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DEVELOPMENT OF THE LAS TRES VIRGENES GEOTHERMAL FIELD, MEXICO

Marco A. Torres-Rodríguez and Raúl A. Sánchez-Velasco

Comisión Federal de Electricidad, México.

ABSTRACT

Ecological and reservoir characteristics of the Las Tres Vírgenes geothermal field are presented. Pressure and temperature logs show a liquid dominated reservoir at 245°C and 61 bars. The granodeoritic with moderate fracturing rock hosts the geothermal reservoir. Production characteristics of well LV-3 were recently evaluated, produced fluids have geothermal genesis and the electrical output is 1.5 MW. At present, LV-1 is on drilling step.

According with electrical needs and behaviour of the production characteristics of the zone, CFE has projected the installation in the near future one 2 MW unit. The characteristics of this turbine are specified, also the ecological criterion. A 115 KV line is needed in order to integrate this project to the existing grid.

In 1995, four new deviated wells will be drilled in order to prove-up 4 MW power capacity and to explore new areas. Two of these wells will be located on the same site as of LV-3. The third well will be drilled on the same site of LV-1. Finally, the fourth injection well will be located 2 km from well LV-3.

LOCATION OF THE FIELD

The Las Tres Vírgenes geothermal field is located in the northern portion of the Baja California Sur State, 45 km from Santa Rosalia City. The Transpeninsular road passes 12 km from the field. Figure 1 shows the location of the field.

EXPLORATION STUDIES

Structural geological studies began in 1983 with Landsat images, geology, geochemistry, geophysics and geohydrology. At present, two wells have been drilled (LV-2 and LV-3) and a third is under construction (LV-1).

Important geophysical work have been made by CFE and in 1993 a six station seismic network was operated from February to September. From this study, two specific seismic features were defined, the more northerly lies under the middle of the Las Tres Virgenes, while the more southerly wich during this period was the more active, lies some distance south-southeast of the most southerly of Las Tres Virgenes. The majority of the locatable earthquake faults have fault plane solutions which demonstrate normal faulting. This normal faulting is on sub-vertical faults striking north-west to south-east which agree with the structural model (Figure 2).

From prefeasibility studies and drilling information, the geological model was built (Figure 3). The heat source is identified at relatively shallow depths inside of a fractured zone. The geothermal system is associated with the volcanic complex of El Azufre and El Viejón.

The reservoir is of the type of liquid dominated contained inside a granodioritic basement, 1200 m. depth with commercial thermodynamic conditions (245°C and 61 bars) for electrical generation, applying conventional technology.

PRODUCTION CHARACTERISTICS OF THE WELLS

At present there are three wells in the field. The injector well LV-2, the productive well LV-3 and a third well in the process of being drilled, LV-1. Production characteristics of the well LV-3 and some characteristics of the well LV-1, are presented.

Well LV-3.- The vertical well LV-3 was drilled with aereated fluids in 1994 to a total depth of 2150 m. The 177.8 mm diameter slotted liner is located from 1200 m to 2134 m (Figure 4). Temperature logs show two permeable intervals: 1300 - 1400 m and 1875 - 1900 m (Figure 8). The first one is the main interval. The injectivity index calculated during completion testing is low on the order of 2.4 m^3/h-bar. The chemical analysis of the return drilling mud from 1350 to 1700 m of depth show high values of chloride, boron, electrical conductivity and Na/K geothermometers. These values indicate the existence of a geothermal brine. The geothermometer value is on the order of 312°C (Table 1).

In order to evaluate the thermodynamical behaviour of the well during the test warm-up, pressure and temperature logs were run.

Figure 9 shows the pressure and temperature logs during the warming-up. The average values in the main feed interval, 1350 m, are 245°C and 61 $bars_m$. At wellbottom, 2150 m, the temperature is on the order of 262°C. One month later, at static conditions, wellhead pressure is 0.83 $bars_m$, and the liquid level in the well is located at 630 m. At that time it was necessary to induce well production using the air lift technique.

