MEXICAN GEOTHERMAL DEVELOPMENT AND THE FUTURE DIRECTION

By Jaime Mario E. Vaca Serrano
Comisión Federal de Electricidad, México

ABSTRACT

Geothermics in Mexico started in 1954, by drilling the first geothermal well in Pathé, State of Hidalgo, which reached 237 meters depth. In 1959 began electrical generation from geothermal origin, with an installed capacity of 3.5 MW.

From 1959 to 1994 Mexico increased its installed capacity to 753 MW, by developing of three geothermal fields: Cerro Prieto in the State of Baja California, Los Azufres in the State of Michoacán, and Los Humeros in the State of Puebla. Currently, 177 wells produce steam at a rate of 36 tons per hour (t/h) each. Comisión Federal de Electricidad (CFE, Federal Commission for Electricity) has planned to increase the geothermal-electric installed capacity through construction and installation of the following projects: Marítaro, 2 units of 20 MW each; Cerro Prieto 100, 4 units of 25 MW each; and Los Humeros, 2 units of 25 MW each. Repowering of operating units and development of new geothermal zones, like La Primavera and Las Tres Vírgenes, will allow also the Mexican geothermal growth, at short and middle term.

INTRODUCTION

Geothermal electric installed capacity in Mexico practically has not changed in the last years. Currently it is 743 MW, with 26 power units distributed in the fields of Cerro Prieto, Los Azufres and Los Humeros. In April 1996 two back pressure units of 5 MW each were moved to the Miravalles geothermal field, in Costa Rica, to accomplish a services contract signed between CFE and the Instituto Costarricense de Electricidad (ICE).

The aim of this paper is to present information about the current situation of production of the fields under exploitation and to describe, in general terms, the program of the main future projects.

GEOTHERMICS IN MEXICO

Contemporary history of geothermics in Mexico began 42 years ago. In 1954 the first geothermal well was drilled at Pathé El Grande, in the area of Tzipathé, State of Hidalgo. The Geothermal Energy Comission was created in 2 May 1955. In 14 January 1956 for the first time in Mexico a steam column flew from the well Pathé 1. In 20 November 1959 in that same field, the first commercial plant in Latin America was operated with a power of 3.5 MW, but due to insufficient steam extraction, the plant never operated at its full capacity during 14 useful years. From that year on, geothermal development in Mexico has increased considerably.

Presently, there are three geothermal fields in operation: Cerro Prieto in the State of Baja California with 23 years of continuous commercial exploitation, and an installed capacity of 620 MW; Los Azufres, in the State of Michoacán, with 14 years of generation, and an installed capacity of 88 MW; Los Humeros, in the State of Puebla, with five years of commercial generation and an installed capacity of 35 MW. Figure 1 shows the geothermal fields in operation and the geothermal areas under exploration.

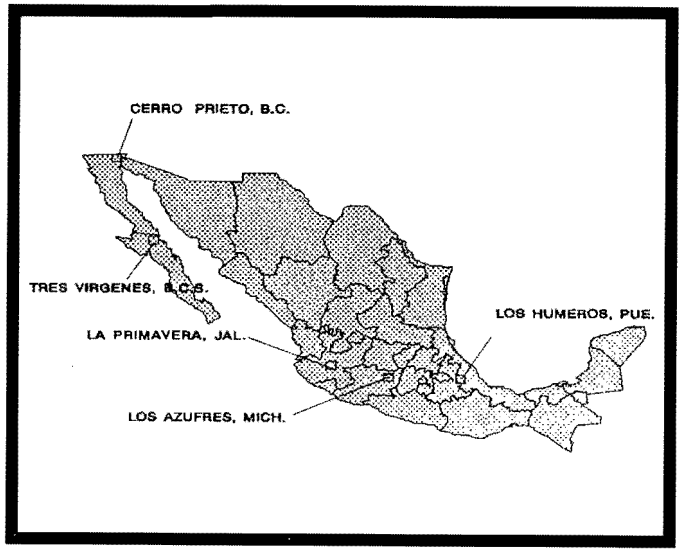

Fig. 1 Location of the geothermal fields in operation and geothermal areas under study

The geothermal installed capacity in Mexico of 743 MW, compared to 33,000 MW of the total electric capacity in the country, represents 2.3%. Geothermics produces 5,700 GWh annually, thus contributing with almost 3.5% of the total electric generation. This is the result of the plant factor of geothermal-electric plants that reached 86%, which is superior to other kind of plants. Table 1 shows the main data of geothermal production in Mexico during 1995, which rank the country in the third world place.

