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CHEMICAL STIMULATION APPLIED IN GEOTHERMAL FIELDS OF EL SALVADOR, YEARS 2000-2009

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ABSTRACT

Successful mechanical cleanouts and acid chemical stimulations in production and injection wells at the Berlin, Ahuachapan, Chinameca and San Vicente geothermal field were performed over the past 10 years, giving great improvements in power generation and permeability enhancement in injection wells. The application of these techniques delivered an accumulative increment of more than 60 MWe in power production and 752 kg/s of injection capacity. Chemical stimulations using the rig to clean up to four zones, has given improvements close to 200% while acid jobs through the well head the improvement has been 40%, when cleaning only the first permeable zone. Chemical stimulation has been applied to production wells with mud and cutting damage, production wells with calcite scaling and injection wells with silica scale and mud damage.

The fluid treatment most used in production wells in the Berlin field is the Mud Acid 10:5, RPHF 5% for wells with calcite scaling in Berlin and Ahuachapan Field, RPHF 6-8% in injection wells with low permeability and high silica scaling potential. Pressure transient tests and analysis of the data have quantified the amount of improvement from most of the cleanouts and stimulations. The reduction of the skin factors suggests the stimulations influenced the matrix of the formation.

The criteria for the design of the acid treatment such as type of rock formation, number and thickness of the permeable zones, extent of skin damage, and level of steam fraction are crucial to take the decision if the well needs to be chemically cleaned. The parameters such as the type of acid for the fluid treatment, strength of the acid, composition and volume of the fluid treatment, and the selection of additives and the results of the acid dissolution tests as well as the operation parameters are very important to take into account in order to obtain excellent results.

1. INTRODUCTION

The use of non-traditional energy sources, has become one of the key elements to address the world's demand for energy resources and at the same time ensure sustainable development. The importance of geothermal energy is stressed by the fact that Central America has a limited reservoir of fossil fuels in its own land. Moreover, the Central American region imports around 75% of its energy demand, and geothermal energy use for power generation in some of these countries represents around 10 -25% of their national electricity production. In fact, according to the World Energy Council, this is one of the richest areas which hold geothermal resources.

Despite its estimated potential of 4,000-megawat (MW) capacity for power generation, the actual installed capacity is now 508-megawat (MW). Most of the projects perform below their potential because of two core factors: a) Reduction of the supply and b) low productivity or injection due to scales on production pipelines and/or skin damage effect. Damage can be caused by several reasons, such as: entrance of drilling mud, migration of clay formations, silica and calcite mineral scales and cuttings entering into the formation when drilling in total loss circulation.

We will describe throughout this document, the results of ten years of research of chemical stimulation executed in El Salvador, in several geothermal fields by a number of operators. Over forty-three stimulation treatments have been performed with a variety of acid systems on volcanic rocks formed by inset andesitic lava, basaltic andesite, or dacite and lithic tuffs. The results of the laboratory analysis of data indicate that it is actually the combination of a well designed treatment and special mixture of acids that have improved stimulation of the geothermal reservoirs significantly.

The improvement may be perceived when the wells are stimulated either by wellhead or drill rig. In Berlin, Usulután, permeable zones with cumulative thickness of 200 m can be cleaned in a ratio of three to four zones at a time, when stimulating productive wells with drill rigs, thus increasing the power output to 10-11 MWe per well. This is due to the fact that the field presents a high fraction of steam (>25% and high temperature) according to case TR5C and TR4B. Nonetheless, in Ahuachapán the increment has been lower because of less fraction of steam (14%).

When stimulating wells through the wellhead, the reported increase is about 4-5 MWe. When treatment fluids are injected, the first permeable zone and most important one, located under the production casing, is the primary production zone that absorbs the acid and is the one that benefits the most from the procedure, according to case TR5B and TR4C. Whereas power generation has increased up to 3 MWe in wells with calcite (Ah) with low vapour fraction (14%) and lower temperature (230° C) problems, i.e. wells Ah34A and Ah32st.

