Using solar energy to produce fresh water

Dr. S. Rosenberg

Scientific and Technical Association "Ecological imperative"

Annotation

Solar energy is directly used in solar photovoltaic panels and for heating water in Israel and in many southern countries. Below we offer an autonomous environmentally friendly technology - the use of solar energy to produce clean fresh water from salt water wells, lakes and seas. Water is obtained by using an evaporator that receives energy from the sun-heated water. External energy of 3 kWh per cubic meter from solar panels is used. as a "catalyst".

The current situation

Currently, reverse osmosis systems are widely used to produce fresh water from seawater, consuming energy from the electric grid of 5 ... 8 kWh / m^3 and consuming 150…200 % of sea water per cubic meter of water produced.

The essence of the sentence

Below we propose an unusual device for using solar energy to produce clean fresh water from salt water wells, lakes and seas. The circuit of the device is shown in Fig 1. The device consists of a multi-stage evaporator and a water collector collecting solar irradiation energy. The device of the multi-stage evaporator-distiller and water solar collector is widely described on the Internet, in the literature and in patents.

The proposed 6-stage evaporator has 7 baths with water (1, 2, ... and 7 - see Fig. 1), which are located one above the other. In the baths there is the original salt water to be treated. The membrane 10 separates the bottom of the lower bath 1 from the water 9 of the solar collector. The solar collector is hermetically sealed with glass 11. Through the membrane 10, water 9 heats the water in the bath 1.

From the water surface of the baths 1 ... 7, the most "fast" molecules leave the water and condense on the bottom of the upper bath. The bottom of baths 1 ... 7 are plastic or metal thin membranes. Water vapor from the upper bath 7 flows into the surrounding air 8.

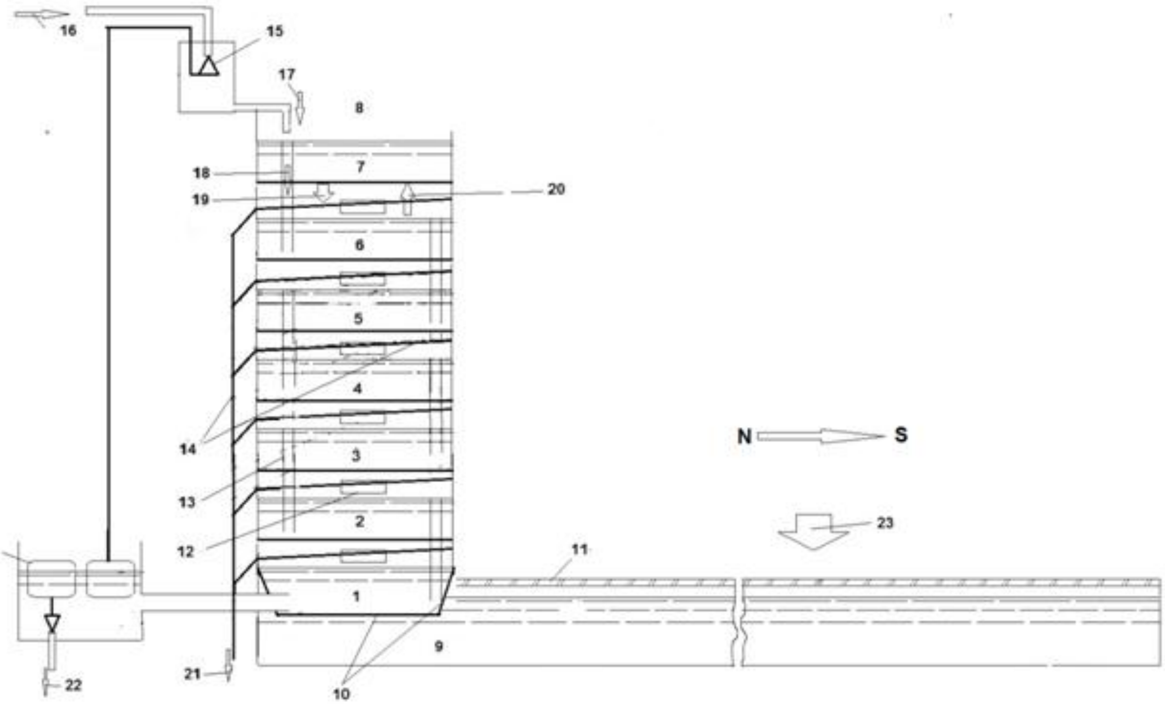


Fig. 1

The molecules that leave the water take away the energy of evaporation from water and, upon condensation, transfer it to the bottom. That is, there is a "heat pipe". Between the water surface of each bath and the bottom of the upper bath there is a device 12 for increasing the efficiency of the "heat pipe" (increasing the productivity of the process).