TABLE 1. MAIN DATA OF GEOTHERMAL PRODUCTION IN MEXICO IN 1996

CONCEPT	CERRO PRIETO	LOS AZUFRES	LOS HUMEROS	TOTAL
Installed Capacity (MW)	620	88	35	743
Steam Production (million tons)	42.4	8.2	4.5	55
Steam Production Rate (tons/hour)	4842	933	509	6284
Wells in production (average)	132	24	21	177
Well production average (tons/h)	36.7	38.9	29.9	105.5
Electricity generation (GWh)	4738	658	286	5682
Plant factor (%)	88.6	76.7	93.2	86.1
Steam specific consumption	8.6	10	12.5	9.7
Generation Cost (pesos/KW/h)	0.038	0.030	0.050	0.042

CERRO PRIETO GEOTHERMAL FIELD

The Cerro Prieto geothermal potential was evident in 1852, year in which an earthquake took place in Yuma and the Mexicali Valley. Exploration surveys started in 1958 in a zone full of intense thermal activity, near the Cerro Prieto Volcano. Simultaneously, geological, geophysical and geochemical studies resulted in the construction of three shallow wells (750 m) one of which resulted to be producer of water and steam of low enthalpy. In 1964 four-exploratory deep wells were successfully drilled resulting in high temperatures, around 300°C, measured in good steam production strata. This gave place to the drilling of 14 more wells in 1967 for the first power unit, named Cerro Prieto I, which started its commercial operation in 1973 with a power of 75 MW.

