Scale Prediction and Inhibitor Selection for Turkish Geothermal Plants

Dr Logan Muller, Dr David Rodman, Dr Jasbir Gill.

[1] Nalco Water, Naperville USA

lmuller1x@nalco.com

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ABSTRACT

As Geothermal power continues to increase in Europe, the need for accurate brine chemistry modelling and risk mitigation has become more apparent. The Geomizer software is designed to predict mineral scale formation for geothermal power plants and helps identify preferred inhibition options. The web application is capable of modelling multiple configurations incorporating binary plants flash plants, reinjection systems, multiple well feeds and separators. This application is capable of predicting scaling issues that may result from the blending of multiple brines and predicts the distribution of gaseous contaminants at variable pressures and temperatures and the impact on the water chemistry. Based on the thermodynamic calculations and the various scale and corrosion inhibition models embedded into the software, an optimum dose of Scale and Corrosion inhibitors is predicted and identifies chemical inhibitors that won't perform in the subjects' environment.

1. INTRODUCTION

Geothermal energy continues to gain popularity in Europe as an alternative and renewable energy source to reduce the reliance on fossil fuels. Greenhouse Gas (GHG) emissions from a geothermal power plant are one of the lowest compared with other forms of power generation. Geothermal power is one of the fastest growing segments in the industry with generating capacity increasing by 80% within the next 16 months in Turkey and over 300% globally within the next 10 to 15 years. It is considered a renewable, green energy source with these plants using geothermal energy from hot brine brought to the surface via deep wells (1,200 – 5,000 m). At the surface, the brines enthalpy is released, through flash tanks and/or heat exchangers creating steam and/or vaporized iso-pentane to drive turbine-generators. The cooled brine is then pumped back into the earth through injection wells to replenish the geologic formation (Eylem et al, 2011).

Geothermal power companies are continuously striving to maximize the utilization of their resources, increase power generation and reduce the total cost of operation. One of the main limitations to this is that brine typically has very high levels of dissolved minerals, up to 30% in some cases, which can be concentrated to even higher levels as steam is removed in flash plants. Like many geothermal plants, European plants suffer from calcite scaling in production wells that limits well life, silica in plant and reinjections systems, stibnite and corrosion reducing production capacity and return on investment (ROI). Kaypakoğlu et al. (2015) presented on the impact of stibnite (antimony sulfide) scaling in a binary plant in Turkey.

The absence of accurate modelling and application of inappropriate scale inhibitors has resulted in deposits that have caused significant power loss in many Binary stations and silica in flash and binary plants alike. This reinforces the need for accurate steam and brine analyses and improved modelling tools to reduce the risks in new power plants.

A number of geochemistry modelling tools exist that allow the user to estimate the scaling potential of individual wells. While very powerful, the applications are typically cumbersome to use and require significant geochemical knowledge to interpret the results.

Nalco Water has developed a web application, Geomizer that is designed to predict mineral scale formation in geothermal power plants and the inhibition of the same using appropriate scale inhibitors. The web application is capable of modelling multiple system configurations or layouts for geothermal power plants and performs a complete process study. The application is also capable of predicting the chemistry that results from mixing of multiple brines, including the distribution of gases at variable pressures and then predicts the scaling and corrosion issues that may result. The application also has the capability to generate a temperature profile for individual wells or mixed brines. The software serves as a very powerful tool with the optimization of all the processes in a geothermal plant.

The web based tool delivers an output that includes all the integrated unit operations in a visually pleasing layout, with detailed pages for each separate unit

operation. Based on the thermodynamic calculations and the various scale inhibition models embedded into the software, an optimum dose of the scale inhibitor is predicted. The details of how the modelling tool works was presented by Gill *et al.* (2015).

In this article, an overview of how the Geomizer application can be used to determine the source of scaling and identify appropriate treatment options.

2 APPLICATION OVERVIEW

2.1 Application Features

Geomizer is a web based application designed for the prediction of scale forming minerals primarily calcium carbonate, calcium sulfate, silica and fluorite that commonly affect geothermal power plants and provide product selection and optimization for these issues. The application gives the technical consultant the ability to further predict saturation indices of metal sulfides in combined brines. Unlike many geochemical models that are widely used amongst the Geothermal industry for modelling scaling issues from the source (production wells) through to brine disposal (reinjection well), the application provides stream mixing capabilities, optimal chemistry selection and dosage estimation.

The tool has the flexibility to model many configurations (layout) for geothermal power production applications and has the ability to input operational and chemical information to identify the system requirements. Geomizer was designed to cover most operating aspects of typical existing and probable future geothermal installations that includes all the unit operations in the geothermal power plant. These include binary versus flash; single versus multiple stage flashes; combined binary and flash. The application models the behaviour of all salts and gases for a wide range of temperature and pressure that cover typical operating limits.