On december, 1994 the well was induced for the first time. The well flowed only during 21 hours with a wellhead pressure oscilating between 2 and 5 $bars_m$. The chemical composition of produced fluids corresponded to chloride-sodium water, in other words, the produced water is a geothermal brine (Table 2).

The Na-K-Ca and Silica geothermometer values are 266°C and 244°C, respectively. These values are in a good agreement with static pressure and temperature logs.

On march 1995, the well was induced for the second time. The well flowed through a totaly open side valve for 4 hours. Wellhead pressure was stable, 2.8 $bars_m$. In a similar behaviour in December, after a stabilized period wellhead pressure it went up to 6.8 $bars_m$ and production ceased.

In order to determined why the well only flowed for a short time, a production testing survey of the well was achieved in April of 1995. The well was induced three times and pressure and temperature logs were run.

Figure 10 shows the behaviour of wellhead pressure versus elapsed time. In a similar manor the well is flowed at stabilized conditions followed by a rise in pressure and flow stops. At flowing conditions, flashing ocurrs in the well at 1600 m of depth and from this depth to wellhead two phase flow occurs (Figure 11). The results of the production survey show that the well is producing from several feed intervals with different characteristics. When the well is flowing through an orifice of 38,1 mm, one feed zone is controling production and conditions are stable. When the well is open to total flow a second feed interval, with temperature less than the first one, starts to control the mechanism of production and flow is ceasses.

In conclusion, well LV-3 is productive and sustained production through a 38,1 mm orifice with 35 t/h of water and 15 t/h of steam at a wellhead pressure of 4 $bars_m$ (Figure12).

The average reservoir pressure and temperature at the main productive interval, 1300-1400 m, are 61 $bars_m$ and 245°C, respectively with an enthalpy of 1063 kJ/kg. The fluid is located in the subcooled liquid region at static conditions.

Well LV-1.- The well LV-1 is located 500 m from well LV-2. At present the deviated well LV-1 is in the drilling stage with aereated fluids at a total depth of 1820 m. Figure13 shows the temperature profiles of the well at different depths. Before the installation of the 244,5 mm casing the maximum temperature was 230°C at 1250 m of depth (T8). At a total depth of 1500 m the maximum temperature was 216°C (T12) and at 1800 m (T16) the temperature was 200°C. The coldest temperatures are due to the large volume of injected fluid during drilling. This was done to avoid warming-up and pressurizing the well. The programmed total depth of 2000 m is necessary in order to intersects the volcanic complex El Viejón.

FUTURE WELLS

In order to maintain a power plant in the field, CFE has programmed 4 new wells. Two productive wells will be located on the same platform of well LV-3, the third productive well will be located on the same platform of well LV-1 and the fourth well will be drilled 2 km away from well LV-3. The last one will be an injector well.

From core samples it is apparent that the alignment of faults at depth are in a vertical and paralell pattern. For this reason the wells will be deviated in order to instersect the majority of faults and, in consequence, to obtain the maximum of flow rate at the surface.

IMPORTANCE OF THE PROJECT

The Las Tres Vírgenes field is located in the middle of a very isolated zone of the country. The main activities are the agriculture at El Vizcaino, near Guerrero Negro, local marketing originated by the national and international tourism and The Exportadora de la Sal one of the most important salt producing companies in the world. This company has developed all the necesary energy to solve his own problems, including electrical needs.

To supply the electricity in this zone, CFE built two isolated power houses located, one in Santa Rosalia city (10.8 MW) where the main electrical consumption is domestic use and the other one in Guerrero Negro (20 MW) where the main electrical consumption is agriculture irrigation. Both power houses are diesel powered. The location of these power plants and the electrical grid is shown in Figure 5.

Neverthless of the 30 MW of installed capacity, only a part is available, because most of the diesel engines are 20 or 30 years old. The real capacity is 8.8 MW at Santa Rosalia and 15.6 MW at Guerrero Negro. Exportadora de la Sal has a 9 MW diesel power house. There is no connection between CFE grid and the Exportadora de la Sal grid.

