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Effectiveness of the Acidizing and Mechanical Reaming of Geothermal Production Well in Kızıldere Geothermal Well in 2009

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ABSTRACT

Kizildere, which is the first high temperature geothermal field utilized for electricity generation in Turkey, has 25 years of production history. High carbon dioxide content makes the calcite scaling the major problem of the wells, surface facilities and the reservoir. Acidizing and mechanical reaming methods have been tried to remove scaling from the wells. This paper will present an up to-date production data and reevaluation of well behavior before and after acidizing of the production wells in the field.

1. INTRODUCTION

Kızıldere is the first geothermal field used for electricity production in Turkey. The geothermal field is named after Kızıldere village, which is located in the south east of Aegean Region of Western Anatolia.

The initial exploration studies in the field go back to 1960s: In 1965, following geological and geophysical studies; General Directorate of Mineral Research and Development of Turkey (MTA) performed the first well drilling (KD-1) in the area to the depth of 540 meters which resulted the discovery of reservoir with a temperature of 198 °C. Between 1965 and 1973, 16 more wells have been drilled in the field whose depths are varying from 370 to 1241 meters. Among these 16 wells 6 of them were found suitable with their temperatures and flow rates for power generation. In 1974 a 0.5 MW_e pilot turbine is constructed by MTA and this turbine is mounted to KD-13. With this pilot turbine, three nearby villages' electricity demand was supplied free of charge in the period of 1974 and 1980. Following this pilot test study, in 1984, the geothermal plant which has a generator output capacity of 15 MW_e and a total capacity of 17.4 MW_e was constructed. Three more wells (KD-20, KD-21, and KD-22) were drilled in 1985 – 1986 to increase the steam supply to the power plant with vapor. At this stage one of the older wells was closed because of its low productivity making the total number of wells producing wells as 8. Other achievements in the field were the drilling of production well R-1 in 1999, which has the ever highest temperature encountered in Turkey with 242 °C and commencing the reinjection in 2002 by using the well R-2. Current reinjection is in the order of 20% of fluid produced from the reservoir.

Although the plant is rated as 15 MW_e it produced 5 – 8 MW_e in the period of 1984 – 1987, 10 MW_e in average from 1987 to 2001 and 12 -13 MW_e afterwards. The main reason behind these low production rates had been the formation of CaCO3 scaling in the wellbores, which eventually caused significant production problems.

The problem of calcite deposition is tried to be solved by applying mechanical reaming and the production of the field has been increased in the short term. In addition, the total production from the wells was tried to be increased many by decreasing the wellhead pressures which lead the shifting of the flash of geothermal fluid in the wellbores and elongated scale section.

After the privatization of Kızıldere Geothermal Plant in 2007 an action plan was realized by ZORLU to increase the power output of the field to the installed rating and the generation capacity of the plant has increased from 5.5 MW_e to 15 MW_e. This significant increase in production is mainly due to the intensive rehabilitation studies of the existing wells in the field. Although the current daily geothermal fluid production from the wells is 980t/h, this value has been about 670t/h before rehabilitation work. In addition, it is planned to prevent scaling in the well bores in the longer term by inhibitor injection. In that respect the wells were acidized before the installation of inhibitor pumping system as an important preparatory work for the effective removal of scaling in the vicinity of wellbore, if exists. It is expected that at the end of all these studies, the optimum production rate will be sustained in Kızıldere Geothermal Field.

In this paper, it is aimed to present the specific calcite scaling prevention methodologies currently applied at the Kızıldere field with some recommendations.

2. SCALING PROBLEMS ENCOUNTERED DURING GEOTHERMAL FLUID PRODUCTION

Scaling is one of the most common problems faced during the production of geothermal fluid from the wells. Geothermal fluid is usually saturated with silica and contains high concentrations of calcite, calcium sulphate, and calcium fluoride and in some cases, if the hot water is acidic, with heavy metals. Changes in temperature and pressure during production disturb the equilibrium, causing the formation of scaling (Patzay et al, 2003).

2.1 Types of scaling in geothermal energy production

Most frequently observed scaling types in geothermal fluid production are calcite and silica depositions.

