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Behavior of the Production Characteristics of the Wells in the Las Tres Vírgenes, B. C. S., Geothermal Field, México

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ABSTRACT

Las Tres Vírgenes geothermal field is located on the peninsula of Baja California Sur, Mexico, 32 km to the NW of the city of Santa Rosalía, within the Las Tres Vírgenes volcanic complex, at an elevation of 720 metres above sea level. The site is located in the granodiorite (intrusive body that constitutes the regional base) and the reservoir is in the subcooled liquid region. The exploration of the field began in October 1986 with the drilling of the LV-2. Power generation began in the year of 2001. At present the installed capacity is 10 MW with two back-pressure of 5 MW generation units each.

The produced fluid is a mixture water-steam with quality around 30 %. Produced brine has a high content of minerals, especially calcium and silica. During the production, in some wells flashing (phase change) occurs inside the well and others into the fractures. This phenomena, coupled with the high content of salts, causes the formation of scaling, mainly calcium carbonate (calcite $CaCO_3$) whose solubility decreases with the increase of the temperature of the solution. Consequently, the production of wells is drastically reduced in short periods of time, as well as the generation of electric power.

A system of scaling inhibitors has been implemented in some wells in order to reduce this phenomenon and sustain the electrical generation. Also, cleaning of wells and formation with acid treatment using flexible tubing, is routinely used with successful results.

Monitoring of the evolution of the mechanical condition of each well and the physicochemical characteristics of the produced fluids are carried out continuously, in order to schedule workover, and ensure the generation of electrical energy.

In this paper is discussed the behavior of the production characteristics of the wells of the geothermal field Las Tres Vírgenes, BCS, México, during the last 12 years of commercial exploitation.

1. INTRODUCTION

The geothermal field of Las Tres Vírgenes is located in the state of Baja California Sur, 32 km northwest of the Santa Rosalía city (Figure 1). Physiographically, it is located south of the Aguajito Sierra and in the northern part of Las Tres Vírgenes volcano. The field is located on a volcanic hydrothermal complex at an average elevation of 720 m.

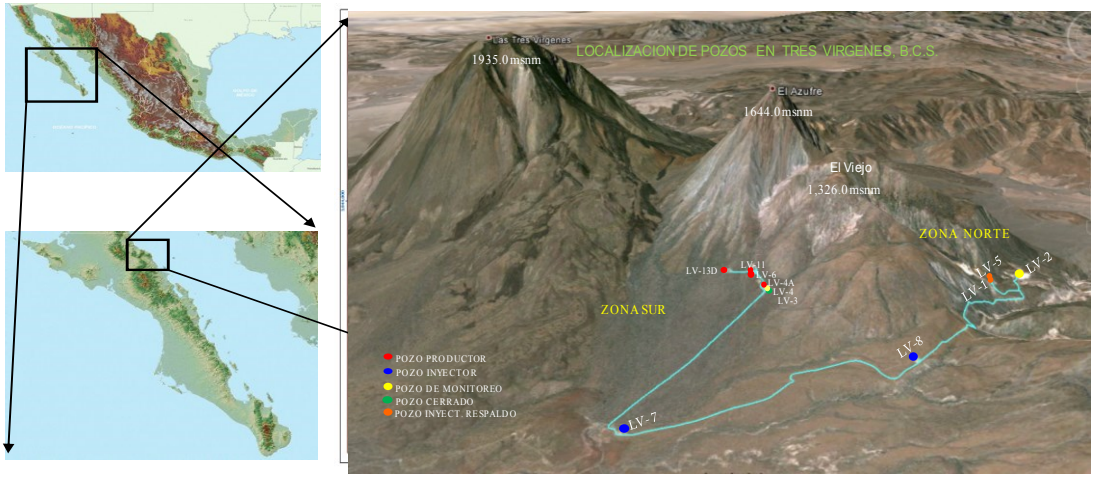

Figure 1: Location of the Las Tres Vírgenes geothermal field.

From geological, geochemical, reservoir and production characteristics, the field is divided into 2 areas: north and south. The second one, presents the highest temperatures and is currently the exploitation area. The first well, LV-2, was drilled in October 1986, and the commercial exploitation started in 2001 with a power plant of 10 MW. Until December 2013, 11 wells have been drilled with depths ranging from 1291 to 2505 m. currently, there are four producers wells, three injector wells and four exploration wells. Of these, 8 are located in the southern part of the field and the rest in the north part. For the year 2014 is scheduled the drilling of two new wells.

