Riskless separation of particles out of big water flows in the deep geothermal energy

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Abstract

Geothermal waters from deep drilling usually contain large quantities of unwanted particles with different characteristics. Under conditions of changing pressure and temperature it turns into mineral scaling which blocks the heat exchangers and piping continuously. As a result, the geothermal utilization is strongly impaired. To overcome these operational difficulties an efficient particle elimination system is highly-desired. Cyclonic separation with an automated purging unit offers an innovative technology for particle removal in a reliable and risk free way for the operator. Particles are separated out of the water stream via centrifugal forces and subsequently removed via automated purging unit to a final storage vessel without any interruption of a water flow or human intervention. Dosing of a neutralizing agent and cooling of a sludge in the purging unit ensures the risk free extraction of particles even under conditions with high temperature and pressure and high concentrations of dissolved gases or aggressive compounds.

1. Introduction

Geothermal energy is heat derived within the sub-surface of the earth. Water and/or steam carry the geothermal energy to the earth’s surface. Depending on its characteristics, the geothermal energy can be used for heating and cooling purposes or to generate clean electricity (IRENA, 2017). Thanks to geothermal utilization the increasing demand for renewable energy could be lowered. However, its full exploitation is still limited by many technical problems which are to be overcome.

The composition of geothermal water from deep drillings is characterized by the macroelements of the reservoir rock and the subsurface environment to which is exposed most of the time. The most frequently observed elements with high concentrations are Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^{2-}, SO_4^{2-} and CO_2. Other micropollutants are heavy metals such as mercury, copper, lead, zinc, silver, iron, zinc, arsenic, manganese, cadmium, uranium, cobalt (GUDE, 2018). Due to changes in temperature and pressure the different equilibria of dissolved gases and solid forms of the components can be shifted towards the formation of mineral precipitations (scaling). Decreased degree of heat transfer in heat exchangers due to clogging, significantly reduced inner diameter of piping, leaking valves or even blocking of the pores of a swallow hole are among the most significant results of these interactions. Therefore, an efficient removal of sand particles, scaling or freshly formed suspended microparticles out of the system using a reliable and risk free way for the operator is inevitable. High degree of salinity, high temperatures and pressures along with large quantities of dissolved gases in water make this a real challenge.

Particle elimination through the application of common backflushing filter systems is not adviseable. The filter screens are often coated with hard mineral coatings and eventually blocked so that automatic backflushing is not possible anymore. Furthermore, high pressure and high temperature bring automatic backflushing filters to their technical limits. Therefore, only barrier filter units with the

possibility of a manual cleaning conducted by the operator can be applied. Unfortunately, the direct contact of the operator with the hard coatings from the filter during the manual backwashing can be dangerous. In many cases the separated particles contain toxic heavy metals or radioactive substances e.g. mercury or arsenic which come along with significant health risks for the operator besides potential hazards caused by temperature, pressure and dissolved gases.

2. Cyclonic separation with automated purging unit

The newly developed and here presented, patented system of cyclonic separation using centrifugal force with connected automated purging unit faces all these difficulties in a unique way not previously reached.

2.1 Cyclonic separation

The cyclonic system removes particles with sizes above 75 micron and a density of above 2.6 from the fluid up to an efficiency of 99 %. Smaller or lighter particles are also eliminated to a decreasing percentage according to their size and density. For separation of a very fine particles double or triple cyclonic separators can be applied. The separation works reliably due to centrifugal forces even with very large flows of water of 1000 m^3 and more. As there are no moving parts, changes in temperature and pressure do not pose a problem to the system. Furthermore, there is no filter element to get coated and blocked by mineral coatings and coarse particles.

Water enters the separator tangentially on the side so that it forms a rotary motion. Due to the cross-section reduction between the upper chamber and the separation barrel, the rotational speed of water is accelerated as far as an effective separation proceeds up to the necessary efficiency via a centrifugal force. The medium flows down the separation barrel, whereas the contained particles are pushed outside to the barrel wall. The separator is constructed in a cylindrical form to minimize the wearing via an abrasion by particles. On the lower end of the separator, there is a solids collection chamber, which is partly separated from the separation barrel by a deflecting plate. The particles are expelled via a rotary motion through a slot between the separation barrel wall and the deflecting plate from the water stream into the collection chamber. The largely particle-free water stream flows via the pressure gradient to the center of the water swirl and is deflected upwards and leaves the separator through the discharge pipe on the upper chamber.

The solids collection chamber is periodically opened to the atmosphere via a valve either manually or automatic (using a timer) in order to sweep the separated particles away. The differential pressure between the system and the atmosphere washes the particle sludge out via a sludge pipe out of the system to waste (e.g. sedimentation tank). By this simple process using system pressure, the sludge extraction takes place without any additional motors, pumps, sensors or other unsafe components. The purge valve is the only moving part in the system. In the event of failure of the sludge automatic system, there is no interruption of the supply to the downstream systems. Only the sludge pipe can get clogged and the particles in the main flow will just pass through the separator not interrupting the process. In this case there is no clarification of the media. The blow-down takes place during the normal operation and the operation occurs without any interruption.

In contrast to the barrier filter systems (e.g. mesh and sand filters), which are manifesting a rising differential pressure with an increasing extent of clogging, the separator is always characterized by a static pressure loss during the operation. The pressure loss (the differential pressure) depends only on the flow rate and rises relatively to the flow rate almost linear up to a maximum of 0.8 bar.

The abrasion is negligible small and the assumed maintenance free life expectancy of the device accounts for at least 5 years. Thanks to the special concept and the high-performance reliability it is not necessary to design the system as a redundant system.

