



APPLICATION OF EVAPORATION IN GEOTHERMAL WATER PROCESSING

V. K. Leontiev, O. N. Korableva, E. A. Girba

Valery K. Leontiev, Candidate of Technical Sciences, Associate Professor, **Olga N. Korableva**, Candidate of Chemical Sciences, Associate Professor, **Evgeny A. Girba**, Candidate of Technical Sciences, Associate Professor, Yaroslavl State Technical University, Yaroslavl, Russia, leontievvk@ystu.ru, korablevaon@yandex.ru, girbaea@ystu.ru

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Abstract. The paper presents a schematic diagram of a geothermal water processing plant. The authors developed new designs of evaporators used for concentrating geothermal water. According to the study, the removal of crystals in hydrocyclone and flow pulsation in pipe space of preheater leads to intensification of the heat exchange.

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Introduction

Underground geothermal water is currently extracted and used for various purposes:

- As a heat transfer fluid for heating buildings and structures. Using geothermal water for heating and hot water allows to decrease the level of atmospheric pollution. In terms of economy, the use of geothermal water heat is competitive with some traditional fuels: fuel oil, hard coal, etc.

- The production of useful components that can be used in the medical, chemical and food industries.

- Saving of drinking quality water through the recycling of geothermal one.

The profitability of using geothermal water depends on many factors: the productivity of the produced water, its temperature, the depth of the wells, the waste water utilisation, the concentration of useful components, and the technology for extracting these substances from the geothermal water.

The choice of processes and methods for extracting chemical compounds from the hydrothermal heat transfer fluid of different deposits plays a major role. The exploitation of geothermal deposits, taking into account the disposal of waste geothermal solutions and the possibility of improving the environment were studied at [1-3].



Main body

Recently, natural mineralised water as a promising source of many valuable chemical products is paid a greater attention [4]. The use of mineralised geothermal water produced in Russia is of great importance, not only due to the possibility of significantly reducing the volume of formation water discharged to the surface, which contributes to improving the environment, but also for the processing of minerals, a more advanced and integrated use of mineral resources [2].

By the data provided on the composition of formation water (FrnW) of Medyaginskaya well, we can conclude the containing of high concentration of valuable chemical elements. Chemical compounds: potassium, magnesium, sodium, calcium, magnesium chlorides; potassium bromide and potassium iodide; reactive bromine and iodine; lithium compounds are promising for essential industrial products. The mass fraction of these substances is quite high, so the relevance of industrial processing of geothermal water is not in doubt. Table 1 shows the composition of geothermal water of the Mediaginskaya well.

Table 1. Composition of geothermal water of the Mediaginskaya well

№	Composition of geothermal water	Content, kg/m	
		Sary Oskol aquifer 1224-1399 m	Mid-upper Cambrian volcano, 2158-2190 m
1	Sodium chloride, NaCl	186.3	196.4
2	Magnesium chloride, MgCl ₂	14.6	16.1
3	Calcium chloride, CaCl ₂	36.63	52.25
4	Potassium chloride, KCl	0.764	1.34
5	Lithium chloride, LiCl	0.037	0.059
6	Rubidium chloride, RbCl	0.00082	0.0013
7	Cesium chloride, CsCl	0.00012	<0,0006
8	Strontium chloride, SrCl ₂	0.58	0.95
9	Calcium sulphate, CaSO ₄	1.49	0.51
10	Potassium bromide, KBr	0.99	1.35
11	Potassium iodide, KI	0.0056	0.0038
12	Silicic acid, H ₂ SiO ₄	0.005	0.03
13	Calcium bicarbonate, Ca(HCO ₃) ₂	0.083	0.105
14	Ferrum, Fe ²⁺ /Fe ³⁺	0,048/0,007	0,128/ -
15	Boric acid, HBO ₂	0.032	0.038

Based on the technological scheme for processing of mineral resources developed by SPU "NEDRA" [1], we propose a block diagram of this enterprise [5], which is shown in Fig. 1.

The presented geothermal water processing scheme is designed for a capacity of 5 m³/h; this mode has a little impact on the reserves and the timing of their use. The developed scheme does not involve harmful wastes and emissions to the atmosphere.

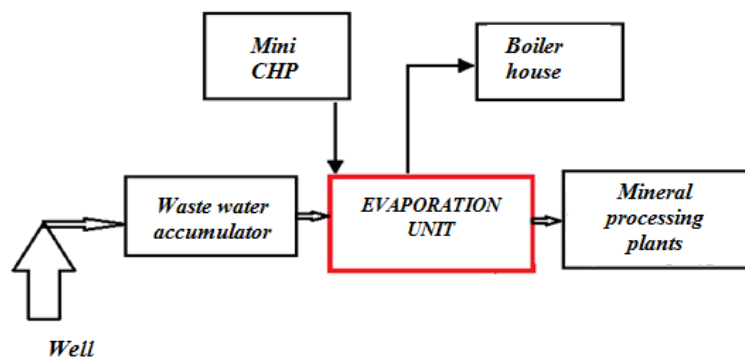


Fig. 1. Block diagram of a geothermal water processing plant

One of the main steps in geothermal water processing is the concentration of multi-component salt solutions until the main component, such as sodium chloride, is saturated, followed by the extraction of other mineral components from the concentrated brine. The evaporation process is conducted in specially designed evaporators for crystallising solutions, as the high mineral salt content of geothermal water leads to the formation of crystalline precipitation (precipitation of sodium chloride, calcium, etc.) on the inner surface of the heater tubes. It leads to rapid build-up and clogging of the heat exchanger tubes by crystallising salt, which in turn reduces the evaporation efficiency. As a result, the apparatus has to be rinsed and the rinse water evaporated, expending additional energy.

