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Acid Treatment in Wells of the Los Azufres Geothermal Field to Steam Production Enhancement

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ABSTRACT

Los Azufres geothermal field is located in the central portion of México in the volcanic belt at an average elevation of 2800 m. It has been under commercial exploitation producing electrical energy since 1982. At present, the installed capacity is 188 MW with seven backpressure units of 5 MW each, two binary cycle units of 1.5 MW each, one condensing unit of 50 MW and four condensing units of 25 MW each. In order to establish the best exploitation strategy of the geothermal reservoir, production declining analysis has been performed in each well, as well as a diagnostic of the mechanical and thermodynamic state. From the results it has been established which wells, based on their condition, were candidates for injection of acid in order to recover initial production or to improve it. The wells that have been acid treated with successful results are the following ones: Az-2A, Az-8, Az-9A, Az-9AD, Az-25, Az-52, Az-56R, Az-68. The most remarkably case is the Az-9AD, which was producing 25 t/h and after the stimulation increased its production by 188%, producing 47 t/h more than before.

1. INTRODUCTION

The Los Azufres, México, geothermal field is located in the northern portion of the Transmexican volcanic belt, 80 km east of Morelia city and 250 km of Mexico city (Figure 1). It is n heavily fractured and faulted volcanic hydrothermal system, located in a sierra at an average elevation of about 2800 m. It is found in a forest area with abundant vegetation, considered a forest reservation zone.

In order to evaluate the likelihood of the existence of a geothermal system in Los Azufres, geological, geophysical and geochemical surveys were carried out in 1972. Drilling activity began in 1976, and currently 75 wells have been drilled at depths ranging between 700 and 3500 meters. In 1982 commercial exploitation of the field started with the start-up of the first five backpressure power units of 5 MW. In 1994 the installed capacity reached 98 MW. One power unit of 5 MW (U-1) was dismantled and sold to the Instituto Costarricense de Electricidad in the Miravalles geothermal field in Costa Rica. In 2002 unit number 8 of 5 MW was dismantled and transported to the Los Humeros geothermal field, México. In 2003, four condensing units of 25 MW each (Los Azufres III project) were put in operation.

At present, the installed capacity is 188 MW. In order to sustain the generation, 1630 t/h of steam is supplied from 43 producer wells. Simultaneously, 891 t/h of brine and condensed steam are injected in six injectors wells located in the west of the field. Of these, 280 t/h are sent to the binary cycle units before being carried to the injection system.

Figure 1: Location of the Los Azufres geothermal field

From the beginning of the development of the field, exhaustive studies on the behavior of the reservoir and wells have been performed. Each year new data from the wells are obtained in order to increase knowledge of the field, allowing analysis of the reservoir and wells' behavior and forecasting on its evolution as a clean source of energy for electrical generation.

Acid stimulation of wells has been useful for cleaning the wells and improving their production and/or their capacity for injection. Since 2005, this method has been applied in wells of the Los Azufres geothermal field: Az-2A, Az-9A, Az-9AD, Az-25, Az and Az-56R-68D and the injector wells Az-8 and AZ-52. Well Az-9AD increased its production by 188% and well Az-68D by 540%.

2. WELL DIAGNOSIS.

Bentonite mud used during drilling behaves as a non-Newtonian fluid. It forms a barrier that slows flow and causes damage in the formation. This damage is called Skin Factor (S). Positive values denotes injury in the rock, zero no damage, and negative values denotes stimulation (Malate, 2002) (Earlougher, 1977).

The cause 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.

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.

By diagnosing the well, the behavior the well is analyzed to determine how its production capacity could be improved. During the exploitation of the field, geochemical studies, geological and geophysical tests are taken. They are also taken during drilling, heating and production because the trend over time is used to understand and diagnose the well.

In order to control the operation of the reservoir and define what wells are candidates for intervention by stimulation with acid, a diagnosis of the mechanical and thermodynamic status of the well is made.

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

- ❖ Characteristics of the well: location coordinates and geological structures (Figure 2).