Diesel engines are one of the most expensive generation technologies in Mexico. In order to catagorize diesel generation costs, taking thermal generation as a base reference index of 100, diesel is 137 and geothermics 85. With this comparation, geothermal generation is very attractive and beneficial for the development of tourist, industrial and agriculture activities.

DEVELOPMENT OF THE LAS TRES VIRGENS

As the power output of well LV-3 and the electrical needs in the area shown in figure 6, geothermal energy will supply the base energy in the consumption curve. So, 4 MW could be installed in a short time. CFE is also working on a feasibility study to install a 2 MW unit on well LV-3.

Technical features of this unit will be skid-mounted, fully factory tested, condensing or binary thermal cycle in which ever will provide the maximal efficiency, unattended and fully automatic operation, and will be located on the LV-3 well platform in order to simplify the pipelines.

ELECTRICAL GRID

The electricity will be sent to Guerrero Negro and Santa Rosalia Systems in order to reduce the diesel generation production. As both are isolated systems, it is neccesary to construct a transmision line from the Las Tres Vírgenes to San Ignacio in 115 KV transmission voltaje (at present transmission voltaje is 34.5 KV). Figure 7 shows the required changes to connect geothermal generation with the grid.

ECOLOGICAL CRITERION

Las Tres Vírgenes is located in the mitigation belt of the protected ecological reserve of El Vizcaino. There are several protected species like Cimarron sheep, Bura deer and important species of plants. In order to preserve this ecological zone, CFE has defined the technical features before the drilling of the wells to mitigate any problems. In addition strong procedures to test wells and develop electrical projects have been adopted. The most important of them are the following:

- Dimensions of the sites to drill the wells is now 35 x 65 m instead of 50 x 100 m that was the common dimensions in the other projects.
- Aerated fluids will be used to drill the wells, reducing the volume of water needed during the construction of the wells. At the Las Tres Virgenes water is not available and it is neccesary to transport it from 15 km away. Also, using aereated fluids pollution decrease because the circulation losses have been less.
- New wells will be located on existing platforms and will be directional drilled, in order to reduce the number of future platforms and will also serve to concentrate the steam production on site.
- Specially designed silencers are used in order to eliminate water droplelets entrained in the steam discharged to the atmosphere.

- Location of the power generation plants will be close to the wells, to keep land requirement as low as possible.
- All the water extracted from the reservoir will be injected back into the periphery of the geothermal system.

CONCLUSIONS

1. The average reservoir pressure and temperature at the main feed interval in well LV-3, 1300-1400 m, are 61 $bars_m$ and 245°C, respectively with an enthalpy of 1063 kJ/kg. The fluid is located in the subcooled liquid region at static conditions.
2. The chemical composition of produced fluids in well LV-3, corresponds to the type of chloride-sodium water, in other words, the produced water is a geothermal brine.
3. The sustained production from well LV-3 is 35 t/h of water and 15 t/hr of steam through a 38.1 mm orifice plate with a well head pressure of 4 $bars_m$.
4. The reservoir is a liquid dominated type contained in fractures in a granodioritic basement.
5. The reservoir has commercial thermodyna mic potential for electrical generation, applying conventional technology.
6. With the potential power output of well LV-3 and the electrical needs in the area 4 MW could be installed in a short time. CFE is working in the feasibility study to install an additional 2 MW unit beside well LV-3.
7. Technical features of the 2 MW unit will be skid-mounted, fully factory tested, condensing or binary thermal cycle, unattended and fully automatic operation, located on the platform of well LV-3 in order to simplify the pipelines.
8. In order to preserve the ecological zone, CFE has defined the technical features before drilling the wells to initigate any problems. In addition strong procedures to test wells and develop the electrical projects.

