



Scaling and Corrosion In Geothermal Operation

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Introduction

Geothermal brine can be extremely difficult to handle in geothermal operation. It is frequently described by our colleagues as the entire periodic table of elements in a pipe. This mixture of water, elements and gases contains enormous amounts of energy for power production. The high temperature solution of elements and compounds, however, causes operational limitations in geothermal power plants. These limitations are due to the severe scaling and corrosion characteristics of geothermal brine and steam. Because of these characteristics, plants may experience extreme plugging and corrosion in wells, lines and equipment. Curtailment in power plant production and even complete plant shutdown are often the end result from these conditions.

Different types of brine with differing chemistry conditions are found in various areas around the world. Substantial differences can even be found within the various wells of a given field. The chemistry of these different brines varies and the differences will depend on several factors including the geology of the resource, temperature, pressure, and water source. Depending on the resource, steam and water ratios in the brine can vary significantly. In the Geysers area of northern California, for example, the steam ratios are very high and can be over 99% of total well flow. In other high temperature areas, steam and water ratios can be about 50/50. The lower temperature resources are more liquid dominated and will often necessitate pumping the brine to the surface with multistage vertical pumps.

The chemistry from these different fields can vary substantially. Higher temperature resources with the higher water ratios have increased levels of silica that cause tremendous scaling and deposit problems. By contrast, the steam fields in the Geysers do not experience the silica scaling problems, but instead have aggressive corrosion problems associated with hydrogen chloride and hydrogen sulfide attack. Still yet, other geothermal fields are hit with a double misfortune and encounter both scaling and corrosion problems at the same time.

Problems Caused from Geothermal Brine

The scaling and corrosion characteristics of brine and steam cause difficult problems in geothermal operation. The variety of problems associated with handling geothermal brine can be extreme – making it critical to understand the chemistry of the brine for successful plant operation. Geothermal brine causes a variety of operational problems and includes the following:

- Equipment Damage and Failure
- Equipment Repair and Replacement
- Brine Leaks and Spills
- Well and Line Plugging
- Reduced Steam/Brine Flow
- Power Production Losses
- Complete or Partial Plant Shutdown

All of these problems are directly associated with the chemistry characteristics of geothermal brine. Plant design can address some of the corrosion problems with the selection of corrosion resistant materials. The use of high alloy metals can be used, but often becomes cost prohibitive. Plant operating conditions can help reduce scaling problems. In binary plants, for example, reducing flow rates and increasing plant internal pressure settings can help control some scaling and corrosion problems. These changes, however, will also reduce brine and steam flows and power production will be correspondingly curtailed.

Treatment programs are frequently employed to help control the severe characteristics associated with handling geothermal brine and steam. Geothermal plants are successfully using treatment programs to protect equipment and to provide more efficient operation and power production. ***PowerChem Technology*** is an industry leader in the development and implementation of cost effective scale and corrosion treatment programs.

Scale in Geothermal Operation

Scale is a major problem in geothermal operation. The plugging and deposit problems caused by scale can reduce power plant production, and create expensive cleaning costs. The reduction in power and increased operating costs caused from difficult scale conditions can directly impact a plants financial outcome.

Different types of scales are found in various geothermal areas and sometimes, even within the various wells of the same field. The major species of scale in geothermal brine typically include calcium, silica and sulfide compounds. Calcium compounds frequently encountered are calcium carbonate and calcium silicate. Metal silicate and metal sulfide scales are often observed in higher temperature resources. Typical metals associated with silicate and sulfide scales include zinc, iron, lead, magnesium, antimony and cadmium. Silica can present even more difficulties, as it will form an amorphous silica scale that is not associated with other cations. All of these scales types can present challenging operating problems for geothermal plants.

Calcium carbonate scale frequently causes operational problems in the brine handling systems. It typically forms as a result of the evolution of CO₂ from the liquid phase.

CO₂ evolves any time a pressure drop occurs. Pressure drops occur in the flash vessels and also in localized areas of production well pumps or elbows in surface piping. As CO₂ is evolved, the liquid phase will experience a corresponding pH increase. At elevated temperatures, even small amounts of calcium in the brine will precipitate with the pH increase. Our experience shows that fluids containing calcium (even small amounts) have the potential to form calcium scale, especially in the production wells. A “hydrodynamic” component associated with the fluid flow to the well – and also through the well pipe – will aggravate calcium scaling conditions. Calcium carbonate scale can form in production wells, plant vessels and equipment, and injection lines and wells.

Silica related scale is arguably one of the most difficult scales occurring in geothermal operation. Silica is found in virtually all geothermal brine and its concentration is directly proportional to the temperature of the brine. As brine flows through the well to the surface, the temperature of the brine decreases, silica solubility decreases correspondingly and the brine phase becomes over saturated. When pressure is dropped in the flash vessel, steam flashes and the temperature of the brine further decreases. In the flash vessel, the brine phase becomes more concentrated and the silica, already unstable, becomes even more unstable. Under these conditions, silica precipitates as either amorphous silica or it will react with available cations (e.g., Fe, Mg, Ca, Zn) and form co-precipitated silica deposits. These deposits are extremely tenacious and can occur throughout the production field, plant and injection systems.