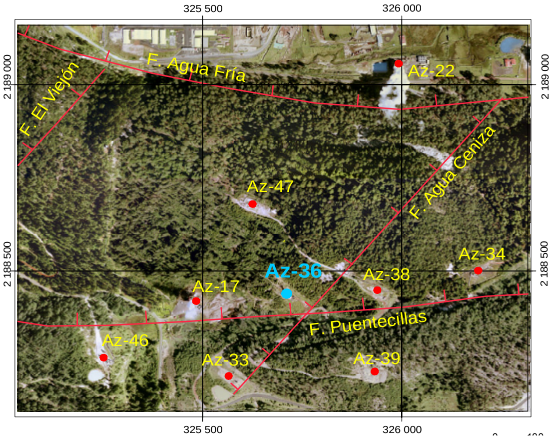

Figure 2: Location coordinates and geological structures

- ❖ Mechanical status: the mechanical status of the pipes is analyzed in order to verify if scaling in the pipe is produced (Figure 3).

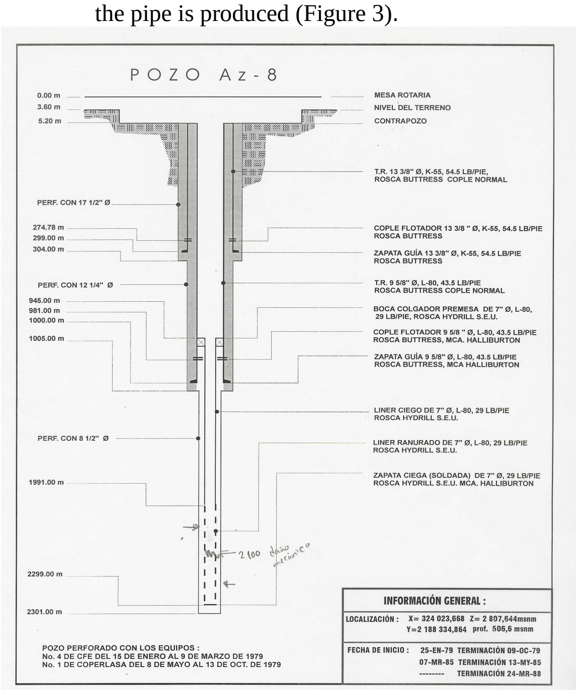

Figure 3: Mechanical status of the pipes in the well

- ❖ Structural analysis: location of failures, lithology and hydrothermal mineralogy are analyzed to identify dome scaling processes (Figure 4).

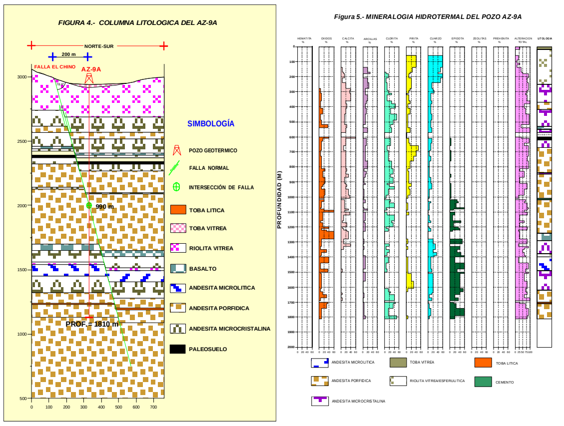

Figure 4: Location of failures, lithology and hydrothermal mineralogy

- ❖ Loss of circulation: identification and quantification of mud losses during drilling (Figure 5).

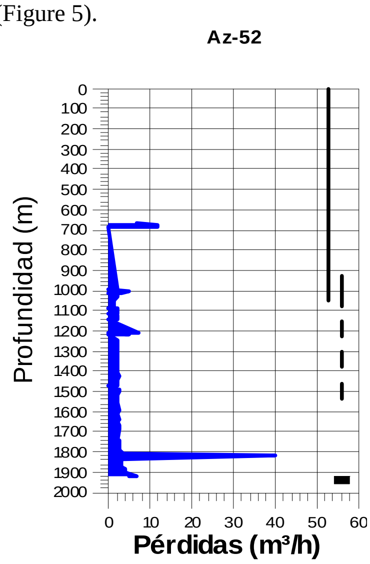

Figure 5: Loss of circulation during drilling

Permeable zones identification: in order to identify permeable zones, pressure and temperature surveys in the well are analyzed. (Figure 6).