The water level in the baths within the specified limits (for example, 5 ... 20 mm) is maintained by means of the tubes 13 and the device 15. The device 15 is, for example, a float system that monitors the water level in the lower bath 1 and supplies fresh water to the upper bath 7. The device 14 collects the condensate. The solar irradiation energy heats the water of the collector 9 and through the membrane 10 heats the water of the bath 1. The device 22 (for example, the float valve) opens the drainage of the brine from the bath 1 when the salt concentration in it is increased by 5 ... 10 times.

The arrows in Fig. 1: 16, 17 are fresh initial water, 18 are the water flow between the baths, 19 are condensate drops, 20 are water vapor, 21 is the condensate outlet, 22 is the brine outlet, and 23 is the solar irradiation flux. In the figure, the thermal insulation is not shown.

Figure 1 shows only the device diagram, which gives unlimited scope for a creative approach to design and patent solutions.

The author made the operating model of the evaporator. Figure 2 shows the operating model of the evaporator, demonstrated in the laboratory of prof. Yuri Kolodny in Herzliya (Israel).

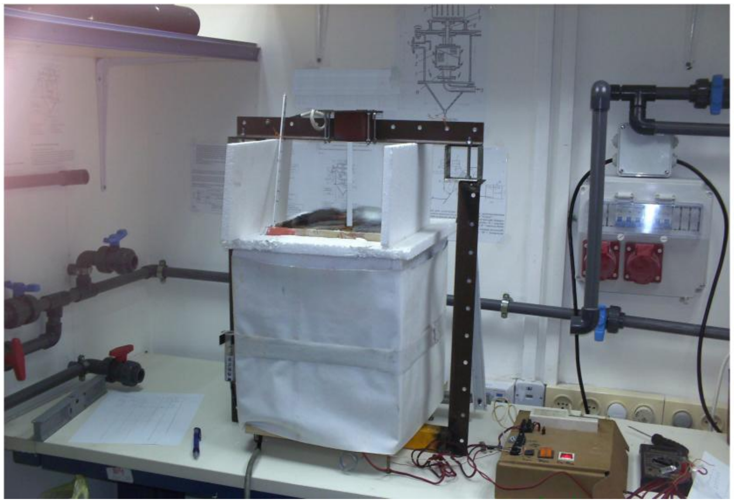


Fig. 2

The author investigated the operating model of the evaporator. In the graph of Fig. 3 shows the thermal resistances R [C^{O} * m^2 / W] measured on the mockup between the surface of the water in the bath and the bottom at the water temperature in the bath t. The temperature difference dt between the water and the bottom was of the order of 10 ° C. The thermal resistance was calculated by the formula R = P / S * dt. . Solar heating of water was simulated by an electric heater in the lower bath. The power P entering the bath water was measured with an electricity meter. The external power consumption for the operation of the device was 10 W / m^2. The graph on Fig.3, of course, is valid only for the used designs of all devices and the applied thermal insulation.

