USES AND ADVANTAGES OF GEOTHERMAL RESOURCES IN MINING

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ABSTRACT

Economic production of minerals along with production of electric power from geothermal power plants can be termed as cascade use of geothermal power plants. Minerals like silica, lithium, manganese, zinc and sulfur can be removed from geothermal fluid or steam to obtain marketable byproduct; these minerals are also a major source of corrosion and scaling which leads to mechanical failures. Methods of metal extraction developed previously and its importance for power plant to operate efficiently will be discussed here.

INTRODUCTION

Geothermal energy is defined as energy stored inside the earth crust. This energy is in the form of high temperature. Because of the magma, rock near to it gets heated and we get molten rocks with minerals in it. This molten rock interacts with rain water which percolates through major faults and fractures results in the formation of a dilute brine (Figure 1).

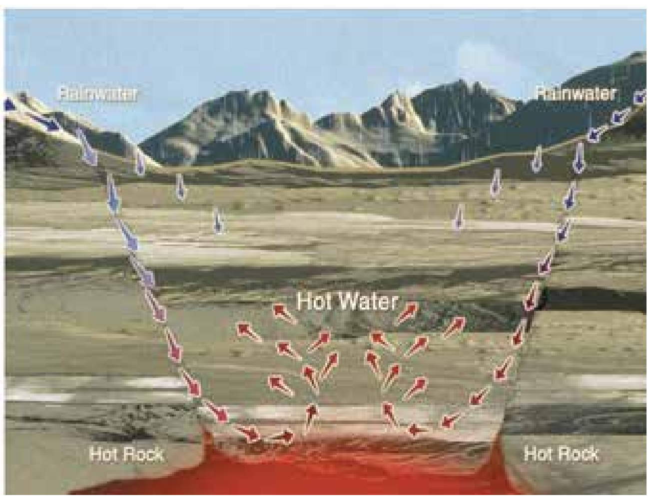

Figure1. Percolation of rain water into fracture and its reheating due to hot rocks (GEO, 2000).

These resources can be increased if we can extract more energy from low temperature reservoir. New technologies are introduced which will help to extract more and more energy from earth. New technologies such as Enhanced Geothermal Systems (EGS) are helping us to extract more heat from areas where there is less availability of underground water.

Geothermal fluid with a range of 200°F (93°C)(low temperature) to 400°F (204°C)(high temperature) can be used for hydrothermal electricity (Kagel, 2008).

Due to the fault formation and other geologic reasons, subsurface temperature of Nevada and California is very high. Besides these regions are rich in minerals which are water soluble. When such minerals are subjected to high pressure and temperature mineral becomes soluble and we get a fluid which has all these water soluble minerals.

GEOTHERMAL AND MINING INDUSTRY

Geothermal fluids interact with the host rocks and tend to become increasingly saturated with various minerals. Some geofluids are rich in minerals and some are free of minerals. Geothermal fluids are mostly water, steam or combination of two. Geofluids are generally hot, salty (because of the mineral content). Any of these fluids acts as a carrier to get geothermal energy up through wells from subsurface to surface.

The resulting chemical compositions of geofluids are determined by:

- Composition of rocks
- Chemical composition of fluid.
- Temperature and pressure during the fluid and rock mass interaction.

$NaCl$, $NaSO_4$ and $Na/CaCO_3$ are some of the major geothermal fluids which are present in Nevada (Trexler, et al., 1990)

Due to large availability of geothermal resources in Nevada and California, geofluid can be used for the extraction of water soluble minerals as well as precious metals.

For example:

1. The use of geothermal fluid in heap leaching for silver and gold extraction. (Trexler, et al., 1990).
2. Extraction of silica from geothermal power plant. (Parker, 2005).
3. Mining lithium from geothermal 'lemonade'.
4. Collection of sulfur from geothermal steam (Li and Brouns, 1978).

Table 1 shows some examples of mineral composition of selected geothermal fields. Figure 2 shows the temperature distribution throughout the USA for use of geothermal.