The total value for chemical cleaning through wellheads ranges from $150,000.00 (TR-5B) to $325,000.00 US dollars (TR-18). Investment was lower for production wells with formation damage by the entry of drilling mud and cuttings (based on cost of additives, hydrochloric acid and ammonium bifluoride for the year 2006). On the other hand, higher investment was made to clean production wells with similar problems plus calcite scaling potential.

Chemical Stimulation of wells with drill rig adds to the total value an extra US$1,000,000.00 for drilling services, pumping services and water supply, over the amount of additives, chemical and personnel used to inject the chemical mixture per wellhead. It is noteworthy that the improvement in the stimulation in this case is much more effective because 3-4 areas are cleaned at a gain of 200% (Case well TR5C).

2. CHEMICAL STIMULATION TECHNOLOGY

All around the world there is a variety of geothermal projects that perform exceptionally well for their initial production and plunge in productivity with time due to cooling processes, decrease in reservoir pressure by overexploitation and/or mineral incrustations (such as amorphous silica, calcite, anhydrite and sulphides) inside production or formation pipelines.

On the other hand, reinjection is a technique currently used to control both the pressure of reservoir and the invasion of cold fluids from upper aquifers. This particular practice prevents contamination of the environment instead of disposing waste fluids on the surface, which contain high contents of total dissolved solids (TDS).

Both injection and production wells can become clogged, reducing its production capacity and injectivity below the existing potential.

The main reasons for these obstructions may be:

1. Invasion of drilling fluids (mainly bentonite mud) inside micro fractures.
2. Entrance of rock fragments during the drilling process.
3. Incursion of great amounts of TDS and silica scaling potential caused by reinjection water.
4. Formation of fine-grained solids displaced by clay migration.
5. Deposits of silica and calcite scales.

The key to ensure a continuous flow for power generation is to control all the possible causes of obstruction. It is a well known fact that the geothermal industry has been using for about 50 years the same technology and practices of the oil industry.

Since oil and gas wells show analogies in regards with scaling problems and mud damage, similar techniques may be applied to prevent permeability problems in order to improve injectivity for the production and injection capacity of geothermal wells. A cost-effective and widely used solution is the application of acids to dissolve scales and obstruction produced by solids.

In El Salvador, the geothermal production in wells is mainly through natural fractures. These fractures are partially sealed by minerals of hydrothermal alteration such as calcite and silica. These conditions may be caused by the production processes themselves or natural phenomena prior to the drilling of the well.

The main purpose of an acidification treatment is to dissolve these minerals and restore the permeability of the natural fractures and to remove the deposits of scales inside the pipeline.

Over the last ten years, four geothermal fields have been chemically stimulated: Berlin, Ahuachapán, Chinameca and San Vicente. Here is a summary of the chemical stimulation performed in El Salvador from 2000 to 2010.

3. FIELD DESCRIPTION

3.1 Berlin geothermal field

The Berlin geothermal field is located on the northern flank of the volcano Tecapa Berlin in El Salvador. The field has two production wells which are located at elevations of 647-1100 m above sea level. The average production is equivalent to 8 MWe per well, with a steam fraction of 25% and the field produces 104 MW. The production area, high permeability and high temperature, is at a depth ranging from -900 and -1000 m above sea level, with an average temperature of 290-300 ° C. Fourteen injection wells are located in an area of lower permeability, 3 of them work with injection pumps.

In the year 2000 the Power Plant faced some difficulties in generating power at full capacity due to problems with reinjection. Commonly, these wells have a low intrinsic permeability, due to low permeability fractures found during drilling and they are usually sealed with secondary minerals such as quartz, calcite and epidote.

From that year on, a variety of efforts by mechanical action and chemical stimulation were conducted by a company. These works were executed using a coil tubing and drill rig. And since 2003, chemical cleansings were conducted through the wellhead. Between the years 2000 and 2010 nearly 85% of the wells with damage formation have been restored under mechanical and chemical cleaning.

