OPERATIONAL DYNAMICS IN WELL SP-4D WITH A CALCITE INHIBITION, MINDANAO GEOTHERMAL PRODUCTION FIELD, PHILIPPINES

by

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ABSTRACT

SP-4D is a production well in the Mindanao Geothermal Production Field (MGPF), Philippines, which develops calcite deposition under flowing conditions. An inhibition system was installed in the well to prevent active deposition after a second mechanical work-over. Prior to running-in the downhole injection assembly, an obstruction was encountered at 830 meters measured depth (mMD) which limited setting depth to 815 mMD. Wellbore simulation studies indicated that if the well were operated at full-open conditions, the flash point depth (FPD) would below 940 mMD, below the calcite inhibitor injection point. With this expectation, the well’s operation was maintained at throttled conditions with a wellhead pressure greater than 12.7 kg/cm² in order to raise the FPD above 815 mMD. The flow dynamics with time were modeled using water flow data from tracer dilution measurements. The results indicated that the injection depth was initially at the boiling transition. The well’s output was observed to have deteriorated after about more than eleven months of utilization despite the continuous anti-scalant injection. This decline necessitated the pullout of the downhole injection set-up and capillary tubing which, surprisingly, was free of any calcite deposits.

INTRODUCTION

Well SP-4D is a production well in Mindanao Geothermal Production Field (MGPF). It contributed 5-6 MWe to the power plant, and its separated brine as one major contributor to the second flash system. The well has an active scaling characteristic when put under flowing condition. This well already underwent three mechanical work-overs. There was no inhibition installed when the well was put in commercial utilization on March 1997 and after its first work-over on April of 1998. Only after the second work-over that a calcite inhibition system (CIS) was installed on May 1999.

There was a constraint in running-in the capillary tubing when an obstruction at 830 mMD was encountered. This raised possible risk of tubing cut limiting the injection setting depth at 815 mMD. In order to still perform the calcite inhibition field trial, the problem was remedied by operationally throttling the well to raise the fluid flash point depth above 815 mMD.

The utilization of the well lasted for more than eleven months. Surface facilities, feed pumps and simple downhole injection system showed to be successful the whole duration of the operation in spite the well ceased supplying steam due to scaling obstruction. This compelled the pull-out of the downhole injection system but surprisingly, the capillary tubing was free of any chemical scales upon inspection.

WELLBORE CHARACTERISTIC

SP-4D was completed on February 1994. This was drilled to a shallower depth at 1490 mMD compared to other production wells reaching >2000 mMD. This was to avert temperature reversal below 1480 mMD since the well was drilled directed towards the outflow region. However, early heat-up surveys still revealed that there were temperature reversals at 1250 up to the bottom (Esberto, M.B., 1994). The well has multi-feed zones (Fig. 1), and the major feed zone at 1200 mMD controls the discharge at liquid condition, except, for the upper
feed zone which has a two-phase condition. The well has a high injectivity index of 350 li/s-MPa and very high transmissivity. The initial output of the well on its first commercial utilization on March of 1997 was approximately 6 MWe. The well underwent three mechanical work-overs, however, it retained its commercial output at 5-6 MWe.

Figure 1. SP-4D well bore configuration

INJECTION SETTING DEPTH

The injection setting depth is dictated by the flash point depth (FPD) where calcite initiates to deposit. This can be prevented when an inhibitor is injected below the FPD. It should be ensured that there is a full mixing, sufficient residence time of the treated brine prior to flashing. It was preferred that the injection head should be 100 meters below the FPD (Nogara et.al., 2000).

Prior to the installation of the downhole assembly, a 5 inches dummy tool (Go-devil) was run-in and tagged depth 830 mMD. This obstruction was presumed to be a casing break limiting therefore the injection head above this depth. This would avert possible risk of tubing cut on-set the operation. This constraint prompted the simulation of the flash point depth by manipulating the well’s conditions by throttling. This was done by initially conducting atmospheric testing by James Lip-Pressure method with the well’s output measured at different well head pressure (Table 1). Then, the flash point depths were calculated using wellbore simulations where the temperature and pressures were matched with the Pressure-Temperature-Spinner (PATS) log data. The simulation results suggested that the well should be operated at a well head pressure above 12.5 kscg in order for the FPD raised above 830 mMD (Fig. 2). The downhole assembly and surface facilities were installed, and the injection head set at 815 mMD. The well was finally operated at choked condition at a well head pressure of >12.5 kscg supplying steam to the power plant rated at 2 MWe (metered in the power plant upon cutting-in).