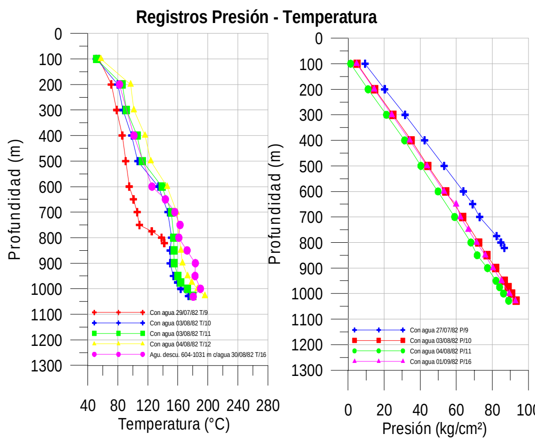

Figure 6: Pressure and Temperature surveys in the well

❖ Production of the well: the behavior of pressure, steam, water flow rates and enthalpy are analyzed (Figure 7).

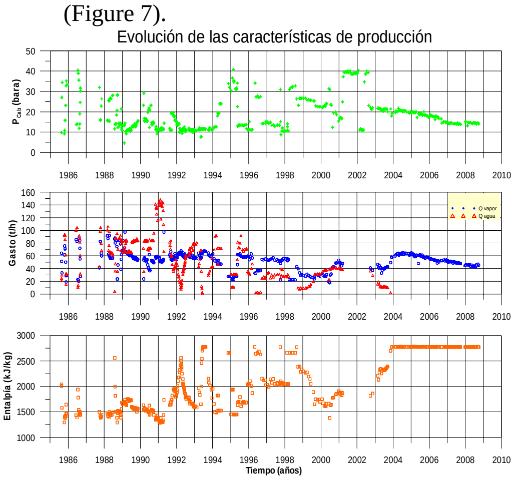

Figure 7: Behavior of pressure, steam, water and enthalpy

❖ 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).

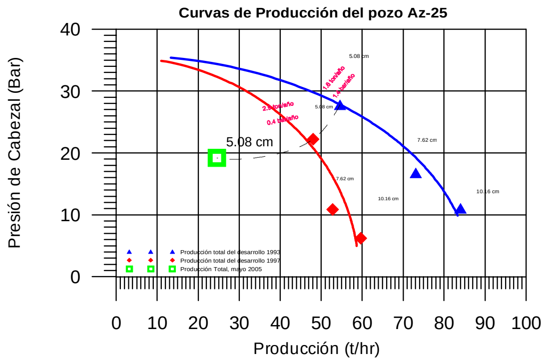

Figure 8: Production curves of the well

❖ Productivity index: it is the capacity of the well to produce fluids. (Figure 9).

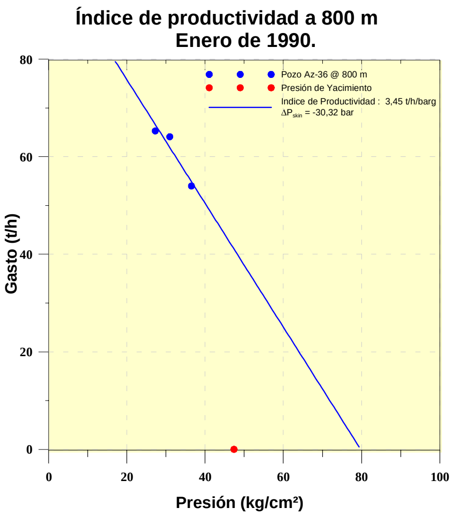

Figure 9: Productivity Index

❖ Well test analysis: the skin factor (S) is defined as an area close to the well with a very low permeability that offers an additional resistance to flow. This reduction of permeability is frequently caused by the invasion of drilling mud, clay particles or deposition of salts or minerals. Using well pressure transient analysis the skin factor and the conductivity of the producing formation (kh) are analyzed, Figure 10.