The given technique has allowed increasing the total injection in approximately 600 kg/s and maximum power generation of 54 MWe in Units I and II. The procedure of stimulation has improved well injection considerably; however, the injected geothermal fluid always transmits a high content of dissolved solids. Thus, these circumstances require that these tasks are considered within the normal maintenance programs.

3.2 Ahuachapán geothermal field

The geothermal field Ahuachapán-Chipilapa is located on the northern slopes of the Laguna Verde – Las Ninfas Volcanic Complex. In Ahuachapán, the production zone of the geothermal field is associated mainly with highly fractured volcanic rocks where the active faults NW-SE, NS, NE-SV and EW are accountable for the permeability. The reservoir rocks show high injectivity index values, productivity and transmissibility, since permeability is completely secondary to geological faults in a lithological area called Unit IV, formed by andesites and breccias.

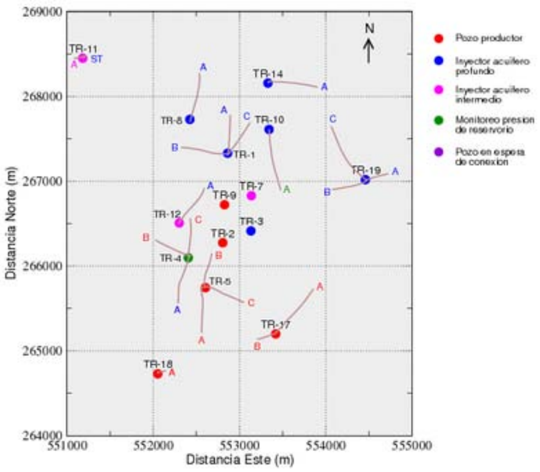

FIGURE 1: Berlín geothermal field

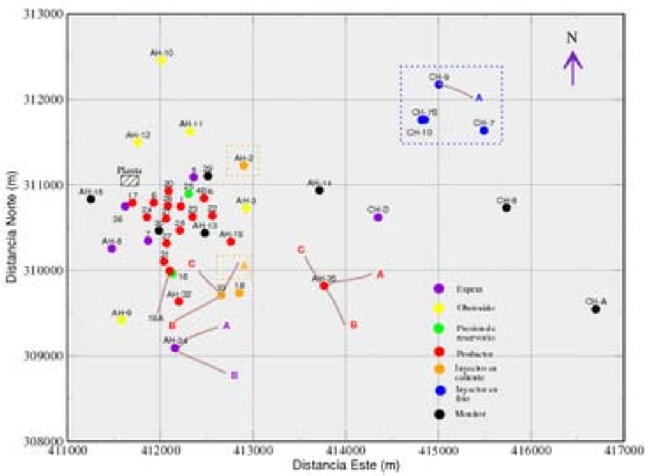

FIGURE 2: Ahuachapán geothermal field

The average power generation per well is 5 MWe and 85 MW are currently produced from 95 MWe of installed capacity. The wells are located at an altitude between 600-1050 m above sea with the production area to +300 m above sea, with a fraction of steam ranging from 15% to 90% and the reservoir temperature between 210 and 240 °C.

From the year 2000 to date, only 3 wells have been chemically stimulated in order to remove the damage from drill mud that entered the formation during drilling, and to dissolve the calcite deposited, within the formation and production casing (Ah35b, Ah33b y Ah35a)

Wells that have problems with calcite scaling are located to the southeast and southwest of the power production area. In 2005, wells Ah34a and Ah32st were cleaned in order to dissolve drill mud like calcite. These wells are in standby to be connected to the steam carrying system to the central plant. In 2007, Ah35c and Ah33c wells were drilled and chemically stimulated afterwards with remarkable results. In 2009, the first reinjection well, CH10, was cleaned to remove the damage caused by amorphous silica scaling, which is contained in the residual fluids of the production wells.

3.3 Chinameca geothermal field

This geothermal field is located on the slopes of El Limbo and Pacaya volcanoes. As of today is on the drilling exploration stage and five wells have been drilled to date. The first two wells, Chi1 and Chi2, were drilled in the 70's and the latter ones (Chi3, Chi3A and Chi3B) have been drilled for production reasons and are located on Chi3 platform.

