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CALCITE INHIBITION IN THE AHUACHAPAN GEOTHERMAL FIELD, EL SALVADOR

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ABSTRACT

Wells located at the Southern area of the Ahuachapán Field exhibit calcite scaling potential mainly attributed to the development of high calcite saturation indexes when the geothermal fluids boil and move towards the surface. In 2002, after the assessment of the calcite problem, a calcite chemical inhibition program started in order to minimize calcite deposition in the wellbore. In ten years of operation five antiscalent chemicals have been tested and used at different periods, all of them proving to be effective in preventing calcite formation when they are injected at the proper dose. Hence, the inhibition method has been successful in prolonging the productivity of wells AH-33B, AH-35A, AH-35B and AH-35C, but several difficulties have been encountered mostly related to inhibitor´s stability. This paper discusses the experiences gained through the operation of the calcite inhibition systems, along with some criteria applied to select chemical inhibitors.

1. INTRODUCTION

Power generation in the Ahuachapán geothermal field started in 1975, with a production area of approximately 5 km^2. In order to provide additional steam supply to the existing power plant, an expansion of the Southern zone was commenced in 1997. Among the wells drilled in the South and now producing are wells AH-35A, AH-35B, AH-33B and AH-35C. All of them are directional wells with measured depths of typically 1500 m, vertical depths of about 1400 m, and reservoir temperatures ranging from 230 to 254°C.

Wells AH-35A, AH-35B and AH-33B were drilled in 1997-1999 and brought into commercial operation on the second semester of 2001. Since the early production wells AH-35B and AH-33B exhibited sustained pressure rundown to below the steam field system pressure, and they had to be closed in very shortly. The underlying cause for the production decline was calcite deposition. The wells with calcite blockage required both mechanical and chemical cleanings to restore their initial production capacity, and after being worked-over each well was put into commercial operation with a calcite inhibition system (LAGEO, 2003).

Well AH-35C was drilled in 2007 in the same pad as AH-35A and AH-35B, and put into service in the same year. The early assessment of the calcite scaling potential of AH-35´s fluids enabled a timely installation of an inhibition system, hence this well has never experienced calcite blockage.

2. CALCITE SCALING POTENTIAL IN AHUACHAPAN WELLS

Calcite may form from hydrolysis (involving replacement of calcium alumino silicates), boiling of geothermal fluids (from fluids having high dissolved carbon dioxide concentrations and in the absence of mineral pH buffer) and heating of cooler peripheral geothermal fluids (Simmons and Christenson, 1993). In a boiling environment, platy calcite precipitates in open spaces upon loss of carbon dioxide with the carbonate species mostly controlling the pH and is described by the reaction:

$$2HCO_3^- + Ca^{++} = \text{calcite}_{\ (solid)} + H_2O + CO_2\ (g) \qquad (1)$$

Calcite scaling in wells AH-33B, AH-35A, AH-35B and AH-35C is mainly attributed to the development of high calcite saturation indexes (log Q/K > 0.2) when the geothermal fluids boil and move towards the surface (Figure 1). The calcite saturation indexes are estimated by the WATCH code using the composition of water and surface gas samples, and the enthalpy of the pre-flashed water in the reservoir. The watch code allows both boiling and aqueous speciation calculations assuming a closed system and no mineral precipitation from fluid samples.

