for the utilization of heat from low-temperature fluids such as exist in the areas of Aeropuerto, Tulecheck and Laguna salada in the Mexicali Valley.

3. Geothermal energy is known to be one of the cleanest energies in the world as it can be exploited without affecting the environment. This has been demostrated in places such as Japan, Italy, the European Union in general, and New Zeland, to name but a few. Unfortunately this has not been the case in México, because of the discharge of non-condesables such as CO_2, H_2S, and NH_3, as well as the residual brine, into the envionment. In the case of Cerro Prieto part of the residual brine is injected and the rest is sent to a natural evaporation pond with an surface area of 18.8 km2 that pollutes the soil and, potentially, the superficial aquifer (Ramirez, 1997).

4. The controversy as to whether geothermal energy is actually a renewable source of energy could be solved if we consider that where extraction of the fluid excedes recharge, it may be considered a non-renewable resource. This implies that we must know sustainably this resource is being exploited.

5. The future development of geothermal energy will depend on the availability of the resource, oil prices, and the decision of stakeholders; in some places there has ben opposition to its development for reasons of natural areas conservation, as in the case of Primavera (Jalisco); although there are geothermal wells, they are not been used because of worries that pollution will affect the Primavera forest.

6. The prospects for developing geothermal in the 21st century seem fairly good. There is a wide interest at an international level in reducing greenhouse gases and geothermal energy offers a considerable advantage in that respect compared to fósil fuels. The choice of energy source is taken with much reserve, however, when decisions are based on the imperatives of the market economy rather than on the environment.

7. Geothermal energy contributes less than 1% to the national energy balance of Mexico, and this figure is not expected to increase in the firts decade of the 21st century; growth has been slow, with geothermal representing an additional source of energy rather than an alternative to convencional sources, where the hydrocarbons predominate (Quintero and Pena, 1989).

8. As regards installed capacity, the forecasted 4,000 MWe by 2010 (Mercado, 1982) once the hot rock technology is being mastered look very optimistic in the actual perspective. This observation is made considering various factors, including the current state of technology, the international oil scenario, which is very unpredictable and the economic situation of México. However, the 2440 MWe forecasted by another CFE expert (Alonso, 1985) is more probable, but unreachable according to an estimate of development in the electric sector by 2007 (SEner, 1998). Another more recent reporte (Hutter, 2001) estimates that 1080 MWe will be installed by 2005.

9. The reserves at Cerro Prieto are estimated at 1200 MWe and the proven reserves at 840 MWe, i.e. 70% of the former. In 2004, the installed capacity is 720 MWe, with the prospects of increasing by 100 MWe within the first decade of this century, assuming that recharge of the reservoir is taking place and that it is an equilibrium with extraction.

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