Rock permeability from the reservoir is linked to a fractured lithological formation associated to andesitic-dacitic lavas. The reservoir is placed at an altitude between 0 to - 200 m above sea and the average temperature is 235°C. Since lavas have a low to medium fracturing, in 2009, at the end of drilling the first production well of the Chinameca Project (CHI-3) this well was cleaned up in order to eliminate damage caused by mud and cuttings that had entered the formation.

The results were outstanding and the injectivity index was increased. Nonetheless, the other wells, Chi 3A and Chi3B, were not stimulated because of the need to recover them rather quickly and discharge them to determine their power potential.

3.4 San Vicente geothermal field

This field is located on the slopes of the San Vicente Volcano. As in Chinameca, it is in the exploration phase with four wells that were drilled from 2005 to 2007 (SV1A, SV2A y SV3) and a pre-existing well that was drilled back in the 70´s (SV1).

The wells drilled north of the volcano, SV1 and SV1A, present a high temperature but low permeability, with the added feature of calcite scaling potential. As for wells SV2A and SV3A, they showed low temperature and high permeability.

Due to low permeability of wells SV1 and SV1A, they were chemically stimulated to dissolve drilling mud, cuttings and mineral calcite. The application of this technique allowed improvements on the injectivity index on the wells and therefore wellhead pressure also.

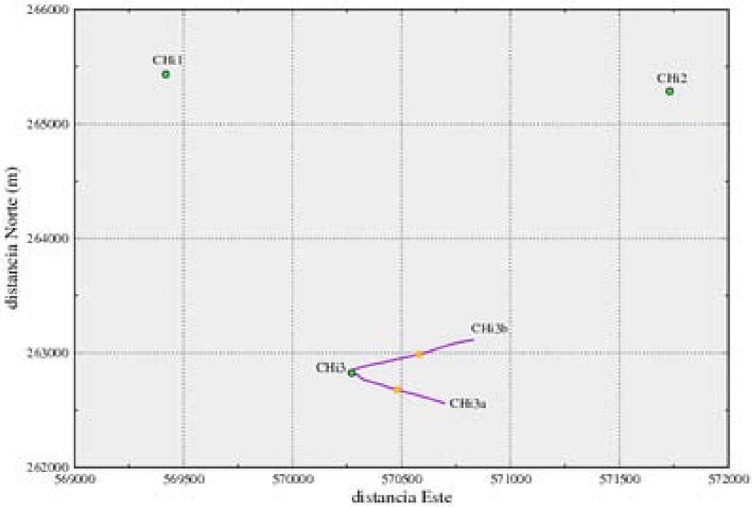

FIGURE 3: Chinameca geothermal field

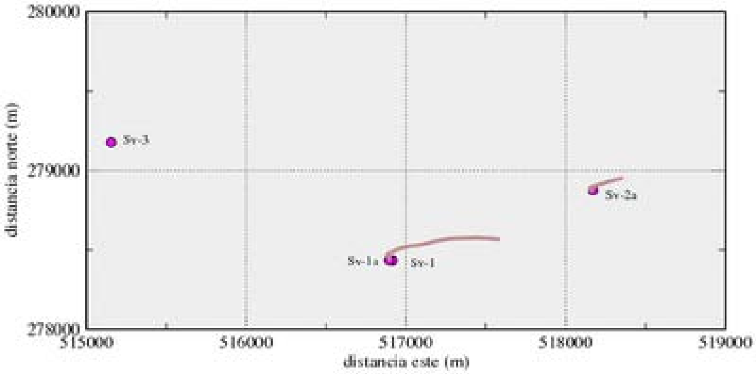

FIGURE 4: San Vicente geothermal field

4. DESIGN OF THE ACID TREATMENT FOR GEOTHERMAL WELLS

During the last ten years the application of acids has been done to all four of the geothermal fields that LaGeo S.A. owns.

