

LOST PRODUCTION AS CONSEQUENCE OF SILICA SCALING IN CERRO PRIETO GEOTHERMAL WELLS MEXICO

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ABSTRACT

Mineral scale deposition occurs in many of the Cerro Prieto wells, but the main problems occurs by silica (SiO₂) scale both pipes and reservoir zones close to the downhole. In Cerro Prieto geothermal field three types of scales are found; calcium carbonate (calcite), amorphous silica (SiO₂), and metallic sulfides (mainly iron, and lesser lead and cooper). The scale causes lost production and it is necessary to make around 12 workover each year to recover the steam lost. When scaling problems occurred inside casing production is more easier to recover the production that scaling occurred in the reservoir zones, because it caused a skin damage (permeability decrease) in the reservoir zones close to the bottomhole. This paper analyze and discuss the scaling problems and discuss the task developed to avoid and minimized the decline wells production, as to recover the production using workover alternatives.

INTRODUCTION

The Cerro Prieto geothermal field is located in Mexicali valley (Mexico) in the southern portion of the Salton Trough, just south of Imperial Valley of California. The wellfield is about 30 km south of the US-Mexico border. It is the biggest and oldest commercial production geothermal field in México. Electrical power generation began in 1973; with installed capacity of 75 MWe. In 1979, it reached 150 MWe, and in 1981, 180 MWe. During 1986-1987 the power capacity was increased in 440 MW (two power plant of 220 MWe were put in line), and finally was added a power plant of 100 MWe, in line during 2000. To present have been passed more than 30 years of commercial exploitation of the Cerro Prieto reservoir, and during this time more than 250 wells have been drilled at different depths and different reservoir

allocations. To present day, only an average of 150 production wells are supplying steam to four power plants with a total capacity installed of 720 MWe. Over the years, the large amount of geothermal fluids extracted (at present about 12,000 tons per hours of mixtures steam-water) have been causing changes in the reservoir original conditions. Cerro Prieto continues to be the largest liquid-dominated geothermal systems under exploitation. The production zone have been divided in four areas CP-1, CP-2, CP-3 and CP-4 (Figure 1). The field is contained in sandstone and shales of the Colorado River delta and is similar in temperature and reservoir rocks to the geothermal field of the Imperial Valley immediately to the N (Verma, M., et al., 1996).

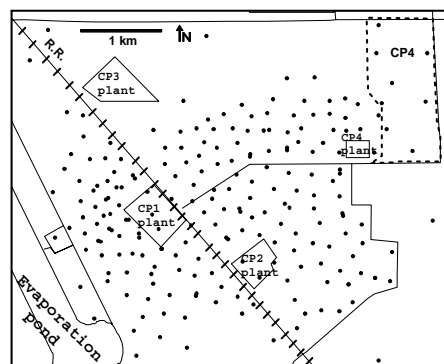


Figure 1. Cerro Prieto Wells allocation

There are two major exploited reservoir developed in sandstone and sandy shales units, that are fed from depth by fluid rising mainly along the faults H, (Halfman et al., 1984). However the faults are important in vertical movements of fluids between reservoir and to surface, intergranular fluid flow, and matrix porosity and permeability dominate the reservoir process (Mahendra, 1996, Ocampo, 2002).

RESERVOIR DISTRIBUTION

The alpha reservoir (α) in the west part of the field is the shallowest and was the first to be exploited (CP 1). It is found at depths between 1000 to 1500 m depth, the original bottom hole temperatures were about 260 °C to 310 °C. The response to pressure decrease as consequence of the exploitation started in 1973, have been caused an influx of cooler water from the sides and above with limited local boiling (Grant et al., 1984; Stallar et al., 1988, Truedell et al., 1989). Besides this influx of cool water have been decreasing the bottom hole temperatures in many zones of this old Cerro Prieto reservoir (Rodriguez, et al., 2000).

The deeper beta reservoir (β) have a depth about 1500 m to 2700 m, and it is extend along of entire geothermal field, the down hole temperatures are in the range of 300 °C to 340 °C. According to hydro-geologic reservoir model developed by Halfam et all (1984), in the natural state, thermal fluids leaked out of the reservoir along it west edge and upward along fault H.