Geothermal brines often become supersaturated with respect to amorphous silica due to changing equilibirum conditions during energy extraction. At supersaturated conditions, the formation of amorphous silica and metal silicate scale may have significant impacts on brine handling and disposal operations (Gallup et al, 2003). Scale inhibition/control methods practiced in geothermal fields are usually specific to composition of the geothermal fluid and the applied process. Gallup et al. (2003) state that processes to control siliceous scaling from brines have generally been successful in a given field, but no single solution to depositional problems is available.

The formation of calcite scaling, on the other hand, has a similar mechanism with that of silica scaling: The geothermal fluid in the reservoir remains at chemical equilibrium with its surroundings at specific temperature and pressure. As the geothermal fluid moves up to the surface, the fluid pressure declines. When the pressure of the fluid is lower than the flashing pressure, alteration occurs in the chemical equilibrium and some of the CO_2 content in the fluid changes into the gas phase, eventually causing the precipitation of calcite. The relevant chemical reaction is explained in Equation 1 (Satman et al., 1999).

$$Ca^{++} + 2HCO_3^{-} = CaCO_3\downarrow + H_20 + CO_2\uparrow \qquad \text{(Eq.1)}$$

2.2 Scale Abatement

Most common scale mitigation and abatement techniques applied in the industry include inhibitor injection to the wellbore, mechanical cleaning of the wells and acidizing. Among these techniques, inhibitor injection can be considered as a proactive measure to prevent the deposition of scaling, while mechanical cleaning and acidizing are techniques towards the mitigation of scaling once it is formed.

2.2.1 Siliceous Scaling Removal

The most common methods employed in siliceous scale mitigation include: (a) hot brine reinjection (Henley, 1983), (b) adjustment of brine pH (Rothbaum and Anderton, 1979 , Hibara et al., 1990), (c) aging or pond retention (Yanagase et al., 1970), (d) crystallization/clarification (Featherstone and Powell, 1981), (e) removal of silica by controlled precipitation with metals (Rothbaum and Anderton, 1975), (f) controlled precipitation of silica by cationic surfactants (Ueda et al., 2000a), (g) dilution with fresh water (Gallup and Featherstone, 1985), (h) evaporation/percolation ponds (Mercado, 1975), (i) organic inhibitors/dispersants (Harrar et al., 1982), (j) reducing agents for Fe(III) silicates (Gallup, 1993), and (k) chelating agents, organic acids and fluoborate for Al silicates (Gallup, 1998).

2.2.2 Removal of Calcite Scaling

The main methods applied in removal of calcite scaling are, inhibitor injection, mechanical cleaning and acidizing.

Inhibitor injection to the well bore aims to prevent scale formation in the well bore and the surface facilities by injecting a certain type of chemical with specifications directly intended to avoid deposition of scale.

Mechanical cleaning aims to remove scaling once it is formed. The process involves reaming the well bore with a drill bit whose diameter is close to that of the casing. Methodology involves moving down from the wellhead to the well bottom and removing the scale deposition by cleaning flow.

Acidizing, despite some rare occasions, is generally applied as a complementary procedure to mechanical reaming. As the fluid production decreases due to scaling, wellhead pressure is also decreased to maintain the production level, causing the scaling to move closer to the reservoir. In most cases, scaling occurs between the reservoir and the casing and in the reservoir fractures. In such cases, it is not possible to clean the slotted liner casings and reservoir by mechanical reaming, and the calcium carbonate deposition is solved by injecting HCl into the reservoir.

3. OCCURRENCE OF SCALING IN KIZILDERE

3.1 Scale formation in Kızıldere

Calcite scaling is a crucial problem for Kizildere Geothermal Field with respect to the maintenance of surface facilities and is responsible on decline in production rate.