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Table 1
Chemical composition of drilling mud in the well LV-3

DEPTH (m)	C.E.	pH	Cl	SO_4	Na	K	B	T_{na-K} (°C)
700	2190	8.2	235	262	483	14		128
1375	1060	8.4	174	89	240	17		189
1400	10380	8.3	3218	107	2032	369	56	274
1425	7570	8.6	2329	44	1470	373	16	312
1450	6500	7.6	1969	50	1226	226	15	276
1475	7340	9.7	2290	38	1442	256	11	272
1500	6320	8.8	2025	50	1284	215	7.4	266
1525	22000	9.6	7951	58	4675	566	157	234
1550	17410	9.4	6247	70	3525	396	125	227
1575	18050	9.0	6626	54	3600	469	145	241
1600	17360	8.0	6436	30	3450	463	142	244
1665	11330	8.1	4371	28	2345	270	78	229
1688	11630	8.1	4371	26	2430	285	83	231
1692	12440	7.8	4662	25	2570	300	87	231
1800	14570	8.7	5634	45	3100	370	104	233
1825	14540	8.6	5634	27	3075	365	104	232
1840	14590	8.3	5634	31	3105	360	107	230
2095	3490	8.2	1359	35	645	65	15	218
2113	2810	8.2	1262	35	530	50	13	212
2132	2840	8.0	1165	28	560	55	14	215
2142	3100	8.5	1457	32	600	60	16	217
2148	2860	8.3	1262	28	550	55	18	217
2150	2860	8.7	1165	28	550	55	13	217

C.E.: Electrical conductivity [mhos/cm]
Concentrations in ppm.

Table 2
Chemical composition of the fluids produced in the well LV-3 (December 1994)