Table 1. Examples of mineral composition of selected geothermal fields (Bouncier, et al., 2003 and Gallup, 1998).

	Salton Sea, CA	Coso, CA	Dixie Valley, NV	Mammoth Lake, CA
Temp. (°C)	296	274	246	165
Silica (mg/kg)	>461	>711	>599	ca 250
Boron (mg/kg)	257	119	9.9	NA
Lithium (mg/kg)	194-230	45	2-4	NA
Zinc, (mg/kg)	438	0.03	NA	NA

Also geothermal energy is used in a number of industrial applications such as pulp, paper and wood processing, diatomite plant, vegetable hydration and waste-water treatment.

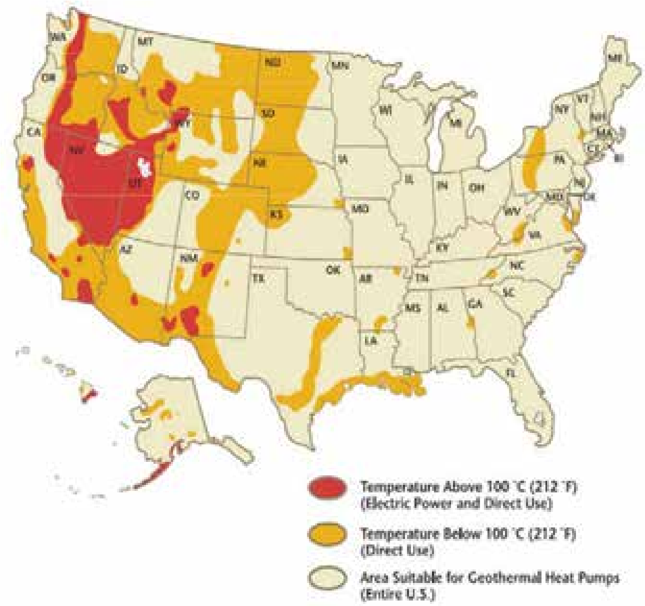

Figure 2. Temperature distribution throughout the USA for use of geothermal (Green and Nix, 2006).

EXTRACTION OF GOLD, SILVER USING HEAP LEACHING WITH THE HELP OF GEOTHERMAL FLUID

Heap leach is an industrial process which is used to extract precious metals such as gold, silver, etc. Heap leaching of gold and silver ores is conducted at approximately 120 mines worldwide (Kappes, 2002). The main advantage of heap leaching is low capital cost. Around 12% of the gold is produced with the help of heap leaching process. Nevada is known as the birthplace of the heap leaching process. Modern day leaching was started in Nevada in 1960 (Kappes, 2002). Figure 3 shows the schematic diagram of the thermally enhanced heap leach process.

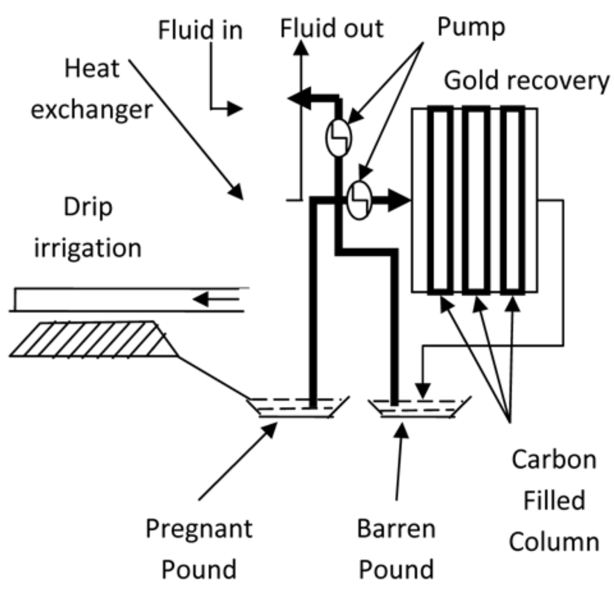

Figure 3. Idealized thermally enhanced heap leach (Trexler, et al., 1990)

Heap leaching may be defined as stacking of metal-bearing ore into a "heap" on an impermeable pad, irrigating the ore for an extended period of time with a chemical solution to dissolve the sought-after metals, and collecting the leachant ("pregnant solution") as it percolates out from the base of the heap (Kappes, 2002).