As mentioned above, when the geothermal fluid flashes there is a loss of CO_2 and the pH of the fluid increases, causing approximately 90% of initial Ca to precipitate in the wells before the fluid reaches the surface (Şimşek et al., 2005). Scaling occurs with a similar mechanism in Kızıldere: The CO_2 concentration of the geothermal fluid varies between 1-1.5% by weight of geothermal fluid. Geothermal fluid, close to saturation with calcite contains CO_2, which is dissolved as bicarbonate ion in high temperature. With the occurrence of flashing, dissolved CO_2 goes into the gas phase, and the pH of the fluid increases. Geothermal fluid becomes supersaturated with calcite, and calcium and carbonate ions react to form insoluble calcium carbonate in the well bores (Yıldırım, 2009). Formation of scaling in the wellbores can be seen in Figure 1

Figure 1: Calcite scaling in the wellbore

3.2 Effects of calcite scaling on production

The decline in production due to scale formation can be observed in Figure 2.

Figure 2 clearly indicates the decline in steam production in two wells, namely KD-6 and KD-15: In KD-6, the steam production decreased by 73% from January to September. In KD-15, the decrease in production in the same period is observed as 54%. The effects of scaling can also be observed in electricity production (Figure 3).

Figure 3 shows the variation in electricity production caused by the choking of KD-15 due to calcite scaling. The cyclic behavior of the well production indicates the increases in production after mechanical cleaning and decreases are due to gradual calcite carbonate deposition.

4. SCALE PREVENTION METHODS APPLIED IN KIZILDERE

In order to prevent the decline in production of the wells, and loss in electricity generation caused by calcium carbonate scaling in Kızıldere, periodic well cleaning studies have been carried out by MTA in the period of 1984-2007. During this period, although mechanical cleaning has been conducted every year, acidizing operation has been performed only in the years, 1987, 1988 and 1992. Hence, in the last fifteen years, production wells have been cleaned up with only mechanical reaming. However, in 2008, after the mechanical reaming operations, acidizing has been conducted for seven wells; six production and one re-injection well.

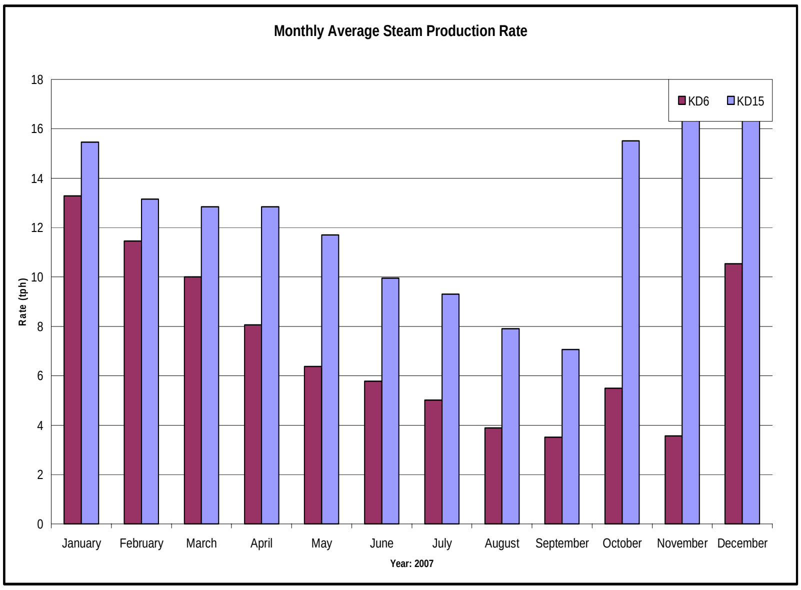

Figure 2: Effect of scale deposition on monthly average steam production rates of Kızıldere field in 2007.