The southern zone is the only area in exploitation, with four wells: LV-4A, LV-6, LV-11 and LV-13D. The production zone is into the Granodiorite.

Discharge is a vapor / water mixture, where the main problem is the deposition of minerals mainly calcium carbonate (calcite $CaCO_3$) whose solubility decreases with the high temperature of the solution. The precipitation of over saturated calcite occurs with the loss of CO_2 , when pressure reach the saturation conditions and boiling starts.

In order to avoid scaling and maintain steam production to keep generating, it was necessary to install an inhibition system of calcite in each one of the producing wells. There are 4 inhibition systems installed below the flashing point, operates 24 hours a day, 365 days a year.

At present, the installed capacity is 10 MW. In order to sustain the generation, 95 t/h of steam is supplied from 4 producer wells. Simultaneously, 273 t/h of brine and condensed steam are injected in one injector well located in south of the field.

2. RESERVOIR TYPE

The geothermal reservoir has an approximate area of 6 km^2, located at more than 1000 m depth in the granodiorite, or at the Comondú base formation. Permeability is low. On surface, there are mainly a set of fumaroles and hydrothermal alteration areas with temperatures around 100 °C (López, 1993).

Thermodynamically, the reservoir is liquid dominated, and due to lowest permeability, when wells are open to production the fluid into the reservoir, in some wells, becomes a mixture steam-water (saturation conditions). The maximum temperature measured in the south is > to 275°C with a pressure of 144 bara. The output at atmospheric conditions is a mixture of water – steam with quality around 30 %. The highest salts concentrations at these conditions, cause a serious scaling problem in the field.

The characteristics of the fluid as well as the flash point is showed in the Curve of Clapeyron, where well LV-4A, LV-6 and LV-11 are in the area of sub-cooled liquid and flashing occurs inside the well therefore fluid travels in the liquid phase from the reservoir to the bottom of the well. LV-13D well fluid is in saturation and flashing occurs into the reservoir site (Figure 2).

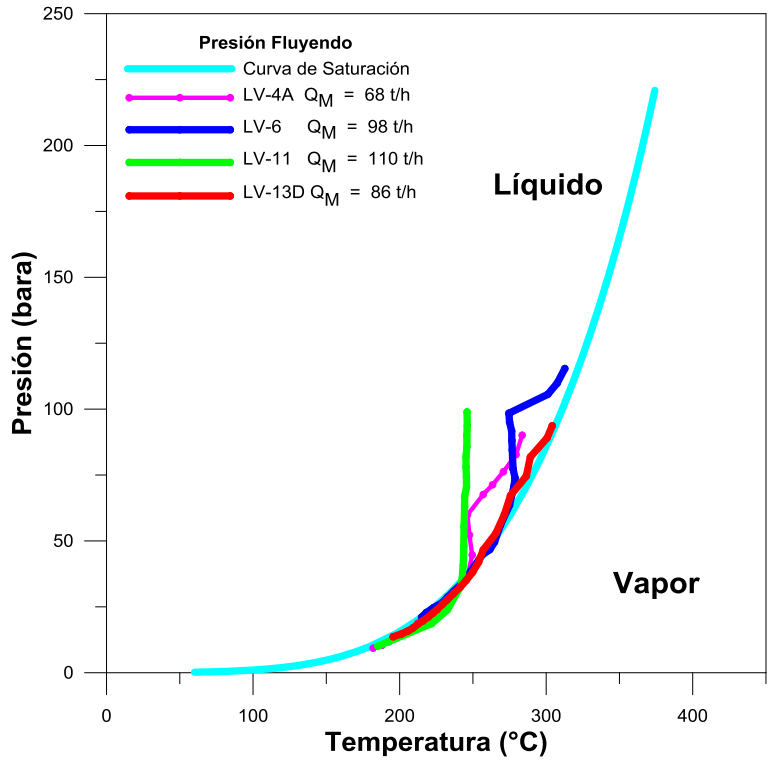

Figure 2: Saturation curve of Clapeyron.

So, in the wells LV-4A, LV-6 and LV-11, the minerals deposition is located into the transversal section of the pipes causing an effective diameter reduction. In well LV-13D, deposition is located into the reservoir because flashing occurs before fluid reaches the well. Calcite deposition causes production declining.