The criteria used to analyze and evaluate whether or not a well should be chemically cleaned is the following:

1. Type of rock formation, hydrothermal alteration in the mineralogy.
2. Number and thickness of the permeable zones. It is crucial to be aware of the well´s injectivity index.
3. Extent of skin damage caused by drilling entry, calcite and silica scaling, etc. The more positive it is the skin, better chances to have a major improvement on the well´s permeability, hence greater production and injection capacity.
4. Level of steam fraction. The higher the steam fraction (over 20%) is the better chance to make more profit from the production well.

The parameters taken into account in the design of acid treatment are:

1. Type of acid for the main treatment.
2. Strength of such acid for the main treatment.
3. Volume of the main treatment.
4. Pre-flush and Main-flush and Post-flush composition and volume.
5. Additive selection: corrosion inhibitors, corrosion inhibitor intensifiers, clay controllers, fine and iron.
6. Operational parameters: injection rate, injection pressure, etc.
7. Results of acid dissolution tests.

4.1 Acid mixtures used in geothermal wells

1. For wells with mud, cuttings and silica scale damage with low content of calcite, the pre-flush treatment is usually performed with Hydrochloric Acid HCl 10-15%. This works if the formation does not have zeolites of low temperature such as chabasite or stilbite. When the main damage is due to mud, cuttings or silica scale the main acid treatment to eliminate the skin can be of two types:

   - Highly concentrated acid mixture (6-8%) and delayed (RPHF: Retarded Phosphonic Hydrofluoric) created from phosphonic acid and hydrofluoric acid. This mixture has been used in reinjection wells in Berlin and Chipilapa in order to dissolve silica minerals and and/or debris of formation found on residual injected fluids.

   - Acid Mixture (**HCl: HF**) consisting of hydrochloric acid and hydrofluoric acid. This mixture is called Mud Acid and has been used in most of the production wells of Berlin Field, which have low content of calcite, high steam fraction, skin damage or skin values of 20. Given the well´s characteristics, the results have been outstanding. (see table of work summary).

2. Nonetheless, if calcite is found both on the formation as in scales inside the pipeline (casing and liner), the pre-flush is usually a high volume of HCl 15% and the main-flush is of choice is usually RPHF at low concentrations (5%), as this is the only acid capable of dissolving silica and other remaining mud without causing insoluble precipitates of CaF2 Fluorite, when in contact with calcite (Malate, 1998). The following formulations have been used: a) Three acids such as HCl, Phosponic acid and HF or b) Clay Acid (HCl, HF and Boric Acid). These two mixtures has been successfully used in El Salvador in wells with high potential of calcite scaling providing excellent results in Ahuachapán and Berlin geothermal fields.

3. When calcite present in the formation and casing existing together with low temperature zeolites, the acid mixture most used has been Acetic Acid at 10% and HCl 15% with Phosphonic acid such as in SV-1.

In order to effectively apply the stimulation technique, Lageo made contact with two international companies as business consultants: a) Schlumberger Surenco S.A. and b) BJ Services & Co. which have had extensive experience in this type of operations over the world for more than 50 years. The LaGeo workforce has benefited from the fact that these companies' expert staff members have transferred their knowledge, monitoring and consulting on how to keep improving the mixtures to make the acid treatments more effective.

Typically volume ratios of acid mixtures are used are as follows:

1. Wells with high contents of silica and damage caused by mud and cuttings:
   - Preflush: 50 gal / ft thick permeable zone.
   - Main Flush: 75 gal / ft thick permeable zone.
2. Wells with potential of calcite and mud damage:
   - Preflush: 100-120 gal / ft thick permeable zone.
   - Main Flush: 75 gal / ft of thick permeable zone.

The strength of the acids used is as follows:

1. For calcite scaling (alone or in combination with hydrated zeolites) in HCl 15% with Phosphonic acid or Acetic Acid 10%.
2. For wells with silica scaling: RPHF 6-8%.
3. For cases with the presence of calcite formation and / or damage from drilling mud, or calcite scaling in the formation of the well: RPHF 5% with a large volume of HCl 15% as a preflush.
4. Large volumes of HCl 10-15% as a pre-flush are pumped to address calcite scaling on the Ahuachapán, Berlin and San Vicente geothermal fields.
5. To clean drilling mud and / or cuttings in the formation with low content of calcite: HCl:HF (10:5) or Mud Acid as the main flush.