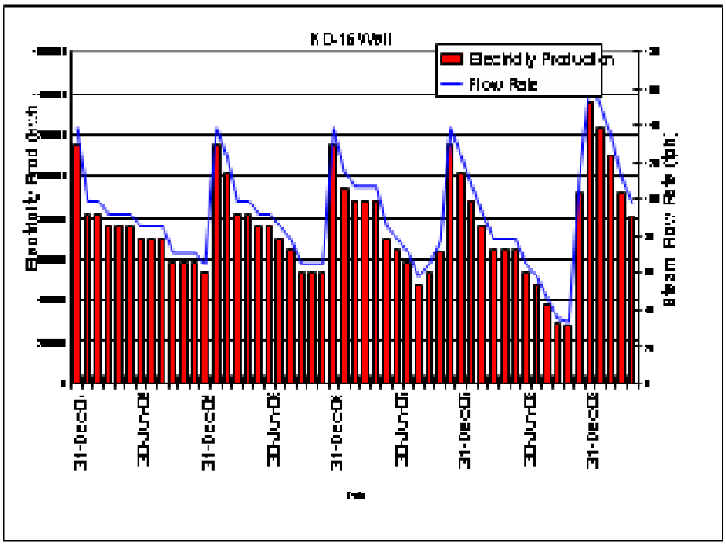

Figure 3: Steam flow rate and electricity production from KD-15

4.1 Mechanical reaming studies in the field

Calcite scaling decreases the production diameter, and causes a choke effect. As a result, considerable decreases occur in well head pressure and production values (Figure 2). In order to preserve the production level, the well head pressure is decreased, causing the flashing point to move to a deeper point.

In Kızıldere, the scale formation in the well is removed by performing mechanical reaming Rotating Control Head Preventer. Unlike conventional mechanical reaming techniques, the process permits continuous production from the wells. Another advantage of this technique is that, production during reaming operation, avoids the plugging of the wells, and also prevents the accumulation of the cuttings in the well bottom. Bottom hole cleaning is carried out with a lip pressure test conducted after the reaming operation. The previous studies have revealed that, production values after mechanical cleaning are very close to production values taken after the previous cleaning (Figure 4 and 5)

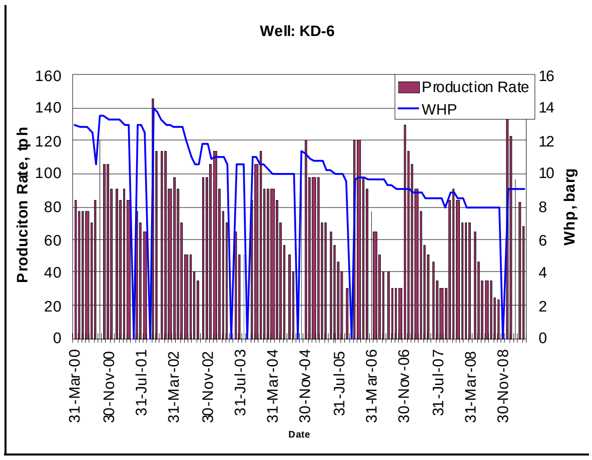

Figure 4: Cyclic behavior production rate and wellhead pressure of KD-6

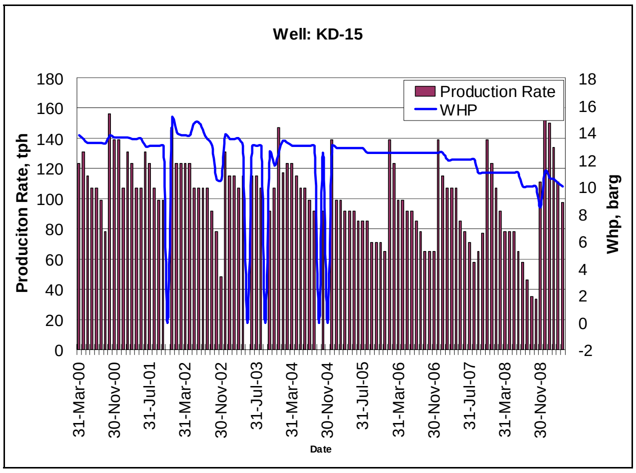

Figure 5: Cyclic behavior production rate and wellhead pressure of KD-15

4.2 Acidizing operation in the field

In 2008, it was decided that, mechanical reaming was inadequate in cleaning the scale deposited within the fractures in the reservoir. For this purpose, following the mechanical reaming, an acidizing operation is conducted in each well to remove the scaling. HCl is found to be the most effective acid to dissolve calcium carbonate, and approximately 40 m^3, 28% HCl solution was injected each well.

The result of this operation is best observed comparing the wellhead flows vs. wellhead pressures of KD-6 mechanical cleaning with acidizing (indicated by the pink line) and mechanical cleaning with acidizing (indicated by the blue line) (Figure 6).

