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Scale Inhibitor Application in KD-14 Well of Kizildere Geothermal Field

Tevfik Kaya [a] , Nazım Yıldırım [b], Neslihan Demirci [a], Mahmut Parlaktuna [c], Aygün Güney [a]

[a]Zorlu Petrogas, Ceyhun Atuf Kansu Cad. No:114 D Blok Kat: 5 06520 Balgat , Ankara –Turkey

[c] Petroleum and Natural Gas Engineering Department, METU, Ankara-Turkey

tevfik.kaya@zorlu.com, nazimy@gmail.com, neslihan.demirci@zorlu.com, mahmut@metu.edu.tr, aygun.guney@zorlu.com

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ABSTRACT

Kızıldere Field is the first geothermal field of Turkey that was used to generate electricity. The field is located in the Denizli and Aydın Provinces of Western Turkey in the northeastern end of the Büyük Menderes Graben. Power production from the field was started in 1984 with an installed capacity of 17.4 MW_e. One feature of the field is the calcite scaling tendency of the geothermal fluid which hinders the power output due to frequent need of mechanical cleaning in the wells. After acquiring the operational rights of the field on September 1, 2008, Zorlu Energy launched a complete remediation operation to produce maximum achievable power from the field. One of the measures taken by Zorlu was to find an alternative solution for mechanical reaming of calcite scaling. A scale inhibitor test with 10 different chemicals was carried out in KD-14 and continuous inhibitor injection was started after having optimized inhibitor concentration as well as type of inhibitor. This paper will address the inhibitor selection test and the results of continuous inhibitor injection in KD-14.

1. INTRODUCTION

Kızıldere Geothermal Field is located in Western Anatolia, Turkey and is approximately 30 kilometers away from the province of Denizli. The Field is the first discovered geothermal field in Turkey with the capacity of electricity production (Figure 1).

Figure 1: Kızıldere Geothermal Field

The first geological, geochemical, and geophysical studies at the site were conducted by MTA in colloboration with United Nations Development Program (UNDP) in 1966. Following the devclopment studies at the site for the next two decades, in 1984, the first geothermal plant which has a generator output of 15 MWe and a total capacity of 17.4 MWe, supplied with steam from nine production wells, was constructed in the Field.

In 2008, Zorlu Energy launched a complete remediation operation to produce maximum achievable power from the field. The major challenge encountered in maintaining demanded amount of production from the wells was the formation of calcite scaling. To solve this problem in the short-term, Zorlu applied mechanical reaming and acidizing program, which immediately increased the electricity generation capacity of the Plant from 5.5 MWe to 15 MWe. However, in order to preserve and even expand electricity generation capacity, Zorlu searched for an alternative solution for the prevention of calcite scaling with permanent effects, and following a test program, it was decided to install an inhibitor injection system at 9 wells in the Field.

2. SCALING PROBLEMS IN KIZILDERE

In Kızıldere field one of the main problems is the extensive deposition of calcite ($CaCO_3$) scales in the wells and pipelines (Durak, 1996; Satman, 1999; Şimşek, 2005). Production is severely affected, with rates dropping drastically, even up to 73% in some of the wells in 2007. Scale analysis conducted by MTA indicate deposition of $CaCO_3$ (70–78%), $SrCO_3$ (18–20%), $MgCO_3$ (0.5–1.8%), SiO_2 (0.2–5%), and traces of aluminium, barium, sodium and iron (Lindal and Kristmannsd´ottir, 1989).

The changes in water chemistry which occur when flashing from Kızıldere wells can be summarized as in the following reactions (Yıldırım, 2009):

$$CO_{2(Aq)} <=> CO_{2(vap)} \quad (1)$$

$$HCO_3^- + H+ <=> CO_{2(vap)} \quad (2)$$

$$2HCO_3^- + H^+ <=> CO_{2(Aq)} + H_20 \quad (3)$$

$$Ca^{+2-} + CO_3^{2-} <=> CaCO_3 \quad (4)$$

$$[(3)+(4)\ Ca^{+2} + 2HCO_3^- <=> CaCO_3 + CO_2 + H_2O]\ (5)$$

The geothermal fluid, which is saturated with calcite, becomes supersaturated at the flashing point, when CO_2 moves out, causing the pH of the fluid to rise. A reaction occurs between carbonate and calcium ions forming calcium carbonate. As the casing internal diameter becomes narrower, the wellhead pressure is increased to preserve the production, while the flashing point goes downward.

