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Geomizer - A Tool to Predict Optimum Dose for Mitigating Scale in Geothermal Systems, Especially Power Plants

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ABSTRACT

This article discusses software, Geomizer, which is designed to predict mineral scaling tendencies in geothermal power plants and to determine the best scale inhibitors and doses required for optimum plant protection. The web application is capable of modeling multiple system configurations or layouts for geothermal power plants and performs a full process study. The process models include process unit operations and streams which can be stored and retrieved for later use. The application is also capable of calculating the chemistry that results from blending of multiple brines for predicting scaling and corrosion issues. The software also calculates the scaling tendencies over typical temperature ranges and can chart these as temperature profiles for individual wells or mixed brines. The paper describes the ability of the tool to predict scaling in all parts of the nominated geothermal process such as Production wells, Flash separation, Binary heat exchangers, Geyser (Dry Steam) systems and Reinjection wells by using a standard thermodynamic modeling tool.

The application predicts the distribution of gaseous contaminants at variable pressures and temperatures and the impact on the water chemistry. The application 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 and corrosion inhibition models imbedded into the software, an optimum dose of scale inhibitor is predicted. Verification of the predicted dose from the software and the successful application in the field is also discussed.

1. INTRODUCTION

Geothermal energy continues to gain popularity as an alternative and renewable energy source to reduce the reliance on fossil fuels and for its lesser impact on the environment. Greenhouse Gas (GHG) emissions from a geothermal power plant are one of the lowest compared with other forms of power generation. Furthermore, it is capable of truly large-scale, base-load power generation with minimal disruption to the landscape, making it a better option than other renewable electricity-generation sources, such as wind, solar and hydro power. Geothermal power is one of the fastest growing segments in the industry with generating capacity projected to increase more than 10% annually for the foreseeable future. It is considered a renewable, green energy source and these plants use geothermal energy from hot brine brought to the surface via deep wells (6,000 – 10,000 ft) where its 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. This high dissolved mineral content leads to scaling and deposition as a result of changes to the physical and chemical properties of the brine as it is produced from the ground and used. Geothermal fluids are extracted through production wells as deep as a few thousand meters below the ground where intimate and long term contact with the encapsulating rock, contributes to the chemical characteristics that lead to high scaling potential, principally from silica and calcium based minerals. If not well managed, these scaling species can form deposits in production wells, on surface equipment, and in re-injection wells. These scaling conditions diminish steam production and reduce power generation capacity, affecting plant availability and increasing the total cost of operation.

Nalco has developed a web application called Geomizer, which is designed to predict mineral scale formation in geothermal power plants and the inhibition of the same using chemical scale inhibitors. The web application is capable of modeling multiple system configurations or layouts for geothermal power plants and performs a complete process study. This application is also capable of predicting the chemistry that results from blending 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. Mixing model can be used to avoid or minimize scaling issues as a result of mixing different wells to a common flash tank. 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 and corrosion inhibition models imbedded into the software, an optimum dose of the scale inhibitor is predicted.

In this article, an overview of the Geomizer web application is provided and comprehensive technical details designed, developed and implemented into the application are discussed. Verification of the predicted dose from software and the successful application in the field is also discussed

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 utilizes an aqueous speciation engine, WATCH 24, that is widely accepted amongst the Geothermal industry for modeling scaling issues from the source (production wells) through to brine disposal (reinjection well). The application provides optimal chemistry selection and dosage and has the ability to rapidly model the effect of applying various chemistries. 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 covers all operating aspects of typical existing and probable future geothermal installations that includes all the unit operations in the geothermal power plant.

The Geomizer application has the ability to contend with multiple style plants – e.g. binary versus flash; single versus multiple stage flashes; combined binary and flash. The application models the behavior of all salts and gases for a wide range of temperature and pressure that cover typical operating limits. In addition, the application has different unit data input options, such as metric and imperial data input and provides the desired unit data output. Once the operational characteristic 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 recommend optimal solution.

