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doi:10.5937/jaes0-28676

Cite article:
Sergeevich, V. E., Evgenievna, N. A., Vladimirovna, T. E., & Viktorovich, A. B. [2020]. Energy efficient water desalination technology. *Journal of Applied Engineering Science*, 18(4), 614 - 617.

Online aceess *of full paper is available at: www.engineeringscience.rs/browse-issues*

Original Scientific Paper

Istraživanja i projektovanja za privredu
Journal of Applied Engineering Science

doi:10.5937/jaes0-28676 Paper number: 18(2020)4, 735, 614 - 617

ENERGY EFFICIENT WATER DESALINATION TECHNOLOGY

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The work relates to the technique of desalination of sea and saline waters and can be used to obtain desalinated water with generation of electrical energy. The proposed technology of water desalination is implemented by an autonomous solar desalination-electric generator, containing a rectangular body, the roof of which is covered from above with photocells with a storage unit, an inclined evaporating tray is placed inside the body, dividing the body cavity into evaporation and condensation chambers, communicating with each other at the sides of the body through vertical slots at the ends of the body and the tray are an inlet manifold connected to a submersible feed pump, and a horizontal outlet slot. The bottom of the body is connected to a condensate collection tank, in which a condensate pump is placed, a condensation chamber, immersed in a reservoir, the inner surface of the ends, sides and bottom of the condensation the chamber is made with vertical and horizontal corrugations, into the grooves of which thermo-electric converters are inserted. The first and last of which with photocells are connected to the output collectors, a storage unit, feed and condensate pumps and other them as consumers of electricity.

Key words: desalination, water, technology, thermoelectricity, electrical energy, desalinator-electric generator, housing, tray, photocell, evaporator, condenser, pump, corrugation, thermoelectric converter

INTRODUCTION

Distillation is the most studied and widespread method of desalting saline, especially sea waters. This process is based on the principle that water is a volatile substance and salts are non-volatile substances [1] to [3]. The principle of distillation is quite simple, but there are many problems with its industrial use. For example, as fresh water evaporates from the vessel in which the sea water is located, the salt solution becomes more concentrated and eventually the salt precipitates. This results in scale formation, which dramatically degrades the thermal conductivity of the vessel walls, clogs the tubes. The solution to this problem is that seawater, after distilling some fresh water from it, must be discharged and a new portion of seawater must be collected instead. But at the same time, all the heat accumulated in the heated sea water is lost, and it is necessary to provide additional heat to the newly collected cold sea water [4] to [6]. Heat losses, in turn, are associated with thermal pollution of the environment and an increase in the cost of the process. This method is useful when there is a large source of cheap heat and a large source water reservoir. [7] to [9].

MATERIALS AND METHODS

For the southern regions of Russia, in need of fresh water, the source of cheap heat can be solar energy, and large reservoirs - basins of the Caspian, Azov and Black Seas.

Based on the above, the technology of water distillation should be carried out in simple and reliable equipment, without intensive scale formation on heat exchange surfaces, ensure efficient use of heat and minimal environmental pollution [10] to [12].

RESULTS

The proposed water desalination technology is carried out by an autonomous solar desalinator-electric generator (ASO–EG), the principle device of which is shown in Figure 1 (general view, units and sections).

ASO-EG technology and operation are based on the property of photocells 3, when exposed to solar rays, converting sensed solar energy into electric and thermal energy [13]. In addition, thermoelectric converters (TC), in the form of U-shaped rows, placed in grooves of corrugations 17, consisting of thermoelectric elements (TEE) assembled from paired wire segments made of different metals and soldered at the ends to each other (in Figure 1 not shown), when heating the internal junctions with condensing steam and cooling the opposite junctions of the TEE from outside with cold water, thermoelectricity is created due to the obtained temperature difference [14]. The ASO – EG arrangement (top - photocell 3, bottom - cover 2) allows simultaneous removal of heat from photocells 4, increasing their efficiency, due to the evaporation of seawater flowing along the inclined evaporator tray 5, the steam of which heats the TC junctions during its condensation generating thermoelectricity. At the same time, the U-shaped arrangement of TEEs in the TC rows allows to significantly increase their specific amount per surface unit of the condensation chamber 8 and at the same time increase the heat exchange area, increasing the vapor condensation rate, and the parallel arrangement of the junctions relative to the outer sur-

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face TC increases the contact area of cooled (heated) surfaces, which intensifies the process of heat transfer between opposite junctions 23.

