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# Chemical Treatments of Fluids on the Miravalles Geothermal Field: Investigation, Application and its Relationship With Reservoir Management.

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## ABSTRACT

Visualising the commercial exploitation of the Miravalles Geothermal Field without the application of chemical treatments to the produced waters would be impossible, since 25 out of 26 producing wells require these treatments. The CaCO3 scaling is observed in 23 producing wells, which would be obstructed in periods that ranges from some days to several months without to correct inhibition process. The appropriate chemical treatment of these wells has assured an uninterrupted production for years and continuous operation of the different geothermal plants installed so far. Also, two other production wells present acid fluids and they require an acid neutralisation treatment. Without this process the corrosion rate into the wells is so high that it would be impossible to exploit them, even for short periods. These two wells have helped to maintain the mass flow requirements of the geothermal plants, when for some reason some of the neutral-flow producer wells cannot be used.

The present document discusses the experience gained in the investigation and uses of chemical treatments in the fluids of the Miravalles Geothermal Field, in answer to its particular conditions. The investigation is not only focused in the industrial process of the exploitation of these fluids, but also in the impact that these treatments have on the operation and maintenance of the geothermal field, and is an integral part of the reservoir monitoring programs and exploitation policies.

## 1. INTRODUCTION

The Miravalles Geothermal Field (Figure 1) is located in the north-western part of Costa Rica. Deep drilling started in 1979, when a high-temperature reservoir was discovered. Subsequent drilling stages completed the steam necessary to feed three flash plants commissioned in 1994, 1998 and 2000, and one binary plant in 2004, totalling an installed capacity of 163 MW. Three wellhead units of 5 MWe each have produced for different periods, and one of them is still producing and belongs to ICE (Instituto Costarricense de Electricidad).

Right from the beginning it was set up a monitoring program since the first productive tests and before the first power plant commissioning (Vallejos et al, 2005). There have also been developed several numerical models, for forecasting the future behaviour of the field according to the data collected (Vallejos et al, 1995). These actions have allowed to maintain a successfully steam supply to the power plants and lately, also the necessary brine for feeding a recently commissioned binary plant. Also, it has allowed to face different problems that have been encountered during the normal operation of the reservoir. Among these problems are included the calcite scaling in wells, acid fluids coming of a different aquifer from the main one, and production drops due to reservoir evolution.

There have been drilled 53 wells, and 29 of them are used as producer. Among them, five are acid wells. 25 out of 29 producer wells are connected permanently to the gathering system, and the rest of the wells remain as spare wells for future utilization as needed. The cumulated production of this wells is about 300 kg/s of steam, and about 1350 kg/s of brine (about 800 kg/s are used for a binary plant) are injected back to the reservoir.

## 2. RESERVOIR CHARACTERIZATION

The Miravalles Geothermal Field is a high-temperature liquid-dominated reservoir related with the nearby 2208 m a.s.l. Miravalles volcano. It is encountered about 700 m depth, and reservoir temperatures naturally decline to the south and west. The estimated thickness of the reservoir is about 800-1000 m. The field is associated with a 15 km diameter wide caldera, which has been affected by intense neo-tectonic phenomena. The interior of the caldera is characterised in general by a smooth morphology. The main aquifer is characterised by a lateral flow of 230-255 ºC. A shallow steam dominated aquifer is located in the north-eastern part of the field, and it is formed by the evaporation of fluid from the main aquifer that moves along the fractures (Vallejos, 1996). Based on their chemical characteristics, in the Miravalles Field there are three different geothermal aquifers (Figure 1):

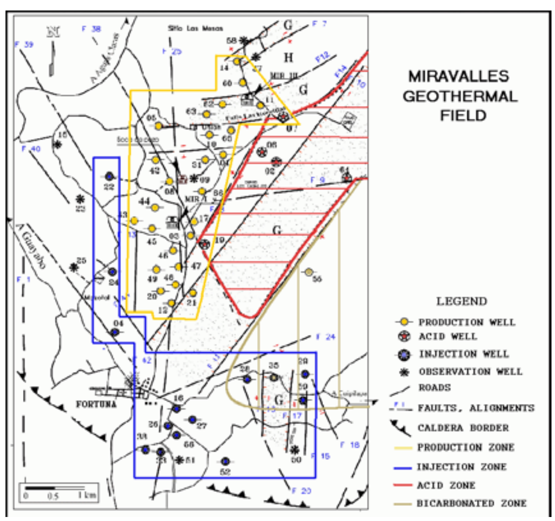


**Figure 1: Mass Production at the Miravalles Field.**

- Sodium-chloride aquifer: it is located at the north and central sectors of the field. It is the main aquifer and presents a sodium-chloride composition, presenting pH values in surface of 7.6 - 8.0, a chloride content of 4100 -5000 ppm, silica of 580 - 620 ppm, calcium of 70 - 130 ppm, bicarbonates of 15 - 70 ppm and TDS of 8000 - 10000 ppm. The production wells of this sector of the field presents CaCO3 scaling in depth, which can lead to the obstruction of the wells in terms of some weeks to several months (Sánchez 1995).

