Silica Scaling Mechanism at Cerro Prieto

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ABSTRACT

Many attempts have been made to install a binary power plant at Cerro Prieto, but solving the silica scaling problem was considered to be too expensive due to the cost of chemical inhibitors. Steam production at Cerro Prieto has declined severely and has obliged to shut down four turbines, decreasing the installed capacity and reducing energy generation levels and the projects profitability. Now the use of binary cycle technology seems to be a viable option and many attempts have been made to minimize silica scaling to use such type of power plants.

Silica scaling mechanism at Cerro Prieto was studied as to take further measures to avoid scaling and be able to use the residual brine or exploit the reservoir directly without flashing units.

Cerro Prieto

Cerro Prieto (CP) is a liquid dominated field, which produces brine with high scaling characteristics because of its silica content; the reservoir temperature is around 290°C. There are 166 wells that produce a total 4346 t/h of steam and 7049 t/h of residual brine. In 2011, due to the lack of sufficient steam, four turbines were shut down permanently, reducing the installed capacity levels from 720 MWe to 570 MWe. There is an urgent need to maintain electrical production levels so the management is looking for other non-conventional alternatives to exploit the field or alternatives that were considered expensive earlier.

The production wells in Cerro Prieto are artesians, but there is a zone in the western part of the field where the reservoir has cooled down, has lost pressure and is not being exploited anymore, but the wells still have temperatures above 130°C.

At CP there are only flashing units, so the brine is separated in primary and secondary steam separators. This first separation removes the acid gas from the residual brine, leaving brine with high silica concentrations and higher pH. This residual brine goes into the secondary steam separator for another flashing, leaving highly concentrated brine with high pH (7.74), this brine has a silica content of 762 ppm and a temperature of about 150°C. This is the brine intended to be used in a binary (Organic Rankine Cycle) power plant.

Binary Power Plant

There are plans to install a 20 MWe binary power plant with the residual brine from the secondary separators (150°C@75psig); some of this brine is sent to an evaporation pond to cool down, letting the silica precipitate before it is reinjected, and a minor amount is used for hot reinjection. Most of the thermal energy in the brine is being wasted, and many attempts have been made to minimize the silica scaling problem and use it to power a binary power plant.

Another attempt being made is the extraction of the heat from the brine by pumping it directly to the heat exchangers of a binary power plant.

Without chemical inhibitors the tubes in the heat exchanger begins to clog because the silica precipitates very fast once the brine begins to cool down. The scales are difficult to remove mechanically.

Silica Scaling

The silica scaling mechanism at CP is dependent on temperature and pH. In silica concentrated brines with higher pH and low temperature silica scaling can be expected. At higher temperatures (above the silica precipitation point) however, no precipitation may occur because the solubility is increased, so it can be said that the scaling process is temperature controlled.

Ionic charges are involved in the mechanism of silica particle nucleation and growth described by Sheikholeslami et al. (2001) and Wahl (1977). According to these authors the process is basically ionic reactions between anion and cations until particles reach charge equilibrium. The mechanism of the double layer and the ionic charge that are involved in the silica scaling process was described by Thomas and Gudmundsson (1989), as well as the polymerization rate modification process by magnetic fields.

To form silica gel it is needed the collision of two silica particles with enough low surface charge that they become in contact and siloxane bonds are formed to hold the particle together. For higher silica concentrations (above pH 6) there will be higher charges on the particles and lower collision and thus less gelling (Matijevic, 1997); it is also mentioned that the higher rate of gelling occurs at about pH 5.

Silica particles tend to collide and grow in a nucleation and growth process forming long chains or silica polymers, but the rate depends on the saturation (pH), temperature, charge and concentration of the brine (Sheikholeslami et al., 2001), after the particle size is big and heavy enough it will precipitate and the scaling process will begin.

Scaling Mechanism at Cerro Prieto

The separated brine from the primary separator is sent to the secondary separator at 150°C via carbon steel pipeline, where scaling begins due to the high silica concentration (fig. 1).

Figure 1. Silica scaling in the water discharge of a primary steam separator.

Some of the brine from the secondary separation (almost 1000 t/h) is injected back into the reservoir (hot reinjection); this cannot be considered as energy loss because this brine is still hot (150°C). It is better to inject at this temperature than at ambient temperature. It has been argued that this can cool down the reservoir because of the temperature difference (about 150°C), but not injecting at all may increase the rate of resource depletion.

The residual brine from the secondary separation, which is not used in the hot reinjection (about 6049 t/h), is sent to a steam silencer at atmospheric pressure and then to an evaporation pondvia open channels where the brine cools down and allows the silica to precipitate, before it is reinjected outside the reservoir.

Once the brine is sent into the steam silencer the silica polymerization occurs rapidly in the first eight meters due to the suddenly temperature drop from 150°C to 100°C; the scales produced in this part are the hardest scales found at CP. This scale change colors depending on its iron content (from the corrosion products of the casing), but it tends to be ivory colored. But near 88°C, the silica that has not precipitated begins to flocculate and quickly precipitates as silica gel forming a plug that is easily removed. All this silica gel ends up in the evaporation pond where it precipitates, but the silica scales formed in the discharge of the silencer are almost impossible to remove mechanically without damaging the channels (fig. 2).

Figure 2. Silica scaling in the water discharge of a secondary steam separator.

New rock filters have been designed to remove the silica gel and analyze the polymerization mechanism, but the results have not been conclusive up to now. The filters are installed in the interphase where the silica gel begins to form (88ºC). If the rock used in the filter is smooth the silica will plug the filter quickly and the scales will work as a cementing making the scaling impossible to remove from the filter. If the rock is porous volcanic the silica will be trapped in the pores and is easily removed with water jet blasting, allowing reusing of the filter.

The gelling process of the silica downstream of the silencer occurs when the pH decreases after the fast silica polymerization process that occurs at the exit of the silencer, which reduces the silica concentration in the brine, the amorphous silica is deposited in the next few meters, leaving brine with low scaling characteristics and silica particles of less energy. It is well known that lower pH reduces silica scaling.

To install a binary power plant at CP under these scaling conditions is impossible. There has to be determined the lowest temperature that the brine may reach to avoid silica polymerization, even with the use of scaling inhibition products. A temperature drop of 30ºC may prevent scaling in the heat exchangers with the use of chemical inhibitors are used, combined with a programed mechanical maintenance at least three times a year.

Conclusions

The understanding of the particular mechanism of silica scaling at CP is needed to develop a plan to avoid scaling and be able to use the residual heat in the secondary separated brine and install binary power plants to maintain electricity production levels.

In theory, with the temperature and the amount of residual brine it must be possible to install a 20 MWe binary power plant, with the appropriate use of scale inhibitors and mechanical cleaning procedures.

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