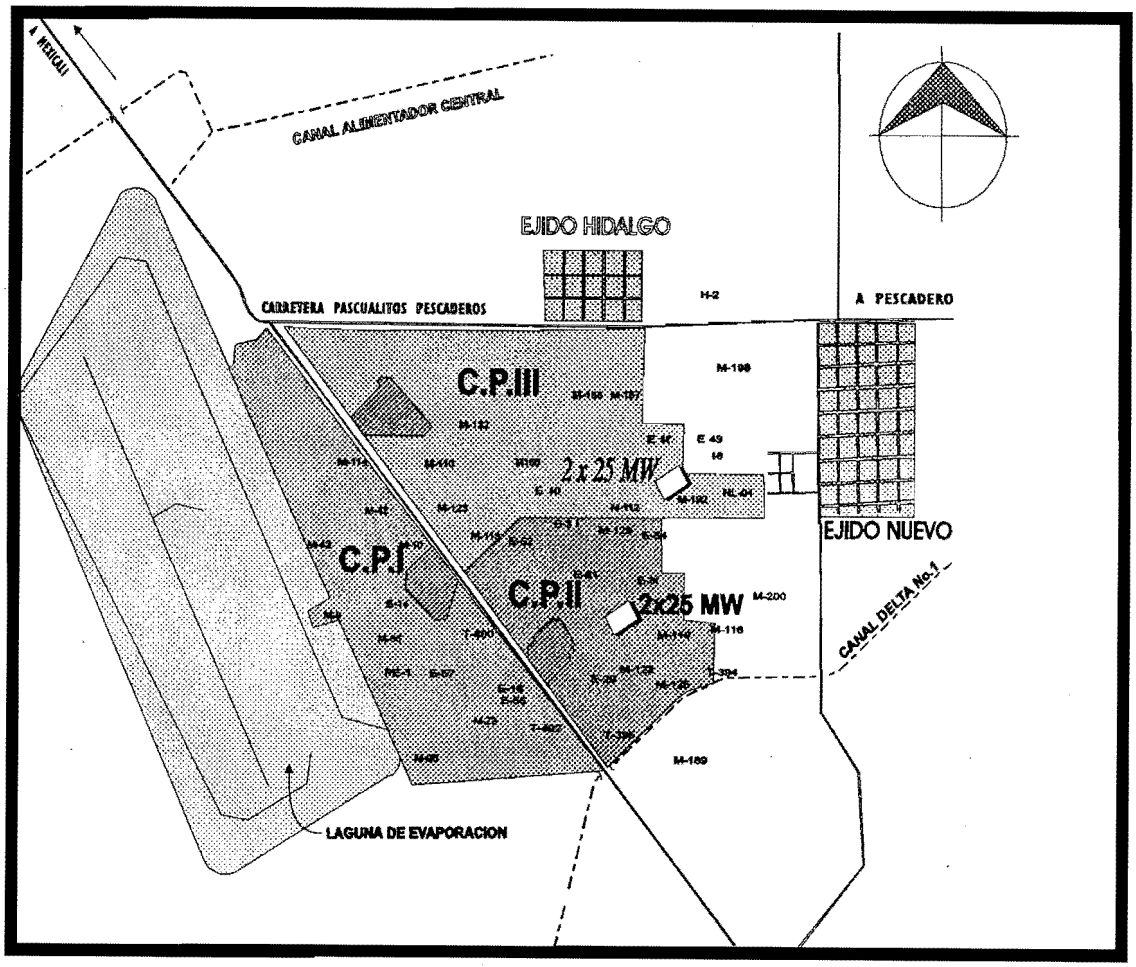

Fig. 2 Location of units for the Cerro Prieto 100 MW project

Exploration continued in the southern zone, and well M-51 was drilled with good results, thus leading to a capacity increase to 150 MW in 1979, and to 180 MW in 1981. After that, well M-53 was located easternly of the exploitation zone of Cerro Prieto I, and drilled to 2,000 m depth, resulting in a production of 100 tons/hour of steam and a bottom temperature of 340°C. So, Cerro Prieto II and Cerro Prieto III zones were discovered, triggering the present development of the Cerro Prieto geothermal field. In 1981 started the construction of two additional units of 110 MW each in Cerro Prieto II, and later another two in Cerro Prieto III, to reach in 1987 a total installed capacity in the three zones (Cerro Prieto I, II and III) of 620 MW, with an average of 132 wells producing approximately 40 tons/hour of steam (Table 2).

TABLE 2. PRODUCTIVE CHARACTERISTICS OF THE CERRO PRIETO WELLS IN 1995 (ANNUAL AVERAGE)

DATA	CP I	CP II	CP III	TOTAL
Wells in operation	46	38	45	129
Average depth (m)	1731	2582	2337	2193
Primary steam production (t/h)	1411	1571	1623	4605
Secondary steam production (t/h)	211	197	119	527
Total production of steam (t/h)	1623	1768	1741	5132
Average steam well production (t/h)	35	46	39	40
Total production of water (t/h)	2422	2656	1831	6909
Average water well production (t/h)	52.8	69.9	40.8	53.7
Total fluid production (t/h)	4044	4424	3573	12041
Average fluid well production (t/h)	88	116	79	93
Average well enthalpy (kJ/kg)	1480	1517	1757	1576
Average reservoir temperature (°C)	304	324	334	320
Average wellhead pressure (bara)	25.2	33.3	29.1	28.9

LOS AZUFRES GEOTHERMAL FIELD

This is the second geothermal field in importance in Mexico. First studies were made in the fifties, by analysing the then existing fumaroles. These studies were interrupted, and resumed in 1972. In 1977 the first producing wells were drilled, which confirmed a geothermal potential considerably high and commercially attractive.

On August, 1982, the first five back pressure units, of 5 MW each, were installed. These units were distributed among the wells with a double purpose: to generate energy and to study the geothermal reseorvoir under continuous exploitation basis. Since 1986 and up to 1993, the installed capacity was increased to 98 MW, due to the setting of a 50 MW condensing unit, four 5 MW back pressure units each, and two 1.5 MW each binary cycle units.

During 1993 generation of electricity was 645 GWh, with an annual average plant factor of 77%. The daily average was 1,811,000 kWh which covered the demand of Morelia City and a part of the Bajío's region. In 1996 two back pressure units of 5 MW each were dismantled and sent to the Miravalles geothermal field in Costa Rica, to accomplish a services contract signed between CFE and the Instituto Costarricense de Electricidad (ICE). So, total installed capacity nowadays is of 88 MW.

Generation of electricity during 1995 was 658 GWh, the monthly average was almost 55 GWh, with a maximum of 71.7 GWh in December and a minimum of 29.4 GWh in April. The annual average plant factor was 76.7%, with a minimum of 69.9% in February and a maximum of 99% in November. This was the highest monthly plant factor in the Los Azufres whole records. During this same year, the wells produced 8.2 million steam tons, the annual average rate was 933 t/h, which represented 15% of the total geothermal steam produced in Mexico. Twenty-four wells were in operation that year, thus giving a steam production average of 50.7 t/h per well (Table 3).

TABLE 3. 1996 PRODUCTION CHARACTERISTICS LOS AZUFRES WELLS (ANNUAL AVERAGE)

DATA	UNIT NUMBER										
	3	4	5	6	7	8	9	10	11	12	TOTAL
Wells in operation	2	2	4	2	10	2	1	1	1 *	3 *	24
Wells depth average (m)	2093	1389	1877.5	1300.5	1233.9	1815	1799	1241			1593.6
Steam production (t/h)	105	98	123	130	593	70	49	69	130*	149*	1233
Steam production average per well (t/h)	52.5	49	30.7	65	59.3	35	49	65			50.7
Water production (t/h)	53	19	59	20	508	124	36	139			958
Water average production per well (t/h)	26.5	9.5	14.7	10	50.8	62	36	139			43.6
Fluid production (t/h)	158	117	182	150	1101	194	85	204			2191
Fluid average production per well (t/h)	79	58.5	45.5	75	110.1	97	85	204			94.3

*Water production (t/h).