Once the operational characteristics of each unit process along with brine and gaseous composition is input, the Geomizer will calculate the scaling potential at each unit process (from production well to injection well) and provide guidance for selection of the optimal solution.

2.2 Speciation Calculations

In Turkey, Italy, Iceland and the Netherlands metal sulfide, including Stibnite and arsenic sulphide, calcite and silica have all presented major problems and costs to some plants. Geomizer uses WATCH 2.4 (Stefan et al, 1982), a well-recognised third party computer program to calculate aqueous speciation in natural waters. It then takes this base information and recalculates mixed brine and steam combinations based on the actual mechanical configuration of the plant. Additional modules have been developed for Geomizer to calculate the solubility of additional species that are not included in the Watch 2.4 calculation engine.

One of the more difficult aspects of calculating the chemistry of the mixed fluids is the estimation of the pH of the final mixture. pH has a strong influence on speciation of some solutes and therefore strongly affects the scale tendencies of these species. The mixing calculations also use the physical input data such as flows and enthalpies to calculate the temperature and pressure of the mixed fluid. Temperature also has a dramatic influence on the solubility of some species (Figure 1).

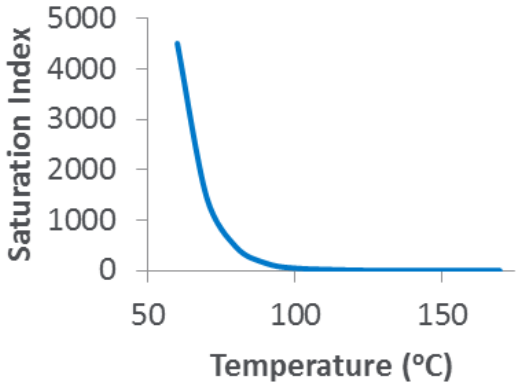


Figure 1:- Saturation indices for stibnite (pH 7.65, Sb 1.84ppm, H2S 25ppm)

As a result, issues such as silica polymerisation, metal sulfide formation and Ostwald ripening can now be more accurately considered. This is of distinct advantage when predicting issues and solutions in the European context.

In one Turkish power company, the use of an inhibitor was increasing the occurrence of scale. The data, together with the composition of the inhibitor was inputted into Geomizer and it predicted the impact this chemical combination would have on the plant. A product was selected that was appropriate for the brine and steam chemistry from Geomizer and the problem has stopped. In New Zealand Geomizer was used to redesign the treatment regime at TOP Energy, a plant that needed to shut every 10 -12 weeks for cleaning. Last year the OEC ran the entire year without the need for cleaning (Muller *et al,.* 2014).

3. ADDRESSING SCALING

3.1 Defining the problem

In Geomizer, the scale issues are quantitatively described by using saturation index values. The saturation index is calculated based on the thermodynamic equilibrium solubility product constants (K) and ion activity products (Q) in the brine chemistry for the different minerals. The predicted saturation index is displayed in a simple tabular structure with data displayed visually to enable rapid identification of problem areas for different unit operations. Outputs are grouped by unit operations in rows and the columns display the primary encountered scale species and a final column for other minerals

that are calculated but not typically encountered as scale and thus not displayed, however by clicking on the details button these minerals can also be uncovered. Figure 2, as an example, shows the saturation index for different minerals for different unit operations.

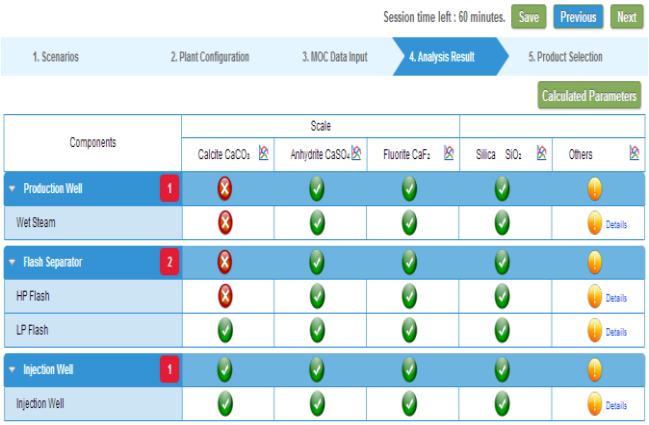
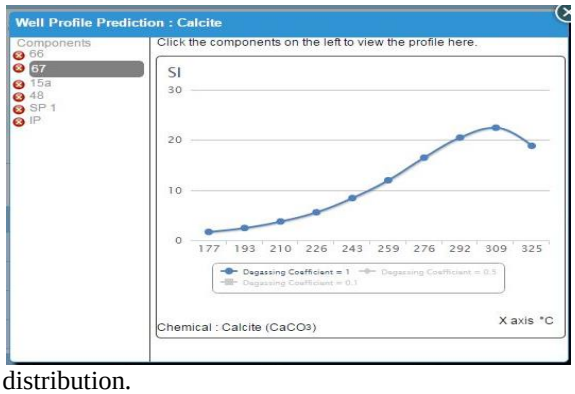


Figure 2:- Screen shot of the Saturation index summary page for all the unit operations.