Following the injection of pre-flush and main flush, diluted acid mixtures are pumped after the injected acid. All of these treatments include water injection as well as cooling and displacement procedures. This is done to separate the reservoir fluids from treatment fluids and prevent the acid from being depleted before getting to the formation.

Cooling is typically 4-5 times the total volume of the inner casing. The intention is also to cool the pipe to reduce the concentrations and volumes of corrosion inhibitors.

Acid mixtures include the following additives:

a) Corrosion inhibitor.
b) Corrosion Intensifier.
c) Iron chelating agents.
d) Clay Controller, Fine Controllers.
e) Surfactant.

Corrosion inhibitors and corrosion inhibitor intensifiers are designed to last for 12 hours. These are applied to protect the production pipes and the slotted pipe while injecting the mixture. Iron chelating agents are added to avoid formation of ferric chloride compounds, iron hydroxides that can precipitate in the formation after the acid is spent.

4.2 Fluid treatments (acid mixtures) used in the past 10 years

TABLE 1: Acid mixtures used 2000-2010

CHEMICAL STIMULATION 2000-2004					
Injection Wells Berlin Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment kg/s**	**Type of fluid treatment used**
TR-14, TR1C, TR-11 st,	**2000**	Mech Intervention and Chemical Stim	Coil Tubing	61.0	Mud Acid 7.5:1.5
TR-14, TR1A, TR12A, TR-10	**2001**	Mech Intervention and Chemical Stim	Drill Rig	83.0	Mud Acid 10:5
TR-10, TR-7	**2002**	Mech Intervention and Chemical Stim	Drill Rig	109.0	Mud Acid 10:5
TR-1C, TR-1A,	**2004**	Chemical Stimulation	Well Head	53.0	Mud Acid 10:5
TR-7, TR11A	**2004**	Chemical Stimulation	Well Head	63.0	Mud Acid 10:5
Production Wells Berlin Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment Mwe**	**Type of fluid treatment used**
TR-5C, TR-4B	**2001-2002**	Mech Intervention and Chemical Stim	Drill Rig	17	Mud Acid 10:5
TR-4C	**2004**	Chemical Stimulation	Well Head	3.1	Mud Acid 10:5
Production Wells Ahuachapan Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment Mwe**	**Type of fluid treatment used**
AH-35B	**2000**	Mech Intervention and Chemical Stim	Coil Tubing	0.8	Mud Acid 7.5:1.5
AH-35A, AH-33B	**2002**	Mech Intervention and Chemical Stim	Drill Rig	2.8	Mud Acid 10:5
AH-35B	**2003**	Chemical Stimulation	Well Head	3.5	Mud Acid 10:5
CHEMICAL STIMULATION 2005-2007					
Injection Wells Berlin Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment kg/s**	**Type of fluid treatment used**
TR7, TR14	**2005**	Mech Intervention and Chemical Stim	Drill Rig	90	Sandstone Acid 7%, 8% (RPHF)