Two features of the beta reservoir in the CP3 area (Figure 2) are worthwhile mentioning. Wells in the eastern part of the area (near E-41 well) encounter this reservoir at depths some 300 m shallower than in neighboring wells (in the area of a cupola shown in the figure). There is a sudden deepening (about 1000 m) of the beta reservoir in the northern part of CP3, between wells M-111 and M-172, possibly due to a impermeable barrier bounding the reservoir to the north. Because of the lower initial pressure in the upper block of the reservoir, and fluid recharge being restricted by the northern impermeable barrier, there is generalized boiling in the CP3 beta reservoir.

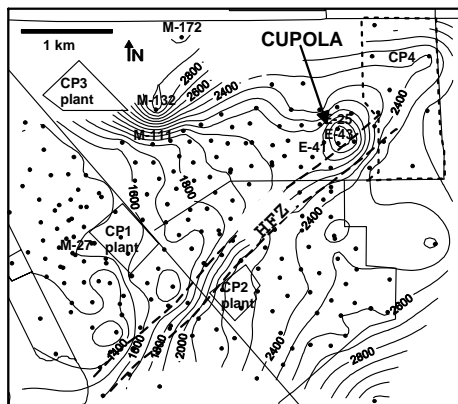


Figure 2. Top of the silica and epidote zone in the Cerro Prieto geothermal field. The main

features shown are H Fault Zone (HFZ), the cupola.

RESERVOIR PROCESS OBSERVED

Extraction of fluid from a reservoir causes a deficit of mass and resulting decrease in pressure. These effects cause entry of fluid from outside the reservoir or boiling in the reservoir with some of the original liquid replace by steam. Using fluid chemistry and wellhead measures it is possible to determinate the character of the response of the reservoir to drawdown and to change well management accordingly. For example, boiling in the reservoir can be delayed by rising wellhead pressures. The location of cold-water inflow is indicated by chemical changes before drastic decreases in temperature occur. Reservoir boiling is accompanied by deposition of minerals (calcite and quartz) in the reservoir. If this mineralization is dispersed it is harmless, but if it is localized around wells it can cause formation plugging (Truedell et al., 1984; Johnson, 1989). The only way to prevent boiling and possible formation plugging over long period of time could be injecting into reservoir liquid. Others alternatives, including raising wellhead pressures and production from deeper zones (saturates with liquid), may delay boiling but cannot prevent it.

GEOHERMAL SCALING

The geothermal scaling is formed mainly by crystalline or amorphous mineral deposited, usually it adhere to superficies or pipes wall and superficial equipment in contact to brine produce from reservoir. The geothermal scaling has some of the follow compounds: amorphous silica or opals, complex silicates, quartz, cristobalita, carbonates (Ca, Mg, Sr), sulfides (Pb, Zn, Cu, Fe), sulphates (Ca, Ba, Sr), complex hydroxides and metallic oxides.

The scaling formed in geothermal system of low temperatures (enthalpy) and high CO₂ concentration are usually carbonates, carbonate of calcium (Calcite). Adverse in high temperature geothermal system the scaling present are composed predominantly by amorphous silica, complex silicates, metallic sulfides and in some cases calcium carbonate.

SCALING OCURENCY

The scaling formation is a natural consequence of physique-chemical equilibrium alteration of the original geothermal fluid condition into the reservoir as consequence of processes related to

production, distribution and disposition of the fluid. Some processes that could occur are: temperature decreasing in separation process, solid dissolve increasing, mixtures of brines of different temperatures and chemical composition, pH change as consequence of gas dissolve separation, etc. The alteration of temperatures, pH and concentration, increase the scaling formation. Almost all minerals involved in scaling problems have low solubility, therefore, a temperature diminish, therefore these precipitate instantaneously. The scaling occurring in different grade, in all superficies in contact with brine, such as reservoir, casing production, pipes, separators, mufflers, valves, orifice plates, pumps, channels, turbines blades, etc.