ASO – EG works as follows. The body 1 is immersed in a reservoir with sea (saline) water 13 so that most of the condensation chamber 8 of the body 1 is immersed in the reservoir 13, the outlet horizontal slot 14 is above the water level in the reservoir 13, and the cover 2 is horizontal (for ensuring uniform reception of sunlight during daylight hours). This position of the body 1 is provided either by the ratio between its weight and the center of gravity, or by placing it on anchors. Next, a submersible feed pump 12 is connected to the intake manifold 10 through a pipeline 11, the immersion depth of which H is selected from the conditions of the absence of mechanical impurities in the water and is included in the operation. When the sun's rays fall on the surface of the photocells 3, the received solar energy is converted into electrical and

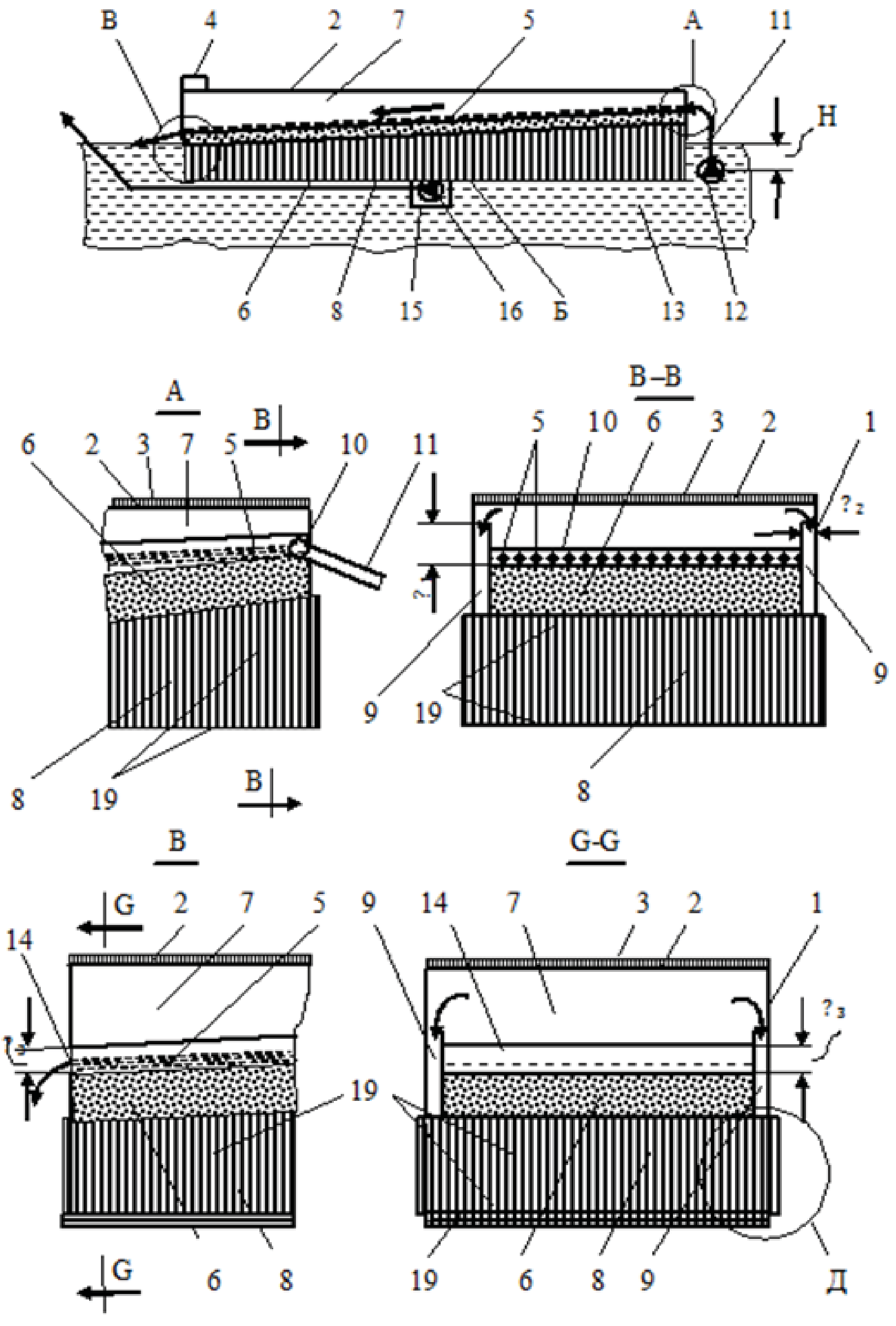

Figure 1: Arrangement of an autonomous solar desalination-electric generator: 1– building; 2 - roof; 3 - photocells; 4 - storage block; 5 - inclined evaporating tray with sides; 6 - a layer of hydrothermal insulation; 7 - upper evaporation chamber; 8 - lower condensation chamber; 9 - vertical slits; 10 - intake manifold; 11 - pipeline; 12 - submersible feed pump; 13 - body of water with sea (mineralized, salt) water; 14 - outlet horizontal slot; 15 - container for collecting condensate; 16 - condensate pump; 17 - corrugations with grooves in which thermoelectric converters are placed

thermal energy. The stable and efficient operation of the photocells 3 is ensured by the continuous removal of heat from them, which is carried out by the fact that, received in the photocells 3 as a result of the transformation of solar energy, the thermal energy is continuously removed through the roof wall 2, made of material with high thermal conductivity, into the evaporation chamber 7. In the evaporation chamber 7, the incoming heat is spent on heating the mineralized feed water moving along the inclined evaporating tray 5 towards its lower end by gravity due to its slope. The last is fed into the inclined evaporating tray 5 by the feed pump 12 through the inlet manifold 10, which is a horizontal perforated pipe plugged at the ends, the perforation of which is made in the direction