LOS HUMEROS GEOTHERMAL FIELD

First exploratory activities on the field started in 1968. In 1981 the first well was drilled, and in May 1990, commercial exploitation started with the construction of seven 5 MW each back pressure power units, the last unit started operating in June 1994.

During 1995 the wells produced 4.5 million tons of steam, representing around 8% of the geothermal steam produced in Mexico. The annual average production rate was 509 t/h. There was an annual average of 21 production wells, with an average production rate of 32.1 t/h of steam per well (Table 4).

The electricity generated in 1995 was of 286 GWh. The monthly average was almost 24 GWh. There was a maximum of 25.3 GWh in July, and a minimum of 22 GWh in April. Annual plant factor was excellent (93.2%), with a minimum of 85.5% in March, and a maximum of 97.4% in July.

TABLE 4. 1996 LOS HUMEROS WELLS PRODUCTIVE CHARACTERISTICS (ANNUAL AVERAGE)

DATA	NUMBER UNIT							
	1	2	3	4	5	6	7	TOTAL
Wells in operation	2	3	2	4	2	5	3	21
Wells depth average (m)	2095	2193	2822	1839	1714	1863	2101	2090
Steam production (t/h)	106	80	80.8	77.4	67	95	98.5	604.7
Steam average per well (t/h)	53	26.66	40.4	19.35	33.5	19	32.8	32.10
Water production (t/h)	5.5	63.5	10	6.5	6	5	4.5	101
Water average per well (t/h)	2.75	21.2	5	1.6	3	1	1.5	5.15
Fluid production (t/h)	111.5	143.5	90.8	83.9	73	100	103	705.7
Fluid average per well (t/h)	55.75	47.83	45.4	32.93	36.5	20	34.33	38.96

FUTURE PROJECTS

The main and immediate projects are Cerro Prieto 100 MW and Marítaro (40 MW).

Cerro Prieto 100 MW

The Cerro Prieto 100 MW project includes the construction and installation of four condensing single flash units, of 25 MW each. Two of them will be located in the sector known as Cerro Prieto II, located near the well E-56, and two in Cerro Prieto III, near the well M-192 (Fig. 2). These areas were selected to take advantage of the present surface installations and the steam gathering systems, reducing environmental impact and thus improving the existing steam supply.

Marítaro (40 MW)

The Marítaro project includes the construction and installation of two condensing single flash units, of 20 MW each. One of them will be installed in the Southern area, near existing unit 7 (of 50 MW), and the other in the Northern area, near AZ-5 well (Fig. 3). Its site was determined according to the availability of wells and the actual steam system. Drilling of new wells is not required, only Maritaro unit 2 requires repairing of just one existing well.

