Presented at "Short Course on Surface Exploration for Geothermal Resources",
organized by UNU-GTP and LaGeo, in Ahuachapan and Santa Tecla, El Salvador, 17-30 October, 2009.

UNITED NATIONS UNIVERSITY
GEOTHERMAL TRAINING PROGRAMME

LaGeo S.A. de C.V.

EXPLOITATION AND DEVELOPMENT OF THE AHUACHAPAN GEOTHERMAL FIELD

José Alberto Amaya Ventura
LaGeo, S.A. de C.V.
Santa Tecla
EL SALVADOR
jamaya@lageo.com.sv

ABSTRACT

Commercial exploitation in the Ahuachapán geothermal field started 39 years ago. At present, there are 19 production wells available to supply geothermal energy to the power plant, which has three units and a total installed capacity of 95 MW. The electricity production has increased from 72.3 GWh in 1975 to 721.2 GWh in 2008. Significant changes have been undertaken in the field as well as in the power plant within the last 30 years.

1. INTRODUCTON

Research for proving the geothermal potential in El Salvador began in the 1950's. Based on the results of the exploration studies at the end of the 1960's, five deep wells were drilled all over the country's promising areas. One of them, well AH-1, with its production characteristics, gave way to the geothermal development in Ahuachapán (Figure 1).

The Ahuachapán geothermal field (Figure 2) has been commercially exploited since 1975. It is located within the northern slope of the Apaneca - Ilamatepeque volcanic chain at the western part of El Salvador. The production zone covers an area of 2.5 km^2, while the cold re-injection zone has a 1.5 km^2 area, approximately 4 km east of the production zone.

A total of fifty-six wells were drilled in the Ahuachapán geothermal field including production, reinjection and monitoring wells, and dry-holes.

The power plant has three units, two double flow units with 30 MWe each and one double flow, double flash (two inlet pressures) unit with 35 MWe, making a total installed capacity of 95 MWe.