of movement of the heated feed water, which ensures its uniform distribution over the width of the canvas of the inclined evaporating tray 5. In the process of heating mineralized water, which heats up to a temperature higher than the temperature of the water in the reservoir 13, part of it evaporates, and the non-evaporated part moves by gravity along the canvas to the lower end of the inclined evaporator tray 5 and through the horizontal outlet slot 14 is drained into the reservoir 13. Obtained in the process heating the feed water saturated water vapor, through the vertical slots 9 enters the lower condensation chamber 8 and condenses there, as a result of which, when the desalter enters the stationary mode of operation, the pressure in the condensation chamber 8 is always less than in the evaporation chamber 7. The condensation of water vapor obtained in the evaporation chamber 7 in the condensation chamber 8 is carried out as a result of the process of heat transfer from the vapor through the walls, the surface of the ends, sides and bottom of the lower condensation chamber 8, made with vertical and horizontal corrugations 17 with grooves, inside which the rows TC are located, with an array of colder water in the reservoir 13, and the resulting saturated steam with a temperature t1 contacts the inner surface TC, heating the internal junctions of the TEE of temperature t1. Simultaneously, the surface TC facing the water is cooled by contact of the corrugation 17 with water. At the same time, the heat released as a result of the operation of photocells 4 from the sun's rays is ultimately spent on heating the internal junctions of the TEE TC, and the cold coming from the water cools the external junctions of the same TEE to a temperature t2, as a result of which on the opposite junctions of the TEE there is a temperature difference (t1 – t2), and thermoelectricity in TC. Electric energy received under the influence of sunlight from photocells 4 and thermoelectricity from TC through output collectors (not shown in Figure 1), enters the storage unit, where voltage, current and electric energy are transformed, part of which is consumed to drive pumps 12 and 16, and the other part is sent to other consumers (other consumers are not shown in Figure 1).