SILICA SCALING

The silica (SiO_2) scaling is common in almost all geothermal systems. The silica can form by several scaling types, it depending of the brine temperatures. At high temperatures occurring cristobalita and quartz deposition, as to crystalline aluminum silicate as to silicates of aluminum and magnesium. At low temperatures, occurring amorphous silica deposition. At highest temperatures the minerals deposition is controlling by theirs solubilities. However, the quartz solubility velocity is a function both supersaturating grade and temperature kinetically. At temperatures higher than 300 °C the precipitation is fast.

SCALING IN CERRO PRIETO FIELD

Mainly in three types of scale occur at Cerro Prieto field: calcium carbonate (calcite), amorphous silica (SiO_2), and metallic sulfides (principally iron, much lesser lead and cooper). CPI area wells experience deposits of calcite and silica scale, with calcite tends to occur at greater depth than silica, but there is a considerable overlap. CPII and CPII area wells experience silica and lesser sulfide scale, the sulfide tending to occur at greater depth. All three types of scale form in response to changes in produced fluids as it moves through the reservoir and up the well. The reservoir fluids are saturated with silica, the sulfides and calcite as a result of water-rock reaction. When the fluid boils in the well or the reservoir (or both), it cools and loses steam, concentrating the dissolved minerals. It also loses dissolved CO_2 gas, which causes a change in pH. Silica forms principally in response to the concentration and cooling sulfides in response to cooling, and calcite in response to the pH change. The amounts of silica and sulfides dissolved in a geothermal reservoir fluid essentially are a

function of temperature; increasing as temperature increases. Silica is controlled by quartz, which reaches maximum solubility at about 340 °C. Because of this, it generally is true that the hotter the reservoir the more scaling occurs when the fluid cools, with or without boiling. This explains the greater amounts of silica and sulfide scales in CPII and CPIII compared to CPI. The sulfide minerals become oversaturated as soon as the fluid cools below reservoir temperatures, although the iron sulfides tend to form only after cooling has advanced beyond saturation, as a result of slow reaction rates. The amorphous silica which form from dissolved SiO_2 the iron sulfides tends to form only after cooling has advanced beyond saturation, as a result of slow reaction rates. The amorphous silica which forms from dissolved SiO_2 becomes saturated only after considerable boiling and cooling.

Calcite scale deposition is a more complex function of initial chemistry (for example, total salinity, pH and concentration of calcium and dissolved CO_2), and the rate of the pH change upon boiling compared to the rate of cooling upon boiling. Calcite always is saturated in the reservoir fluid, and there always is a chemical potential to form calcite which develops when the fluid boils. However, unlike silica and the sulfides, calcite becomes less soluble as temperature increase. As result, the most severe calcite scale deposition tends to occur from lower temperature geothermal fluids (below about 220 °C to 240 °C) and it is relatively unusual to find calcite scale at wells as hot as those in the CPI area. Even though there is a chemical potential for scale formation, the reaction rates are just slow enough to prevent it. Because of this, it may be that the CPI area scale is forming as a result of special condition. One possibility is that the scale forms only when there is wellbore mixing between deeper, hotter and shallower, cooler component. Both components would be calcite- saturated, but the mixture would be oversaturated and have a particularly high scaling potential upon flashing.

The principal scale management actions at Cerro Prieto are control of wellhead pressure to affect the depth boiling and extend of cooling in a well and mechanical reaming to remove scale which as formed. There are numerous wells where sulfide and silica scale can form at great depth, even along the production liner both inside and in nearby reservoir rocks. When a high wellhead pressure is maintained the scale formation is displaced up the wellbore, ideally above the production zone, where it can removed mechanically, or even out of the well an in to surface pipes. Because of this, orifice

restrictions currently are installed on nearly all of the Cerro Prieto wellheads. There is a possibility that the calcite scale formation could be managed also by downhole injection of chemical inhibitor, or by changing well completions to avoid wellbore mixing (if significant, see above). There are no economical, commercial chemical for downhole control of silica or sulfide deposition.