- Sodium-chloride bicarbonate aquifer: the wells located in the southeast sector of field present fluids of this composition, with pH values in surface of 7.4 - 8.2, a chloride content of 4000 - 4300 ppm, silica of 550 - 560 ppm, calcium of 60 - 70 ppm, bicarbonates of 160 - 215 ppm TDS of 8000 - 8400 ppm. These wells present severe CaCO3 scaling in depth, which can lead to obstruct them in term of days.

- Sodium-chloride acidic aquifer: the wells of the northeastern sector of the field presents fluids of this composition, with pH values between 2.4 and 3.2. This corrosive character would cause irreparable damages in the wells casings and surface equipment, which would force to discard them after few weeks of production.

Due to the previously exposed, under natural conditions the fluids of the Miravalles Geothermal Field are so aggressive (severe scaling tendency or highly aggressive acidity) that the commercial exploitation of the wells would not be technically neither economically sustainable without an appropriate deep chemical treatment of its reservoir fluids.

## 3. CHEMICAL TREATMENTS IN PRODUCTION WELLS

Excepting for well PGM-65, the remaining 25 producer wells of the Miravalles Field connected to the productive system have required deep chemical treatments right form the start of its commercial integration: 23 of them for the inhibition of CaCO3 scaling and two of them for pH modification (neutralization).

Before the first power plant commissioning (1994) the scaling condition of the wells was known; for this reason a $CaCO_3$ inhibition system was implemented and later improved. A well with acid fluids was drilled that year, but subsequent drilling lead to the location of an unknown (in that moment) acid aquifer. The lack of technology for facing this condition forced ICE to carried out some studies and tests leading to exploit this kind of fluids.

### 3.1 Calcium Carbonate Scaling Inhibition

The formation of calcium carbonate inside the geothermal wells in production is related to the boiling phenomena that is given into them, in those cases that the fluids are near the $CaCO_3$ over saturation condition (Figure 2). The $CaCO_3$ scaling process mechanism in geothermal fields has been broadly discussed in different documents, reason why the present work omits to discuss it in depth.

As it has been mentioned early in this document, since the start of commercial production of Miravalles 23 of the producer wells have required $CaCO_3$ inhibition systems. This system which consists on a constant injection of a diluted chemical inhibitor to an average depth of 1200 m.

The structural part of a $CaCO_3$ inhibition system has as main elements an electrical supply support system, a storage tank, an injection pump, inserting and fastening elements, capillary tubing for injection in depth, an injection head and a chemical inhibitor (Sánchez 1995). The next paragraphs briefly present each one of these components, based on the experiences accumulated over the 10 years of the system utilization (Figure 3).

*Electrical Supply Support System*: it guarantees a constant operation of the dosing pumps and the different on-line monitoring elements. The required reliability degree depends on the scaling velocity, since the failure time allowed won't be the same in the case of a well that takes months or years of becoming obstructed compared with one that takes some days. In the case of the Miravalles Field the wells located in the southeast area present a high scaling indexes, being able to form from 600 to 1200 kg. of $CaCO_3$ every day of production. It means that short stops of few hours can generate an important deposition (Figure 1) and for avoiding this problem it requires a highly reliable electrical supply and support systems.

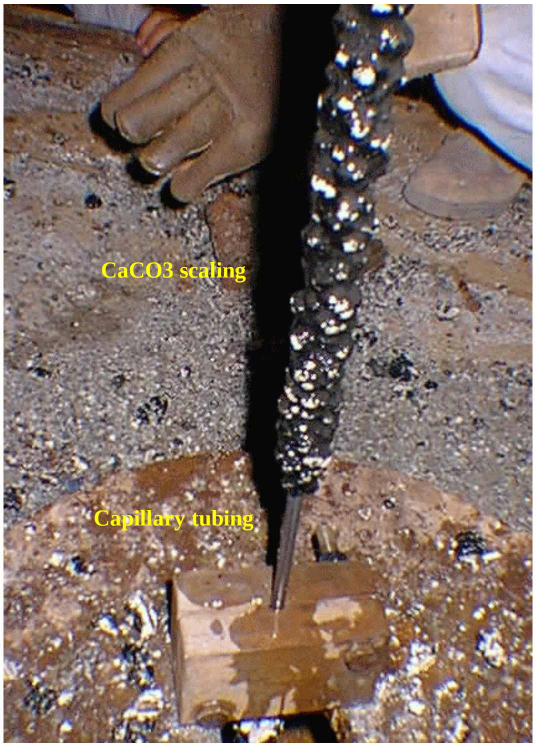


**Figure 2: Calcite scaling on a capillary tubing in well PGM-29, after a stop of the inhibition system due to an electrical system failure. Accumulated time of stop of the system was less than 48 hours.**