2.2 Speciation Calculations

Geomizer is using WATCH 24 (Stefan et al, 1982), a third party computer program to calculate aqueous speciation in natural waters. The primary area of application of WATCH 24 is for geothermal fluids, but it is useful for non-thermal waters as well. The WATCH 24 program reads chemical analyses of water, gas, and steam condensate sample collected at the surface and computes the chemical composition of down-hole, or aquifer, fluids at some suitably chosen reference temperature. In Geomizer, the input data is stored and passed to the WATCH 24 program for speciation calculations. The output data from the Watch 24 were used for further calculations in Geomizer. These data includes solubility product constants (K), ion activity products (Q), well chemistry (below the surface), steam and brine chemistry distribution, concentration factor, and temperature of the brine (below the surface) based on various Geo-thermometers. Based on the output calculations, scales issues are predicted and inhibitor dosages calculated using Geomizer.

2.3 Thermodynamic Calculations

In addition to thermodynamic equilibrium speciation calculations, Geomizer also uses STEAM 97 for calculating the thermodynamic and transport properties of water and steam. The calculations are used for calculating missing data and for estimating the steam fraction based on the temperature and pressure.

2.4 Unit Conversions

Geomizer has inbuilt unit conversion functionality for the chemical and operational parameters. User can input data for operational parameters such as temperature, flow in a preferred unit. The software will then automatically convert from one unit to another, if desired, and displays the calculated results. Unit conversion functionality is also available for brine chemistry and steam chemistry.

3. PLANT CONFIGURATION

The Geomizer web application follows a sequential navigation approach (wizard approach) and input data entry is validated in each web page. The design of any geothermal plant is done using a dedicated plant configuration web page. The plant configuration in the application is designed in such a way to model any geothermal plant for the analysis. Although there are only four basic types of geothermal power plants, the plant equipment configuration may be unique for each plant. The plant configurations can be based upon type of power plant, number of production and reinjection wells used, number and type of surface equipment and connection between the wells and the surface equipment. In Geomizer application a variety of unit operations are available to design the geothermal plant and perform the analysis for the entire plant. The calculations are performed for individual unit operations and the impact of each connection between the unit operations is also captured.

3.1 System Connections

In geothermal power plants, it is vital to understand the impact of downstream unit operations when a production well is connected. The unit operations or system components in Geomizer can be connected for executing the downstream component calculations and analysis. The process or calculated data is passed to the downstream unit operations by using these connections. The calculated data is used as an input for the downstream unit operation calculations. For each unit operation, an instance of WATCH 24 program was initiated the output data are stored in a web server and can be retrieved for future analysis.

3.2 Mixing and Splitting

The Geomizer application has the capability to calculate the impact on the water chemistry that results from mixing different streams or splitting single stream to study the impact on the geothermal power plant. The ability to this is particularly helpful to analyze the impact of mixing different production wells prior to separation of the steam and brine or heat exchangers to predict the potential for scale formation. In addition to this, it is possible to determine the impact of mixing external water sources with brine prior to reinjection. This kind of mixing can result in unexpected scale and / or corrosion related issues, especially if the brine contains easily oxidizable ions such as Fe or Mn. The blow down from the cooling water can also be configured into the reinjection stream.

4. SCALE ISSUES PREDICTIONS

4.1 Process Calculations

In Geomizer, the process calculations are sequential to enable mixing and splitting of streams prior to entry to downstream process operations. By identifying all of the system unit operations and connections, the application automatically determines the order in which the calculations need to be performed. The calculations are performed in stage wise operation.

