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Economical Aspects of the Scale Inhibitor Injection System Operation

Tevfik Kaya, Neslihan Demirci, Remzi Kaya, Ayse Alpagut Bükülmez, Volkan Dedeoğlu

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

tevfik.kaya@zorlu.com, neslihan.demirci@zorlu.com,,remzi.kaya@zorlu.com, ayse.alpagut@zorlu.com, volkan.dedeoglu@zorlu.com

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ABSTRACT

Kizildere Geothermal Field is the first field of Turkey utilized for electricity generation. Although the field was discovered in 1968, electricity generation started in 1984 at an installed capacity of 17.4 MW_e. Up to date, the field produced electricity without injecting scale inhibitors, despite the severe calcite scaling tendency of the produced fluid. After the acquision of the Plant by Zorlu Energy, the Company carried out a calcite scale inhibitor injection test aiming to find a suitable inhibitor which is both technically and economically feasible. After having successful selection of the inhibitor during the tests in KD-14, a chemical injection system is designed for nine production wells of the field.

The scope of the present paper is to give all the necessary information to operate properly the 9 sets of designed chemical injection system equipment which will be built to inject scaling inhibitor down hole in Kizildere Geothermal Wells. The setting depth and its equipment have been designed according to production and wells test. The total cost of the system including operation cost will be compared with the mechanical reaming and acidizing costs for each well.

1. INTRODUCTION

The formation of scaling inside the wellbore of a geothermal production well has been one of the major problems encountered in the operation of Geothermal Power Plants. Formation of scale in the wells results in lower rates of geothermal fluid production, which causes significant reductions in the amount of electricity generated in the Plant.

Kizildere Geothermal Field, which has been operated by the State for electricity generation since 1984, also faces the scaling problem: When the geothermal fluid production rates during the period of 1984-2008 are investigated, the variations in fluid production due to scaling can easily be observed. Although, this problem in the Field has been handled by mechanical cleaning methods up to date, the reduction in the efficiency of the Power Plant could not be prevented. After the acquisition of Kizildere Field by Zorlu Energy in 2008, the Company has sought for other means of prevention of scaling problem and decided on the application of inhibitor injection systems to achieve continuous, cost-effective and efficient production.

This paper tries to explain the inhibitor injection system constructed at the Field and aims to evaluate the benefits associated with the application of inhibitor injection system utilization. In this regard, the paper is organized as follows: Firstly, the scaling problems encountered in Kizildere Field will be explained. Next, the proper solution suggested for the prevention of scaling -inhibitor injection systems- will be presented. Finally, the cost-effectiveness of the inhibitor injection system will be demonstrated by comparing conventional mechanical cleaning to inhibitor injection systems.

2. SCALING IN KIZILDERE GEOTHERMAL FIELD

Scale formation is one of the major problems in achieving efficient geothermal fluid production. When geothermal water is saturated with scale forming materials under equilibrium conditions a change in conditions can either reduce or increase solubility and trigger precipitation or cause more of the material to dissolve. Precipitation occurs when concentration exceeds solubility under the new conditions (Yıldırım, 2009). Flashing and steam fractionation trigger the precipitation of dissolved solids at different depths within the production wells (Simsek et.al., 2005). Most encountered scaling problems include calcite scaling, scaling of metal sulphates and silica scaling.

Similar to most geothermal fields, scaling is the major problem faced in attaining requested production rates in Kızıldere, and the formation of scaling in the wellbores has caused significant production decreases in the power generation.

2.1 History of Production in Kızıldere Field

Production of geothermal fluid in Kızıldere field has commenced with the drilling of the initial well KD-1 in 1968. KD-1 was proven to be a productive well and hence, 16 new wells have been drilled until 1973 whose depths are varying from 370 to 1241 meters (MTA, 1975). In 1974 a 0.5 MW_e pilot turbine is constructed by MTA and this turbine is mounted to one of the newly drilled wells, KD-13. With this pilot turbine, three nearby villages' electricity need is supplied free of charge between 1974 and 1980. In 1984, a new single flash power plant with 17.4 MW_e capacity was put in operation.