2.2 Purging system

Separated solid particles are stored temporarily in a purging system consisting of several chambers isolated from each other by automatic valves. Particle treatment is conducted according to a patented procedure. The subsequent risk free extraction out of the system occurs automatically without any interruption of the water flow. The Fig. 1 depicts the cyclonic separator with an automated purging unit for the applications in deep geothermal energy.

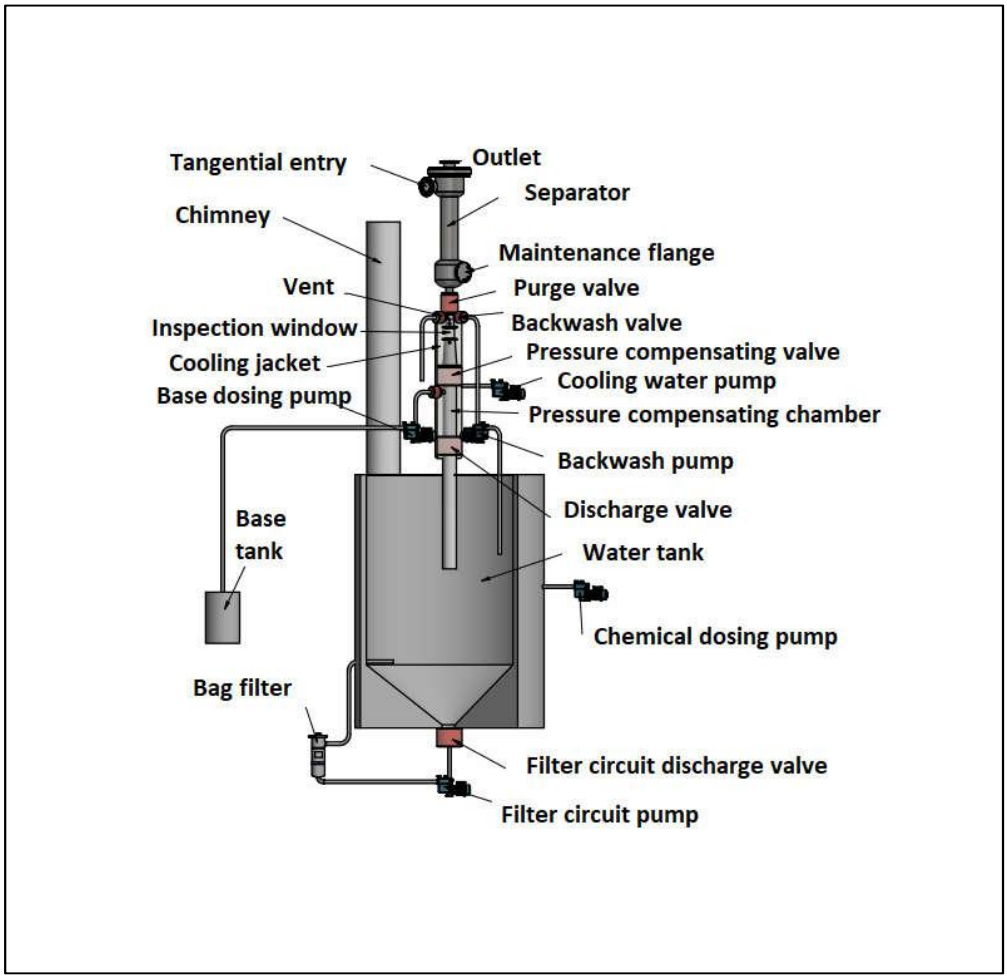

Fig. 1: Cyclonic separator with associated automatic purging unit for deep geothermal energy.

The purging unit comprises a purging chamber downstream the separator sludge outlet, in which separated particles are temporarily stored before being extracted securely. The chamber is isolated by two automatic valves, the upper valve between the sludge outlet and the purging chamber is

open so that the particles fall into the chamber by gravity, the lower valve is closed. After the purging chamber has been filled and the level sensor has been activated, the upper valve would close and the lower valve would open in order to empty the chamber.

Adjacent to the purging chamber there is a dosing chamber for injection of a neutralizing agent in order to neutralize the dissolved gases or chemical and physical reactive compounds in the pressurized fluids and to avoid their abrupt evaporation under atmospheric pressure. As a neutralizing agent an alkaline or acidic solution can be applied. In this way for instance CO_2 can be converted after adding an alkaline solution to sodium bicarbonate (HCO_3^-), which can be extracted without any risk out of the system. The adjustable valve between the purging chamber and dosing chamber allows unpressurized introduction of the neutralizing agent into the dosing chamber. By connecting the purging chamber with the dosing chamber, a sufficient mixing for the appropriate chemical reaction is ensured. Furthermore, both chambers are covered with a cooling jacket for fluid cooling below its boiling point e.g. 100°C for water so that the temperature of reaction of gases or particles with a neutralizing agent is supervised and a water evaporation is prevented. Cooling water or cooling air can be used as a cooling agent. After the neutralization process has been completed a safe extraction of particles can be conducted.

The complete system is designed for fully automatic operation at the highest safety level for the operator and environment under the most difficult operating conditions. Even pressures up to 40 bar, temperatures above 200°C and high quantities of dissolved and aggressive compounds and gases in concentrations typical for deep geothermal energy can be handled.

This concept in a simpler version is certainly suitable for separation of particles out of groundwater close to the surface area, in heating and cooling district networks and in cooling towers for the cooling water treatment.

3. Outcome

Cyclonic separation offers an effective method for a particle elimination in water streams. An automatic purging unit installed on the purge outlet of the separator allows a safe extraction of the particles even under conditions of high temperature and pressure along with high concentrations of dissolved gases or aggressive compounds. Therefore, its application in deep geothermal energy is appropriate for scaling prevention. The simplicity and safeness of the total system is guaranteed by the highest technical and safety standards used in the manufacturing of the systems.

Sources

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