WHP (bar)	Na	K	Ca	Cl	SiO_2	Li	HCO_3	TSD
3.79	4192	757	104.8	7758	640	22	89	13880

B	SO_4	Mg	Fe	Mn	$T_{Na-K-Ca}$ (°C)	T_{sIO2} (oC)
142	73	0.24	0.12	0.14	266	244

Concentrations in ppm.
WHP: Wellhead pressure
TSD: Total solid dissolved

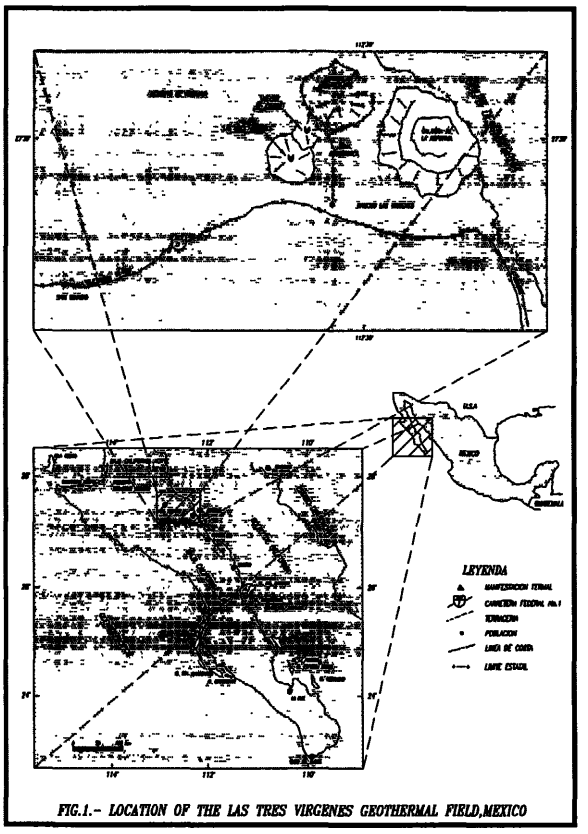


FIG.1.- LOCATION OF THE LAS TRES VIRGENES GEOTHERMAL FIELD,MEXICO

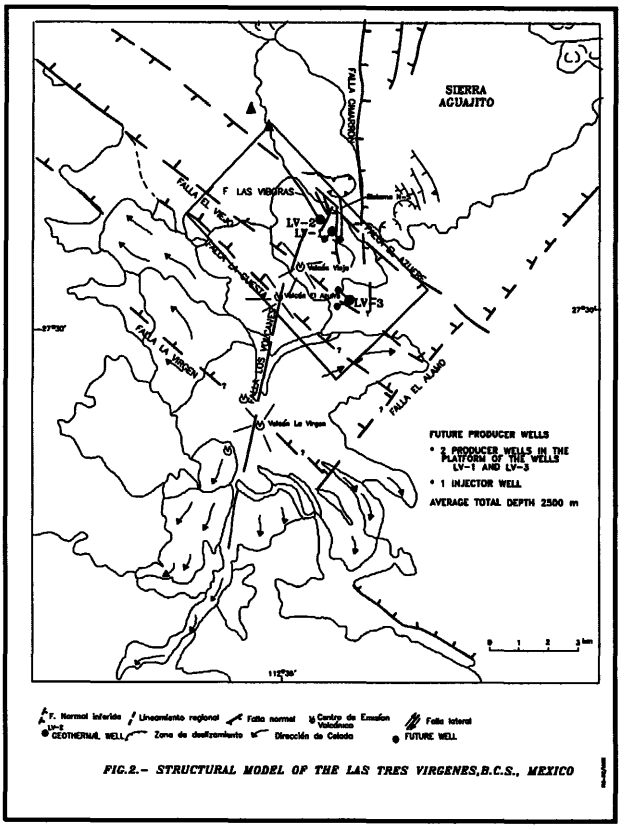


