Effect of sulphuric acid (H$_2$SO$_4$) and sodium hydroxide (NaOH) addition to prevent silica scaling in geothermal power plant projection pipes at PLTP X

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Abstract. Geothermal energy is energy stored in the form of water or steam in certain geological conditions at a depth of several kilometers in the earth's crust. Power plants utilize geothermal combined cycle units that are more efficient than conventional types of geothermal power plants. PLTP X has 3 steam turbines with a pressure of 20 bar as the main generator drive and 18 steam tubs with a pressure of 10 bar. The process of Integrated Geothermal Power Plant is divided into two plants, namely dry steam power plant and binary cycle power plant. Heating working fluid in the binary cycle power plant itself uses condensate and brine water. One of problems in this PLTP X is the presence of silica scaling in production pipe and the increase of acid pH value in some production well which causes corrosion in production pipe. Therefore it is necessary to modify pH. The addition of sulfuric acid (H$_2$SO$_4$) and sodium hydroxide (NaOH) is needed to slow down the rate of silica deposition and to prevent corrosion of pipe.

1. Introduction

Geothermal is one of the new renewable energy sources that are formed in the earth’s crust. In Indonesia, geothermal energy sources are quite potential. The geothermal category in Indonesia is classified as medium to high enthalpy. Therefore, geothermal can be used as an alternative electricity generation to support an increase in the electrification ratio in Indonesia [1]. Indonesia has many volcanic and non-volcanic geothermal sources, with a total of 276 locations [2]. Based on the National Electricity General Plan year of 2008 - 2027, geothermal potential is estimated to reach 27.5 Gwe which is the largest potential in the world that is 40% of the world’s potential in 256 locations spread across Indonesia [3].

The integrated combined cycle process is the most advanced and good technology among all geothermal power generation process technologies. Requirements to implement integrated combined cycle technology, which has a high enthalpy. This process combines binary cycle and combined cycle technology so that the maximum energy transfer and has a large energy efficiency. In addition, in the integrated combined cycle process 100% of steam taken from geothermal wells is injected back into the geothermal source so that the life of the well and geothermal reservoir can produce longer [4].

In Indonesia, PLTP X used an Integrated Combined Cycle system in one of its processing units. The Integrated Combined Cycle System (Condensing and Binary System) can be seen in Figure 1.
2. Research description

The advantages of using integrated combined cycle technology are use of longer production wells, utilization of condensate and residual brine to produce more electricity. But there is also drawbacks to the use of this technology, which is the scaling of the pipes used. According to Ciptadi and Patangke with the scaling that occurred the SSI (Silica Saturation Index) will be analyzed. This SSI is an indicator of silica deposition in pipes [5].

a. If \( SSI > 1 \), fluid is supersaturated and silica deposition is possible.

b. If \( SSI = 1 \), the fluid is saturated.

c. If \( SSI < 1 \), the fluid is not saturated (undersaturated), so silica deposition is not possible.

Silica deposition on the surface (lower temperature than reservoir temperature) is controlled by equilibrium with amorphous silica which is more soluble than quartz. The relationship between solubility of amorphous silica with temperature is shown by the Fournier and Rowe equations [7]:

\[
\log C = 4.52 - \left( \frac{731}{T} \right)
\]  

where \( C \) and \( T \) are respectively the quartz concentration (mg/kg) and temperature (kelvin).

Like quartz, amorphous silica solubility is also influenced by salinity and pH. If salinity increases, amorphous silica solubility decreases. At low concentrations (salinity <0.1 m), the effect of salinity is small. Amorphous silica solubility increases sharply when fluid is alkaline (high pH), but for fluids that are neutral and acidic, the effect of pH becomes very small [5]. The effect of salinity on silica solubility is shown by the Setchenow equation [7]:

\[
S(T,m) = C(T, m=0) \times 10^{-mD(t)} S(T,m)
\]  

where \( D(t) = -1.0596 - 0.001573 t \) (3)

S is silica solubility corrected in mg/kg at temperature (T, in kelvin) and salinity (m, in molal). \( D(t) \) is the equation given by Chen and Marshall [7], namely:

In addition, another problem at PLTP X is some production wells have a pH that is too acidic which can cause corrosive. Therefore, it is necessary to add caustic or NaOH to overcome it. One way to resolve silica scaling in integrated combine cycled system is to modify the pH. This modification aims to control the pH of a material to get the optimum pH in ongoing operating system. Modified pH appears to resolve the problems that often occur in geothermal processing, including scaling problems caused by silica [6].
3. Results and discussions

3.1. Addition of sulphuric acid (H$_2$SO$_4$) in PLTP X1 and PLTP X2

Addition of sulphuric acid is conducted before brine from the reservoir is used to prevent scaling in the brine pathway. The pH in the brine pathway is maintained at 4.5 - 5.0. A comparison of sulphuric acid addition on pH brine changes in PLTP X1 and PLTP X2 was presented in Figure 2.

![Figure 2. Effect of sulfuric acid addition in pH changes in PLTP X1 and PLTP X2.](image)

Figure 2 showed the profile of H$_2$SO$_4$ flow vs pH in PLTP X1 region with brine rate and condensate rate were 160,000 and 50,000 kg/h respectively. While, in PLTP X2 region with brine rate and condensate rate were 1,667,000 and 53,000 kg/h. From the data above can be seen that the greater volume of H$_2$SO$_4$ used, the smaller pH of brine used towards Brine OEC. The best volume injected into brine to adjusted pH with a range of 4.5 - 5.0 in PLTP X1 and PLTP X2 were 3.68-11.96 and 3.68-12.8 tons/day respectively.

3.2. Addition of sodium hydroxide (NaOH) to one of production wells in PLTP X

One of production wells in PLTP X has a pH of 2-3. This is dangerous for production pipe which can cause corrosive so that the addition of NaOH is needed. The effect of addition of NaOH to brine pH was presented in Figure 3.

![Figure 3. Addition of NaOH to brine pH.](image)

Figure 3 showed that pH value has increased along increasing of NaOH flowrate. Addition of NaOH of 1; 1.25; 1.5; 1.75; 2.00; 2.25; 2.50; 2.75; and 3.00 L/h were increased pH value of 4.825; 4.921; 5.001; 5.068; 5.126; 5.177; 5.223; 5.264; and 5.302 respectively.
3.3. Relationship of temperature with silica saturation index (SSI)
Relationship between temperature with silica saturation index (SSI) was presented in Figure 4. Based on the graph below, we can see that in PLTP X2 region, the SSI value at temperature of 136.7; 210.4; 213.3; and 223.3 °C were achieved at 1.6537; 0.8839; 0.8658; and 0.7658 respectively. While in PLTP X1 region, the SSI value at temperature of 117; 179.9; 213.3; 214.3; 215.3; 216.3; 217.3; 218.3; and 219.3°C were achieved at 1.8090; 0.9950; 0.7696; 0.7641; 0.7587; 0.7534; 0.7481; 0.7429; and 0.7378 respectively. Figure 4 showed that SSI value has decreased along increasing of brine temperature (scaling is not possible).

![Figure 4. Relationship of temperature with SSI.](image)

4. Conclusions
PLTP X uses an Integrated Combined Cycle system which has brine to vaporize pentane, on the other hand the pH must be maintained to avoid silica scaling in the pipe flow. The pH modification aims to control the pH throughout the process flow. This modification is identical to the principle of acid-base titration to find out how much acid or base was added. pH 5 in the brine flow in the PLTP X power plant is used as a standard pH to slow down silica scaling. Addition of NaOH (caustic) to the well-pad (x) is needed due to a decrease pH in brine.

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