*Storage tank*: A compatible recipient with the chemical inhibitor product to being used and the aggressiveness it has. Experience has shown that any high density polyethylene container is a good option. The tanks or places where they are located should have prevention and contention systems of spills, for fulfilling all the environmental norms.

*Injection pump*: The market offers a great diversity, but not all of them are qualified for working in long periods of time under the working pressures required and with the aggressiveness of the chemical used. The injection capillary tubing inner diameters (3.95 mm) and its longitude (1500 meters) poses another problem and it is required to the pumps to have fine mesh filters.

*Inserting and fastening elements*: necessary components to ease the introduction, withdrawal and fastening of the capillary tubing inside the well (Figure 4). The designing objective is not only the functionality but the easiness and security of these procedures, which can take from 1 to 2 hours. It should have pulleys with appropriate diameters for not causing an unnecessary fatigue to the capillary tubing, that can lead to premature failure for rupture.

*Capillary tubing for injection in depth*: a considerably sensitive part of the system (Figure 4). The selection of their diameter and material should be compatible with the volume to be injected, the chemical product to be used and the temperatures to be exposed, otherwise it can suffer attacks which would originate obstructions and ruptures. The fabrication norms of the tubing should be strict, mainly those are referring to welding (longitudinal and in joints).

*Chemical inhibitor*: during the 10 years of the Miravalles production there have been carried out laboratory tests to an important quantity of products, but there have only been tested directly into a well seven inhibitor products of four different commercial companies. One of them didn't show any inhibitor property and it obstructed the capillary tubing in less than a day of test. Also, it didn't show to be thermally stable. The other six remaining products exhibited appropriate properties in the inhibition of $CaCO_3$ scaling, but four of them showed undesirable secondary effects, being these effects mainly the degradation for micro organisms and attacks to the capillary tubing material (SS 316L), what generated formation of obstructions. The products that generated attacks to the SS 316L showed to be compatible with Cr-Ni alloys. Excepting some wells the material of the $CaCO_3$ inhibition system capillary tubing of Miravalles is SS 316L.

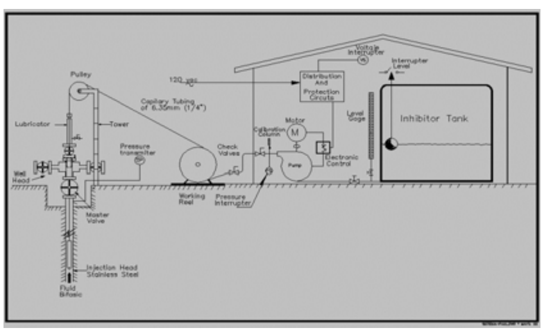


**Figure 3: Calcium Carbonate Inhibition System.**

The logistical part of a $CaCO_3$ scaling inhibition system includes the determination f the inhibition necessities of any well and the design of the system, the control program during the productive stages of the well and the monitoring of the chemical and hydraulic field evolution, focused on defining the inhibition policies.

As it was previously mentioned, the $CaCO_3$ formation inside the production geothermal wells is related to the boiling phenomena and it is represented by the equation:

$$Ca_2^+ + HCO_3^- \Leftrightarrow CaCO_3 + CO_2 + H_2O \qquad (1)$$

Based on this it is important to understand which is the limiting reagent in the reaction: the calcium or the bicarbonate, since this will define the understanding and interpretation of the future processes involved.

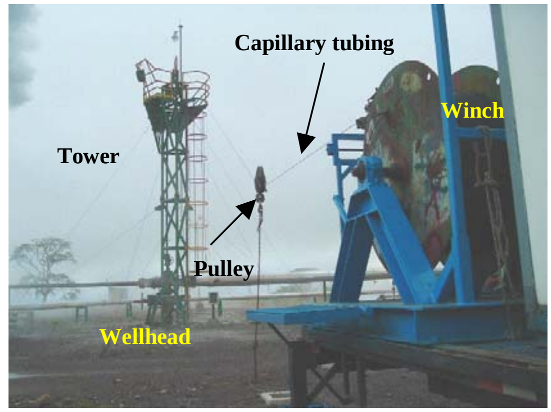


**Figure 4: Introducing a chemical treatment system in depth in a well producing at the Miravalles Field.**

<u>3.1.1 Design of the system and determination of the well´s inhibition needs</u>