FIG.2.- STRUCTURAL MODEL OF THE LAS TRES VIRGENES,B.C.S., MEXICO

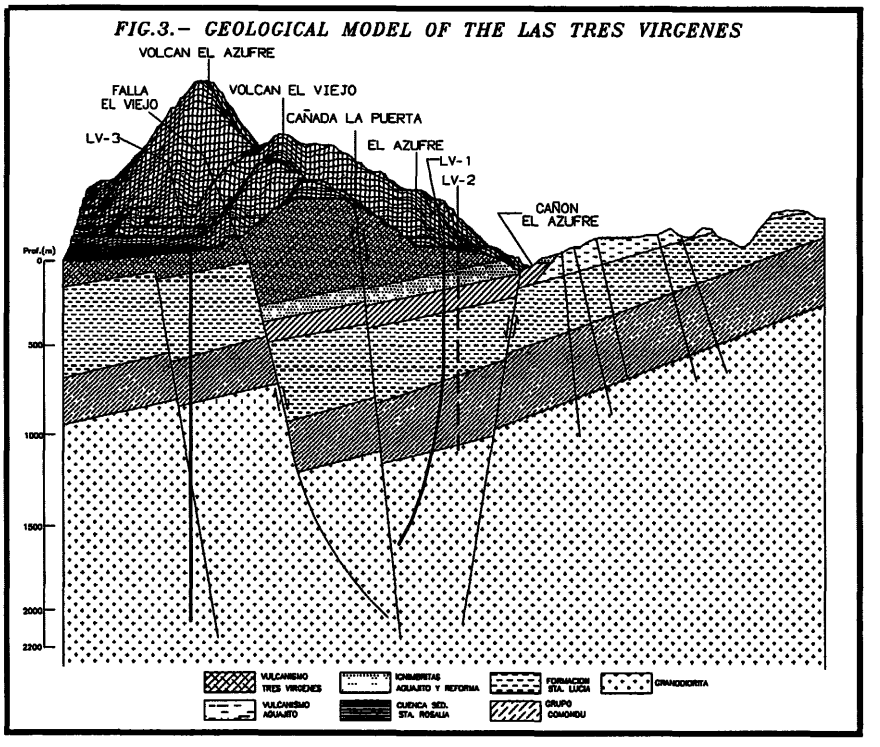


Figure 5.- Actual Generation Systems in the Zone

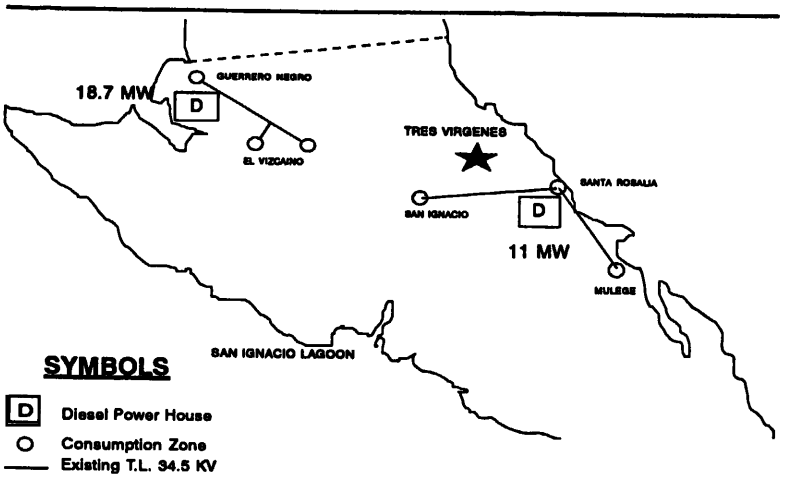


Figure 7.- Integration of geothermal generation to existing grid

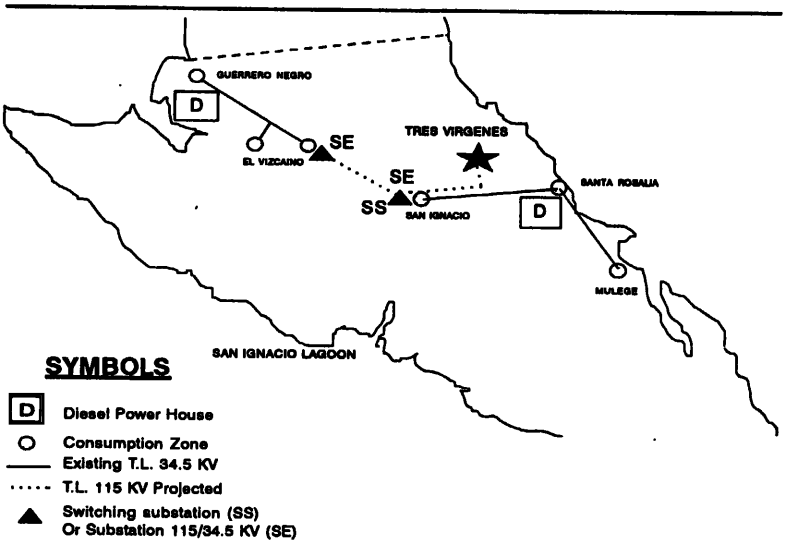
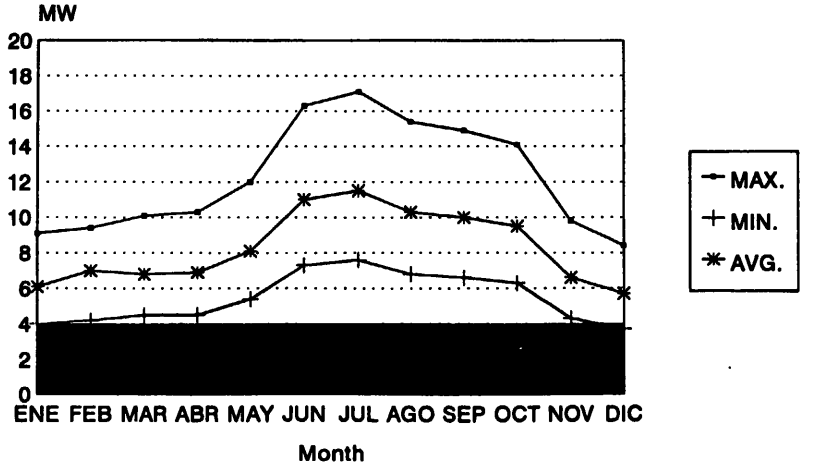


Figure 6.- Variation of the Energy Consumption (1994)

