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Reverse Osmosis in Geothermal Systems

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Abstract

Reverse osmosis (RO) is a water purification process that uses a semi-permeable membrane to separate water molecules from other dissolved or suspended substances, and is used in industrial processes for production of potable water.

RO retains the solute / large molecules on the pressurized side of the membrane and the purified solvent passes to the other side. R.O. differs from filtration in that the mechanism of fluid flow is reversed, as the solvent crosses membrane, leaving the solute behind. RO involves 56 solvent diffusion across a membrane that is either nonporous or uses nanofiltration with pores 0.001 micrometers in size.

Geothermal power plants use large volume of geothermal water. Brine or condensates are usually reinjected back into the reservoir as a way of disposing it or maintaining reservoir pressure. There have been cases of blockage in the reinjection wells, and scaling and corrosion in equipment caused by precipitation of salts out of the brine. This can be reduced by desalinizing the water through R.O. Therefore, after electricity production, the waste water, can be passed through an RO membrane to desalinize the water for recycling. The waters should undergo pre-treatment steps like filtration to remove larger particles that could clog the membrane.

A pump applies significant pressure to the geothermal water, overcoming the natural osmotic pressure and pushing the water through the membrane. The rejected contaminants, like salts and minerals, become increasingly concentrated on the "feed" side of the membrane, forming a brine that is typically disposed of or further treated depending on the application. Predicting and preventing sediment precipitation in membrane systems is a key aspect of their operation, therefore several commercially antiscalants are usually applied.

It is important to take care of the membrane by increasing its life span so as to serve the cause effectively.

Keywords

Reverse Osmosis, Geothermal, Membrane

Introduction

Reverse Osmosis (R.O) is a water purification process that uses a semi permeable membrane to separate water molecules from other dissolved or suspended substances, and is used in industrial processes for production of potable water. Osmosis is a net movement of solvent molecules from an area of low concentration of solutes to area of high concentration. This process is called reverse osmosis since the water molecules move in an opposite direction to the normal osmosis.

Geothermal power plants use large volume of geothermal water (brine) in the production of electricity, which is usually injected back into the reservoir after the cycle, for maintenance purposes. There have been cases of scaling and blockage in the reinjection

wells, caused by condensation and precipitation of solutes from the brine onto the pipes. This problem can be reduced by desalinizing the water by passing it through an R.O membrane to separate the solvent and solutes before reinjection.

A Reverse Osmosis System Contains the Following Sections
Pre-treatment
Before passing through the membrane, the brine should be treated to remove any large particles that could clog the membrane. The brine should be cooled down to safe membrane limits (40-50°C). The decrease in temperature would cause precipitation of salts out of the brine, which might damage the membrane. Chemicals used to prevent scaling (antiscalants) are then added to the brine 5mg/L controlling minerals like silica, $CaCO_3$, $MgCO_3$, and $CaSO_4$. The antiscalants work by;

1. Threshold inhibition where they keep the salts dissolved in the brine.
2. Crystal modification; when crystals form, the antiscalants adsorb onto the crystal surface distorting the crystal shape making it less adherent and easier to wash away.
3. Dispersion; where they prevent the fine particles from clumping together.

After addition of antiscalants the brine can then be passed through a filter to remove the suspended particles. There are two types of filters sediment filters and carbon filters. Sediment also called cartridge filters use physical barriers that trap the contaminants on the filter medium with varying pore sizes allowing the filtered water to pass through. Carbon filters remove contaminants through adsorption where contaminants are attracted to the surface of the activated carbon and held there. These sediment and carbon filters are further differentiated into other types based on the type of material used in the making of the filters. After the course filtration process, the brine is safe to be passed through the membrane for further

Limestone can also be used when the water has a low PH to remove H_2SO_4, Fe^{3+}, Al^{3+}, and Fe^{2+}.

R.O Membrane
The membrane is a, thin, porous, molecular sieve that allows certain molecules, water, to pass while blocking others. In a geothermal system, the natural osmotic pressure of the brine is expected to be high because of the high amount of dissolved solutes; therefore a high pressure pump would be needed to provide a higher pressure to push the brine to the less concentrated side of the membrane.

Commonly used membranes are the asymmetric and Thin Film Composite membranes (TFC). In the structure of a membrane, there are layers that help in the separation of solutes from solvents and provide structural support to the membrane. In an asymmetric membrane, the same polymer is used for the dense surface and the porous sub layer, while in TFC membrane; layers are made from 2 different polymers. The TFC is commonly used in water purification systems but can be used in geothermal system if: The membrane is made be heat resistant up to 80°C, chemically stable, and selective for key ions. TFC is the structure and membrane itself but there are also designs by which the membrane layers are arranged. There is the spiral wound, plate and frame, hollow fiber and tubular designs. The spiral wound or cylindrical membrane is advised as it offers a large surface area to wrap up more flat sheets around the tube.

Advantages of TFC Membranes

- High rejection rate; TFC are very effective in rejecting and removing contaminants from the brine.
- Durability; TFC are more resistant to fouling and chemical damage compared to other membrane types.
- High performance

Spiral wounds modules consist of a sandwich of flat sheet TFC membranes, spacers, and porous permeate flow material wrapped around a central permeate collecting tube. The membranes are separated by feed channel spacers that allow uniform passage of water through the membrane. The membrane and the feed spacer are then glued along the three open edges forming membrane envelope, and the 4th open side is fixed around the central tube. Feed passes axially down the module across the membrane envelope and a portion permeates into the envelope where it spirals down to the centre exiting through the collection tube. The concentrates leave the module at the opposite end to the feed. Short multi envelope design minimizes the pressure drop encountered by the permeate travelling toward the central pipe. For a treatment system to treat more water, more membranes must be present, therefore, in a geothermal system a module can have 6-7 membrane envelopes to up to 8 inches for effectiveness.

Fouling and scaling on the membrane may reduce its lifespan by reducing its permeability, limiting the overall performance of the system; therefore, there is need of frequent chemical cleaning and flushing of the membrane and changing of filters after every 6-12 months.

Energy Recovery
After the treatment process the permeate coming out of the membrane would have just as much pressure as the feed water, and wasting it would be a loss of energy. The hydraulic energy can be recovered through the following ways:

1. **Pressure Exchanger**

- The pressure exchanger (PX device) is the most efficient method. There is a direct transfer of pressure between waste brine and feed water inside sealed chambers. Pressurized waste brine from the system pushes new water fed in almost same pressure into the system. This reduces the need for the high-pressure pump significantly by almost 90%.

2. **Hydraulic Turbine**

- The pressurized waste brine can drive turbines, recovering the energy as electricity in smaller systems.

3. **Binary Geothermal Power plant (ORC)**

- The hot waste brine can be passed through a heat exchanger, which on the other side is a working fluid with a much lower boiling point than water. The brine stays liquid but its heat causes the working fluid to flash into high pressure vapor that can be directed into a turbine to generate electricity.