<table>
<thead>
<tr>
<th>WHP (kscg)</th>
<th>Mass flow (kg/s)</th>
<th>Power (MWe)</th>
<th>Flash point depth (mMD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0</td>
<td>69</td>
<td>5.8</td>
<td>940</td>
</tr>
<tr>
<td>8.4</td>
<td>64</td>
<td>5.0</td>
<td>890</td>
</tr>
<tr>
<td>10.0</td>
<td>53</td>
<td>3.8</td>
<td>850</td>
</tr>
<tr>
<td>10.5</td>
<td>48</td>
<td>3.3</td>
<td>730</td>
</tr>
<tr>
<td>10.8</td>
<td>45</td>
<td>3.0</td>
<td>700</td>
</tr>
<tr>
<td>11.4</td>
<td>40</td>
<td>2.6</td>
<td>550</td>
</tr>
<tr>
<td>12.0</td>
<td>35</td>
<td>2.2</td>
<td>500</td>
</tr>
<tr>
<td>13.5 Maximum discharge press. Well choked beyond this WHP</td>
<td></td>
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</tbody>
</table>

Table 1. Initial calculation of the flash point depths (FPD) during its atmospheric discharge on May 1999

Figure 2. Simulated flash point depths (FPD) with well head pressures
CHEMICAL INJECTION DOSING

A chemical inhibitor was injected on-line to the system. The injection flow was regulated at 14-17 li/hr providing the total discharge a concentration of 5 ppm. This concentration was arbitrarily chosen to effectively inhibit calcite scaling (Nogara et.al., 2000). The pump pressure was maintained at 200-250 psig the whole duration of the test.

GEOCHEMICAL TRENDS

Geochemical parameters Chloride reservoir (Cl_res), Calcium reservoir (Ca_res), Carbon-dioxide total discharge (CO2TD), Quartz geothermometer (TQtz) were plotted with time (Fig. 3). Water geochemical parameters Cl_res and Ca_res showed increasing trends, and on the other hand CO2TD showed a declining trend. These indicated SP-4D was affected by reinjection fluids. No thermal front, however, was detected as manifested by the stable TQtz trend. The reinjection return was postulated to be from the adjacent Matingao wells (Sambrano et.al., 2000), where sixty-five percent (65%) of the production total separated brine was injected in these wells.

The calcite saturation indices (CSI) were calculated AT 230°C using the WATCHWORKS speciation software (Klein, 2000; Arnorrsson and Sgurdsson, 1982). The calculated CSI with time remained oversaturated (log Q/K > 0) despite the continuous shift of the fluid geochemical components. CSI fluctuated from 3-5 between May 1999 to December 1999, and during this period, water flow declined gradually. Beginning January 2000 up to May 2000, CSI dropped to ~1 which coincided with the rapid decline in water flow (Fig. 3), and increase in CO2TD.

SIMULATED FLASH POINT DEPTHS AND WATER FLOW TRENDS

The outputs of the well which were used in the simulation were indirectly monitored from the water flow trends measured by tracer dilution method. Sodium Benzoate was used as the liquid tracer where the site laboratory was capable of analyzing this component and was able to provide results on timely basis.

The calculation of the flash point depth was done belated when all the water flow data were consolidated. The enthalpy was assumed constant.
at 1013 kJ/kg, thus, the total mass flow can be obtained at the sampling point pressure. The declining water flow trend was correlated with the depression in flash point depth with time. This explained that the fluid was not inhibited from forming calcite. It should be noted that the injection head was placed initially at 815 mMD when the expected FPD was at ~500 mMD at 12.0 kscg. However, data of water flow taken after 10 days of utilization revealed that the FPD was at 830 mMD, 15 meters below the injection head. The early simulation results indicated shallower flash point depths primarily because the discharge was not stable. This was correlated later to the geochemical parameter Cl\text{res} which indicated the discharge was finally cleared from work-over fluid only about a week of continuous flowing at choked condition. With time, the FPD reached 1025 mMD at the later part of the well’s utilization which was caused by the pressure drop due to mass flow reduction.