4.2 Saturation Index Display

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 1, as an example, shows the saturation index for different minerals for different unit operations

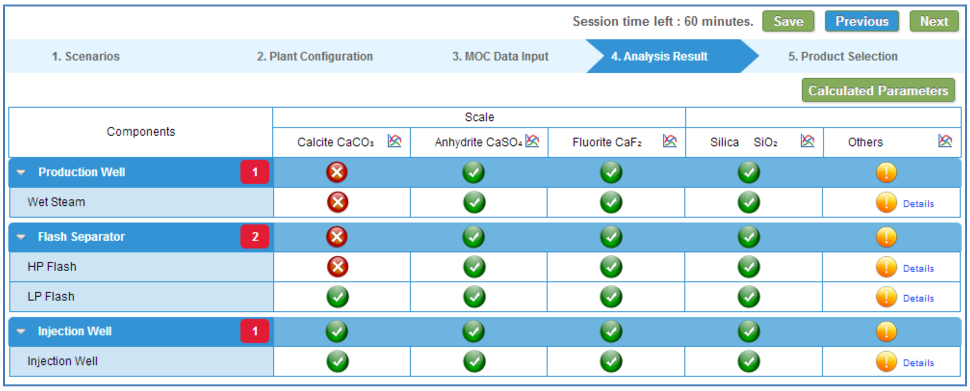

Figure 1: Screen shot of the Saturation index summary web page for all the unit operations.

4.3 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. Figure 2 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.

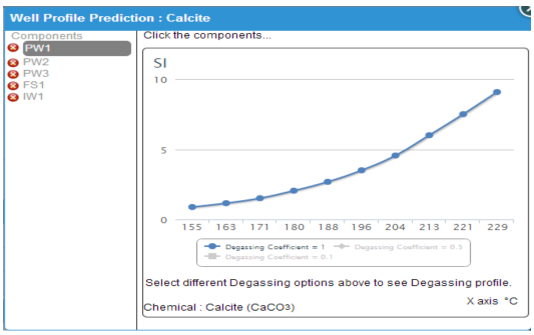

Figure 2: Screen shot of the well profile plotted for a production well data.

4.4 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. For heat exchangers, the conductive cooling method is used.

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 the addition of cooling tower blow-down to reinjection brine, which may result in changes in temperature, pH, concentration and chemical composition that will lead to scale formation in the reinjection line. Other potential uses for this 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.

5. INHIBITOR RECOMMENDATION

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 application will only allow selection of inhibitors that have the capability 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. 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. Each inhibitor is studied for hydrothermal stability (Dinesh, 2013) up to 320°C with respect to molecular structure (using NMR) and performance as scale inhibitor after subjecting to the target temperature. 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. Figure 3 and 4 shows the screen shot of the inhibitor selection and dosage recommendation.

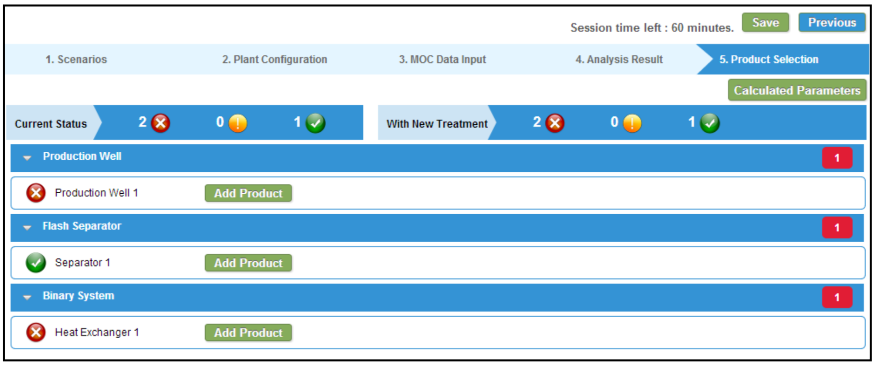

Figure 3: Screen shot of the Inhibitor selection web page

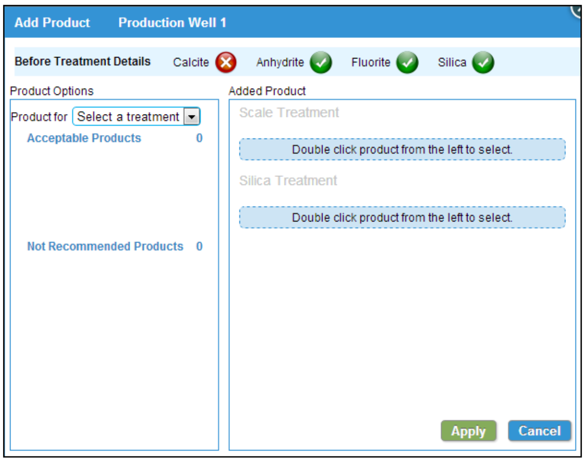

Figure 4: Screen shot of the product addition for optimized dosage and recommendation.