From chemical point of view, the fluid produced is of the type chlorinated - sodium and CO_2 gas. Considering the state of saturation of minerals and the solubility of CO_2 in the liquid during boiling, the produced fluid has a high concentration of carbonates (CO_3^{-2}) and calcium (Ca^{+}), the fluid produced is supersaturated in calcite ($CaCO_3$) at flashing temperature higher than 150 °C.

The deposition of calcite occurs in the flash point, so bellow sets the inhibition process and gets slow formation extending the lifespan of wells. When scaling is developed causing a highest steam production declining, it is necessary to take actions that ensure the supply of steam such as chemical treatment consisting in the injection of acids (HCl and HF), mechanical cleaning.

It is worth mentioning that according to the evaluation of wells and in order to reduce scaling by calcium carbonate (CaCO3) and extending useful life of producing wells to keep the field of Las Tres Vírgenes generating, the inhibition system installed consists in an inhibitor of embedding commercial calcium based on synthetic polymers (polyacrilatos) establishing its optimal efficiency and dosification for each well.

During the exploitation of the field transient pressure testing is important, because the reservoir pressure plays a major role in the producing life of the field.

The information required for the diagnosis of the well is the following:

During the exploitation of the field, geochemical studies, geological and geophysical tests as well as the well during drilling, heating and production are important because the trend over time is used to understand and diagnose the well.

By diagnosing the well, the behavior the well is analyzed to propose how it production capacity could be improved. With the purpose to control the operation of the reservoir and define what wells are candidates for intervention by stimulation with acids, a diagnosis of the mechanical and thermodynamically status of the well is made. The effect of the skin factor has been identified as an area of very low permeability close to the well, and it adds an extra hydraulic resistance to the natural flow in the reservoir. An acid treatment will remove mineral precipitated from the formation, restoring the original permeability.

3. BEHAVIOR OF PRODUCTION

The commercial exploitation starts from year 2001, with the commissioning of two units generating 5 MW each. Only the south part is exploding with wells LV-4A, LV-6, LV-11 and LV-13D. In general are in intersection with El Viejo 1 and El Volcan faults and permeable zones are associated with fault planes and the production area is located in the Granadiorite, considered the area with geothermal features.

Correlating the permeable zones identified from profiles of temperature, the production interval ranges 1600 – 1900 m (800 to 950 meters above sea level) related to the El Viejo 1 fault where the reservoir is hosted, considered with significant geothermal features in the steam production (Figure 3).

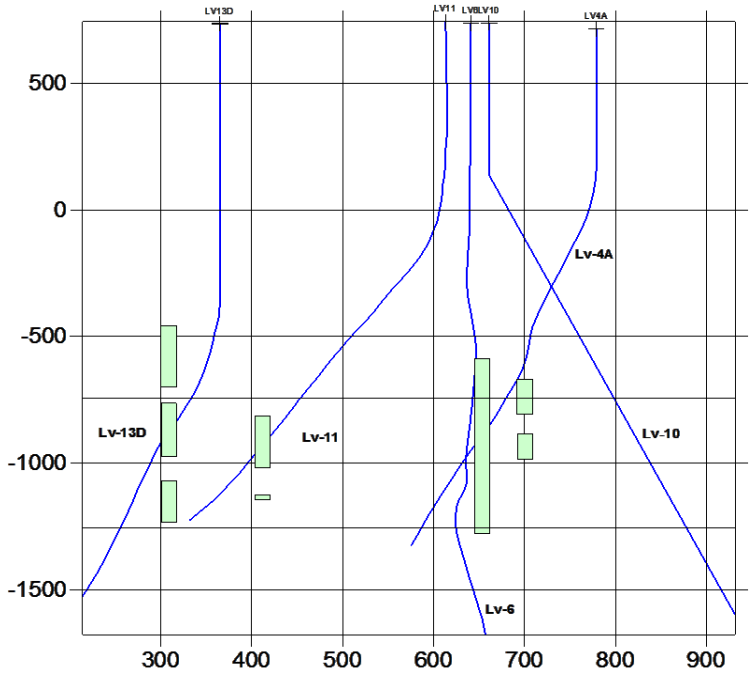

Figure 3: Wells section and feed zones.

After drilling, the well is cleaned from bentonite mud waste deposited in the fractures and pores of the rock where the fluid is hosted.

The flow rate in the producing wells LV-4A, LV-6, LV-11 and LV-13D at generating conditions, is around 70 and 155 t/h. Variations in the wellhead pressure with a tendency to declining as well as its producing of steam is observed during the production stage of the well. By way of reference in relation to the productivity of the area, to higher productivity index higher production rate, for this wells this index is average of 2.5 to 10.2 t/h-bar, finding enabling environments for the production.