**Figure 4. Calcite Saturation Index (CSI) at 230°C correlated with the water flow trend**

**WELL HEAD PRESSURE AND WATER FLOW TRENDS**

Well head pressure (WHP) could be a useful monitoring tool in tracking well output and downhole pressure with time. The WHP was controlled at pressure >12.5 kscg by manipulating the production isolation valve (PIV). At the later part of the well’s utilization particularly on March 2000, the PIV was adjusted to 1” opening to raise the FPD. However, the WHP continued to decline further vis-à-vis the downtrend of water flow at a rate of -1.2 kg/s-month at 1-1/8” PIV opening (Fig. 5).

**Figure 5. Calcite Saturation Index (CSI) at 230°C correlated with the water flow trend**

**CIS PULL-OUT AND OBSTRUCTION LOGS**

The well ceased supplying steam on May of 2000. The anti-scalant injection was terminated at the same date, and the capillary tubing pull-out followed. It was surprising that no mineral deposit was found on the tubing.

The well was worked-over for the third time on May 2000. The obstructions tagged were tabulated (Table 2). Since the wellbore simulation, using tracer dilution method, would suggest that the initial flashing occurred at 830 mMD, it could be correlated that the initial flashing occurred between 830 to 847 mMD at stable condition. It suggested that the deposits tapered to a shallower depth to 730 mMD, where this was initially tagged during the third work-over. This explained why the tube was clear of any mineral deposition. There was no mechanism yet which would explicate the
occurrence of the deposits below 1200 mMD. A possible phenomenon that could explain the latter mechanism was the inflow of colder fluid. Since calcite has a reverse solubility, upon the ascend of the fluid and heated-up, its saturation thus increases making the fluid more potential to form the mineral. There were also obstructions below 830 mMD that were logged during the 1998 and 1999 work-overs (Table 2).

<table>
<thead>
<tr>
<th>2000 work-over (mMD)</th>
<th>1999 work-over (mMD)</th>
<th>1998 work-over (mMD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>739-763</td>
<td>795-855</td>
<td>619-814</td>
</tr>
<tr>
<td>824-857</td>
<td>1227-1255</td>
<td>1318-1342</td>
</tr>
<tr>
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<td>1321-1388</td>
<td>1432-1481</td>
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<td></td>
</tr>
<tr>
<td>1463-1469</td>
<td></td>
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</tr>
</tbody>
</table>

Table 2. Obstruction tagged (meters-RKB) during the 3rd work-over on 2000, 1999 and 1998 work-overs

NATURE OF THE DEPOSITS

The well was cleared and ejecta were collected during its vertical discharge. The thickness of the ejecta collected varied from 9-17 mm which represented the inner diameter of the liner 7-5/8” (Nogara et.al., 2000). These ejecta were primarily composed of calcite and of platy morphology. This indicated that the deposit was formed during the fluid flashing. The formation temperature of 235°C of the mineral based on fluid inclusion correlated the flash point temperature of SP-4D (Dulce et.al., 2000).

CONCLUSIONS

SP-4D was operated commercially for more than eleven months with the calcite inhibition system. The operation of downhole injection assembly, surface facilities and injection pumps proved to be successful. The well was operated at throttled condition to raise the flash point depth (FPD) above the blockage at 830 mMD, as such the injection head was set at 815 mMD. The initial simulation of the FPD was 300 meters above the injection depth since the data were taken at unstable condition. The simulation using tracer dilution method and the obstructions logged, on the other hand, proved that initial flashing occurred at 830-847 mMD at stable condition. This depth was below the injection depth causing initiation of calcite in the bore. There was no explanation yet being formulated to explain the obstructions tagged below 1200 mMD. When the well finally ceased supplying steam to the power plant, anti-scalant injection was terminated and the downhole assembly was pulled-out. Surprisingly, there were no deposits found on the tubing.

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REFERENCES