6. FIELD TRIAL VALIDATIONS

A major geothermal customer in New Zealand had been facing a calcite scaling problem with one of their production wells, causing them to carry out well reaming (removing deposit through high-pressure water jetting of the well due to deposition). The customer was looking for a solution that would help them offset the maintenance cost avoiding the tedious process to prevent the need to "rework" the wells, avoid the cost loss of generation capacity due to production decline from the scaling and avoid the damage of the wells caused by re-drilling. Geomizer was used for this customer to identify a solution through simulation and program recommendation. By performing the Geomizer analysis, it was observed that calcite deposition was a concern (as shown in Figure 5) and there were no concern for anhydrite, fluorite, and silica deposition in the production well.

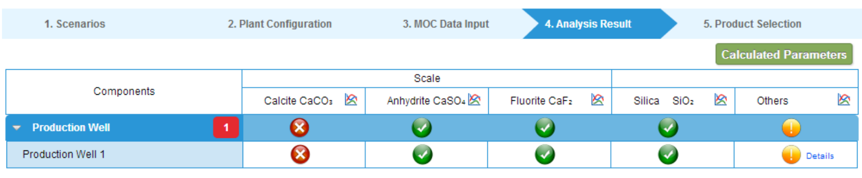

Figure 5: Screen shot of the customer data analysis for scaling.

Based on the Geomizer modeling, the Calcite Saturation Index (SI) curve was generated, and it was shown (Fig 6) that the production well has calcite deposition concern with the SI being more than 1. From the Geomizer simulation result, the optimum

chemical program and dosage were recommended to address the calcite deposition concern. The production well steam flow has been well maintained after six months of implementing the solution, and there was no plan for well reaming in the foreseeable future. Geomizer simulation program and scale inhibitor has helped the customer change its paradigm to manage geothermal resources. Geomizer helped the company predict the issues and provide the chemical solution at less than a fraction of the well-reaming cost, giving the confidence of managing its geothermal resource

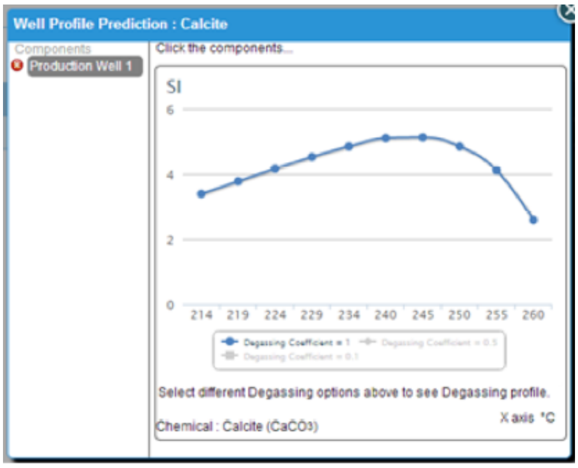

Figure 6: Screen shot of the production well profile for the customer data.

7. CONCLUSION

A web application, called "Geomizer", has been developed for predicting mineral scale formation potential and its inhibition in geothermal power plants. An overview of the application capability to model multiple system configurations or layouts of geothermal power plants is shown. Additionally, the applications capability to calculate complex interactions that result from mixing and splitting of streams and the importance of this is shown. The ability to rapidly prepare saturation profiles for individual unit operations using single or mixed brines has also been described. Scale inhibition algorithms are extremely helpful in selecting the optimum inhibitor and its dose. Finally, technical validation in the field and its success is discussed.

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