In September 2008, Zorlu Energy has acquired all licenses of the Field and the Power Plant. After the acquisition, Zorlu Energy evaluated the current state of the Plant and the Field, and prepared a plan for the further development of the Field. One of the initial actions taken within the scope of this plan was to operate the existing plant effectively, i.e., increase the utilization capacity. For this purpose, a well rehabilitation program is prepared and conducted at the 9 wells in the Field for the mechanical cleaning and acidizing of the wells. The studies have revealed that mechanical cleaning and acidizing, although are short-term solutions, had significant effects on the efficiency of the plant, increasing the production capacity from 5.5 MW_e to 15 MW_e.

Another important field development activity in this period was the gathering and analyzing all relevant data and information on the Field, and one of the major outcomes of this investigation is stated in a report published by Zorlu. The report states that "While the maximum temperature of the first reservoir is 170°C, the maximum temperature of second reservoir is 212°C. R-1 and R-3 deep exploration wells were drilled (242°C) for searching potential of the third reservoir and reinjection. So, new potential opportunities have come out for development of the area and establishment of the third reservoir (Şimşek et al, 2009)".

Based on this promising assessment, Zorlu Energy has accelerated its work on the Field to achieve the most efficient exploitation strategy to construct a new power plant with a capacity of 60 MW_e as first stage of field expansion. In this respect, one of the major challenges is obtaining continuous production from the wells, in other words, prevention of scaling. Zorlu has decided to take a proactive measure, and start the injection of inhibitor to the wells via an inhibitor injection system.

2.2 Scaling Problems Encountered in Kızıldere

Type of scaling is directly related to type of the geothermal water. In Kızıldere, alkaline bicarbonate ($NaHCO_3$) and alkaline earth bicarbonate ($CaHCO_3$) type of geothermal water is observed. Following table presents the chemical analysis results of the geothermal well samples collected from the weirbox. (Table 1).

Table 1: Chemical composition of geothermal water in Kızıldere (Yıldırım, N., Ölmez, E., 1999)

	KD-6 W.B.	KD-13 W.B.	KD-14 W.B.	KD-15 W.B.	KD-16 W.B.	KD-20 W.B.	KD-21 W.B.	KD-22 W.B.	Wastewater	R-1 W.B.
Sampling date (month/year)	4/96	4/96	4/96	4/96	4/96	4/96	4/96	4/96	4/96	9/98
Reservoir temperature (°C)	196	195	207	205	211	201	202	202	92	242
Sampling temperature (°C)	92.5	92.1	93.6	94.2	96	89.6	92.3	96	63.6	96
Conductivity (µS@25 °C)	5830	5940	6160	5890	5835	6180	5940	5830	5500	5820
pH (@25 °C)	8.97	8.89	8.96	8.82	8.94	8.92	9.02	9.3	9.25	8.8
TDS (ppm)	4550	4880	6010	4910	5100	4720	4740	4910	4870	6380
Na	1220	1300	1410	1340	1400	1375	1325	1275	1400	1556
K	116	138	152	138	148	140	131	140	138	245
Ca	1.2	2.0	1.2	1.2	3.2	1.6	1.8	1.2	1.2	2.67
Mg	0.36	0.25	0.2	0.15	0.24	0.15	0.24	0.24	0.6	0.23
B	20.4	26.5	24.4	24.6	24	24.1	24.5	25	26	30
SiO_2	364	364	392	393	398	367	387	392	345	416
HCO_3	1586	1525	2403	1464	1525	1159	1220	1586	1342	3074
CO_3	540	600	720	660	730	780	780	600	720	100
SO_4	560	773	737	730	714	710	710	729	735	792
Cl	124	128	144	140	136	140	140	136	136	134
F	17.8	20.0	24.8	22.3	23.5	22.5	21	22.5	21.7	26.4

In Kızıldere geothermal field, calcite scaling is frequently encountered in the production wells and in surface facilities (Figure 1).