As a result of our work on integrated geothermal water processing, we have developed the design of an evaporator for crystallising solutions [6, 7]. The scheme of the evaporator is shown in fig. 2.

The evaporator operates as follows. The incoming circulating liquor (geothermal water) is fed into the circulation pipe at a temperature of 65 °C. The circulating liquor is then pumped by pump 3 through a hydrocyclone 4 into the boiling pipes 5, where it is boiled by heating steam from the small-scale cogeneration unit. The vapour-liquid mixture enters the boil-off tube 6 and then enters the separator, where the secondary vapour is separated from the liquid and the crystals formed. As the circulating liquor passes through the hydrocyclone, centrifugal force causes the solids particles to be thrown back against the wall of the unit and move downward in a spiral flow into the lower cone of the hydrocyclone towards the discharge orifice. By separating the crystals from the circulating liquor in the proposed evaporator for crystallising liquors, overgrowth and clogging of the tubes by the crystallising salt is greatly reduced. As a consequence, the evaporator's operating intensity and capacity are increased and retained for a long time, and the cleaning interval and operational reliability are increased [8].

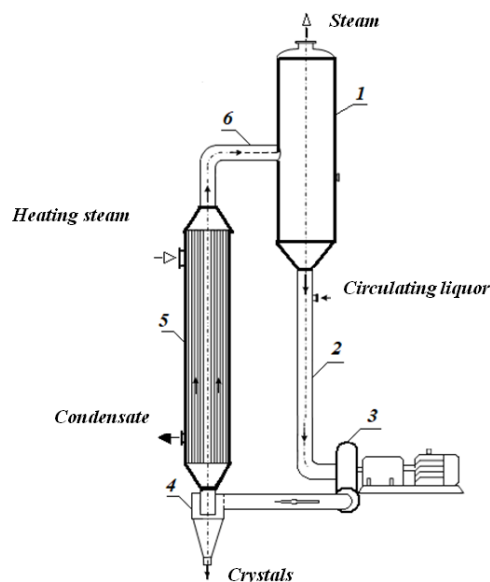


Fig. 2. Evaporator for crystallising liquors: 1 - separator; 2 - circulation pipe; 3 - pump; 4 - hydrocyclone; 5 - evaporator heater boiling pipes; 6 - boiling pipe



In order to intensify the heat exchange and mass transfer process, flow pulsation, rough wall flow, use of nozzles, etc. are widely used [9]. Pulsation devices are of great interest for intensifying the evaporation process. Various pulsation devices are used to communicate fluid flow with pulsation, the action of which leads to increased turbulence and dispersion of the flow, which contributes to a significant increase in the heat transfer coefficient [5, 6]. The pulsers are widely used because of their simple design and high power density, and the periodic flow pulsation does not cause a significant increase of hydraulic resistance. To improve the efficiency of the evaporation process we have proposed a new design of evaporator with pulsatile motion of solution through the heater pipes (Fig. 3) [10].

The principle of operation of the presented evaporator is similar to that of the crystallising solution evaporator. But additionally, a membrane-type pulsation device is attached to the lower part of the heating chamber. To generate pulsation of the solution in the boiling tubes, a flexible membrane 7 is used, which is driven in reciprocating motion by a pulsator - a piston pump. The vibration amplitude is 10-25 mm.

Thus, the proposed evaporator with a pulsating membrane-type device for crystallising solutions due to increased flow turbulence provides significantly reducing of overgrowing and clogging of tubes with crystallising salt. As a consequence, the evaporator's operating intensity and capacity are increased and retained for a long time, and the cleaning interval and operational reliability are increased [8].

In order to compare the efficiency of the proposed evaporator designs, we used the known dependencies for determining the heat transfer coefficient for flow pulsation in boiling pipes. Calculations show the heat transfer coefficient in the evaporator with flow pulsation is higher than the coefficient in the smooth tube of the evaporator boilers by 20-40%.

Conclusions

Thus, the evaporation process is one of the most important for geothermal water processing. Highly efficient evaporation apparatus designs was developed for this process. At the same hydraulic resistance, the heat output of the evaporators of the proposed designs is 20-40% higher in compare with conventional evaporators.

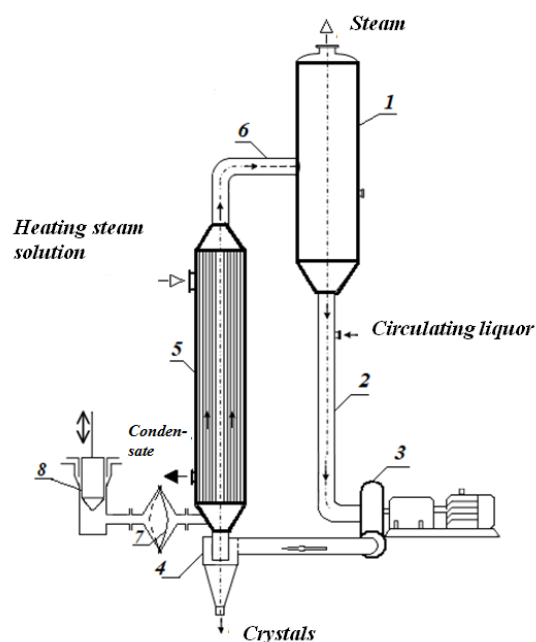


Fig. 3. Schematic of an evaporator with pulsation motion of the liquor through pipes: 1 - separator; 2 - circulation pipe; 3 - pump; 4 - hydrocyclone; 5 - evaporator heater boiling pipes; 6 - boil-off pipe; 7 - flexible membrane; 8 - piston pump



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