Pregnant solution is pumped through activated charcoal at the process plant, which absorbs gold and silver. Cyanide solution is pumped to a holding basin, where lime and cyanide are added to repeat the leaching process. Gold bearing charcoal is chemically treated to release the gold and is reactivated by heating for future use. The resultant gold bearing strip solution, more concentrated than the original pregnant cyanide solution, is treated at the process plant to produce bar of impure gold. The gold is sold or shipped to a smelter for refining. The heap leaching process uses hot geofluid which is available in most of the parts of Nevada. For example, gold ore from the Freeport Jerritt Canyon Mine in northern Elko county and silver ore from Gooseberry Mine in Washoe County used to use the thermally-enhanced cyanide heap-leaching operation (Flynn, et al., 1986)

Geothermal fluid can be used for direct heating or indirect heating. During indirect heating, pipes carrying hot fluid can be laid throughout the heap leach pad to keep the heap leach pad warm and enhance the chemical processes by providing a higher temperature. While, in case of direct heating, geothermal fluid is directly circulated through leach to get the same results as that of indirect heating. During direct use of the geofluid some chemistry related difficulties may arise because of the chemical composition of geofluid. Geofluid may contain some metals and non-metals which has the ability to react with cyanide which is a major chemical component in heap leaching process. Non precious metal and non-metal which may react with cyanide to create precipitate and disturb the chemical process by plugging the cyanide dripping through the leach pad are called cynocide (Bloomquist, 2006). Amount of cynocide is also important, if the amount is not much, cynocide will not stall leaching process.

ADVANTAGE OF USE OF GEOFLUID IN HEAP LEACHING

Due to the heating of the chemicals recovery of the precious metal is speeded up. Also because of the temperature enhancement the mine operator can operate the leaching pad throughout the year. The above two reasons will help the mine operator to generate more revenues and will give year round employment opportunities. Heating of the cyanide solution will help to enhance gold and silver recovery by 5 to 7% (Bloomquist, 2006).

EXTRACTION OF SILICA FROM GEOTHERMAL POWER PLANT

Extraction of silica from geothermal fluid is termed as a cascaded use of geothermal energy. Geothermal fluid contains silica which clogs tanks and pipes. So by removing the silica from geothermal fluid geothermal industry will provide silica as a marketable by-product. And the geothermal energy will be generated. This experiment was carried out in Livermore's mobile laboratory at the Mammoth Pacific LP geothermal power plant in Mammoth Lakes, California. The Livermore extraction process involves running a geothermal fluid through a reverse-osmosis separation process to create freshwater and concentrated brine. The freshwater is used for evaporative cooling, and the concentrated brine is pumped into a reactor where chemicals are added and silica is extracted. The silica-free brine can then be pumped through another process for extraction of other metals before the fluid is pumped to a surface pond and re-injected into the subsurface (Parker, 2005).

Metals like Lithium, Manganese and Zinc can be extracted from geothermal fluid. Figure 4 shows a schematic diagram of the system which extracts silica from geofluid.