In the Miravalles Field the limiting reagent in the process of calcium carbonate scaling in producing wells is the bicarbonate. Since the initial evaluations it is taken a careful monitoring of the concentrations of $CO_2$ in the steam and $HCO_3$ in the liquid, in order to determine the scaling tendency of each well. Different software packages can be used for balance calculations to determine the saturation of the fluid under different well conditions (Figure 5). Although these programs give only an approximation to the reality, it is important to give them representative data, reason why the samples should be taken under non scaling conditions. In other words if the sample is taken in surface when the well is incrusting in depth, the $Ca^{+2}$ and $HCO_3^-$ values introduced to the calculations will be smaller to the real ones, and the saturation shown by the programs will be smaller to the real one. When using these programs of thermodynamic balance it is advisable to take the sample when the well is being inhibiting or to take downhole samples, either under static or dynamic conditions below to the boiling point.

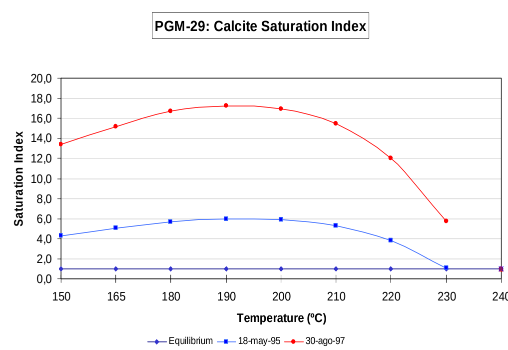


**Figure 5: Saturation index calculation with WATCH II, using data of well PGM-29 (samples taken in surface under scaling and not scaling conditions).**

Once these first calculations are made the design of the field test is done. Here is very important to determine the injection depth of the inhibitor correctly. For doing this, it is necessary to use the data obtained of the dynamic temperature and pressure profiles, taking into consideration that these profiles are usually carried out under MDP and that the boiling point at maximum flow conditions will vary from some meters to up to hundred of meters, depending on the well permeability. What is wanted is to locate the inhibitor injection point about 50 to 100 meters below the boiling point under the well´s commercial operation conditions, which not necessarily coincide with the conditions in that the temperature and pressure dynamic profiles were carried out. The field tests usually begin with an inhibitor over dosage, and then when the calcium values under total inhibition conditions are found the dosage is lowered until optimum values are determined. In other words, if when reducing the inhibition doses the calcium values lower it means that the well is under dosed and this will generate a partial scaling of the well.

### 3.1.2 Control program during the well productive stages

It consists on a series of periodic samplings where the necessary information for determining if the inhibition system is fulfilling entirety its function are taken. The frequency of these samplings depends on the gravity of the scaling problem (time in what a well becomes obstructed), and the time taken can be one week or to require on-line devices for a constant control. It is important the speed of answer of the analyses and the order of the data processing, in order to be able to have a fast determination (Figure 6).

| Data | Sample # | $Ca^{+2}$ ppm | $Cl^-$ ppm | Rel. Ca/Cl*3000 | Dosa ppm | Inhib. Unid | $HCO_3^-$ ppm |
|---|---|---|---|---|---|---|---|
| 06/01/04 | 82901 | 68 | 4141 | 50,0 | 1,50 | 11,0 | |
| 06/01/04 | 82902 | 68 | 4155 | 49,1 | 1,50 | 10,8 | 73 |
| 06/01/04 | 82903 | 68 | 4148 | 49,2 | 1,50 | 10,9 | 73 |
| | Average | 68 | 4148 | 49,4 | 1,50 | 11,1 | 73,0 |

**Figure 6: Typical parameters control of $CaCO_3$ inhibition.**

The control values are referred to the data under total inhibition conditions and total scaling conditions, the values obtained in the column "Inhibition Unit" (Figure 6) indicate satisfactory inhibition, the zero values meaning maximum scaling and intermediate values indicate partial scaling. The $Ca^{2+}$, $Cl^-$ and $HCO_3^-$ values of each well are used for determining its scaling range and controlling their behaviour in time.