Santa Rosalia and Guerrero Negro Systems



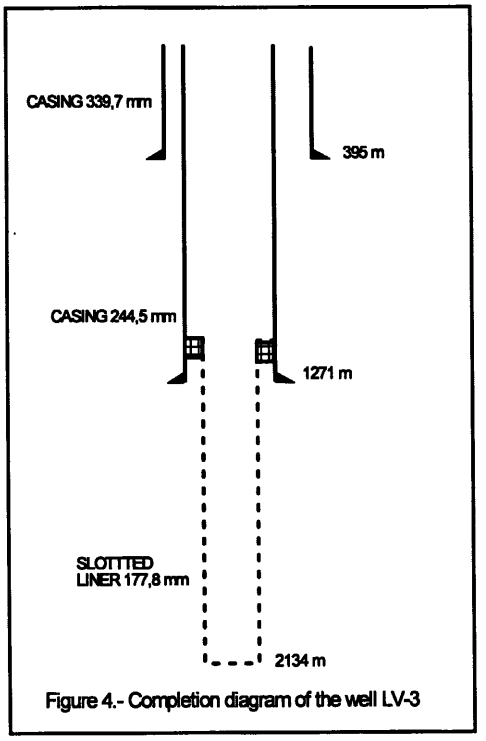


Figure 4.- Completion diagram of the well LV-3

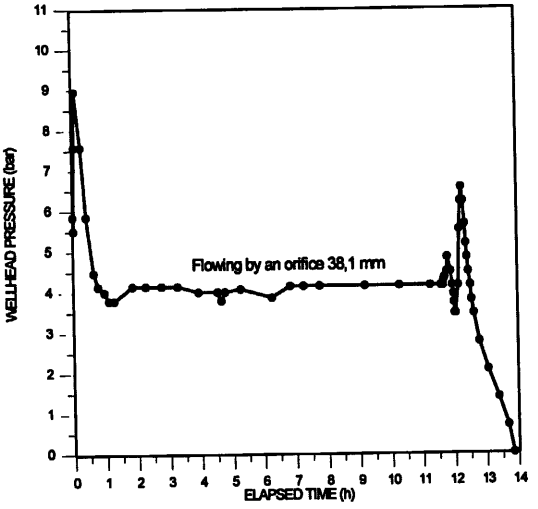


Figure 10.- Wellhead behaviour in the well LV-3

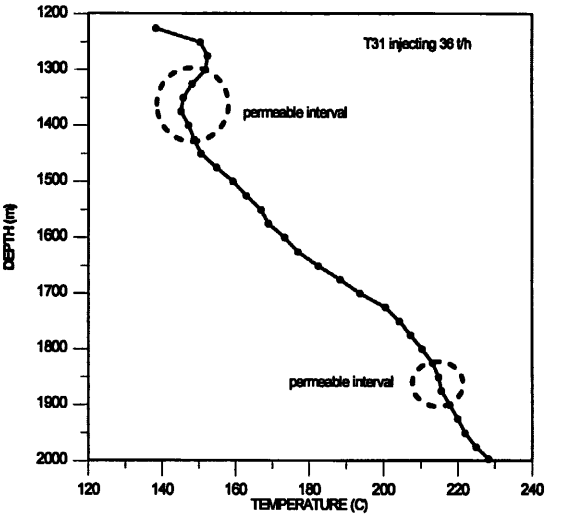


Figure 8.- Temperature profile of the well LV-3 during the injection testing

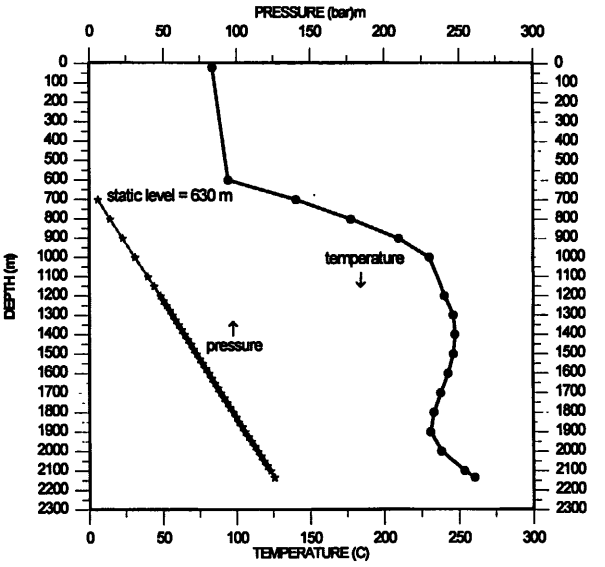