Figure 1: Occurrence of calcite scaling in the wells.

Historically, in Kızıldere, the problem in the wellbores was solved by mechanical cleaning using a drilling rig: In order to be able to clean the scale formation in the wellbores, the earlier application was as follows: the production from the well is stopped for a temporary period (usually 1-2 weeks), then a rig is assembled at the wellhead, and the well is mechanically cleaned to a certain depth. In some cases, although not as frequent as mechanical reaming, the well is acidized to dissolve the scaling in the fractures, which is caused by the downward movement of flashing point. Although this method has proven to be effective in removing calcite scaling, this is not a proactive measure to prevent calcite deposition, and in the long term, new calcite formations in the wellbores are observed. Figure 2 shows the behavior of the KD-6 after mechanical cleaning.

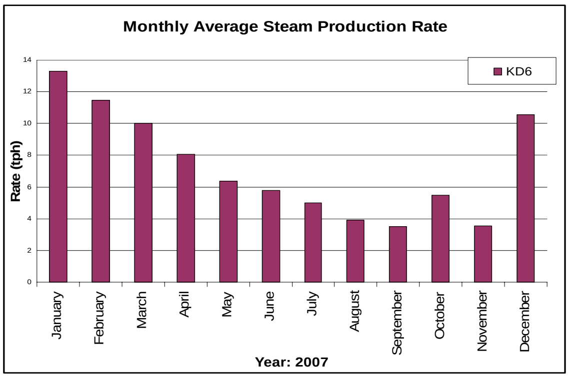

Figure 2: Monthly production of the wells KD-6 in year 2007.

As can be observed from Figure 2, considerable decreases in the productivity of KD-6 is observed with increasing calcite formation in the wells: While the steam production of KD-6 decreases from 13.3 ton/hour in January to 3.5 tons/hour in September, after the mechanical cleaning operation in November the steam production increases to 10.5 ton/hour in December. The increase in October, on the other hand, is due to the decreased wellhead pressure to maintain production rate.

Apart from the calcite scaling observed in wellbores, scaling is also observed at the surface facilities. Calcite formation at the surface is removed by more primitive methods, i.e. hammering method. Thus, it can be concluded that the method is inefficient and costly in terms of revenue loss from electricity generation.

Because of these reasons, in order to achieve continuous production, Zorlu has decided to use inhibitor injection system to prevent calcite scaling in the production wells. For this purpose, initial tests of inhibitor injection have been performed in November-December 2008, to select the most efficient one among 10 different inhibitors (Figure 3).

Figure 3: Inhibitor tests.

The schematic diagram of the inhibitor test facility system is given in Figure 4. The key components of the test system are "Production Well Inhibitor Storage and Pumping System" and “Production Well Inhibitor Downhole Feed System”. Production Well Inhibitor Storage and Pumping System is mainly composed of inhibitor storage tank, two dosage pumps (one of them as reserve), calibration pot, pressure gauges. Production Well Inhibitor Downhole Feed System, on the other hand, includes stuffing box, lubricator, hay pulley, weight (sinker) bar, chamber, capillary tubing and drum.

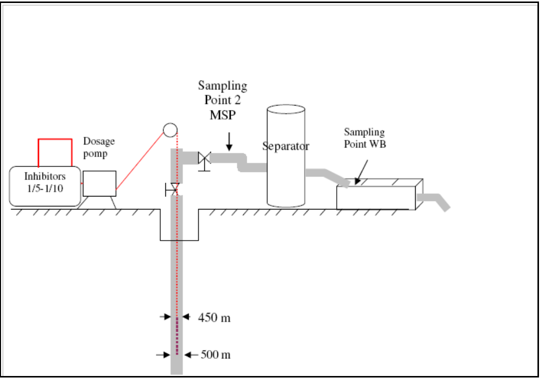

Figure 4: The inhibitor injection system.