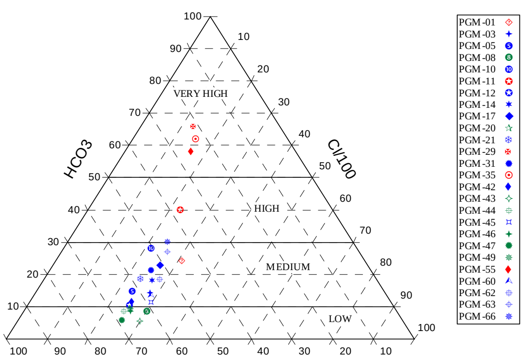


**Figure 7: Ternary graph, range of inlay of CaCO3 of the deferential wells producing of Miravalles, January 2004.**

### 3.1.3 Monitoring of the chemical an hydraulic evolution

Monitoring the evolution of the field is useful for determining and tracking the changes that can affect the performance of a $CaCO_3$ inhibition system, specially those related to the working dosage and the inhibitor injection depth. Since the limiting reagent in the process of $CaCO_3$ formation in Miravalles is the bicarbonate, a $CaCO_3$ content evolution monitoring should be taken because its decrease will force to lower the inhibitor dosage and vice versa. Being the limiting reagent the calcium, it would be this component the one to be monitored in their variation in time and to determine what causes the variation. Following a correct monitoring program it is possible to have a control of the bicarbonate values, calcium and other components in time. By using appropriate graphical tools it is possible to follow the individual tendency of each well or to the whole field (Figures 8 and 9).

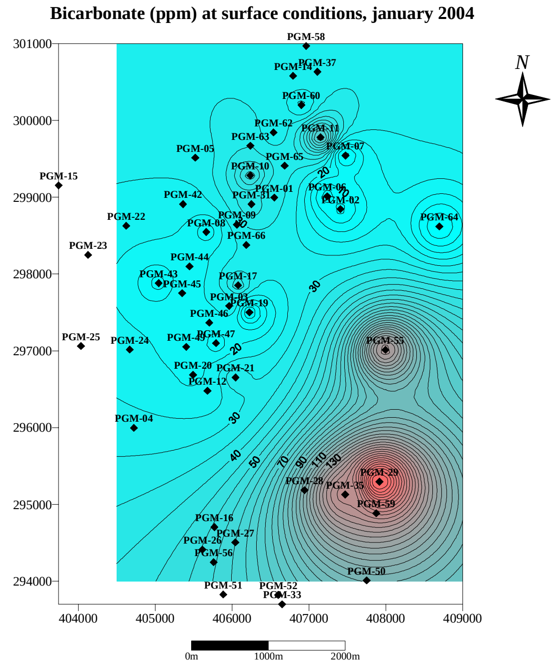


**Figure 8: Isoconcentration Map of Bicarbonates.**

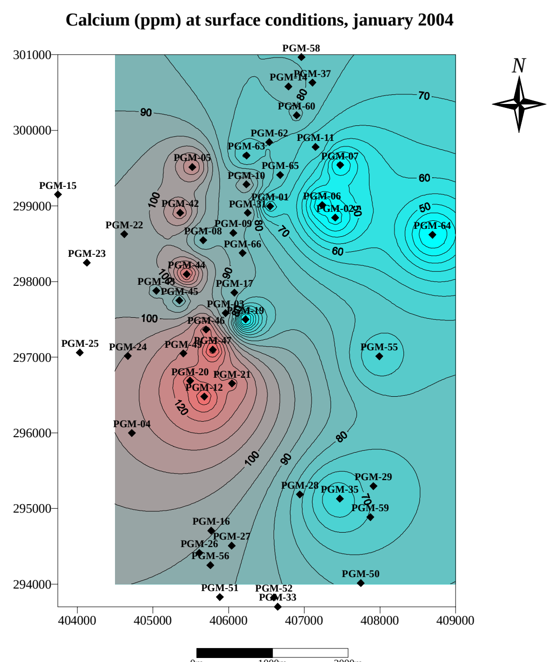


**Figure 9: Isoconcentration Map of Calcium.**

The geochemical characterization of the Miravalles Field prior to their commercial integration showed that the bicarbonates values were not the same in all the wells. With the beginning of the massive exploitation and the displacement of big masses of fluid the bicarbonate concentration of the fluids started to change, and this required to update the dosages applied. On the other hand the arrival of injection returns (degassed fluids due to the separation of the steam fraction) caused a decrease of bicarbonate, led to the decrease of the inhibitor dosage. It is necessary to emphasize that in fields where the limiting reagent is the calcium the arrival of injection fronts richer in this component (concentrated fluids) would originate an increment in the scaling tendency, and this would demand an increase of the inhibitor dosage. Also it is very important to monitor the pressure drawdown due to the continuous exploitation, since if this drop is fast it will produce a quick deepening of the of boiling point and suddenly the inhibitor injection head is above this point, leading to a partial or total scaling. Since this phenomenon is gradual the variations of the data in surface can mistakenly being taken as changes taken place by the evolution of the reservoir.