TR11A, TR8A	**2005**	Chemical Stimulation	Well Head	43	Sandstone Acid 6%(RPHF)
Cold Injection Pipeline	**2005**	Chemical cleaning	Surface	Silica scale 50%	Sandstone Acid 6% (RPHF)
Hot Injection Pipeline	**2005**	Chemical cleaning	Surface	Silica scale 50%	Sandstone Acid 7% (RPHF)
TR-14A	**2006**	Chemical Stimulation	Drill Rig	100	Mud Acid 10:5
TR-11A	**2006**	Chemical Stimulation	Well Head	22	Sandstone Acid 7% (RPHF)
TR-1B	**2006**	Chemical Stimulation	Well Head	22	Sandstone Acid 6%(RPHF)
TR-11A	**2007**	Chemical Stimulation	Well Head	25	Sandstone Acid 7% (RPHF)
Production Wells Berlin Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment Mwe**	**Type of fluid treatment used**
TR-5A	**2005**	Chemical Stimulation	Well Head	4.3	Mud Acid 10:5
TR-5B	**2006**	Chemical Stimulation	Well Head	5	Mud Acid 10:5
Production Wells Ahuachapan Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment Mwe**	**Type of fluid treatment used**
AH-34A. AH-32st	**2005**	Chemical Stimulation	Well Head	5	Sandstone Acid 5% (RPHF)
AH-35C, AH33 C	**2006**	Chemical Stimulation	Drill Rig	18.6 and 6.7 kg/s steam	Sandstone Acid 5% (RPHF)
Production Wells San Vicente Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment kg/s Injection capacity**	**Type of fluid treatment used**
SV-1A	**2006**	Chemical Stimulation	Drill Rig	21	Sandstone Acid 5% (RPHF)
SV-1	**2007**	Chemical Stimulation	Drill Rig	Not tested	Acetic Acid 10%
CHEMICAL STIMULATION 2008-2010					
Injection Wells Berlin Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment kg/s**	**Type of fluid treatment used**
TR-11A	**2008**	Chemical Stimulation	Well Head	25	Sandstone Acid 6%(RPHF)
TR-14, TR14A	**2010**	Chemical Stimulation	Well Head	100,100	
Production Wells Berlin Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment Mwe**	**Type of fluid treatment used**
TR17B, TR17A	**2008**	Chemical Stimulation	Well Head	5.4	Sandstone Acid 5%(RPHF)
TR-18	**2008**	Mechanical Intervention and Chem Stim	Drill Rig	8.1	Sandstone Acid 5%(RPHF)
Production Wells Chinameca Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment kg/s**	**Type of fluid treatment used**
CHi3	**2009**	Chemical Stimulation	Drill Rig	ND	Sandstone Acid 5%(RPHF)
Injection Wells Chipilapa Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment kg/s**	**Type of fluid treatment used**
CH10	**2009**	Chemical Stimulation	Well Head	50	Sandstone Acid 6%(RPHF)
Production Wells Ahuachapan Field	**YEAR**	**ACTIVITY**	**Comment**	**Increment Mwe**	**Type of fluid treatment used**
AH-35 B	**2010**	Mechanical Intervention and Chem Stim	Drill Rig	ND	HCl 15%
TOTAL		**756 kg/s Overall Increment and 61.1 Mwe Power Production**			