Sulfide scales can also be encountered in geothermal operation. Sulfide scales have been observed in high temperature as well as in low/medium temperature resources. Sulfide scales are associated with other metal cations forming scale compounds that are very hard and difficult to handle. Sulfide scale has been observed in production wells with two-phase flow and has caused plugging or choking of the brine flow from the well. Antimony has been observed in low/medium temperature resources and can form antimony sulfide deposits in binary plant heat exchangers. Because antimony is extremely insoluble, low levels of antimony (100 part per billion) in a resource fluid can cause antimony sulfide deposit problems.

Solutions to Scaling Problems

Calcium and silica scale cause severe operational problems that result in plant and equipment degradation as well as power production losses. **PowerChem Technology** has developed a complete line of scale inhibitors for controlling the difficult operational problems caused from calcium, silica and other types of scale. Successful treatment applications include:

- Production Wells
- Flash Plant Vessels
- Binary Plant Heat Exchangers
- Injection Lines and Wells

Please contact our office for more information on specific plant projects and applications.

Corrosion in Geothermal Operations

Geothermal steam and brine can exhibit extreme corrosion characteristics. Corrosion attack occurs in many geothermal operations and this results in severe equipment damage. Production wells, steam and brine gathering systems, injection lines and wells are subject to the extreme corrosion tendencies of geothermal steam and brine. In many instances, the steam turbines will also encounter stress corrosion cracking (SCC) related to the chemistry characteristics of geothermal steam.

There are multiple mechanisms of corrosion attack contributing to the failure of pipe and equipment in these systems. These mechanisms involve the following types of contaminants and conditions in the steam and brine:

- Carbon Dioxide
- Hydrogen Sulfide
- Hydrogen Chloride
- Iron Sulfide
- Sulfuric Acid
- Oxygen
- Temperature
- Suspended Solids
- Flow Hydrodynamics

In liquid dominated binary plant operation, the major species associated with corrosion attack is carbon dioxide. In the presence of carbon dioxide, the corrosion tendency of steel is controlled by the properties of the iron carbonate (siderite) corrosion product. Dense iron carbonate films prevail at higher temperature and a more porous iron carbonate prevails at lower temperature. At higher temperature (>170 deg. F.), the more dense iron carbonate is formed at the metal/brine interface and protects the steel substrate from attack. As temperature decreases, there is an abrupt transition to a more corrosive condition characterized by the formation of a more porous iron carbonate that does not effectively impede the corroding steel substrate.

In flash plant operation where steam and water ratios vary, corrosion attack may include any or all of the contaminants previously listed. Hydrogen chloride and hydrogen sulfide attack frequently occurs in the production and steam/brine gathering systems. To further complicate things, corrosion by-products are generated and can react with silica and sulfide to form deposits in the system. Oxygen is introduced into the injection system as condenser condensate passes through the cooling tower system. The injection fluid, now containing oxygen, becomes very corrosive as the fluid passes through high temperature injection wells. Injection well pipe integrity is severely jeopardized under these conditions, and injection well collapse and failure can occur.

Solutions to Corrosion Problems

The aggressive corrosion characteristic in the steam and brine cause dramatic and often catastrophic failures in geothermal operation. **PowerChem Technology** is an industry leader in developing cost effective corrosion inhibitors for controlling operational problems caused from the extreme corrosive tendency of geothermal brine and steam. Successful treatment applications include:

- Production Lines
- Heat Exchangers
- Injection Lines
- Injection Wells
- Bi-Phase Turbine

Current projects include corrosion protection in steam lines, steam turbines, and two phase production well flow. Please contact our office for more details on specific plant projects and applications.

Summary

The complex of chemistry compounds contained in geothermal brine and steam creates difficult operational limitations in power plants. The extreme scaling and corrosion characteristics of geothermal brine cause dramatic and, at times, catastrophic failures in plant operation. Production wells and gathering systems, plant vessels and generating equipment, and injection lines and wells are all exposed to the extreme and harsh conditions of geothermal brine and steam.

PowerChem Technology has developed and implemented successful treatment and control programs in major areas of geothermal operation. Scale control programs have been designed to protect geothermal equipment from severe plugging and fouling conditions. Corrosion control programs have also been designed to protect geothermal equipment from the aggressive corrosion problems that cause equipment degradation and failure. The successful development and implementation of scale and corrosion control programs have allowed geothermal power plants to operate at higher levels of power production efficiency while protecting the valuable investment in their plant and equipment.

PowerChem Geochemical Services is a chemical engineering company providing specialty chemical products and services to the worldwide geothermal industry. Products and services provided include brine scale control treatment, brine and steam corrosion control treatment, cooling water treatment, resource chemistry evaluation, plant engineering and operating studies. **PowerChem** has made several important advancements in difficult brine treatment applications including – silica, calcium and stibnite deposit control; and carbon dioxide, hydrogen sulfide, and chloride corrosion control. We work with geothermal operators, owners, developers, and OEM's. Please contact us for more information on our products and services.

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