### 3.2 Neutralization of Acid Fluids

The first long neutralization tests in Miravalles were carried out in 1996. The neutralization process consists in adding a solution of sodium hydroxide to the geothermal fluid. This neutralizes the $H^+$ acid groups, thus raising the pH The injection of the sodium hydroxide must be continuous and it has to be accomplished to an adequate depth within the well, to protect the casings and all the surface equipment against the corrosion.

Since February 2000 (PGM-19) and October 2001 (PGM-07), acid neutralization systems have been used successfully in two wells, which has allowed to gather steam from these wells to the generation units. These wells give an equivalent of about 10 MWe to the power plants, and they become an important part of the system. Experience has indicated that by using neutralization systems it is possible to incorporate acidic fluids into production with no corrosion and at a reasonable cost.

The problem of the acidity in the Miravalles Geothermal Field and the results of the commercial integration of acid wells have been discussed in previous documents (Sánchez, 1997; Sánchez et al, 2000; Moya and Sánchez 2002).

The structural part of an acid fluids neutralization system fluids is similar to the $CaCO_3$ scaling inhibition system, differing mainly in the fact that most of the components are doubled, the metallic parts are made of appropriate alloys for supporting an aggressive environment and the monitoring is in real time. The main elements of the system are: electrical supply support system, storage tanks, injection pumps, on-line dilution pumps, introduction and fastening elements, capillary tubing for injection in depth, an injection head and a chemical neutralizer. The next paragraphs briefly present a practical consideration of each one of these components, based on the experiences accumulated over the four years of the system utilization (Figure 10).

*Electrical supply support system*: it guarantees a constant operation of the dosing pumps and the different on-line monitoring elements. Due to the high reliability degree required the system is usually doubled and sometimes tripled, since small interruptions in the electrical supply would expose the well casings, surface equipment and pipelines to an extremely corrosive environment.

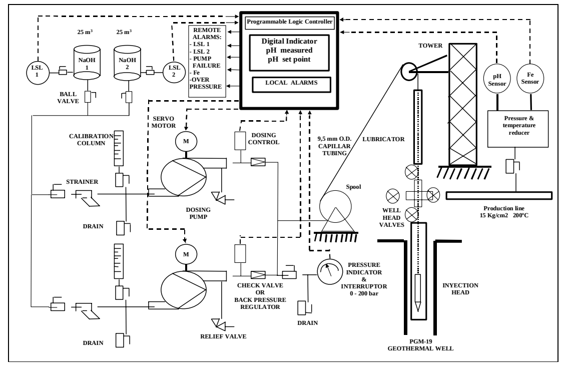


**Figure 10: Neutralization System.**

*Storage tanks*: *Storage tank*: A compatible recipient with the chemical product to being used and the aggressiveness it has. Experience has shown that any high density polyethylene container is a good option. The tanks or places where they are located should have prevention and contention systems of spills, for fulfilling all the environmental norms.

*Injection pumps*: The requirements are more demanding than in the CaCO3 inhibition systems. The aggressiveness of the NaOH at higher concentrations is bigger and the working pressures are considerably higher. The positive displacement pumps of duplex type pistons have had better performance in meeting the demands. The injection capillary tubing inner diameters (3.95 mm) and its longitude (1500 meters) poses another problem and it is required to the pumps to have fine mesh filters.

*On-line dilution pump*: Used to lower the concentration of the commercially acquired NaOH to a compatible concentration with the operation conditions (capillary tubing material and maximum exposure temperature). The lowering of the NaOH solution viscosity also helps in considerably lowering the injection pressure generated mainly in section of the capillary tubing that goes from the end of the pump to the wellhead.

*Inserting and fastening elements*: They have the same principle that in the $CaCO_3$ inhibition system, of having the function of to ease the introduction, withdrawal and fastening of the capillary tubing inside the well (Figure 4). The designing objective is not only the functionality but the easiness and security of these procedures, which can take from 1 to 2 hours. It should have pulleys with appropriate diameters for not causing an unnecessary fatigue to the capillary tubing, that can lead to premature failure for rupture.

*Capillary tubing for injection in depth*: a considerably sensitive part of the system (Figure 4). The selection of their diameter and material should be compatible with the volume to be injected, the chemical product to be used and the temperatures to be exposed, otherwise it can suffer attacks which would originate obstructions and ruptures. The fabrication norms of the tubing should be strict, mainly those are referring to welding (longitudinal and in joints).

*Neutralizer chemical*: The practice has shown that the NaOH industrial solutions fulfil the expectations. The use of less aggressive or purer products is not discarded, but with the obtained technical results and the cost of the industrial NaOH it has not been seen the need of a change.