With the time there is declining in the producing Wells, is affected by manifest embedding in mechanical damage in the pipe. Obeying the characteristics of production, the wells are handled according to the thermodynamic condition of the fluid, pressure drop, thereby extending its useful life and therefore ensuring the generation.

With the evaluation of the physical characteristic of the produced mixture, pressure head, production, enthalpy and decline analysis method using the technique of normalization of expenditures through dynamic material balance (Sanyal et al 1989), the trend of

declining in production is observed. Under the 2010 – 2013 extraction scheme declining in the producing area is average 4.5 % of the standard spending (Figure 4), 0.7 t/h-year of steam (Figure 5) and 3.5 t/h-year of mixture. The declining for the year 2013 is 2 % and the rhythm of extraction include the life of the wells and this goes from 4 to 5 years, in addition to the use of inhibitors of minerals present in the fluid.

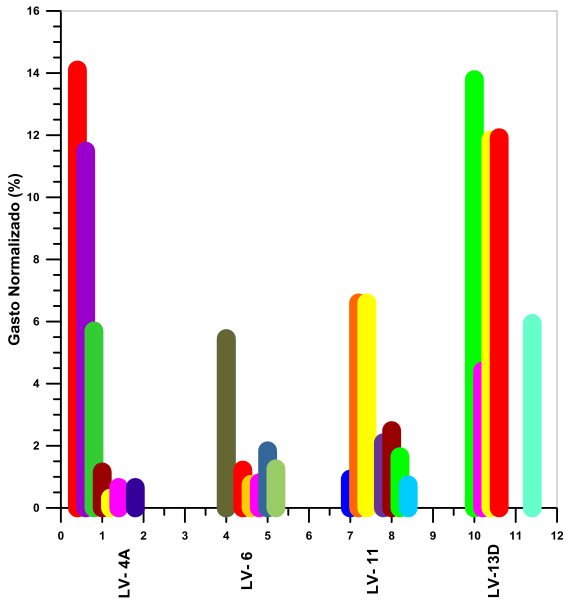

Figure 4: Decline 2010 – 2013 production wells.

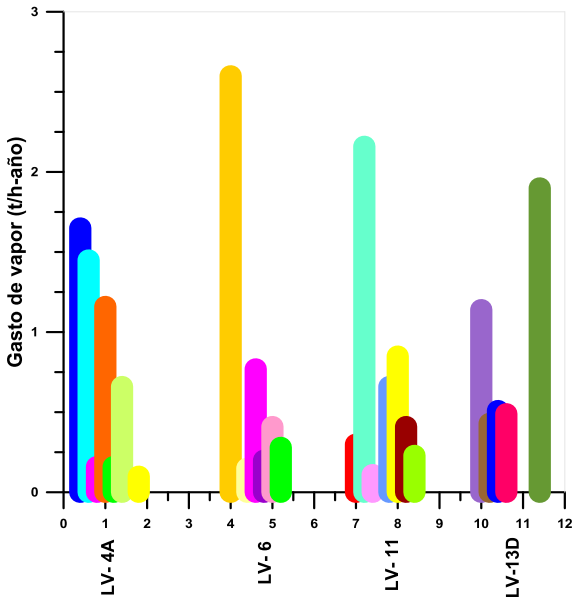

Figure 5: Steam decline 2010 – 2013 production wells.

The evolution of the characteristic of production has been affected by the entry (new wells) or output (intervention of wells), where the trend in the production of steam and water is to decline over time, again increasing his production with acid stimulation. The evolution of the characteristics of production, declining in addition to scaling by calcium carbonate (CaCO3) are a reflection of the needs of steam in the field. It has a liquid phase reservoir in addition to a low permeability therefore the relation water – steam is maintained with high enthalpy at low pressure and the behavior is down to reach stability (Figure 6).