The resulting condensate by gravity due to gravity moves from all sides of the condensation chamber 8 through the channels formed by the rows of TC 19 and flows into the condensate collection tank 15 located in the center of the bottom of the chamber 8, drains there due to the force of gravity, accumulates there and is supplied by the pump 16 to the consumer.

The height of the sides $\Delta 1$ of the inclined evaporation pan 5, the width of the vertical slots 10 $\Delta 2$ are selected so that the feed water is not overflowed and the steam passes freely at the maximum load of the desalter. The width of the horizontal outlet slit $\Delta 3$ should ensure free drainage of the heated feed water into the reservoir 13, but at the same time, its air resistance should be significantly greater than the resistance of the vertical slits to water vapor, which is verified by aerodynamic and hydraulic calculations. The length of the inclined evaporating tray 5 is selected from the condition of minimum salt deposition on its surface, the width is taken based on the conditions for ensuring uniform distribution of feed water on the surface along its width and length. The performance of the proposed solar desalination plant can be increased by placing in parallel several inclined evaporating trays 5 in one housing 1.

The number of photocells is 3, the dimensions of the body 1 and the cover 2, the depth of immersion of the condensation chamber 8 in water, the dimensions and pitch between the corrugations 17, their length is determined depending on the external conditions of the installation site (outdoor temperature, water temperature, solar illumination) and the required power ... The value of the difference in the electric potential on the collectors 21 and 22, the strength of the electric current depends on the characteristics of the photocells 3, the duration and intensity of solar irradiation, the characteristics of metal pairs from which wire segments 21 and 22 are made, the number of TEE 20 and TC 19 in the U-shaped rows 24 and their number in the chamber is 8, as well as the temperature difference on opposite junctions 23 TEE 20. The resulting electric current, in addition to ensuring the operation of pumps 12 and 16, can be used for servicing various technical devices, as well as heating and lighting residential and industrial premises on the shore of the reservoir [15] to [17].

CONCLUSIONS

1. The proposed highly efficient technology of water desalination and equipment for its implementation allows to carry out a large-scale process of desalination of sea or saline (salt) water directly in the reservoir itself using solar energy;
2. The technology ensures the transportation of desalinated water to the consumer and the generation of electricity through the use of solar energy and low-potential energy of saline (sea) water;
3. The design of the desalinator, due to the continuous flow of seawater, prevents the formation of scale on the heat exchange surfaces;
4. These technologies and equipment, due to the above factors, ensure minimum environmental pollution.