FIGURE 1: Drilling of well AH-1 in 1968

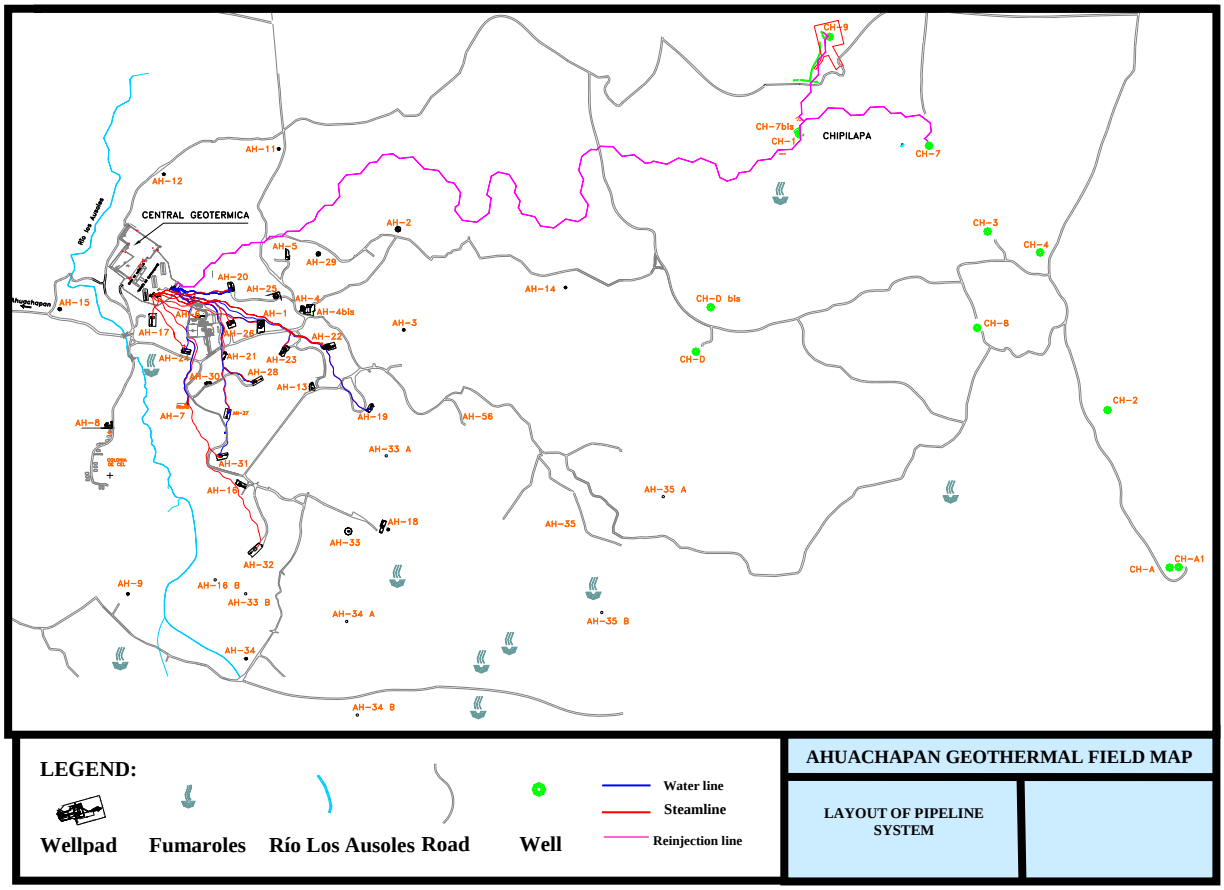

FIGURE 2: General view of the Ahuachapán – Chipilapa geothermal field

1.1 Exploitation

The production area is surrounded by coffee plantations; however, several hydrothermal manifestations are found like steaming grounds, hot springs, mud ponds and small geysers (which local people call "ausoles"). It has a water-dominated reservoir, where the steam fraction in production wells ranges from 12 to 25%, however, there are two wells which produce mainly dry steam from the top of the reservoir. A promising area has been found at the south-eastern part of the field, producing around 200 kg/s of total flow and at present, no direct connection has been identified with the central part of the field.

The first reinjection strategy was to reinject the waste water into the wells inside the production area. Due to some problems like quenching and killing a production well, this practice was abandoned and the waste water was sent to the Pacific Ocean by a concrete channel in 1978. In order to avoid environmental issues and to recharge the reservoir, the waste water was reinjected again farther from the production area and the use of the channel was suspended in August 2004.

At present, there are 17 production wells in service and 5 wells serving as reinjection wells.

2. WELLS

The first well drilled in 1968 was AH-1 with a depth of 1,195 m, and due to its production characteristics, a massive drilling campaign was carried out in the 1970's with a total of 29 wells drilled, and followed by two more wells in the early 1980's. At the end of the 1980's, a new drilling campaign focused on the Chipilapa area, to obtain more steam for the construction of a new power plant in that area. The last well was drilled in 1993, but the production characteristics of those wells

were not good enough to operate a power plant. In the year 2000, two wells were drilled in the Tortuguero area (2 km southeast of Chipilapa), but neither of them had satisfactory results.

Two more wells were drilled successfully in the southern part of the Ahuachapán production area and one in the Chipilapa area for reinjection, which so far is the best reinjection well (injection capacity of 320 kg/s)

3. SUCCESS RATE

From the wells drilled in the 1970's, 16 wells were drilled and used for production, which means 50% success rate. The rest of the wells have been used as monitoring wells for field conditions (pressure and temperature), others to determine the limit of the geothermal field and some failed (collapsed) during the drilling activities.

The last drilling campaign, in the 21st century has improved the success percentage. Five wells were drilled: two as production wells and one as a reinjection well, bringing a total success percentage of about 60%. However, the remaining two wells were unsatisfactory and have been used for exploratory purpose in the Tortuguero area.

4. CHIPILAPA AREA WASTE WATER DISPOSAL SYSTEM

As mentioned earlier, the waste water disposal system was carried out near the production area, but has caused some problems, thus a concrete channel was built to send the waste water to the Pacific Ocean.