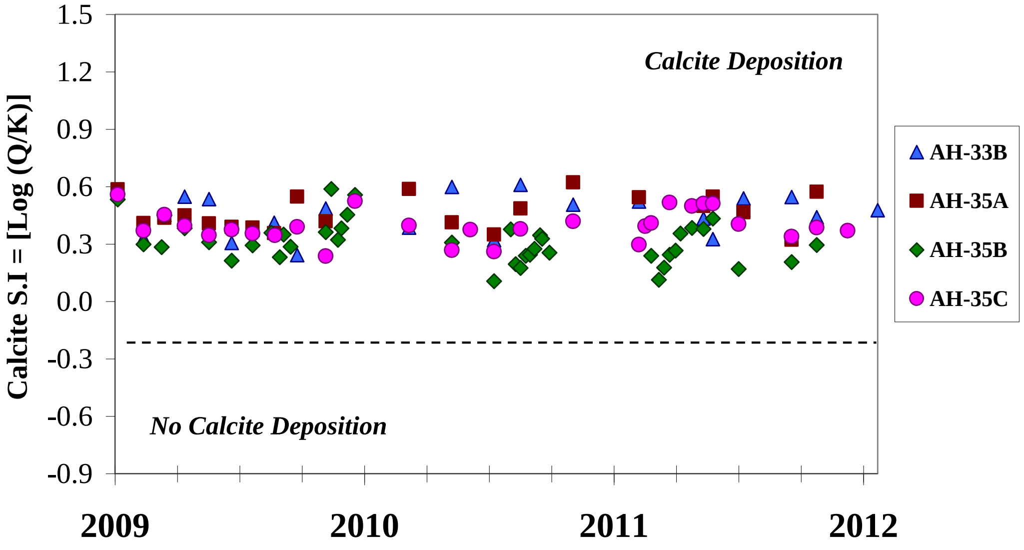

FIGURE 1: Calcite saturation index of wells AH-33B, AH-35A, AH-35B and AH-35C

3. CALCITE CHEMICAL INHIBITION SYSTEM (CIS)

Chemical inhibition is a widespread technique for preventing calcite deposition inside the wellbore. The method consists in injecting a calcite inhibitor in the wellbore below the flash point, thus the inhibitor mixes with the geothermal fluids before the increase of the calcite saturation index occurs. The injection depth is based on either the measured flash point by dynamic PT loggings, or the simulated flash point using HOLA or WELLSIM.

The success of a scale inhibition program depends upon delivering the chemical to the proper depth in the well as consistently as possible when the well is flowing. Therefore, a proper operation of the CIS requires the most attentive selection of both the injection system and the type of inhibitor to be used.

3.1 Injection system

The injection system comprises both surface and downhole facilities (figure 2). The surface facility includes a feed tank containing the inhibitor, and a high pressure dosing pump used to inject down the desired concentration of chemical through a ¼ inch capillary tubing. The downhole injection facility is composed of 1000-1500 m length of a 6.35 mm (0.25 in) Incolloy 825 capillary tubing, the *inhibition chamber* and a weighted sinker bar. The inhibition chamber is a 2 7/8 inch diameter metallic basket enclosing the injection head. The injection head is the lower end of the capillary tubing connected to a check valve to prevent geothermal fluids from entering the tubing. This section of the capillary tubing contains injection port holes. The inhibition chamber is held at the desired injection depth by a sinker bar weight that withstands the force of the rising fluid, but is still within the safe mechanical load limit of the capillary tubing. Furthermore, in directional wells where the chamber tends to lie on the inner top of the casing, a centralizer is added to create a gap between chamber and casing, allowing a better dispersion of the chemical in the surrounding geothermal fluids.