Figure 9.- Pressure-temperature profiles of the well LV-3. warming-up step.

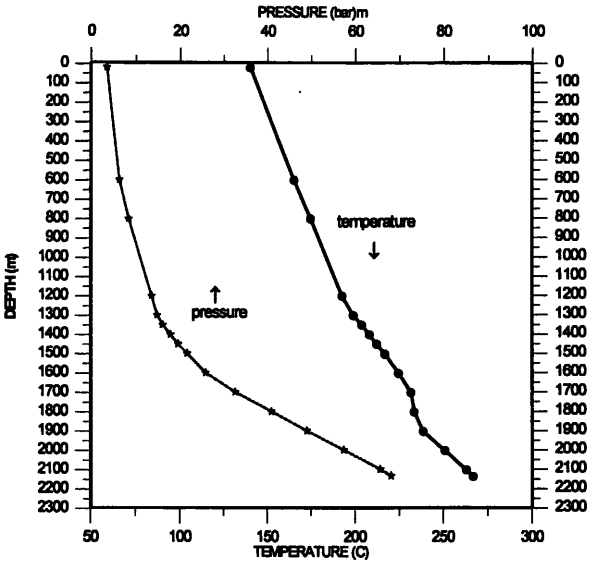


Figure 11.- Pressure-temperature profiles of the well LV-3. flowing by an orifice 38,1 mm

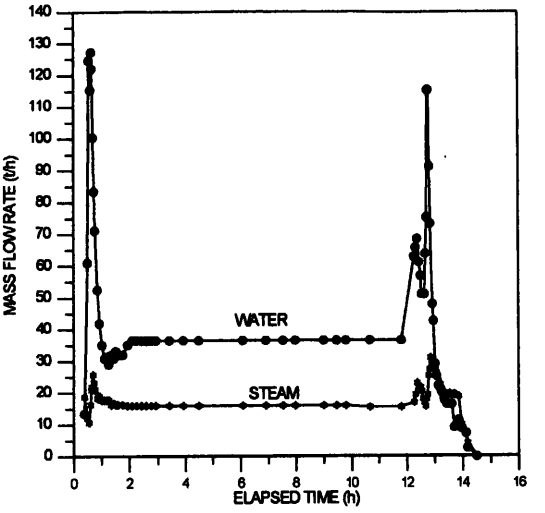


Figure 12.- Steam and water flow rate in the well LV-3

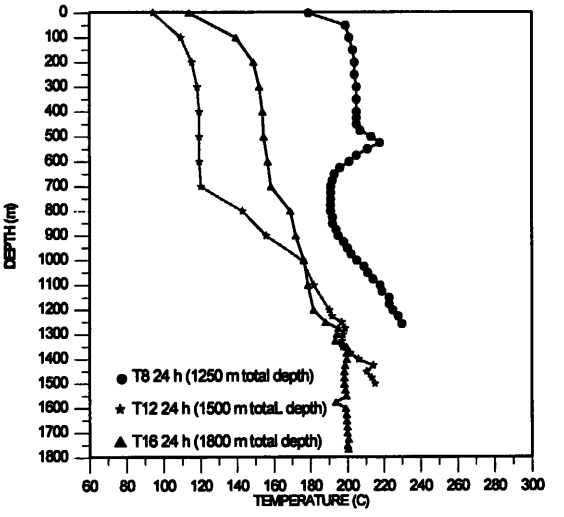


Figure 13.- Temperature profiles of the well LV-1.