During the production history of Kızıldere, the scaling in the wells had been cleaned by periodic mechanical reaming operations carried out each year. In addition to these studies, acidizing was carried out in the years 1987, 1988 and 1992. After the privatization of the Field, a well rehabilitation program was prepared by Zorlu in order to meet the short term production targets of electricity generation; which is increasing the electricity generation capacity from 5.5 MWe to 15 MWe. Within the scope of this plant, a combined mechanical reaming and acidizing operation was performed in the wells. However, when the effects of mechanical reaming studies in the previous years were investigated, it was observed that the performance of the wells decrease gradually in a few months time. Therefore, Zorlu considered installation of inhibitor injection systems so as to obtain constant and permanent well performance. For this purpose, in November 2008, an inhibitor test study has been carried out in the well KD-14 and the optimum inhibitor was selected as a result of this study.

3. INHIBITOR TEST STUDIES

KD-14 was selected as the pilot well for the inhibitor injection test. The well was located just in the mid of the Kizildere geothermal field (Figure 2).

Figure 2: KD-14

Total depth of the well was 597 m. After mechanical cleaning and acidizing workover, the flow rate recovered to a maximum level of 210 t/h. Since scaling rate greatly depends on the flow rate of the well, if tried inhibitors do not work effectively during the test or the injection head is not enough, flow rate of the well possibly will drop. This is good evidence for judgment of the inhibitors. Technical and economical prevention (or minimization) of carbonate scales requires a through knowledge of many of the reactions leading to its formation. A wide variety of types of scale deposition can be expected because of the differences in brine compositions. Almost every field exhibits different type and also rate of scaleing at various depths depending on the location within the field and operational conditions. KD-14 and R1 produced the most concentrated fluids among the other wells of the field and hence became eligible for the pilot inhibitor tests.

For the selection of optimum inhibitor, firms were invited to submit proposals on mid-September 2008. The qualified companies were briefly informed on the following:

- Bottom hole temperature of the well.
- Fluid composition of the well.
- Wellhead pressure of the well.
- Flow rate of the well.
- Dosage pump capacity.
- Depth of flashing point of the well.
- Test procedure and duration.
- Maximum expected total hardness.

Besides these properties, the companies were also asked to provide inhibitors with basic properties in order to increase the life of tubing during the operation period.

3.1 The Test

The inhibitor selection tests activities were performed on well KD-14 with 10 different inhibitors. The test lasted for about 23 days in two periods.

Calcite inhibition system was already installed in KD-14. The calcite inhibition system basically consists of surface injection facility for the preparation and injection of chemical solution and a down hole injection facility to allow injection of inhibitor below the flashing point depth.

According to total pressure $P_{(tot)}$ calculation, the flashing point (450 m) starts in the liner of the total depth of well (597 m). The flashing point depth of the well changes with variable operating well head pressure. Since the availability of the injection setting depth was limited to 500 m the well was produced under throttled conditions with 150 tons/hour instead of available 210 tons/hour during the inhibitors test. This was a precaution to keep the flashing point within the liner as well as at a level shallower than the setting depth of inhibitor. Inhibitor was injected to the well by a metering pump having a maximum flow rate of 14.5 l/h and a maximum operating pressure of 150 bar.

The inhibitors diluted with water according to their technical data sheets and field laboratory determinations, in 1:5 and 1:10 ratios. The dilution ratio was witnessed to be sufficient.

Inhibitor performance was monitored by chemical analyses and by specially shaped mild steel coupons placed at critical locations throughout the unit. The coupons were checked at regular intervals (Figure 3)

Figure 3: Scale coupons

The performance af each inhibitor was followed regularly with calcium (Ca), magnesium (Mg), total dissolved solid (TDS), total hardness (TH), chloride (Cl), palkalinity, m-alkalinity. The homogeneity of the samples always checked with chloride concentration and conductivity. The silica precipitation and suspended material in the sampled water was monitored with silica analyses and turbidity measurements. The pH readings of the samples always were conducted to see if all dissolved CO_2 released in order to maintain equal condition among the analyzed samples. The evaluation of the anti-scaling effectiveness was checked by measuring the above mentioned chemical composition of the fluids. The presence of Ca and Mg ions (TH) in particular reference to uninhibited samples from weir was a good measure of what remained in the well casing and in the surface equipment.

Scale formation is a special case of precipitation whereby the precipitate forms a hard shell that cannot be easily removed. This was detected by monitoring test coupons in three critical locations at a surface installation at the well (Figure 4)

a) High pressure side just after main valve.

b) Moderate pressure side before separator.

c) Low pressure side after separator.