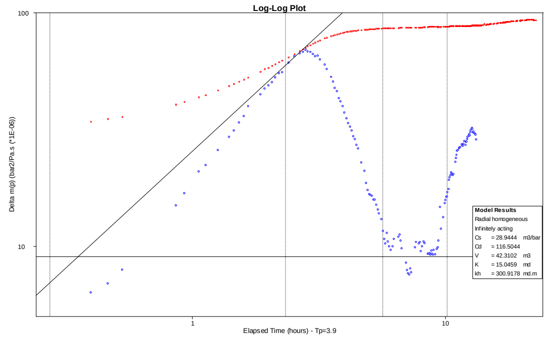

Figure 10: Well test analysis to the skin factor (S)

❖ Gain analysis: with ΔPskin calculated from pressure transient testing. It is assumed a complete acid treatment. The production expected after the acid treatment is calculated by

Expected gain = (Productivity index) (ΔPskin)

Moreover, using the equation of flow efficiency (EF) derived from the Darcy equation for flow in porous media and calculating the flow from the well in optimal conditions (Skin = 0), the following equation can be used to calculate the well gain:

$$EF = \frac{\ln \frac{re}{rw}}{\ln \frac{re}{rw} + S} = \frac{Q_{daño}}{Q_{optimo}}$$

According to the analysis of the information that exists on file for each well: the permeable zones, loss of circulation zones, PT or PTS surveys and zones of interest defined by petrographic and mineralogical analysis, zones are defined for acid stimulation at intervals of 50 m each with a length no greater than 200 m deep.

3. ACID TREATMENT

The wells that are candidates for acid treatment must be operated until the pressure head is less than that required to operate a turbine.

The acid stimulation of the rock matrix should be realized with the appropriate concentration for the dissolution of silica, using a mixture of acids with the following characteristics:

❖ 10 % HCl pre-acid

❖ 5 % HF – 10 % HCl main-acid

- 10 % HCl post-acid
- Divergent when required

Fresh water or geothermal water should be pumped through the annular space to maintain the temperature in the well below 150 ° C and to prevent intrusion of acid in the above areas. The injection of acid is made step by step.

- For each stage, the pipe is located at the required depth to be acidified. The injection of the acid should be done from the more shallow to the deepest zone.
- A volume of fresh water or geothermal water is pumped, and it must be verified that the tubing is free.
- In the pre-wash the volume of 10% HCl is pumped at a rate of 1.27 -1.6 m^3/min. The pipe must be moved along the interval, at a speed no greater than 10 m /min.
- In the main wash 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.
- In the last wash a volume of 10% HCl is pumped.
- In the final step the remnant acid is pumped and then fresh water is pumped.

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- The fresh water or geothermal water is pumped to complete the post-wash
- The divergent is pumped in the intervals where required.

During the injection of acids, chemical parameters are monitored (pH) in the producing wells adjacent to the well being acidized. In the event of any drastic change, these wells must be closed.

To determine the conditions of the pipe, it should be calibrated with a calibration tool of 5 " of diameter to be sure that the pipe is free of any obstruction.

To know the conditions of the reservoir prior to the stimulation, a pre-acidification test is performed. This test is a test of injection at three different flow rates. The injectivity index, the factor of damage and the pressure drop caused by the skin are calculated (Figure 11).

At the end of stimulation a post-acidification test is performed with the same parameters used in the pre-acidification test with the purpose of determining the improvement in the well after the acid treatment.

Once the acidizing and testing in the well have finished the well is shut in for at least 5 days. During the work of inducing well, the pH and chemical content of fluids produced should be monitored according to the safety standards.