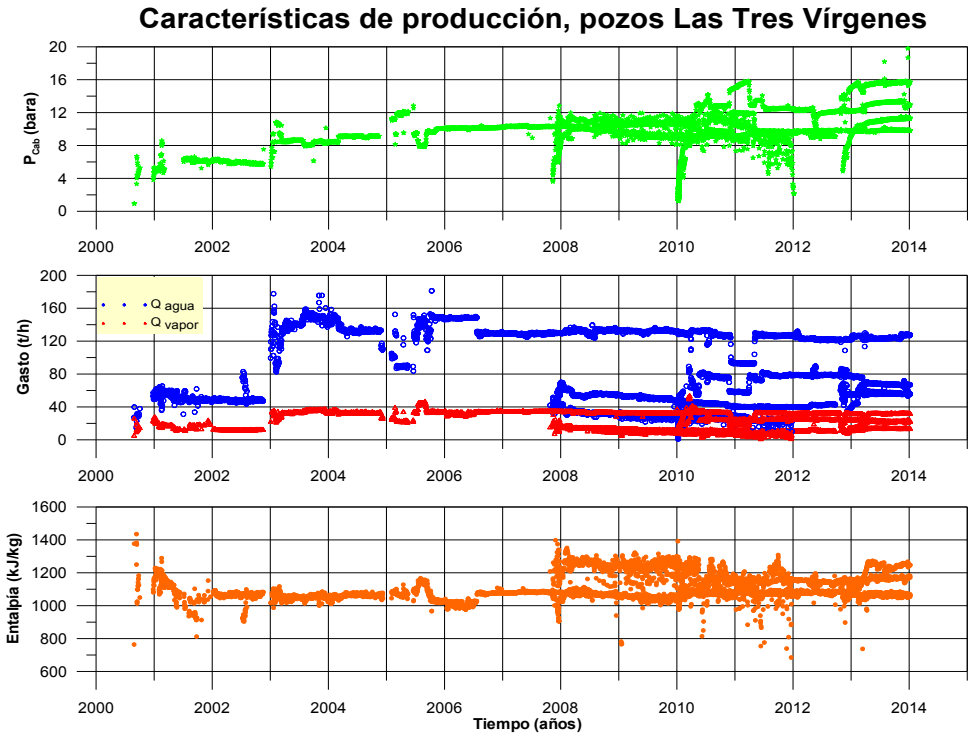

Figure 6: Behavior of pressure, steam, water and enthalpy, 2001 – 2013.

After the intervention of acid conditions of production from well recovers up to 100 % or more (Figure 7).

Characteristics production curves: The characteristic curve of the well is created during production testing. This information is important to analyze the evolution of the well and to identify if it is declining. (Figure 8).

The producing Wells have allowed a sustainably geothermal Project since 2001. Fluid extraction has increased over time and during 12 years of continuous operation of the southern area of the field, are taken from the reservoir to December 2013 a volume of mixture of 30´288,246 tons of which 23´118,114 tons are fluid and 7´170,132 are steam. In the year 2013, the greater volume of mass extracted has been mixing water – steam (Figure 9).

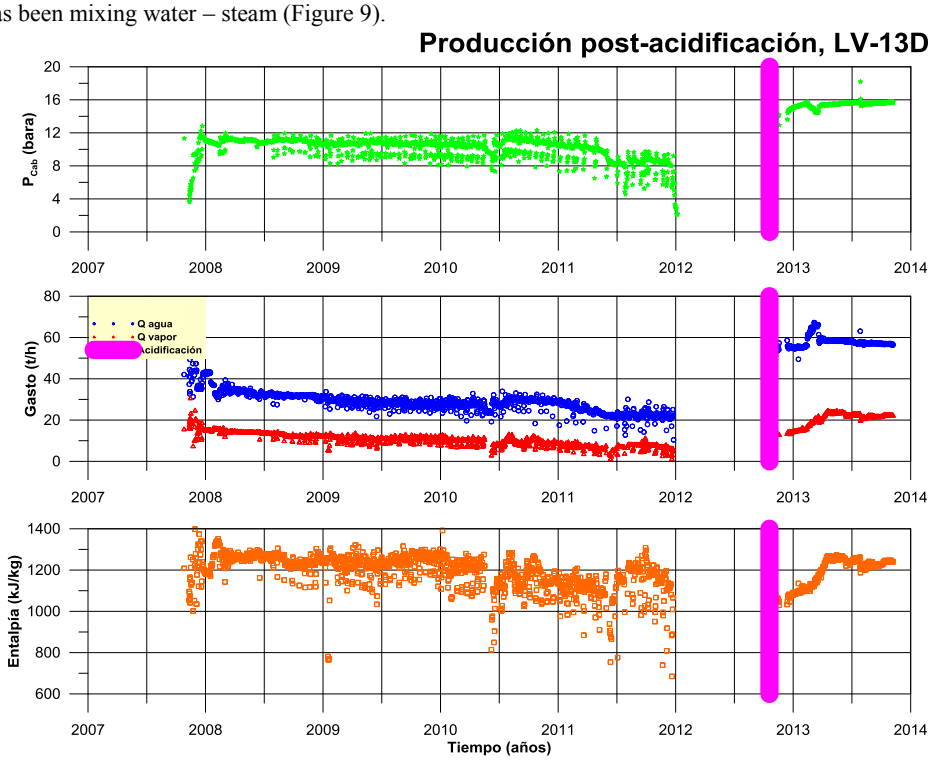

Figure 7: Behavior of pressure, steam, water post-stimulate, LV-13D well.