The logistical part of an acidic fluid neutralization system includes the determination of the neutralization needs of any well and the design of the system, the control program during the productive stages of the well and the monitoring of the chemical and hydraulic evolution of the field, focused on defining the neutralization politics.

3.2.1 Design of the system and determination of the well´s neutralization needs

Contrary to the $CaCO_3$ inhibition system where the wells should be tested and carried several studies to determine if it is required or not the chemical treatment, in the acid wells the matter is clear from the beginning. It is necessary to carry out laboratory tests to determine the necessary NaOH requirements for raising the pH to an appropriate working point. These data together with the well mass flow are required to determine the pumps required capacity to be used in the tests. The depth of the injection point won't depend on the boiling point location but on the constructive finish of the well, trying to locate the dispersion head to a depth from 50 to 100 meters below the casing shoe. In the acid wells finish it is advisable not to use the slotted liner but to let this part of the well discovered because the high silicification of the rocks adjacent to the acid zones give bigger stability to the walls of the well. In the acid wells of Miravalles it has been noticed that the initial acidity goes lower with the production of the well until it achieves certain stability. This condition is related to the fact that the sources of emanation of deep gases that originate the acidity are active. Due to the above-mentioned the initial neutralization tests of a well can be extended a minimum period of 30 days.

3.2.2 Control program during the well productive stages

It consists on a series of on-line controls and periodic samplings where the necessary information for determining if the neutralization system is fulfilling entirety its function. The on-line pH values and iron content monitoring are required to determine if the used dosage is the correct for guaranteeing that the system is neutralizing to depth and from the injection point. The volume of injected NaOH and injection pressure monitoring guarantee the control of possible failures like pumping problems and formation of obstructions inside the capillary tubing. The chemical control of the fluids allows to determine the changes that are given in time and neutralization policies can be updated (Figure 11).

| Well | Data | Sample # | $Ca^{+2}$ ppm | $Cl^{-}$ ppm | Relation Ca/Cl*3000 | pH | Fe ppm | $SO_4^{-2}$ ppm | Dosa ppm |
|---|---|---|---|---|---|---|---|---|---|
| PGM-07 | 04-May-04 | 86025 | 33 | 3573 | 27,7 | 6,62 | 0,39 | 355 | 65 |
| | 04-May-04 | 86026 | 33 | 3538 | 28,0 | 6,59 | 0,41 | 347 | 65 |
| | 04-May-04 | 86027 | 34 | 3542 | 28,8 | 6,57 | 0,44 | 348 | 65 |
| | | Prom. | 33 | 3551 | 27,8 | 6,59 | 0,41 | 350 | 65 |
| PGM-19 | 02-Mar-04 | 84228 | 43 | 3909 | 33,0 | 6,57 | 0,22 | 472 | 30 |
| | 02-Mar-04 | 84229 | 43 | 3916 | 32,9 | 5,72 | 2,09 | 527 | 30 |
| | 02-Mar-04 | 84230 | 42 | 3938 | 32,0 | 5,70 | 2,20 | 556 | 30 |
| | | Prom. | 43 | 3921 | 32,6 | 6,00 | 1,50 | 518 | 30 |

**Figure11: Typical control of parameters of neutralization of acid wells.**

3.2.3 Monitoring of the chemical an hydraulic evolution

Under in same principle of any chemical treatment, what is looked for is to determine and to follow the changes that can cause a neutralization system to be affected in its operation. Related to the working dosage, since a low pH would cause an excessive corrosion and a high pH would generate big deposits inside the well and in surface (mainly of silica) the monitoring goes beyond pumping more or less a NaOH quantity according to the well requirement but understanding the causes of those changes for defining the appropriate operation policies. In the case of Miravalles it is observed that since the emission of gases of magmatic origin is active, in the periods in that an acid well remains closed an accumulated of sulphates in the fluid is generated. For this reason, when a well is open for production it presents high acidity levels which will be lowered as the exploitation of the well advances, until it achieves an stability. The duration of this acidity peak will depend on the time that the well was in production before being closed and the time it was closed thereafter (Figure 12).

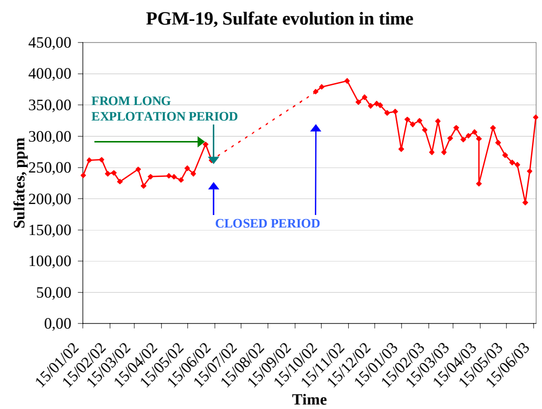


**Figure 12: Sulphates content behaviour after a well non productive period.**

## 4. CONCLUSIONS

The Miravalles Geothermal Field presents three different geothermal aquifers: a sodium-chloride aquifer, sodium-chloride bicarbonate aquifer and a sodium-chloride acidic aquifer.

