

Effect of Mineral Scaling on Geothermal Wells

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Carbonate Scaling
possibly
spanning multiple lines



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by

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Preface

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Literature Study

In this chapter an introduction to the geothermal wells along with an introduction to scaling and its effects is given followed by some relevant chemical reactions and their properties.

1.1. Introduction to Geothermal Wells

As of 2040, Energy Information Administration (EIA) expects an increase of 28% in world energy consumption. The majority of this consumption is projected to account from developing countries such as India, China and other third world countries since the economy is increasing rapidly. [2]

In order to overcome this fast increase, the human kind cannot rely only on fossil fuels and other sustainable technologies like solar, wind, geothermal are required. However, the emission of CO₂ is also increasing from 6000 million metric tons carbon in year 2000 to 10000 million metrics tons in 2010. That's why many countries such as Denmark, Norway, Germany, The Netherlands etc., are moving away from traditional fuel sources to the new energy. One of these energy is Geothermal energy.

As the name suggests, *Geothermal* comes from the greek work, *geo*: which means Earth and *therma* meaning heat. Geothermal energy is the fraction of the natural heat of the Earth that is transported by the magma flow, conduction or/and convection from the Earth surface to the drilling range of the surface. The heat comes from the decay of the natural radioactive material that is transmitted to the surface from the molten core in the earth. It has been estimated that about 42 million megawatts of power flow from earth's interior by conduction.[5]

It is important to mention that there are mainly two types of geothermal resources: Low Temperature and High Temperature Resources. Low temperature resources are less than 180 degree C and are enough to supply only heating whereas high temperature resources (more than 180 degree C) are hot enough to generate electricity. The High Temperature resources supply about 99% of its geothermal energy and are considered in this report. [4]

1.2. Introduction to Scaling

Despite the fact that geothermal is one clean energy and almost CO₂ free, it does have some major drawbacks mainly, scaling and corrosion. Moreover, that's not the only problem associated with this. Scaling is site specific which is a major problem in the wells.

To get a more detailed understanding of the effect we need to understand how does geothermal reservoir works. In the reservoir, fluid with certain chemical composition is available which is then brought to the surface by production well. Upon reaching the surface the heat is lost to heat exchangers. As a result of which there is a change in temperature which then causes the change in chemical composition. which then leads to mineral scaling and clogging of the piping of the power plant. The same happens when the fluid is reinjected into the reservoir, which changes the temperature and hence chemical composition. Despite the fact that scaling is site specific, a statistical approach with a geochemical simulation using PHREEQC, an approach can be attempted to solve and estimate the effect in the lifetime of geothermal well.

Scale formation is generally divided into these main classes:

- Carbonate

| | Pressure range (bar) | Temperature range (°C) | Presence of oxygen | Type of fluid |
|---|----------------------|------------------------|--------------------|--|
| 1 | 20 - 300 | 150 - 400 | No | Two phase or superheated steam |
| 2 | 5 - 50 | 150 - 280 | No | Two phase or superheated steam |
| 3 | 3 - 50 | 150 - 280 | No | Steam (with entrained droplets) |
| 4 | 3 - 50 | 150 - 280 | No | Liquid |
| 5 | 0.8 - 5 | 90 - 180 | No | Steam (with entrained droplets) |
| 6 | 0.08 - 0.12 | 25 - 35 | Yes | Liquid (with dissolved CO ₂ and H ₂ S) |
| 7 | 1 | 35 - 50 | Yes | Liquid (with dissolved CO ₂ and H ₂ S) |
| 8 | 1 - 30 | 50 - 150 | Possible | Liquid (possible bubbles) |

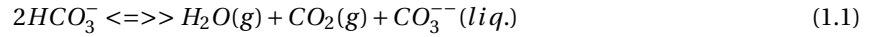
Figure 1.1: Typical thermodynamic conditions in a geothermal reservoir [1]

- Silica and Silicates
- Sulphate and Sulphides

Carbonate and Silicates are the most common scaling mechanisms which can occur in a geothermal reservoir followed by sulphate and sulphides. However due to the much higher complexity of silicates, they are not discussed here. For the sake of simplicity and the level of this report, the main focus is on carbonate scaling. As mentioned earlier, scaling is very site specific, hence understanding the mechanism behind the formation can change from site to site. In order to understand this situation better, a geothermal reservoir (in this location) is used for simulations and modelling. However, typical thermodynamic conditions in geothermal power plants have been considered which can be seen from Fig. 1.1

1.3. CaCO₃ Scaling

Henry Law states that the amount of dissolved gas is proportional to its partial pressure in the gas phase. Since all geothermal reservoirs contain dissolved CO₂, and this carbon dioxide present in water solution should then be proportional to partial pressure of CO₂ in equilibrium according to the Henry's law. It is important to mention that the concentration of the dissolved carbon dioxide also includes carbonic acid H₂CO₃ and the exploitation of the geothermal reservoir starts with a constant and static CO₂ charged liquid with no vapour phase. As the production starts, there is a shift in equilibrium from left to right due to the decrease in pressure. [1]



The concentration of the CO₃²⁻ ions increases which results in the precipitation of the CaCO₃ because of the solubility product of CaCO₃

$$(\text{Ca}^{2+}) \cdot (\text{CO}_3^{2-}) = K_p \quad (1.2)$$

Since during flashing the CO₃²⁻ concentration increases, precipitation of CaCO₃ begins with flashing. As a result of which scaling can occur depending where the flashing is more prominent. If flashing occurs in part of the productive well, in-hole scaling is to be expected. However, formation plugging can occur if the flashing begins in the formation. Finally, if flashing begins at the surface equipment encrustations are expected in the equipments. [1][3]

using the equilibria equation of the above mentioned equation and the partial pressure of CO₂, it is found that the concentration of calcium ions (Ca²⁺) depends upon:

- Temperature
- Partial Pressure of CO₂
- Ionic Strength, I

Using these, saturation index I_s can then be defined as the ratio between the measured Ca²⁺ concentration in equilibrium condition as:

$$I_s = \log F_s \quad (1.3)$$

where F_s is

$$F_s = \frac{[\text{Ca}^{2+}] \cdot \text{Alk}^2 \cdot k_{\text{HCO}_3} \cdot \gamma_{\text{Ca}^{2+}} \cdot \gamma_{\text{Alk}}^2}{k_{\text{H}_2\text{CO}_3} \cdot k_{\text{CO}_2} \cdot P_{\text{CO}_2}} \quad (1.4)$$

1.4. Prevention: CaCO₃ scaling

In order to prevent calcium carbonate scaling, prevention methods can be designed and tailored depending upon the site and the conditions at the site. There are mainly three ways to avoid calcium carbonate scaling:

- acting on CO₂ partial pressure
- acting on the pH of the solution
- using chemical additives

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