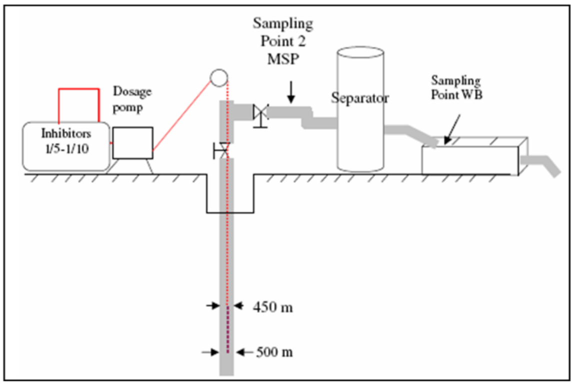

Figure 4: Schematically, representation of the injection system in KD-14

3.2 Results of the Test

In order to optimize the inhibitor dosage, the 10 inhibitors were tested by gradually decreasing the amount of inhibitor from 20 ppm to the optimum dosage.

There are several methods available to monitor the anti-scaling effectiveness of an inhibitor. The most frequently used ones in geothermal applications are by chemical monitoring and by coupons placed at the critical points at the surface equipment. Precipitation of dissolved solids results when super saturation occurs from a temperature drop, pH shift, or other changes. Coupons are not always practical to monitor the scaling occurrence. But, the success of an inhibitor is readily witnessed both by means of chemical monitoring and coupon observations at certain points.

Chemically the upper limit that should be seen at the weir is observed when there is little difference from total hardness in the reservoir of KD-14. Lower concentration of calcium in the weir compared to successful inhibitors means that some of calcium ion has remained in the well-bore while fluid has ascended to the surface or at the lower pressure side of surfical equipments.

After evaluating test results, inhibitors can be investigated in two groups:

1) Unsuccessful inhibitors, those which provide maximum expected total hardness at 20 ppm and above (G, J); those which can not provide total hardness at high dosages (F, H, I)

2) Successful inhibitors, which can provide expected total hardness below 20 ppm (A, B, C, D).

After the direct elimination of the first group of inhibitors, succesful inhibitors were tested at lower concentration to determine the most optimal dosage rates.

As can be observed from the graph, the inhibitors which provide total hardness at lower dosages are identified. The next step is to make cost comparison in order to choose the most effective and economic inhibitor.

4. CONCLUSION

Chemical inhibition has gained importance both technically and economically in preventing calcite deposition inside the wellbore. The test showed that, a successful calcite inhibition program is cost effective in the long term. Aside from eliminating the down time of production wells with calcite blockages, the application also reduces the risk and cost involved in conducting periodic work over.

Because of scaling deposition in the wellbore and wellhead equipment, the production of KD-14 was decreased 50-60 % in six months. (Figure 5). But after starting the inhibitor injection, the production was constant and there was no change in the well head pressure at the constant injection rate. (Figure 6).