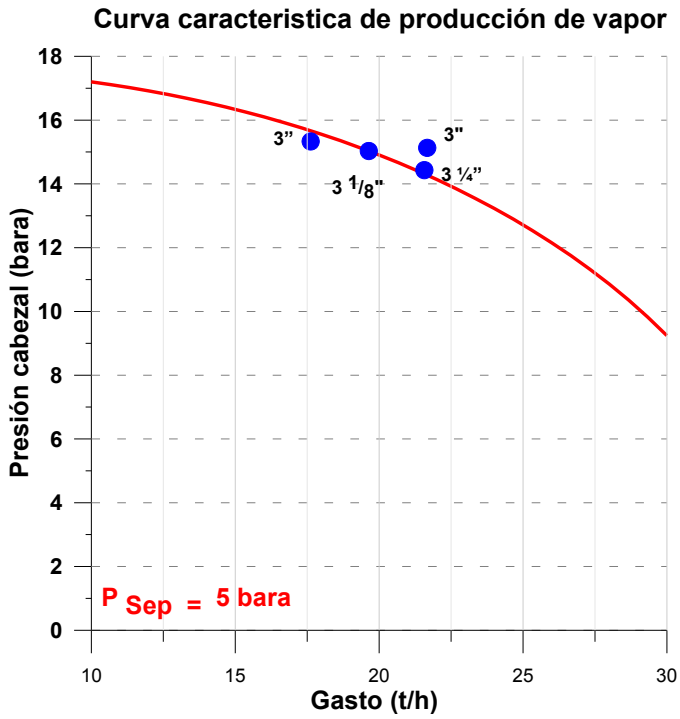

Figure 8: Production curves of the well.

In response to exploitation, the produced fluid changes with the regime of extraction from the reservoir. Important attention is the forecast of vapor whereas the decline in each of the wells, in determining the strategy of steam generation units. Dependent on

installed capacity, specific consumption of 9.5 t/h.MW and the availability of the date of 92 t/h steam, is enough for a generation of 95 % with 4 producing wells (Figure 10).

Figure 9: Mass flow 2001 – 2013.

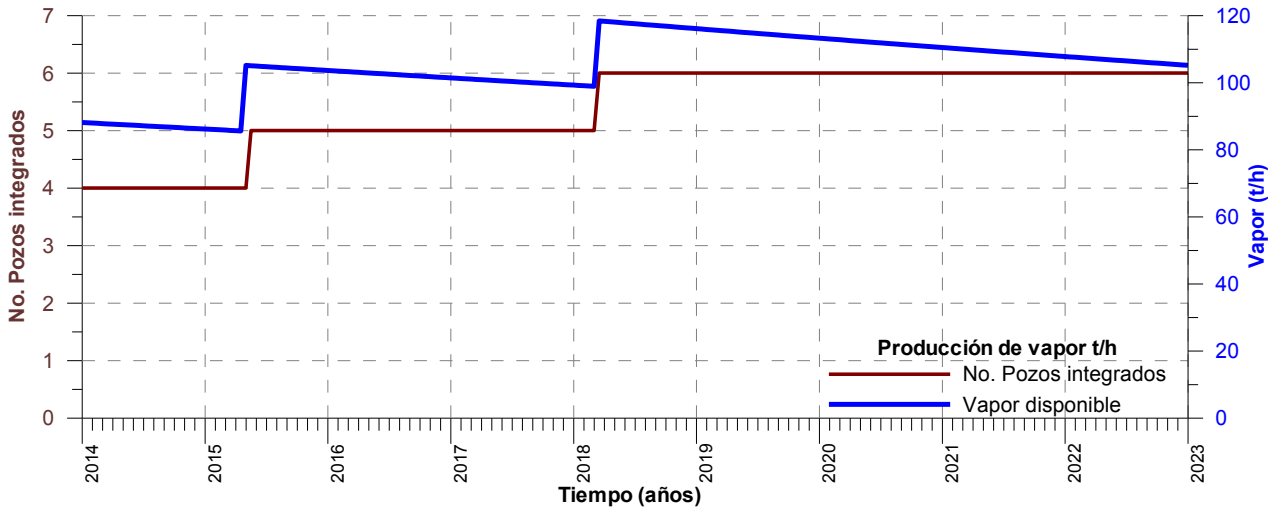

Figure 10: Steam available and producer wells.