Taking advantage of the Chipilapa project, a system of pipelines was built in December 1999 in order to reinject the waste water back into the reservoir by gravity using three wells (Ch-7bis, 9 and 7). Not all the water was absorbed by the wells, some were still sent to the concrete channel through the help of a pumping system in the second pipe line. However, since 2004 all the waste water has been reinjected to the wells for environmental reasons.

5. FLOW RATES

From 1975 to 2009, the mass flow rates show a small increase in the steam flow and fluctuating values in water flow (Figure 3). It was decreasing from 1987 to a minimum value of around 300 kg/s in 1994. But from 1999 a constant increase is shown up to the present value of 650 kg/s. The period from 1994 to 1999 presents low water flow rates due to the extraction strategy which used wells with higher values of steam fraction.

6. ELECTRICITY PRODUCTION

The steam from the reservoir has not sufficient to meet the total capacity of the power plant (95 MW). To date, a total of 15,653.9 GWh has been generated. In 1984, due to the electricity demand of the country, the third unit was commissioned temporarily, resulting in a reservoir pressure drop from 31 to 24 bars in the reservoir, which eventually led to one of the units not being used while two of the units continued in service up to 2005. However, in 1998 the Ahuachapán optimization project brought the third unit back on line, and the average production has been 82 MW gross output. A pumping system was installed comprising of four pumps of 240 l/s, 400 HP to manage the waste water from the flashers, two pumps of 55 l/s, 150 HP to manage the condensate from the cooling towers and two pumps to handle the water from the emergency tank. Figure 4 shows the Ahuachapan plant.

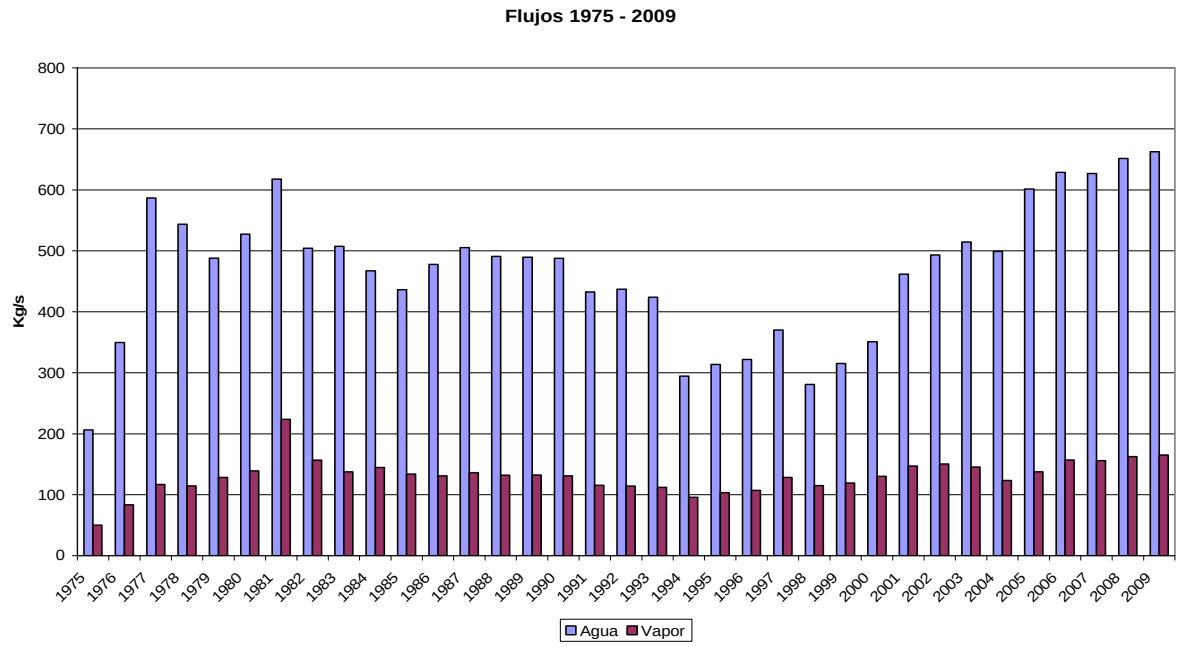

FIGURE 3: Flowrates from the Ahuachapan geothermal field from the start of production in 1975