In order to run the inhibitor injection system properly and effectively, the following points must be given special attention:

1. The selected inhibitor must preserve its resistance when subjected to high temperature.

2. Flashing point must be clearly identified for each well so that tubing can be retrenched to at least 50 meters below this point.

3. The pump capacity must be selected in a flexible manner to be able to adopt changing well production rates.

4. The system must have an automated monitoring system for an healthy inhibitor injection operation (ex. in case of pump failure, decreasing inhibitor level in the storage tanks, etc.)

5. Weight (sinker bar) calculations must be made for successful retrenchment of the tubing with chamber.

6. It is known that in the determination of the tubing diameter, required inhibitor dosage is an important parameter. However, as the inhibitors may change phase (become jelly like) when exposed to high temperature for long periods, the tubing may get choked. Therefore, in tubing diameter calculations, this fact must be considered along with the required inhibitor dosage.

7. The type of material used in the inhibitor injection system must be designed so as to resist corrosion, high temperature and pressure. One of the important factors influencing corrosion is the chemical composition of the fluid. Therefore, when choosing the system, the material most suitable to the specific field conditions must be investigated.

3. ECONOMIC COMPARISON OF INHIBITOR INJECTION SYSTEM WITH MECHANICAL REAMING

The utilization of inhibitor injection system in Kızıldere field has been considered to be inapplicable due to relatively high costs. However, the field studies have proven that, despite the initial investment and operating costs of inhibitor injection systems, when the decline in electricity generation due to decreasing geothermal fluid production is considered, the utilization of inhibitor injection system turns out to be more efficient and economically sound compared to the application of mechanical reaming.

3.1 Cost of Mechanical Reaming

The cost of mechanical reaming and acidizing operation in 2008 for the removal of the calcite formation is presented in Table 2.

Table 2: Cost of mechanical reaming

Name of the Well	Depth (m)	Total Cost of Mechanical Cleaning ($)	Total Cost of Acid ($)	Cost of Corrosion Inhibitor ($)	Cost of Acidizing Operation ($/well)	Total Cost ($/well)
KD-13	587.86	30813	6123	4216	35495	76647
KD-14	528.00	27675	6123	4216	35495	73509
KD-15	436.13	22860	6123	4216	35495	68694
KD-6	500.00	26208	6123	4216	35495	72042
KD-21	550.00	28828	6123	4216	35495	74662
KD-22	560.00	29353	6123	4216	35495	75187
KD-16	550.00	32289	6123	4216	40010	82638
KD-20	513.00	30117	6123	4216	40010	80466
R 1	1041.0	61116	6123	4216	40010	111464
TOTAL						**$ 715.309**

3.2 Cost of Inhibitor Application

A pilot inhibitor injection system has been constructed in two wells, KD-14 and KD-20. The inhibitor injection optimization in these wells has shown that application of 5 and 6 ppm dosages provides the maximum total hardness values. It is anticipated that an inhibitor injection of whose dosages vary between 4 to 8 ppm will be applied in 9 production wells.

3.3 Cost of Electricity Generation Loss

3.3.1 Electricity Generation Loss Due to Scaling

Scale formation has direct influence on the amount of steam supplied to the Plant since the productivity of the wells may decline 70-75% in 8-9 months, as shown as an example for KD-6 (Figure 2). Furthermore, shutting down a well for mechanical cleaning also creates additional loss of steam provided to the Plant. Figure 5 explains the cyclic loss in electricity generation caused by the decline in steam production caused by calcite scaling.

The utilization of an inhibitor on the other hand, would stabilize the electricity generation at a steady level, and cumulative amount of electricity generated would show a noteworthy trend compared to electricity generation with mechanical cleaning of the wells (Figure 6).