4. SCALING PROBLEM AND SOLUTION

Since 2004, in the Las Tres Vírgenes geothermal field have been made acid treatment in wells. The transient pressure test using the technique of curve type (Pan – System) lead to the conclusion of the damage in the formation and/or pipe wells (Figure 11). The additional restrictions to the flow that affect the optimum performance in wells is caused by the mineral deposition present in produced fluid. It is very important the behavior analysis of the characteristics of the well as well as the use of carbonated material (synthetic polymers) inhibitor injecting continuously and save (prolonging) the life of the well.

It is necessary to have steam support that provide security in the generation, therefore the objective of the intervention is mainly dissolved (remove) minerals that are housed close to the well and permeable zones, helping to repair wells with mechanical problems or formation, improving the permeability of the formation, head pressure and its production capacity and acceptance.

Acid stimulation treatment design criteria is to use a mix of acid HCl and HF 10 % to 5 %. Acidizing operation starts from the shallow to deeper areas. Figure 12 shows the behavior during operation.

- 10 % de HCl pre-acid
- 5 % de HF – 10 % de HCl main-acid
- 10 % de HCl post-acid
- Divergent when required

In the main washing the volume of HCl 10% HF-5% is pumped at a rate of 1.27 - 1.6 m^3/min. The flexible tubing must be moved along the interval at a rate of not greater than 10 m /min.

5. CONCLUSIONS

Continuously carbonates inhibitor injection is useful to prolong the life of the Wells by minimizing the production decline.

The matrix intervention of wells by treatment with acids (10% HCl + 5% HF) allows cleaning of structures and formation, improving production capacity.