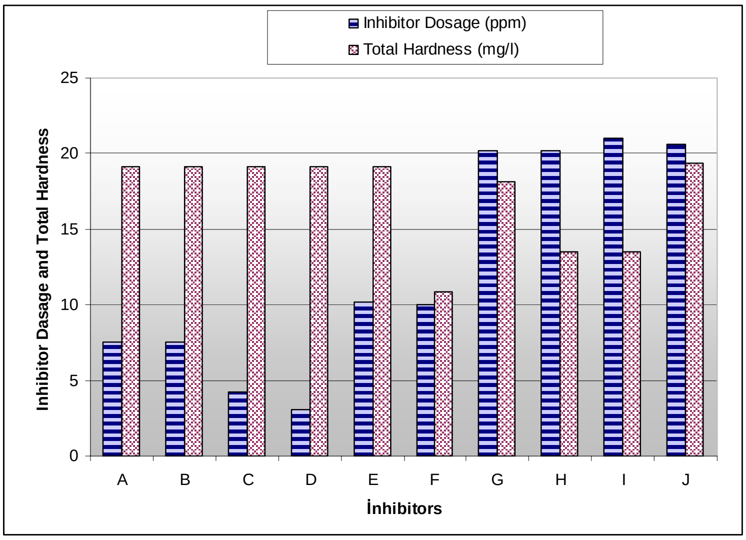

Figure 5: KD-14 Scale Inhibitor Test Results

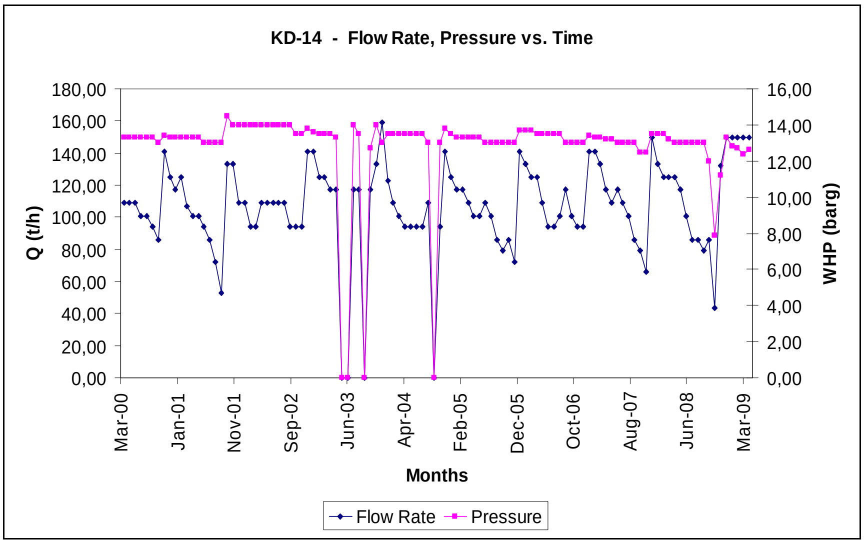

Figure 6: Flow rate and WHP of KD-14 when doing the mechanical cleaning

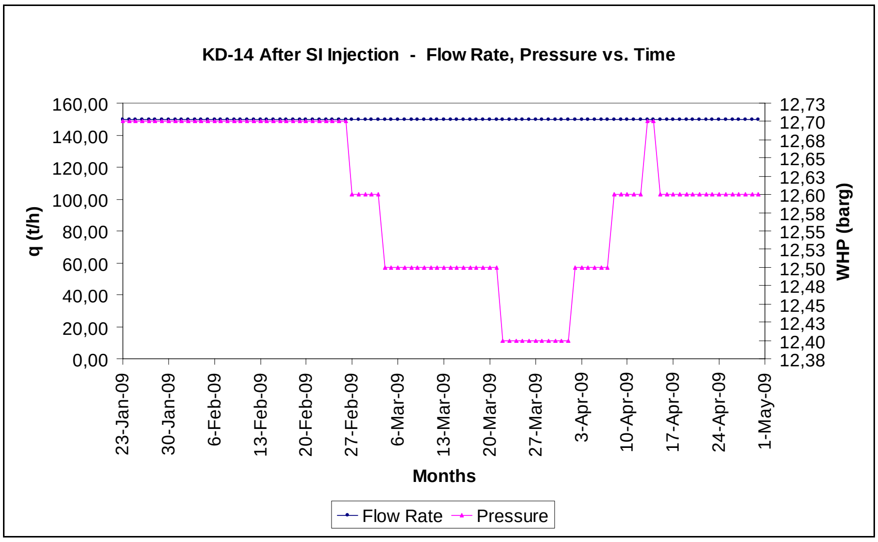

Figure 7: Flow rate and WHP of KD-14 with inhibitor injection

The success of chemical inhibition hinges mainly on the thermal stability of the inhibitor. The choice of suitable inhibitor should not be based only on the cost but as well as on its effectiveness at the measured subsurface temperature and pressure of the reservoir. KD-14 test was conducted to check the inhibition property and thermal stability of a ranged inhibitors prior to long term application in other wells. Determination of the well flash point depth was also important since theoretically, if the reservoir fluids are already saturated with respect to calcite, it is at this point where deposition of calcite blockage will likely occur due to flashing. Moreover, the injection of inhibitor is normally set below the flash point depth. The injection of inhibitor solution should be continuous to ensure that the required effective concentration of the inhibitor at the well discharge fluids is maintained. Thus, the pump used in delivering the inhibitor through the capillary tubing should have flow rate capacity and operating pressure well above the required dosing rate and injection pressure. In the case of the Kizildere well KD-14, chemical inhibition was generally successful in reducing the decline rate in the mass flows. Drawdown in the field can cause flashing in the reservoir before the liquid enters the well or in deeper parts of the well. For effective inhibition the sinker bar should be at least 30 m below the flashing point in the well. Otherwise the desired performance can not be archived from inhibitor applications.

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