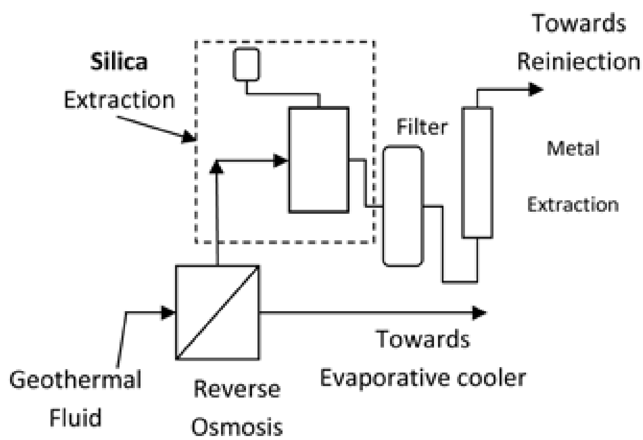

Figure 4 Extraction of silica from geothermal fluid $H_4SiO_4 \rightarrow 2H_2O + SiO_2$ (Dissolved Silica)(Quartz siliceous sinter) (Parker, 2005)

Silica production from a 50 MWe Salton Sea, California and Coso power plant, California power plant could provide $10.2 and $12.9 million per year respectively. These values were calculated assuming 60% silica recovery rate, a selling price of $2200 per metric ton and a plant capacity of 95% (Bloomquist, 2006).

Removal of silica from geothermal fluid enhances the performance and reduces the maintenance cost associated with scaling in surface facilities and injection wells (Figure 5) It also facilitates the co-production of marketable minerals.

Figure 5. Scaling in geothermal pipeline (Bloomquist, 2006).

MAJOR ENGINEERING CHALLENGES BECAUSE OF THE SCALING

Temperature, pressure, chemistry and content of non condensable gases in geofluid influence the power plant operation and may affect the mechanical, volumetric and thermal efficiencies of the power plant. This will affect power production and cost per kWh. Any kind of extraneous material that appears on the inner surface of the pipe which carries a fluid is called fouling. Fouling reduces heat transfer and flow through a pipe. This affects mechanical, volumetric and thermal efficiency of the geothermal power plant. This extraneous material may react with pipe to cause corrosion. To avoid fouling the following methods can be used:

- Use of fins on inner surface of the pipe
- Use of copper-nickel alloys. Carbon steel can be used at low cost to reduce corrosion (Kagel, 2008).
- And flow rate should be managed in such way that, material should accumulate on the inner surface.

Figure 6 shows the scaled and corrode tubes from Hoch Geothermal Facility.

Reduction in fouling will help to reduce corrosion and more mineral can be extracted out on the surface.

Figure 6. Corrosion of tubes (Kagel, 2008).

EXTRACTION OF LITHIUM FROM GEOTHERMAL POWER PLANT

Because of the boost in silica extraction from geofluid, the extraction of Lithium will also turn out to be advantageous. Figure 7 shows the lithium extraction schematic diagram. In this process, fluid is extracted from production well and steam and brine are separated. The steam is then used for electricity generation. The steam condensed to cooled water. Which is reused to mix with waste brine; later this steam is sent to the Lithium Extraction Plant. After lithium extraction water is re-injected into an injection well. In this process, zinc and manganese can also be recovered along with lithium

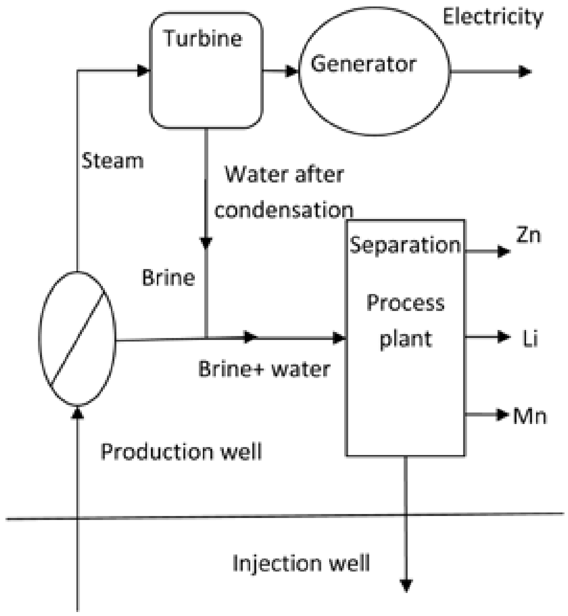

Figure 7. Lithium extraction with Geothermal Fluid (Harrison, 2010).