4.3 Chemical stimulation results 2000-2009

From the year 2000 to 2004 there was an improvement of 27.1 MWe and 369 kg/s of injection capacity. During this period, half a million US dollars were invested on a flexible pipeline for chemical stimulation. There was also an investment/expenditure of close to a Million US dollars on chemical stimulation performed with drill rig. For that reason, in 2003 chemical stimulations were performed with the injection of the mixture through the wellhead, reducing costs significantly.

The chemical stimulation through the wellhead called chemical cleaning makes possible to clean only the first permeable zone or production zone which is usually below the production casing. The amounts invested or spent per wellhead have been in a range from $ 150-$315 thousand US dollars. This mostly depends on the volume of total mixture used, providing only a 40% improvement with respect to the attained improvement with rig which can than one zone at a time (up to four).

In the year 2005, the accumulative improvement in injection capacity was 272 kg/s and 13.89 MWe of production. In the year 2006 the improvement in injection capacity was 50.0 kg/s and 13.7 MWe of production.

The accumulative improvement in the injection capacity until the year 2010 was 756 kg/s and the overall improvement in production from 2000-2010 is: 61.1 MWe

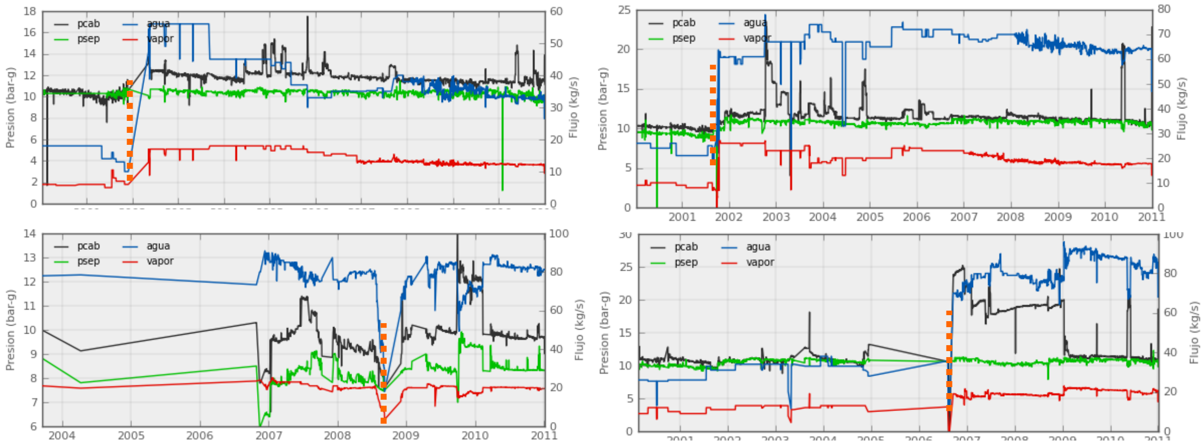

FIGURE 5: Production improvement in wells TR4B, TR5C, TR18 and TR 5B
(........ Chemical Stimulation)

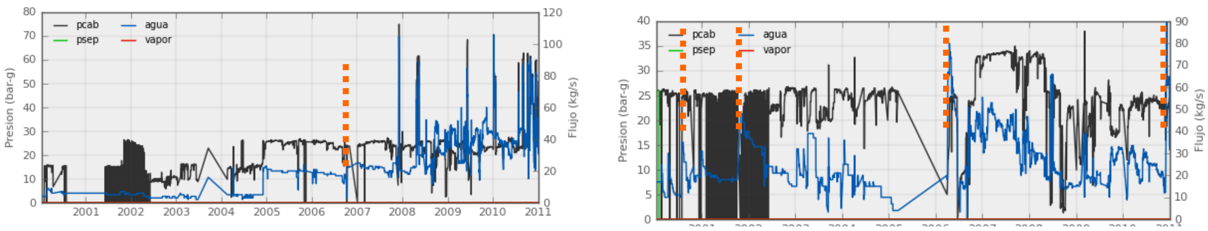

FIGURE 6: Injection improvement in wells TR1B and TR14
(........ Chemical Stimulation)

5. CONCLUSIONS

1. Given the general conditions of the geothermal fields of production, in terms of temperature, mineralogy and processing of geothermal energy reserves, acid stimulation is an effective technique of maintenance costs of energy production.
2. For producing wells with problems of calcite, the best results in terms of increasing production (compared to initial production) were obtained by using HCl RPHF pre-flush and main- flush, compared with treatments with HCl:HF (Mud Acid 10:5) with HCl and pre flush post flush and treatments with HCl alone or in acetic acid alone.
3. The best results for reinjection wells have been attained with RPHF mixture at high concentrations (8%).
4. For producing wells as the ones in Berlin, with little calcite and extensive damage by the entry of drilling mud and cuttings, the best results have been achieved when applying the mixture HCl:HF (Mud Acid 10:5).
5. For wells with problems of calcite and the presence of hydratable zeolites, as in the case of SV1, Acetic acid 10 % has been the most effective mixture.
6. Injecting the mixtures with rig presents close to 200% improvement as they are able to clean more than one zone at a time (approx. 2 to 4).

7. The injection of chemical mixtures with wellhead offer and improvement of 40% as only one area can be cleaned, but offers a higher profitability, because it employs only half or one third of what would be used when cleaning with rig or flexible pipeline.
8. The maximum amount invested in a chemical cleaning with wellhead has been less than half a million US dollars while the maximum amount invested in a chemical stimulation with rig in a production well has been more than 1 million US dollars.

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