Under natural conditions, the fluids of the Miravalles Geothermal Field are so aggressive that commercial exploitation of the wells without an appropriate deep chemical treatment of its reservoir fluids.would not be technically neither economically sustainable.

The chemical treatments applied to the fluids are Calcium Carbonate Scaling Inhibition (23 wells) and Neutralization of Acid Fluids (2 wells).

There have been drilled 29 producer wells, and 25 of them are connected to the gathering system. 23 of them need the inhibition of CaCO3 scaling and two of them need pH modification (neutralization).

ICE's methodology, equipment and operating experience with the Calcium Carbonate Scaling Inhibition system was described in this paper.

At the beginning of commercial exploitation of the reservoir the acidic aquifer was unknown. After drilling some wells with had acid fluids, the need of recover the investment in these wells led ICE to start studies looking for put them online. The continuous evolution of the field and later modifications in the capacity of the field for supplying the mass necessary for meeting the steam supply requirements of the power plants, forced ICE to seriously consider the utilization of two wells (PGM-07 and PGM-09) that were not used previously because they produce acid fluids. This required the development and installation of systems to neutralize the acidity, and now there are 2 neutralization systems in continuous operation at the Miravalles Geothermal Field. ICE's methodology, equipment and operating experience with these systems were described in this paper.

Monitoring the evolution of the thermal, hydraulic and chemical parameters of the field is useful for determining and tracking the changes that can affect the performance of the chemical treatment systems ($CaCO_3$ Inhibition System and pH Modification System), specially those related to the working dosage, inhibitor injection depth, NaOH dosage and corrosion control (iron content). The conditions into the reservoir are not completely homogeneous, and some particularities can affect the performance of the chemical systems for fulfilling its tasks. For this reason is very important to continuously monitor the reservoir changes for having a good control of the chemical system parameters and modifying them as necessary, according to the reservoir changes present.

This is very important because at the end, the mass production and the conditions of the fluids given to the power plants would be affected if the chemical treatments cannot work properly. These effects include obstruction of producer wells and equipment (calcite and silica scaling) and the related loss in mass production (and in electrical generation), costs generated by mechanical cleaning of wells and pipelines, damages in wells, pipelines and surface equipment by corrosion and the related mass production.

**REFERENCES**

Vallejos, Osvaldo; Sánchez, Eddy and González, Carlos. 2005. Reservoir Management At The Miravalles Geothermal Field, Costa Rica. Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005.

Vallejos, Osvaldo; Acuña, Jorge and González, Carlos. 1995. Monitoring of Reservoir Pressure at Miravalles. Miravalles Geothermal Field 16th Advisory Consultant Panel Meeting. Costa Rica. (In Spanish).

Vallejos, Osvaldo. 1996. A Conceptual Reservoir Model and Numerical Simulation Studies for the Miravalles Geothermal Field, Costa Rica. Geothermal Training in Iceland 1996. UNU G.T.P. Report 18. Iceland. Pp. 418-456.

Sánchez, E. 1995. Sistema de inhibición de carbonato de calcio. Miravalles Geothermal Power Project 15th Advisory Panel Meeting. Departamento Recursos Geotérmicos, Instituto Costarricense de Electricidad (In Spanish).

Sánchez E. 1997. Results of the test of neutralization of the well PGM-19 carried out in 1996 and proposal for their commercial use. Miravalles Geothermal Power Project 16th Advisory Panel Meeting. Departamento Recursos Geotérmicos, Instituto Costarricense de Electricidad (In Spanish).

Sánchez, Eddy; Guido, Hartman and Vallejos, Osvaldo. 2000. Commercial Production of Acid Wells at the Miravalles Geothermal Field, Costa Rica. Proceedings World Geothermal Congress 2000. Japan. Pp. 1629-1634.

Moya, P., Sánchez, E. 2002. Neutralization System for Production Wells at the Miravalles Geothermal Field. Geothermal Resources Council Transactions, Vol. 26, September 22-25, 2002, pp. 667-672.

Heubner U., et al. 1998. Nickel Alloys and High-alloy Special Stainless Steels. Renningen-Malmsheim: Expert Verlag. 2nd edition. Germany. 1998. Pp. 212-215.