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Increasing the Temperature of Geothermal Fluids as a Mitigation Measure Against the Formation of Unwanted Solids

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INTRODUCTION

There are water-dominated geothermal systems with saturated two-phase fluids, whose typical operating ranges are between 150 and 180°C, associated with pressures on the order of 5 to 10 bar. In these types of systems, mineral precipitates can occur, such as those associated with the formation of amorphous silica.

These precipitates can generate significant operational impacts, including blockages in heat transfer equipment (binary cycles) and scaling phenomena in steam turbines (flash-condensation cycles), as a result of the entrainment of suspended solids in the gas phase. In operational terms, these processes manifest as a progressive decline in electricity generation, accompanied by more frequent and prolonged maintenance interventions, with significant economic impacts, reduced equipment lifespan, and compromised electrical system reliability. Furthermore, blockages can occur in pipeline systems, reinjection wells, and even impacts on the reservoir itself.

These complexes can carry other components during the formation process. These components adhere to the internal walls of separator stations, pipelines, and other elements, such as blades and critical components, causing a progressive loss of power.

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METHODS

Pressure and Temperature Increase: Two-phase fluids produced by wells operate under conditions close to thermodynamic equilibrium. When combined in separation stations, this equilibrium can be modified by a controlled increase in pressure, which raises the system's saturation temperature and, consequently, increases the solubility of the mineral phases (amorphous silica) in the liquid fraction. In flash-condensation systems, this effect is achieved through surface pressure adjustments without altering the plant's nominal operating pressure. Operationally, this is implemented by progressively adjusting the conditions of one or more separation stations by increasing the pressure set point, restricting downstream valves, and, when necessary, making controlled adjustments in producing wells. Once the new equilibrium is reached, the corresponding adjustments are made in the reinjection systems.

Evaluation of the change: Effectiveness is verified through the stabilization of electricity generation (decay mitigation) and changes in the chemistry of geothermal fluids.

Other analytical methods:

Inspection and sampling of pipes, separators, stabilization tanks, and turbine components. Laboratory analysis: chemical and metallographic testing, X-ray diffraction, spectrometry, and ion chromatography. Application of coupled geochemical-operational models to evaluate saturation conditions (Arnórsson, 2000; Stefánsson et al., 2017). Operational evaluation of separator efficiency and geochemical characterization of the fluid under different pressure conditions. Implementation of steam scrubbing using controlled spray systems at the plant's steam inlet.

RESULTS

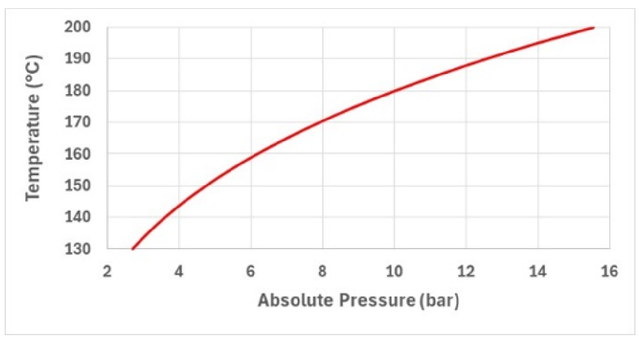


Figure 1. Absolute Pressure vs Temperature. Source: Data from Moran et al. (2014)

Some basic premises: The reservoir pressure must allow for an increase in surface pressure without adverse effects. This point is also related to the wellhead pressure of the production wells.

Surface structures must allow for an increase in operating pressure without affecting their structural or operational integrity, with minimal effects on process efficiency (e.g., cyclone separators). For permanent changes, the possibility of installing pressure regulating valves should be evaluated.

One of the most important variables related to precipitation scaling in geothermal systems is energy generation. When this phenomenon occurs (in flash or binary systems), it has a direct effect on generation, reducing it over time. This reduction can be mitigated by increasing the pressure (between 4 bar and 10 bar) and the temperature (between 145°C and 180°C) at the separation stations (Figure 1), provided the systems allow it. The increase in the solubility of silica-related salts with temperature can be estimated using graphs (e.g., Figure 2).

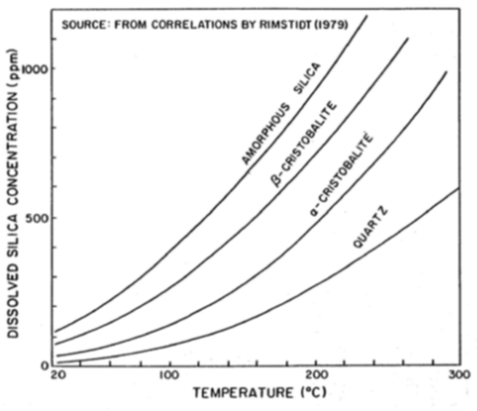


Figure 2. Equilibrium solubilities of silica phases as a function of temperature. Source: Ngothai et al. (2010).

However, because these are sensitive changes in thermodynamic and geochemical equilibria, it is expected that significant operational variations (such as the integration or removal of wells) will alter the equilibrium reached, returning to a state of evident precipitation. When salt carryover occurs in the vapor phase, the complementary application of steam scrubbing can mitigate the decay trend and even partially reverse it.

Another important effect of temperature changes is a possible reduction in the extracted mass observed in the liquid phase. While steam quality increases with increasing temperature, the total amount of steam remains practically the same before and after the change, unlike the amount of brine. Significant negative effects may not occur in binary systems because the brine would arrive in smaller quantities but at a higher temperature.

DISCUSSION

An increase in pressure and temperature in geothermal systems through separation stations can stabilize the decline in electricity generation when one of the main causes is the precipitation of amorphous silica. When these precipitates are suspended in the vapor phase, they can lead to additional problems, such as erosion and corrosion in the steam pipes, which are then carried to the turbines (in flashing systems), where they deposit and reduce their efficiency.

Some elements within the geothermal complex may be more critical than others. One or more wells could be located within a particular reservoir context and contribute significantly to the problem. Therefore, it is necessary to characterize all wells in detail. Immediate action involves removing problematic wells, provided the system allows it. However, this action reduces the field's operational capacity. If a well cannot be removed, alternative measures should be evaluated, such as specialized separators, special collectors, pH modification, or the use of inhibitors.

Suspended solids can not only affect plant performance but also compromise system integrity, reducing the lifespan of high-cost components and increasing maintenance intervals, with significant economic and operational impacts.

Other salts present can decrease the solubility of amorphous silica to some extent when concentrations are high. On the other hand, other compounds, such as calcite, decrease its solubility with increasing temperature. However, their effect is usually not significant.

CONCLUSION

Increasing pressure and temperature in critical separation stations can effectively halt the decline in power generation when the precipitation of salts such as amorphous silica is a primary cause. However, modifications made after equilibrium is reached can accelerate the decline process again.

Controlled pressure and temperature increases represent a quick and low-cost measure; however, they reduce the operational flexibility of the reservoir, especially in lower-pressure wells. Additionally, separation stations have design limitations for sustained operation at high pressures, which can affect their performance.

Once problematic wells are identified, specific operational strategies can be defined to mitigate the impact of fluids with high solids content. Complementary actions include well traps, operational adjustments, steam scrubbing, periodic inspections, and other combined mitigation measures.

Other options under evaluation include neutralization treatments to modify acidity at depth, corrosion inhibitor testing on casings, and the potential implementation of advanced solids retention systems. A direct effect of the increased temperature and pressure of the system is the reduction in the mass extracted from the reservoir, observed at the surface in the liquid phase. This phenomenon can have favorable long-term consequences for the sustainability of the reservoir.

Acknowledgements

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