FIGURE 3: Aerial view of the Ahuachapán geothermal power plant

7. UNITS

Unit 1 (Mitsubishi Heavy Industry - MHI) generates 30 MW. It is a double flow turbine and uses medium-pressure steam at 5 bar-a. It started supplying electricity to the electricity grid in June 1975. In 1992 the diaphragms were replaced, along with its rotor because of a silica scaling problem. This unit, together with Unit, 3 has been on line most of the time. It has been reliable and has had a steam availability of more than 90% for the last three years as shown in Figure 4.

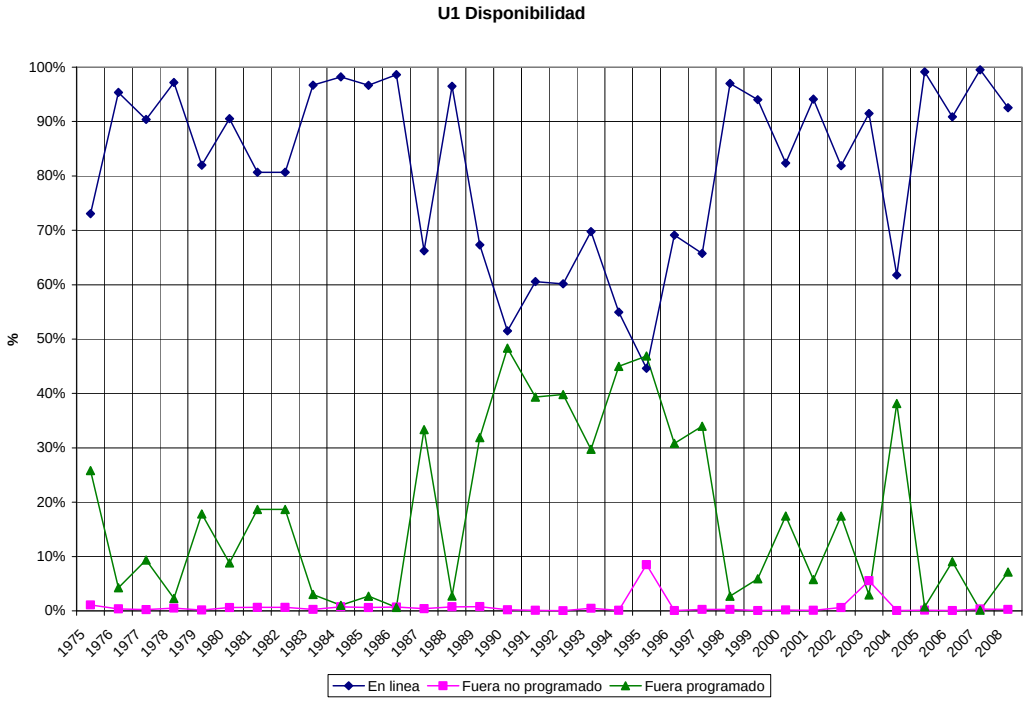

FIGURE 4: Steam availability for Unit 1

Unit 2 (Mitsubishi Heavy Industry - MHI) generates 30 MW and was commissioned in May 1976. No major changes have been undertaken in this unit. During the last inspection in 2007, the stationary blades showed severe erosion conditions. The stationary blades were removed from Unit 2 as a result of scaling problem and were sent to a foreign company for repair works, and will be reinstalled in the next overhaul (2010). The availability of steam since 2006 is more than 90% (Figure 5).