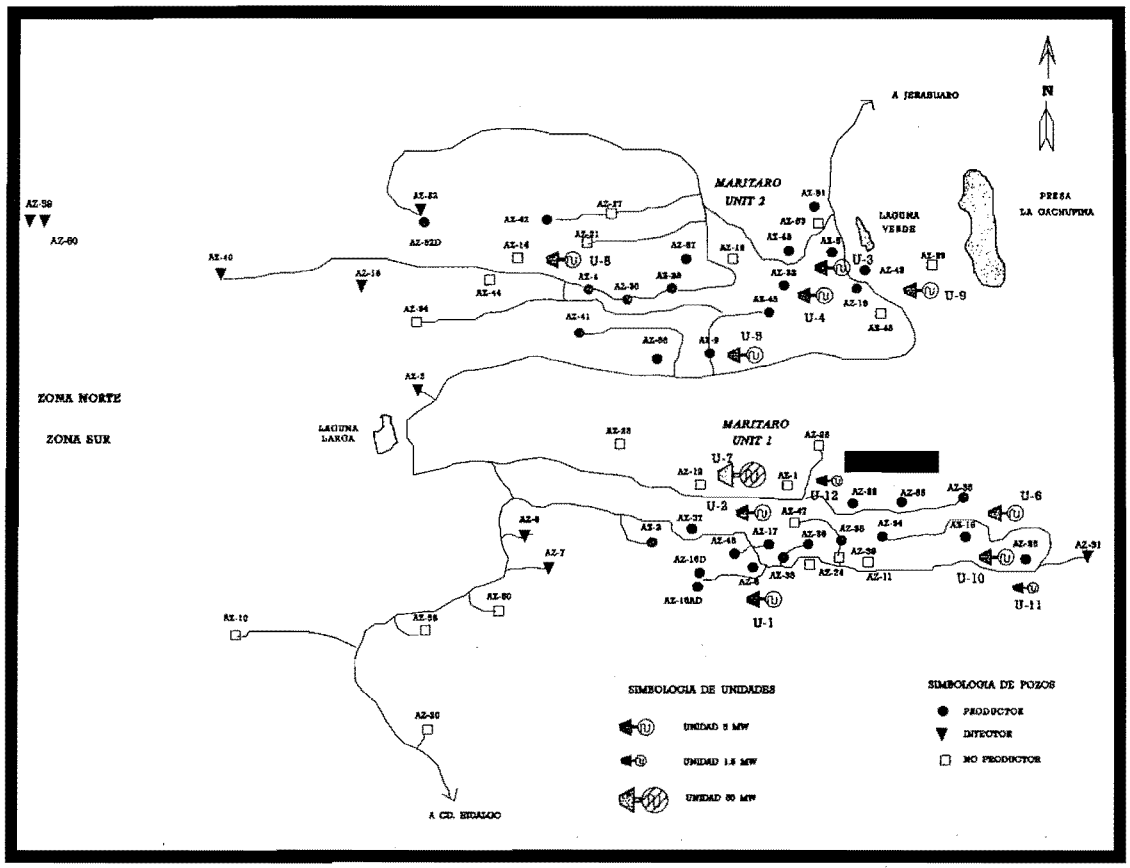

Fig. 3. Location of wells and units in Los Azufres.

Cerro Prieto geothermal field additional projects

CP-I (25 MW)

This project includes the repowering units 1, 2, 3 and 4 of Cerro Prieto I, which are the oldest in this field. These units have a specific consumption of 11 tons/MWh. After the repowering is completed, the expected specific consumption will be 9 tons/MWh. The exceeding steam will be enough for the 25 MW condensing unit.

CP-IV (2 x 25 MW)

This project includes the construction and installation of two 25 MW each condensing units, in the Cerro Prieto zone known as CP-IV, located east of Cerro Prieto II and Cerro Prieto III. Exploratory deep wells have been drilled, obtaining average steam production of 40 t/h.

Biphase pilot plant

After an agreement signed between CFE and private companies Biphase Energy Co. and Biphase de México, a small biphase turbine will be installed on a Cerro Prieto well. If the plant properly operates, similar turbines could be installed in other wells.

Other projects at the Los Azufres, geothermal field

El Chino (2 x 25 MW)

This project is composed by two 25 MW each units, located in the Northern zone, to take advantage of the field potential. The existing wells in the zone will be used to provide the required steam, some of the wells need to be repaired.

Nopalitos (2 x 25 MW)

This project is similar to El Chino. Both 25 MW units will be in the Northern zone. Some of the wells will be used to feed these units, after their repairing.

Project Los Humeros 2 x 25 MW

This project includes the construction and installation of two 25 MW each units. These units will be similar to the ones to be installed at Cerro Prieto. Feasibility and location studies are presently being done.

Projects to be developed in other geothermal fields

Las Tres Vírgenes

Recent preliminary studies on this field, located in the State of Baja California Sur (to see Fig. 1), show a geothermal potential of 25 MW. CFE is planning to develop this potential in two stages: one of 10 MW and other of 15 MW. For this purpose CFE has drilled some wells, and others are in a drilling program. More exploratory studies will be made in order to evaluate the possibility of installing additional 50 MW.

La Primavera

CFE has drilled 13 wells in this field (Fig. 1). Its geothermal potential has been determined to be 75 MW. Development plans have been detained since 1989 due to ecological problems, but which are going to be satisfactorily solved. Two projects have been considered: La Primavera I (2 x 5 MW) and La Primavera II (3 x 20 MW).

CONCLUSIONS

The last geothermal-electric units in México were installed in 1992. Eventhough during the four past years construction of new plants has been stopped, there are plans for new projects.

It is expected that construction of Project Maritaro be started in 1997, and that bidding for Project Cerro Prieto 100 MW will conclude this year. Besides, future projects for Cerro Prieto, Los Azufres, Los Humeros, Las Tres Vírgenes and La Primavera, are almost ready for bidding. In every case, these projects are technically and economically feasible.

CFE is not in the possibility of financing the investments for all the projects. Therefore, the financing scheme for those projects should be BLT (build, lease and transfer) and IPP (independent power producer), or some kind of joint ventures between CFE and private investors.

ACKNOWLEDGMENTS

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REFERENCES

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