3.3.2 Electricity Prices in Turkey

The law on renewable energy enacted in 2005 guarantees the purchase of electricity generated from renewable resources at a rate of 5.5 €cent/kWh, and this current amount is expected to be increased to 10 €cent/kWh in the near future. On the other hand, Turkish electricity market is partially liberalized and price of generated electricity is around 10 €cent/kWh in the market, and the cost of electricity generation calculations in based on this value.

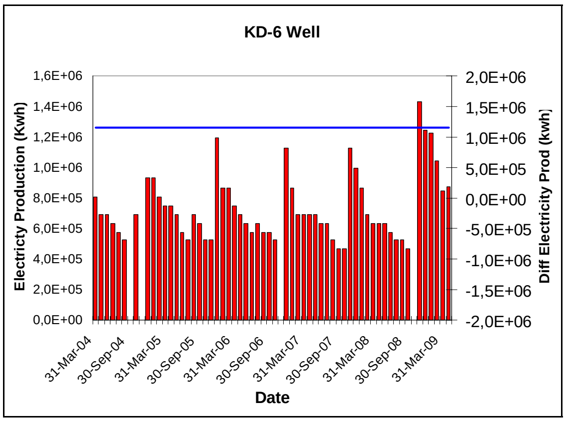

Figure 5: Loss in steam and electricity generation.

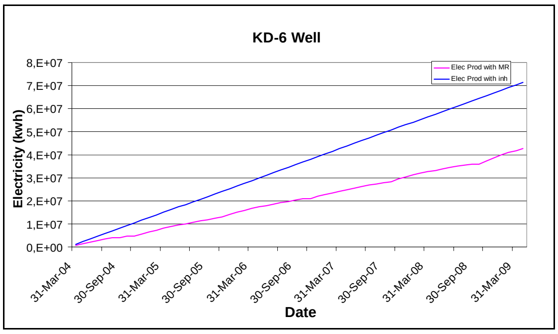

Figure 6: Comparision of cumulative electricity generation with and without inhibitor injection.

3.3.3 Comparison of Costs of Inhibitor Injection and Mechanical Reaming

In order to test the cost-effectiveness of constructing an inhibitor injection system, a simple cash flow analysis for two different cases of geothermal fluid production (production with inhibitor injection and production w/o inhibitor injection) is performed for a period of 10 years and compared under the following assumptions:

- The production values used in the analysis belong to the year 2007.
- It is assumed that, the wells exhibit similar behavior after the completion of mechanical cleaning in each year.
- Costs of acidizing and mechanical cleaning is provided in Table 2.
- Yearly interest rate used in the analysis is 12%.
- In case of electricity production without inhibitor injection to the wells, acidizing operation is performed in every 10 years, and mechanical reaming is done every year.
- In case of electricity production with inhibitor injection to the wells, acidizing operation will be performed once in the life of the system, while mechanical cleaning will be done every 5 years.
- It is anticipated that, even if inhibitor is injected to the wells, there still might be some slight loss due to scaling. Therefore, a yearly production decline rate of 4% is assumed.
- Electricity prices are assumed to be $13 cent, equivalent to 10 € cent.

When a cash flow analysis is performed under these assumptions for a period of 10 years, it is observed that electricity production with inhibitor injection system generates a revenue of $89.5 M. Meanwhile, electricity production without the application of a inhibitor injection system generates a revenue of $75.6 M. Hence, utilization of inhibitor system in Kızıldere Geothermal Field creates an increased profit of approximately $14 M.

5. CONCLUSION

Calcite scaling is one of the major challenges observed in production of geothermal fluid from Kızıldere Geothermal Field. Deposition of calcite in the wellbores due to chemical composition of geothermal water causes significant declines in brine production and therefore in electricity generation.

In order to achieve continuous electricity production and prevent cyclic production declines in the wells, it has been decided to construct an inhibitor injection system in the Field. Initial investigations and results of the test studies have proven that application of inhibitor injection system as a preventive measure is an effective approach in terms of both achieving continuous electricity generation and cost-effectiveness.

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