REFERENCES

1. Ahmadvand, S., Abbasi, B., Azarfar, B., Elhashimi, M., Zhang, X., Abbasi, B. (2019). Looking Beyond Energy Efficiency: An Applied Review of Water Desalination Technologies and an Introduction to Capillary-Driven Desalination. Water (Switzerland), vol. 11, 696, DOI: 10.3390/w11040696.
2. Mathioulakis, E., Belessiotis, V., Delyannis, E. (2007). Desalination by using alternative energy: Review and state-of-the-art. Desalination, vol. 203, 346–365. DOI: 10.1016/j.desal.2006.03.531.
3. Qasim, M., Darwish, N.A., Sarp, S., Hilal, N. (2015). Water desalination by forward (direct) osmosis phenomenon: A comprehensive review. Desalination, vol. 374, 47–69, DOI: 10.1016/j.desal.2015.07.016.
4. Akhatov, J.S. (2017). Energy and exergy analysis of solar PV powered reverse osmosis desalination. Applied Solar Energy, vol. 52, 265–270. DOI: 10.3103/S0003701X16040034.
5. Piyadasa, C., Ridgway, H.F., Yeager, T.R., Stewart, M.B., Pelekani, C., Gray, S.R., Orbell, J.D. (2017). The application of electromagnetic fields to the control of the scaling and biofouling of reverse osmosis membranes - A review. Desalination, vol. 418, 19–34, DOI: 10.1016/j.desal.2017.05.017.
6. Kasaeian, A., Rajaee, F., Yan,W.M. (2019). Osmotic desalination by solar energy: A critical review. Renewable Energy, vol. 134, 1473–1490, DOI: 10.1016/j.renene.2018.09.038.
7. Polivanova, T., Semicheva, N., Ryabtseva, S. (2020). Development of technology for reducing the technogenic impact of sugar factories on the environment of localities. *Journal of Applied Engineering Science*, vol. 18, br. 2, str. 238-242, DOI: 10.5937/jaes18-26301.
8. Yezhov, V., Yemelianov, S., Semicheva, N., Bursev, A, Tolmachyova, V. (2015). Direct heat energy conversion into electrical energy: An experimental study. *Journal of Applied Engineering Science*, vol. 13, br. 4, str. 265-270, DOI: 10.5937/jaes13-9392.
9. Frog, B.N., Pervov L.G., Water preparation (2015). Moscow, Association of Construction Universities.
10. Deshmukh, A., Boo, C., Karanikola, V., Lin, S., Straub, A.P., Tong, T., Warsinger, D.M., Elimelech, M. (2018). Membrane distillation at the water-energy nexus: Limits, opportunities, and challenges. Energy & Environmental Science, vol. 11, 1177–1196, DOI: 10.1039/C8EE00291F.
11. Hosseini, M., Azamat, J., Erfan-Niya, H. (2018). Improving the performance of water desalination through ultra-permeable functionalized nanoporous graphene oxide membrane. Applied Surface Science, vol. 427, 1000–1008, DOI: 10.1016/j.apsusc.2017.09.071.
12. Antia, D.D.J. (2015). Desalination of water using ZVI (Fe0). Water (Switzerland), vol. 7, 3671–3831. DOI: 10.3390/w7073671.
13. Ezhov, V.S. (2017), Autonomous solar desalination plant-electric generator, Patent of the Russian Federation, no. 2622441, bull. 7.
14. Yezhov, V., Ezhova, T., Semicheva, N., Makhova, V. (2017). Outdoor air conditioning. *Journal of Applied Engineering Science*, vol. 15, br. 3, str. 313-318, DOI: 10.5937/jaes15-14668.
15. Ezhov, V.S. Semicheva, N.S., Burtsev, A.P. Ermakov, D.A., Perepelitsa, N.S. (2020). Development of experimental designs of the integrated heater for the disposal of low-potential waste heat of ventilation emissions. IOP Conference Series: Materials Science and Engineering. CIBv 2019, vol. 789, Issue 1, 5 no. 0120202019, DOI: 10.1088/1757-899X/789/1/012020.
16. Yezhov, V., Semicheva, N., Pakhomova, E., Burtsev, A., Brezhnev, A., Perepelitsa, N. (2018). Characterization of Thermoelectric Generators for Cathodic Protection of Pipelines of the City Heating. Advances in Intelligent Systems and Computing. International Scientific Conference on Energy Management of Municipal Facilities and Sustainable Energy Technologies, EMMFT 2018, vol. 983, 670-678.
17. Kim, S., Piao, G., Han, D.S., Shon, H.K., Park, H. (2018). Solar desalination coupled with water remediation and molecular hydrogen production: A novel solar water-energy nexus. Energy & Environmental Science, vol. 11, 344–353, DOI: 10.1039/C7EE02640D

Paper submitted: 02.10.2020.
Paper accepted: 04.12.2020.