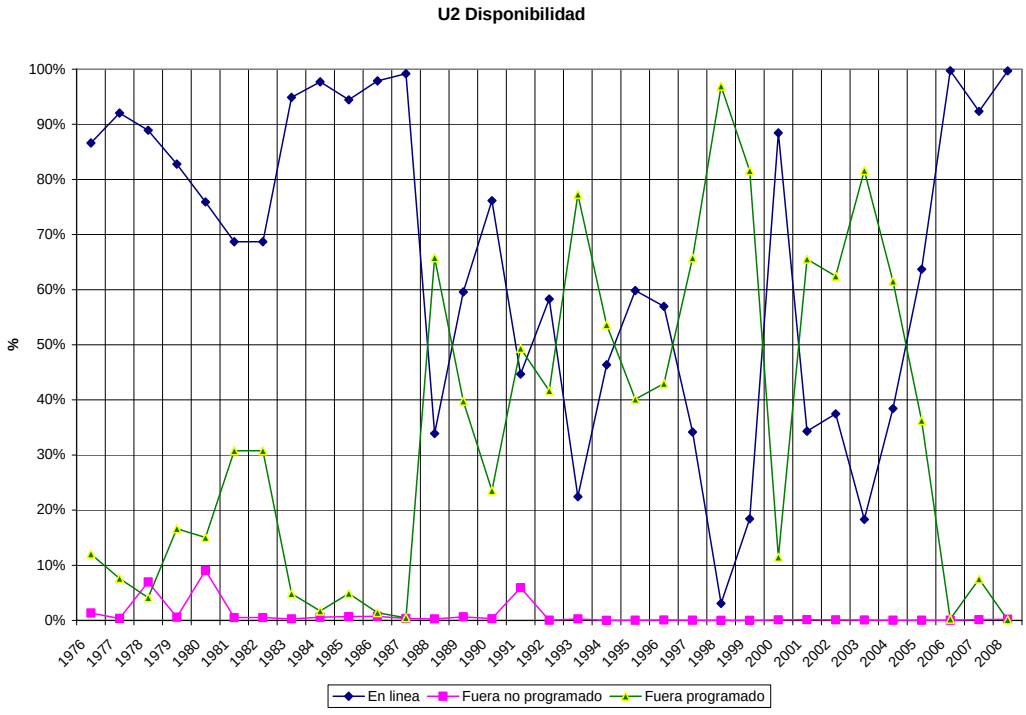

FIGURE 5: Steam availability for Unit 2

Unit 3 (Fuji) generates 35 MW and was commissioned in September 1980. It is a double-flow and double-flash unit with an inlet medium-pressure steam of 5 bar-a and a low-pressure steam of 1.6 bar-a. In the year 2000, a motoring accident left the unit idle for nine months, and led to the installation of extra protection breakers in all the units. A new rotor was installed in this unit in 2002. However, in 2007 a tip blade (L-1) breakage was encountered. The damaged rotor and diaphragms were sent to an American company for repair and were successfully reinstalled in 2008. Figure 6 shows the steam availability of the unit.