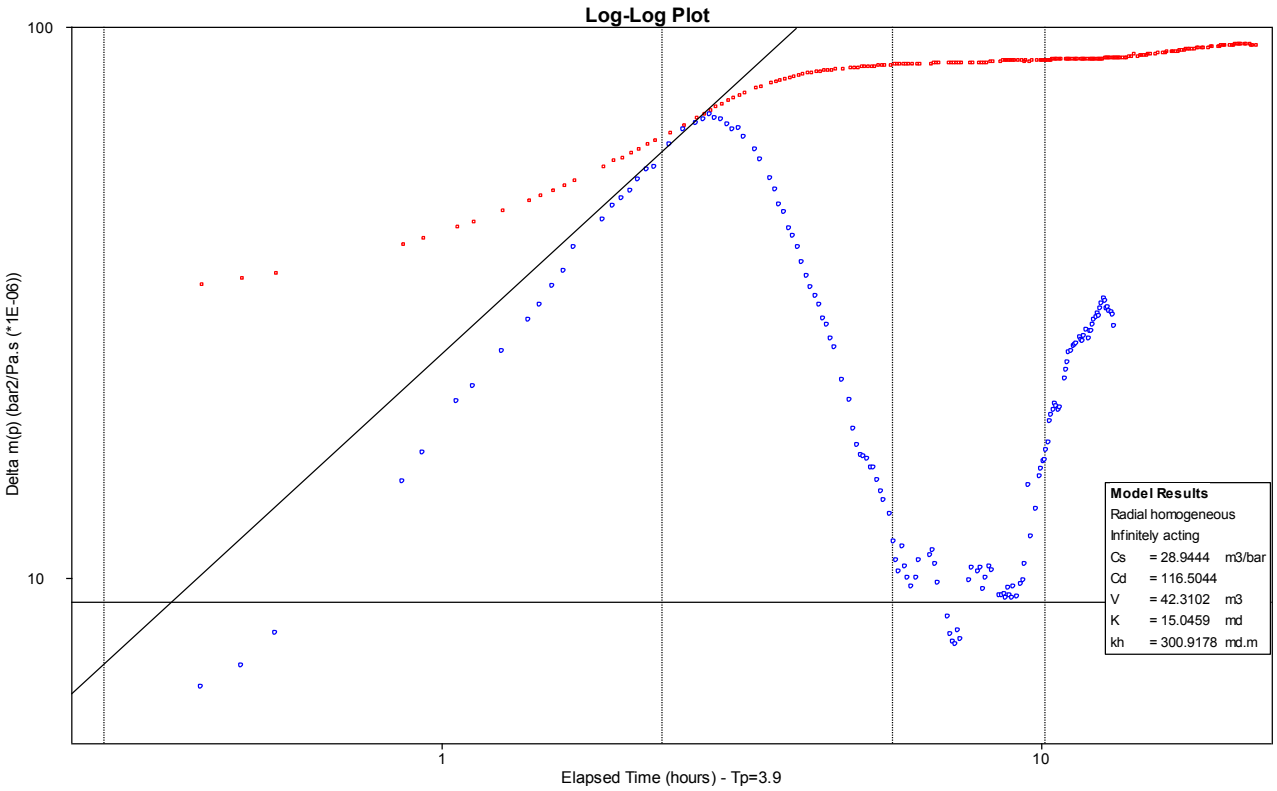

Figure 11: Well test analysis to the skin factor (S).

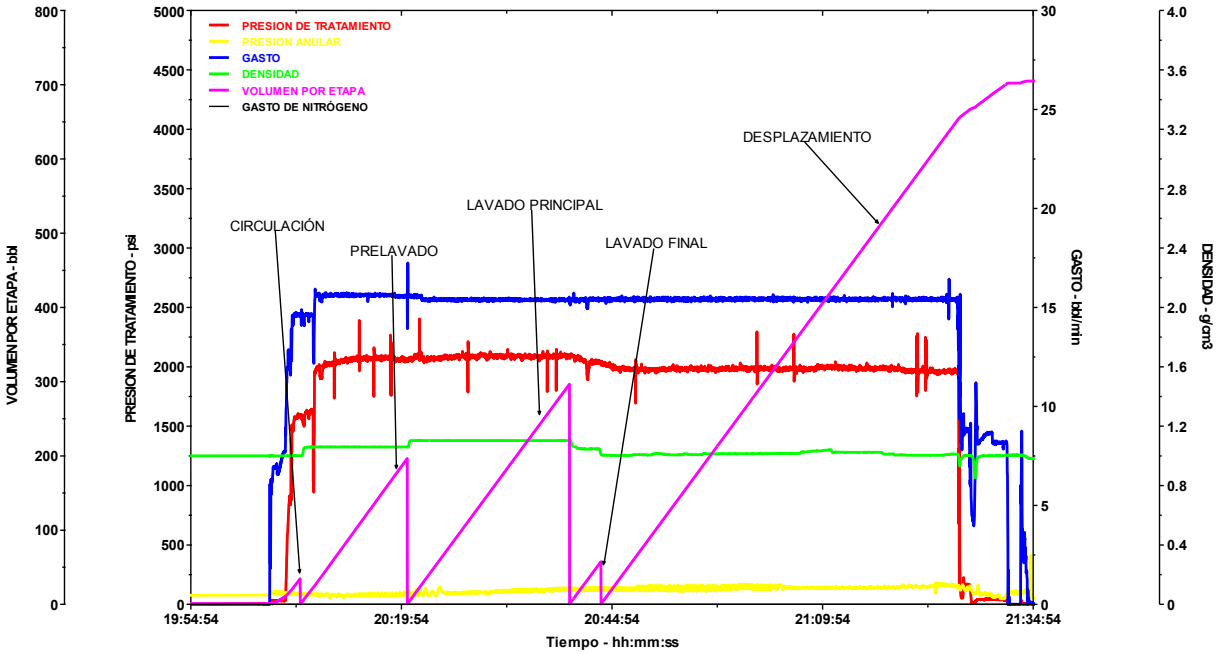

Figure 12: Behavior of different parameters during of stimulation.

The decline in the geothermal field Las Tres Vírgenes with the extraction from 2010 – 2013, on average is 4.5 % of standard normalization expenditures, where the decline of steam is 0.7 t/h-year and mixing of 3.5 t/h-year. In the last year, the decline is 2 %.

From the beginning of the commercial exploitation in 2001 at the end of 2013, increased 69 % mixture fluid extraction.

The intervention with acids is proposed when the wellhead pressure is less than 5 bara that it is the operation pressure of the generation units

According to the results in each well after acid treatment It is carry on an exhaustive monitoring of production, geochemical and geological variables in order to obtain new data of the behavior of the wells and continuing applying acid treatment to improve the production/injectivity of the wells in the field.

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