STUDIES OF FIELDWIDE SCALING

CFE personnel at Cerro Prieto made a statistical analysis of workover between 1988-1991, the results pointed out that the steam recovered percentage after workover in 11 wells using a mechanical scale remove, inside the production casing was 45 % respect to the initial steam flow rate produce, Arellano, et al., (1991), developed a procedure to diagnose production abatement in Cerro Prieto wells, the found a silica deposition rate parameter (Rd) equal o greater than 10 kg/h. Gutierrez Puente, H. and Mendoza, M.A., 1995, point out that each year in Cerro Prieto geothermal field, 12 to 16 wells are repaired as consequence silica scaling that cause a production decrease. Ocampo and Pelayo., 1997, analysed 27 workover of Cerro Prieto wells, during 1994 to 1997, the results shown pour steam recovering in wells cleaned inside the production casing, the best results were obtained in wells deepened. Beall et al., 1997, estimated a range of the silica subsurface deposition between 0 to 120 pound per hour, in some CP2 and CP3 wells.

WORKOVER WELLS

During 2002, Comision Federal de Electricidad in Cerro Prieto geothermal field, repaired twelve production wells, in 9 of these was founded scaling in production casing and production zones, it number represent the 75 % of wells repaired this year, besides was detected mechanical problems in many of these wells, it difficult the evaluation of production decreasing as consequence of silica scaling, table 1, shows a summary of this 12 workover.

Table 1.- Cerro Prieto Wells Repaired in 2002

Well	CP	Depth (m)	Problems found during workover
420	4	3205	Scaling inside of 9 5/8" ϕ
608	2	2600	Scaling inside of 8 1/2" ϕ open hole

M-120A	3	2790	Without information
M-155	3	2904	Mechanical damage
E-40	2	2700	Scaling inside of 7 " ϕ casing and mechanical damage
E-30	2	3143	Scaling inside of 9 5/8" ϕ and 7 " ϕ casing
E-23	3	2508	Scaling inside of 9 5/8" ϕ and 7 " ϕ casing
E-25	3	2836	Scaling inside of 7 " ϕ
217	2	3043	Mechanical damages
615	3	2500	Scaling inside of 9 5/8 and 7 " ϕ casing
631	3	3005	Scaling inside of 9 5/8
618	2	2442	Scaling inside of 9 5/8 and 7 " ϕ casing

Figure 3, shows a typical Cerro Prieto vertical well completion, this figure includes some places where are usually founded scaling inside the casing or production zones, when scaling problems were detected in reservoir zones close to the down hole, it is a routine task to deep the production interval or make a sidetrack to get a new feeding zone without permeability damage.

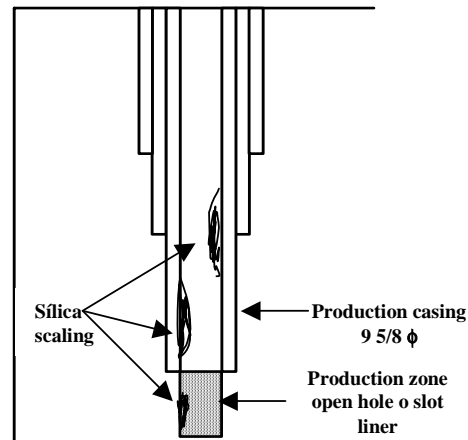


Figure 3.- Typical Cerro Prieto completion well

CONCLUSION

- 1.- Mineral scale deposition occurred almost Cerro Prieto wells, however the main problem occurs by silica (SiO₂) scale.
- 2.- Three types of scale are found in Cerro Prieto wells, calcium, carbonate (calcite),,

amorphous silica (SiO₂), and metallic sulfides (mainly iron, and lesser lead and copper).

3.- The calcium carbonate scale is typical of Cerro Prieto 1 wells, the Silica scale is typical of Cerro Prieto 2 and 3 wells.

4.- Each year are repaired around 12 wells in Cerro Prieto geothermal field, many of these as consequence of silica scaling that cause a steam production decrease.

5.- During 2002, were repaired 12 production wells in Cerro Prieto field, in 9 of these (75 %) were founded scaling inside of 7" ϕ and 9 5/8" ϕ casing production, also were detected scaling in production zone.

6.- Its hard too tray to evaluate the real impact of silica scaling problems over the production, because the information obtained from workover is poor.

7.- Many of wells repaired during 2002 by Comision Federal de Electricidad, show besides scaling problems mechanical damage.

8.- It is necessary to get more information of the scale problems in Cerro Prieto wells to evaluate better a possible alternative that avoid or minimize this problems.

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