COLLECTION OF SULFUR FROM GEOTHERMAL STEAM

Geothermal steam contains contaminants such as CO_2, H_2, H_2S, NH_3, CH_4 and N_2. Most of these gases are not only environmentally objectionable but also they accelerate corrosion of power generating parts, which gives rise to issues like safety and increase in maintenance cost. Figure 8 shows the corroded steam vent at The old Covefort power plant.

Figure 8. Corroded Steam Vent (Kagel, 2008).

Steam containing hydrogen sulfide is purified and sulfur recovered by passing the steam through a reactor packed with activated carbon in the presence of a stoichiometric amount of oxygen oxidizes the hydrogen sulfide to element sulfur is adsorbed on the bed. The carbon can be recycled after the sulfur has been recovered by vacuum distillation, inert gas entrainment or solvent extraction. This process of purifying geothermal steam is very suitable if steam contains some other non-condensable gases. In general geothermal steam contains 99% of steam and 200 parts per million of H_2S.

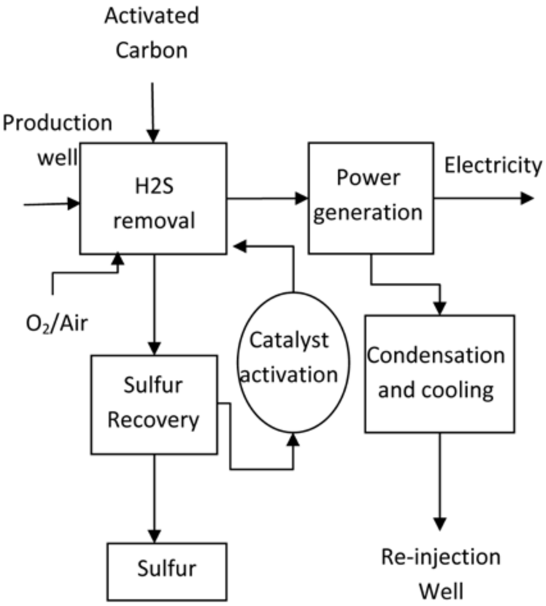

Figure 9. General Flow Diagram of the Catalytic Oxidation Process for H_2S Removal from Geothermal Steam (Li and Brouns, 1978)

ECONOMICS OF MINERAL EXTRACTION

At Mammoth Lake, preliminary data suggested that silica removal could lower the electricity generation costs by as much as one cent per kilowatt hour (Bourcier, et al., 2005). Feasibility of mineral extraction from geothermal fluid depends on the demand of that mineral in market. For example, if the supply of mineral gets more than its demand the market price of the mineral gets affected. To keep continuing the extraction of mineral it should be economical as well as profitable for the company which extracts that mineral.

CONCLUSION

Geothermal energy extraction provides various economic benefits other than its direct use such as mineral extraction. For example, approximately 35,000 m^3 of brine passes through a geothermal power plant facility which is around 50 MWe in capacity. Even if we consider concentration of only 1 mg/kg approximately 30 kg of metal passes through the facility each day (Gallup, 1998)

In the Salton Sea hypersaline geothermal reservoir, located in the Imperial Valley of southern California, each 50 MW geothermal power plant can also produce 16,000 tonnes of lithium carbonate equivalent, 24,000 tonnes of electrolytic manganese dioxide and 8,000 tonnes of zinc metal. According to Simbol Mining Corp, from an initial resource agreement there can be more than four 50 MW plants developed near Salton Sea (Harrison, 2010).

Geothermal is a clean source of energy. It helps power industries to generate electricity as well as reduce carbon emissions. The ability to remove silica from geothermal fluid can add to energy extraction, reduce operation and maintenance cost. Recovery of silicon opens the way for the recovery of metals like zinc, lithium, manganese, cesium, rubidium and even precious metals like gold, silver.

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