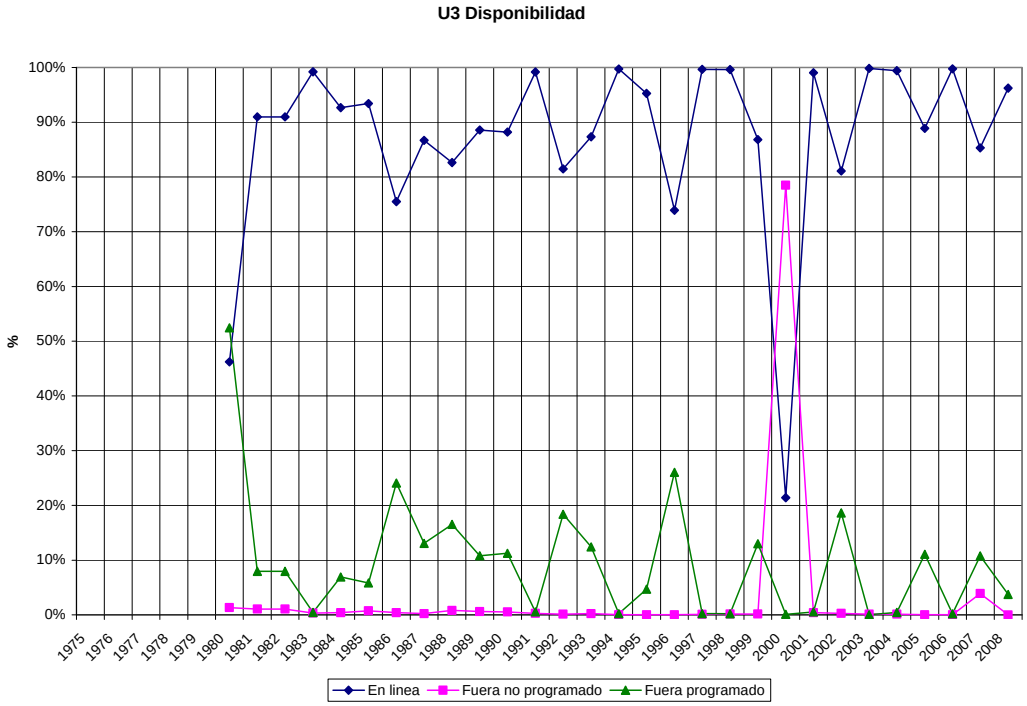

FIGURE 6: Steam availability in Unit 3

8. PERFORMANCE

Three performance indicators are usually needed to describe the technical performance of a geothermal power facility, which are as follows:

- Capacity factor (%) = Total MWh generated in the period x 100/ (Installed capacity MWe x period h)
- Load factor (%) = Total MWh generated in the period x 100/ (Maximum Load MWe x period h)
- Availability factor (%) = Total hours of the plant in operation during the period x 100/Total length of period hours

Only Unit 3 is on line to full capacity, but Units 1 and 2 have been on line at approximately 75% of their capacity because of the lack of steam supply at the centre of the production area. This led to the drilling in the south-eastern part of the field, where three producing wells now supply Unit 3.

During 2008, the performance of the three units was as shown in Table 1:

TABLE 1: Performance of the three units in the Ahuachapan geothermal power plant

Month	U1 capacity factor (%)	U1 load factor (%)	U2 capacity factor (%)	U2 load factor (%)	U3 capacity factor (%)	U3 load factor (%)	Plant capacity factor (%)	Plant load factor (%)
January	77.83	98.65	80.18	97.28	103.61	98.48	87.20	98.14
February	78.79	97.67	79.28	97.88	103.68	97.23	87.25	97.59
March	79.20	99.33	79.67	96.93	105.08	98.71	87.99	98.32
April	79.56	98.39	78.65	97.47	104.87	98.48	87.69	98.11
May	81.35	91.66	77.55	96.19	103.57	98.53	87.49	95.46
June	82.20	99.27	79.42	98.57	98.61	93.11	86.75	96.99
July	83.84	90.39	86.18	86.83	60.08	55.61	76.70	77.61
August	12.00	15.15	93.76	94.01	107.52	98.20	71.09	69.12
September	79.90	98.64	78.82	98.49	107.23	98.92	88.65	98.68
October	79.79	93.51	80.21	93.99	106.78	98.09	88.93	95.20
November	81.54	98.79	79.96	95.98	106.01	97.41	89.17	97.40
December	82.45	99.04	80.82	97.84	105.63	97.79	89.63	98.23

Every month a unit's efficiency is recorded. It has ranged from 72.4 to 76.1% for Unit 1, 62.4 to 65.4% for Unit 2 and 70.4 to 76.7% for Unit 3.

9. POWER PLANT IMPROVEMENT

From 2000 to 2003, a new data acquisition system was installed in the three units obtaining an improvement in the operational process. Similarly, due to the exploitation, the amount of non-condensable gases increased, thereby a new system to extract these gases was installed in 2003. Furthermore, to extend the generator's life, the original coils of rotor and stator were removed and replaced by new coils with better isolation characteristics for Units 1 and 2 in 2003 and 2005 respectively, and the stator in Unit 3 in 1996. Finally, in 1993, most of the wooden materials of the cooling towers were replaced; and in 2010, a project to replace deteriorated wooden materials by synthetic fabrics has been programmed to be undertaken.

10. SOME OTHER WORKS

The people living in the area have not been forgotten. As part of the social responsibility of the company, some works have been addressed to the nearby communities such as improving access roads, pedestrian bridges, sport facilities, a window to the world, small health care clinics, and small productive projects.