3.2 Saturation Index Profiling

Geomizer calculates the saturation indices for the common scale species for each unit operations at different temperatures and plots these as a chart. This chart has been termed as a saturation index profile and is designed to be used to study the potential impacts of changes in temperature and pressure as the geothermal brine travels through the process.

Error! Reference source not found. shows an example of the well profile plotted for a production well. The saturation index profile can quickly help determine the point of scaling issue as a function of temperature. For production wells, an additional analysis based on the degassing coefficient constant values (0.1, 0.5, 1) are available to chart. The degasing coefficient is a measure of how well the gases are separated from the brine and is useful when studying the effect of incomplete degassing on aqueous species



distribution.

Figure 3:- Screen shot of the well profile plotted for a production well data.

3.3 Downstream brine chemistry calculations

For flash separators, the adiabatic boiling method is used to predict brine composition and potential scale issues for a range of operating temperatures/pressures that is determined from the user input reference temperature/pressure. For heat exchangers, the conductive cooling method is used. This feature of Geomizer allows the user to rapidly determine what, if any, chemistry problems will arise if the operating pressure of flash separator or temperature of a heat exchanger is adjusted. Geomizer can also be used during the design of the plant to more rapidly determine what the chemistry limitations are.

As previously mentioned, the application is capable of calculating the impact of mixing streams across a range of temperatures. This is particularly useful for studying the impact of adding other sources of water to the brine for reinjection. A typical example of this is determining the impact of co-disposal of cooling tower blow-down to the reinjection brine. Geothermal cooling water typically has very different characteristics to geothermal brine that will result in changes in temperature, pH, concentration and chemical composition that could lead to scale formation in the reinjection line.

Other potential uses for Geomizer is to assess the potential impact for co-disposal of wastewater or supplemental addition of an external water source to provide replenishment of geothermal aquifers that may not be self-sustaining through natural permeation.

4. INHIBITOR SELECTION

For those unit operations where scaling has been predicted, the application provides a list of inhibitors that are capable of preventing scale under the operating conditions provided and predicts the dosage using the calculated saturation index and other key operating parameters. The inhibitor recommendation is provided at the component level, meaning that different products and dosages can be specified for individual unit operations, e.g. individual production wells. For each unit operation the dosage is calculated for the maximum saturation index identified for the proposed operating conditions.

The inhibitor algorithms are derived from both laboratory studies (Gill, 2008) and field data. These algorithms take into account, saturation index, temperature and the residence time. If no inhibitors are capable of controlling the scale for the identified conditions, the application will provide a warning and will not allow a product to be selected.

In addition to the scale inhibition models, each inhibitor has been studied for hydrothermal stability (Dinesh *et al.*, 2013) up to 320°C with respect to molecular structure (using NMR) and scale inhibition performance after subjecting to the target temperature.

It is very important to establish the hydrothermal stability, as it is known that some traditional scale inhibitors, in particular phosphorus containing products, can degrade at high temperatures (Dinesh *et al.* 2013) and add to scale formation.

Calcium based scales are very typical in the geothermal environment and simple chemistries often work well without issue, but there are circumstances where the inhibitor can become part of the problem, even without thermal degradation. Calcium tolerance of inhibitors varies significantly and is highly sensitive to temperatures and pH. Calcium tolerance is a measure of a chemical compound's ability to remain soluble in the presence of calcium ions (Ca^{2+}) under both high pH and high temperature, such as in geothermal brines. As pH and temperature increases, calcium tolerance decreases rapidly.

Gill (2008) demonstrated that many traditional inhibitors had very poor calcium tolerance under the conditions of temperature and pH experienced in geothermal brines.

Importantly, the Geomizer application will only allow selection of inhibitors that have the capability, including thermal stability, to inhibit the scale at the maximum identified conditions for saturation index and temperature. The optimum inhibitor and its dose selection are very unique to this Geomizer tool.

5. CONCLUSION

The Geomizer application has been successfully used in a number of geothermal plants to identify the primary scale risks at each part of the plant and help choose the lowest risk solution.

In all Europe and Turkey no two brines are the same. Although ORMAT are using one prevalent design in Turkey, the issues encountered by each plant are clearly different. Geomizer has the ability to model the entire waterside of the power plant to predict the likely scale species that might arise and assist with the selection of the best scale prevention approach.

This professional approach to mitigating scaling in a holistic plant approach can save power producers considerable sums of money and reduce risk and improve ROI.

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