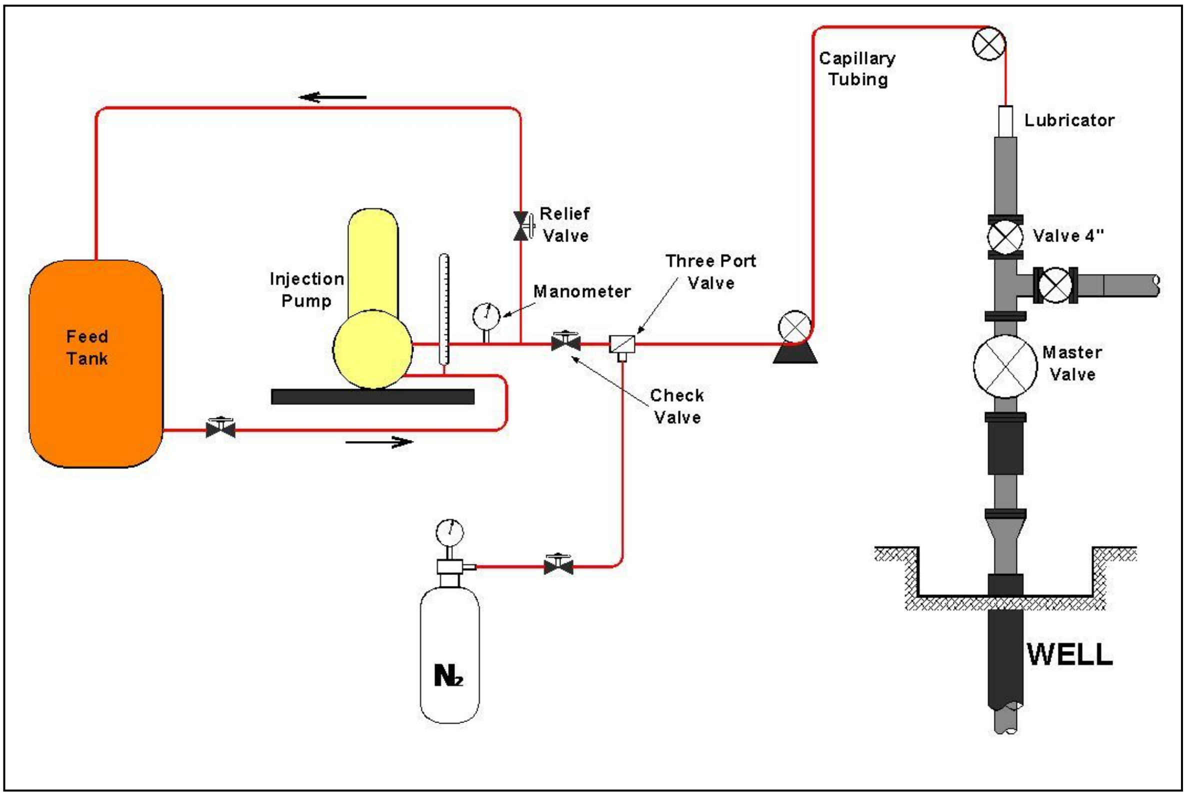

FIGURE 2: The calcite chemical inhibition system

3.2 Inhibitors

The choice of a suitable calcite inhibitor is critical. Inhibitors must prove good inhibition capabilities and perform well under downhole conditions. It is known that most chemicals that had been utilized for carbonate scale inhibition are successful in eliminating the scale, but a good chemical inhibitor must also allow trouble-free operation. This entails meeting the following additional requirements:

- Thermal stability under expected downhole pressure and temperature of the well. Some inhibitors degrade and/or change their physical properties by exposure to high temperatures, forming high viscosity materials or even crystals that block the capillary tubing.
- Microbial stability. Growth of microorganisms (e.g. algae, molds and others) inside the feed tank may decrease the active ingredient concentration, lowering the efficacy of the treatment.

Besides, microorganisms may form clusters that can block either the dosing pump or the capillary tubing.

- Chemical stability with geothermal fluids. Inhibitors are chemical molecules which may react with some components in the geothermal fluids. Formation of solid by-products due to a chemical reaction between the inhibitor and the geothermal fluids may prevent a good dispersion at the injection point and eventually lead to clogging.

Prior to field testing, laboratory trials can be used to evaluate the performance of the inhibitor under critical conditions. Tests at high temperatures provide information regarding the inhibitor´s thermal stability e.g. crystallization, formation of black deposits, increase of viscosity. These experiments can be carried out under open or closed conditions, and can even be combined with pumping trials to assess presence or absence of clogging material.

4. MONITORING THE PERFORMANCE OF A CALCITE INHIBITION PROGRAM

The ultimate purpose of calcite inhibition is to extend the production period of wells which otherwise should be worked-over to remove calcite deposits. Thus, a successful calcite inhibition is achieved when the well production capacity remains unaffected through an appropriate period of time.

There are several chemical and physical parameters useful for monitoring the performance of calcite inhibition, among which wellhead pressure, discharge enthalpy and total flow-rate are of major concern. Changes in composition of chemical species involved in the calcium carbonate formation are also important, thus pH, calcium and bicarbonate content are frequently measured (figure 3). Furthermore, dynamic PT loggings and production tests are periodically carried out to keep the production data updated (Jacobo, 2011).

Well properties monitoring is accompanied by a regular maintenance of surface and downhole facilities. The inhibitor solution is replaced every week and the pumping pressure is registered daily, so any anomaly can be promptly detected. The inhibition chamber is visually inspected on a regular basis, and when needed it is disarmed and cleaned of deposits to prevent clogging of the system. Finally, go-devil surveys are conducted to ensure that the well is cleared down to its total depth.