The results of the test have shown that, while the geothermal flow produced from KD-6 is 490 t/h at 4 kg/cm^2 wellhead pressure after the mechanical cleaning in 2007, the same values are recorded as 490 t/h at 5.8 kg/cm^2 wellhead pressure following the mechanical cleaning and acidizing operation in 2008. Actually the deliverability curve of the well shifted to higher values of production rate for all wellhead pressures.

5. CONCLUSION

Historically calcite scaling has been the most important problem in geothermal fluid production from Kizildere Geothermal Field. This problem has been solved by the application of periodic mechanical cleaning studies since 1992. After the privatization of the plant and the field, in order to increase the electricity generation from 5.5 MW_e to the short term production target of 15 MW_e, Zorlu initiated a comprehensive well cleaning program which included the mechanical reaming in combination with acidizing. The results of this mechanical cleaning program, conducted in 7 production wells in the Field have revealed that, a combined mechanical reaming and acidizing program is more efficient than the sole application of mechanical reaming: When compared to the effectiveness of mechanical cleaning in the previous years, the combined mechanical reaming and acidizing operation increased production capacities of the wells significantly, directly affecting electricity generation to achieve the targets set for the short term.

The reservoir modeling studies have revealed that Kızıldere Geothermal Reservoir has the capacity to produce at least 60 MW_e for 30 years. In order to exploit the reservoir in the most efficient way and to reach the above mentioned production target in the long term, the application of a continuous well cleaning program is required. Although both mechanical cleaning and acidizing are proven to be effective techniques in mitigation of scale formation in Kızıldere Field, it should be noted that these measures are not towards preventing scaling in the longer term and therefore require periodic applications. Hence, a proactive approach for scale mitigation is being adopted to attain constant electricity generation rates, an inhibitor injection system is being constructed at the Field.

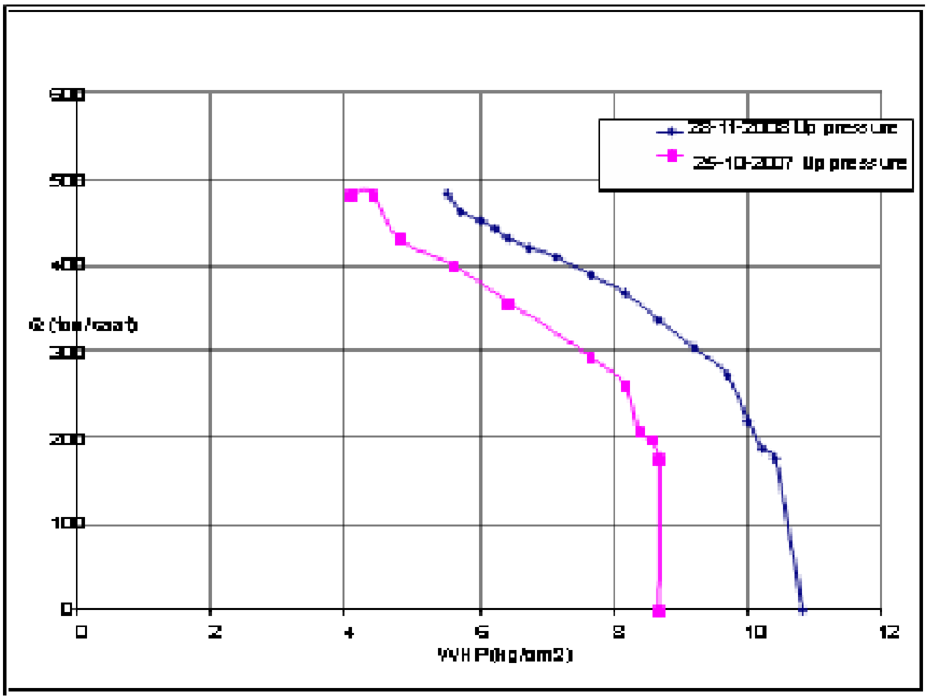

Figure 6: Lip pressure test results for KD-6 in 2007 and 2008.

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