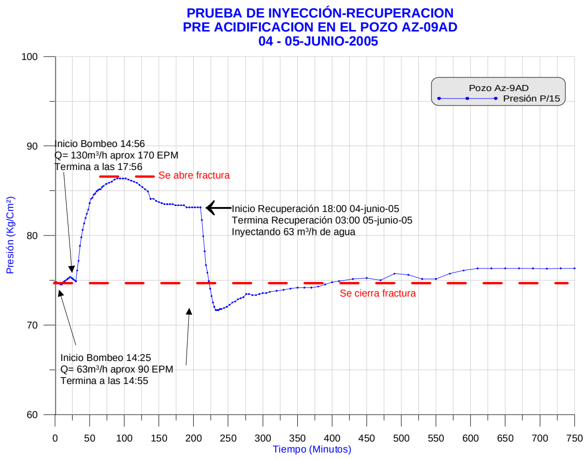

Figure 11: Injectivity Index before acidification test

4. ACIDIZED WELLS

Since 2005, acid treatment have been made in wells in the Los Azufres geothermal field. Seven producer wells: AZ-2A, Az-9A, Az-9AD, Az-25, Az-56R, Az-64, and Az-68D and two injector wells: Az-8 and AZ-53.

Table 1.- Wells acidized in the Los Azufres geothermal field

WELL	BEFORE ACIDIZING	AFTER ACIDIZING	IMPROVMENT
Az-9AD	Wp = 12 bar Steam = 25 t/h @ Psep= 0.74bar Water = 0 t/h	Wp = 20 bar Steam = 68 t/h @ Psep= 10 bar Water = 4.2 t/h	188%
AZ-25	Wp=16,8bar Steam=16 t/h @ Psep= 10 bar Water = 8 t/h	Wp = 16,8 bar Steam = 30 t/h @ Psep= 10 bar Water = 52 t/h	87.5%
AZ-68D	Wp = 12 bar Steam = 10 t/h @ Psep= 0.74 bar Water = 8 t/h	Wp = 18 bar Steam = 64 t/h @ Psep= 0.74 bar Water = 96 t/h	540%

5. CONCLUSIONS

The reduction of production from the wells caused by scaling on the pipe and in the formation is recovered by acid treatment. In the injection wells the injectivity is improved.

The zones to be stimulated are obtained from an analysis of permeable zones, loss of circulation records, and PTS surveys.

Intervention with acid is proposed when the wellhead pressure is less than 8 barg. That is the operation pressure of the generation units

According to the results in each well, after acid treatment it is determined whether the intervention in each well was successful.

The appropriate concentration for the dissolution of silica is 10% HCl - 5% HF after washing with 10% HCl and followed by a volume of the same concentration of HCl and geothermal water to move wastes.

An exhaustive monitoring of production, geochemical and geological variables is continuing in order to obtain new data of the behavior of the wells and acid treatment will continue to be applied in order to improve the production/injectivity of the wells in the field.

REFERENCES

Torres-Rodríguez, M.A. and Flores-Armenta, M.: Pressure and Enthalpy Evolution in Wells of the los Azufres Geothermal Field, Transactions, vol.22, Annual Meeting, Geothermal Resources Council, San Diego, CA (1998).

Alcántara-Suáres, J.G., and Flores-Armenta, M,: Simulación numérica de la Zona Norte, Campo Geotérmico Los Azufres, Internal Report, Comisión Federal de Electricidad, México (1996).

Torres-Rodríguez, M.A. and Flores-Armenta, M.: Reservoir Behaviour of the los Azufres Geothermal Field, After 16 Years of Exploitation, Transactions, World Geothermal Congress, Japan (2000).

Tello-López, M.R, Waldo-Zalapa, R, and Gómez-López J.G.; Diagnóstico del pozo Az-25 del Campo Geotérmico Los Azufres, Internal Report Comisión Federal de Electricidad, México (2006)

Tello-López, M.R. and Ramírez-Montes M.; Proyecto de acidificación de los pozos Az-25, Az-36 y Az-68D, del Campo Geotérmico Los Azufres, Internal Report Comisión Federal de Electricidad, México (2007).

Robert C. Earlougher,Jr.:Advances in well test analysis, Henry L. Doherty series, SPE of AIME, (1977).

C.S. Matthews and D.G. Russell,:Pressure builup and flow tests in wells, Monograph volume 1, Henry L. Doherty series. SPE of AIME. (1967)

Thomas C. Frick and R. William Taylor,: Petroleum Production Handbook, Volume II Reservoir Engineering, SPE of AIME