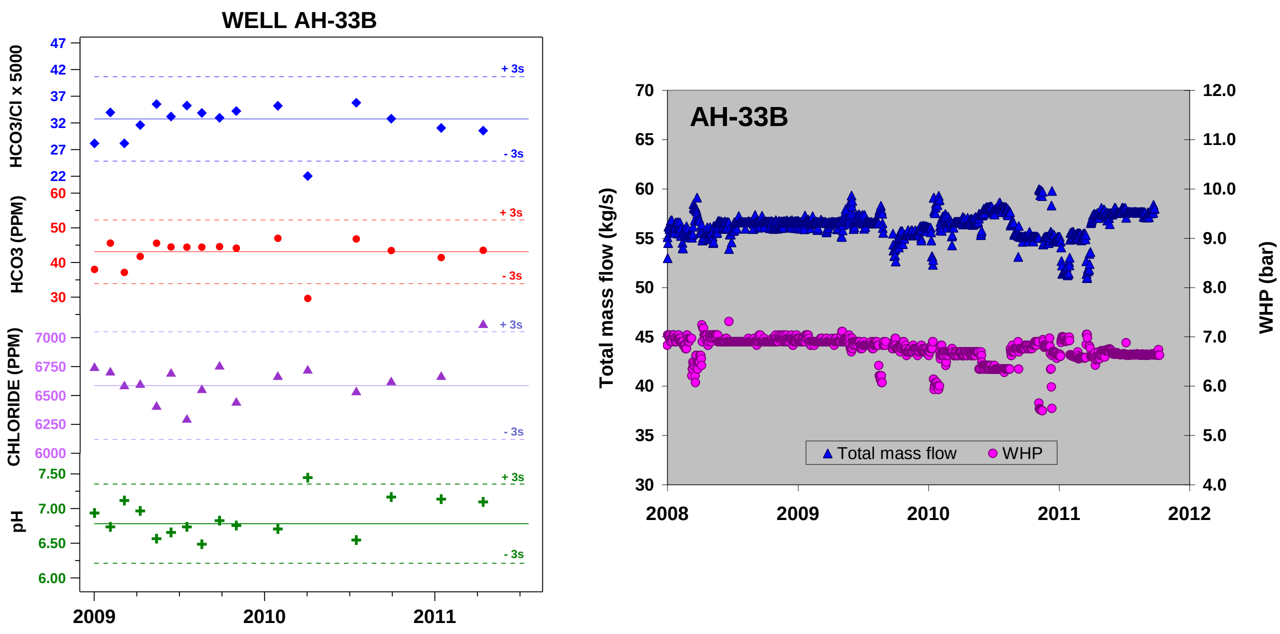

FIGURE 3: Chemical and production monitoring of well AH-35B

5. EXPERIENCES WITH DIFFERENT CALCITE INHIBITORS IN THE AHUACHAPAN GEOTHERMAL FIELD

Chemical calcite inhibitors used in Ahuachapán wells are carboxylate copolymers (e.g. PMA´s-PolyMaleic Anhydride, PAA´s- Polyacrylic Acid) and PAPEMP (polyamino polyether methylene phosphonate). Inhibitors having a polar functional group of COO- (carboxylate) rendering them the negative charges in water, attach to the growing calcium carbonate or calcite (CaCO3) crystals. When the crystals become negatively charged, the calcite crystals are prevented from growing by dispersion. The net effect is therefore crystal distortion and dispersion in this chronological order, governed by the principle on crystal growth and the basic concept on reaction that “like repels like”. In this manner, small calcite crystals are formed which can readily be transported by the flowing geothermal fluid (Daco-ag and Belas-Dacillo, 2010). PMA’s and PAA’s have almost the same action in inhibiting massive calcite crystal formation through crystal distortion and then dispersion, whereas PAPEMP has high chelation and dispersion effects.

In Ahuachapán three screening tests are used for selecting the appropriate inhibitor: thermal stability trials, inhibition efficiency and performance in the field (trouble free operation). Up to date all inhibitors tested in Ahuachapán wells have been successful in preventing calcite scale formation when injected at the proper dose, however they have also yielded some solid by-products entrapped inside the inhibition chamber. Usually solids are only deposited at the bottom, whereas the injection holes remain clean, but in some extreme cases the amount of solids inside the chamber has been so large that the inhibitor injection failed.

FIGURE 4: Inhibitor´s solid by-products deposited in the injection system.

6. CONCLUSIONS

The success of a scale inhibition program depends upon delivering the chemical to the proper depth in the well as consistently as possible when the well is flowing. Therefore, a proper operation of the CIS requires the most attentive selection of both the injection system and the type of inhibitor to be used.

The performance of a calcite inhibition system can be evaluated by monitoring the production capacity (e.g. wellhead pressure, discharge enthalpy and total, flow-rate) and chemical properties of the fluid. Well properties monitoring must be accompanied by a regular maintenance of surface and downhole facilities.

Inhibitors must prove good inhibition capabilities and perform well under downhole conditions. Prior to field testing, laboratory trials can be used to evaluate the performance of inhibitors under critical conditions.

In Ahuachapán the CIS with chemical inhibitors has been successful in prolonging the productivity of wells AH-33B, AH-35A, AH-35B and AH-35C. Up to date five chemical inhibitors have been tested and used at different periods, all of them proving to be effective in preventing calcite formation when are injected at the proper dose. Nevertheless, several problems have been encountered, mostly related to inhibitor´s stability.

Some inhibitors are susceptible to thermal degradation when exposed to high temperatures leading to blockage of the injection system. Others react with chemical species in the fluid and yield solid by-products. Some inhibitors are easily polluted with microbial organisms when expose to working environment. Because all chemical inhibitors offer advantages and limitations, when selecting a suitable inhibitor for a particular well proper studies should be conducted prior field testing and during normal operation of the well.

REFERENCES

Jacobo, P.E., 2011: *Performance of calcite inhibition systems in the Ahuachapán geothermal field*. LaGeo, Gerencia de Estudios, internal report (in Spanish), 12 pp.

LaGeo, 2003: *Review and assessment of calcite scaling in the Ahuachapán geothermal field*. LaGeo, internal report, 97 pp.

Daco-ag, L.M., and Belas-Dacillo, K.A., 2010: Experiences with different calcite inhibitor in the Mahanagdong Geothermal Field. *Proceedings World Geothermal Congress 2010, Bali, Indonesia*, 10 pp.