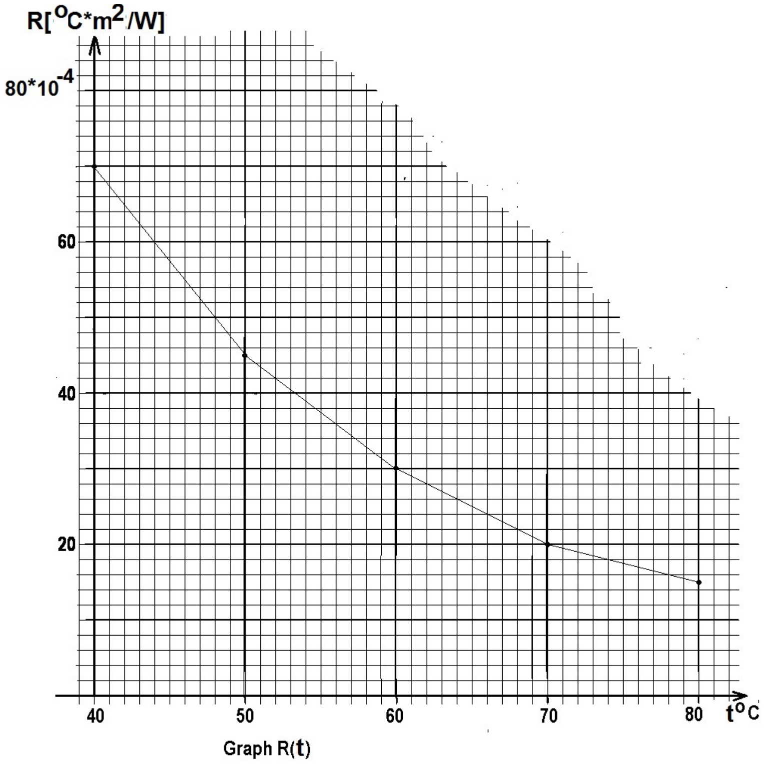


Fig.3

Below, for an example, the calculation of an evaporator having 6 stages of water condensation is given. The calculation is based on the graph of Fig.3. The calculation does not take into account the heat loss through the thermal insulation and loss of vapor through leaks.
We have p1 is the power introduced into the bath number 1. Here p is the power per m^{2} of the surface of the bath water.
We take for the first bath t1 = 80^{O}C, from the graph at temperature t1 = 80^{O}C we have R1 = 15 * 10-4 ^{O}C * m^{2} / W.
We take dt1 = 3.9 ^{O}C. We have on 1 m^{2}:
p1 = dt1 / R1 = 3.9 / 15 * 10-4 = 2600 W / m^{2}. Those, we have 2600 watts of thermal solar energy injected into the water of bath number 1 per 1 m^{2} of water surface.
For 1 hour the energy will be A1 = 2600 * 0.24 * 3600 = 2246 kcal / h * m^{2}. The mass of the condensate will be M1 = A1 / 575 = 2246/575 = 3.9 kg / h * m^{2}. We take that the condensation energy of 1 kg of water is 575 kcal / kg.
For the 2nd bath we have t2 = t1-dt1 = 80-3.9 = 76.1 ° C. From the graph at the temperature t2 = 76 ° C we have R2 = 17 * 10-4 ^{O}C * m^{2} / W, p2 = p1 = 2600 W, dt2 = p2 * R2 / S = p2 * R2 / 1 = 2600 * 17 * 10-4 / 1 = 4.4 ° C. The mass of the condensate will be M2 = M1.
For the third bath we have t3 = t2-dt2 = 76.1-4.4 = 71.7 ° C, from the graph at the temperature t3 = 71.7 ° C we have R3 = 19 * 10-4 ^{O}C * m^{2} / W, p3 = 2600 W, dt3 = p3 * R3 / S = p3 * R3 / 1 = 2600 * 19 * 10-4 / 1 = 4.9 ° C. The mass of the condensate will be M3 = M1.
For the 4th bath we have t4 = t3-dt3 = 71.7-4.9 = 66.8 ^{O}C, from the graph at temperature t4 = 66.8 ^{O}C we have R4 = 21 * 10-4 ^{O}C * m^{2} / W, p4 = 2600 W, dt4 = p4 * R4 / S = p4 * R3 / 1 = 2600 * 21 * 10-4 / 1 = 5.5 ^{O}C. The mass of the condensate will be M4 = M1.
For the 5th bath we have t5 = t4-dt4 = 66.8-5.5 = 61.3 ^{O}C, from the graph at temperature t4 = 61.3 ^{O}C we have R5 = 29 * 10-4 ^{O}C * m^{2} / W, p5 = 2600 W, dt5 = p5 * R5 / S = p5 * R5 / 1 = 2600 * 29 * 10-4 / 1 = 7.5 ° C. The mass of the condensate will be M5 = M1.
For the 6th bath we have t6 = t5-dt5 = 61.3-7.5 = 53.8 ^{O}C, from the graph at the temperature t6 = 53.8 ^{O}C we have R6 = 39 * 10-4 ^{O}C * m^{2} / W, p6 = 2600 W, dt6 = p6 * R6 / S = p6 * R6 / 1 = 2600 * 39 * 10-4 / 1 = 10.1 ° C. The mass of the condensate will be M6 = M1.
For the 7th bath we have t7 = t6-dt6 = 53.8-10.1 = 43.7 ^{O}C, from the graph at the temperature t7 = 43.7 ^{O}C we have R7 = 61 * 10-4 ^{O}C * m^{2} / W, p7 = 2600 W, dt7 = p7 * R7 / 1 = 2600 * 61 * 10-4 / 1 = 15.9 ° C. The mass of the condensate M7 = M1 goes into the ambient air. The ambient air has a temperature t8 = t7-dt7 = 43.7-15.9 = 27.8 ° C.
The sum of the condensate from all the baths will be M = M1 + M2 + M3 + M4 + M5 + M6 = 3.9 * 6 = 23.4 kg / h * m^{2}.
Total we have t1 = 80 ^{O}C, t2 = 76.1, t3 = 71.7, t4 = 66.8, t5 = 61.3, t6 = 53.8, t7 = 43.7, t8 (air) = 27.8 ^{O}C.

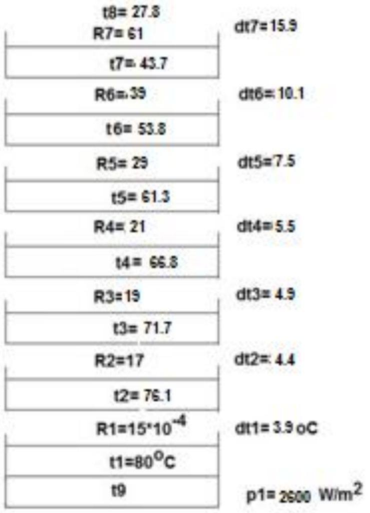


Fig.4

In Fig. 4, all calculated values of temperatures and thermal resistances are shown for clarity. If the ambient temperature is below 27.8 ° C, then the temperature drops dt will be higher and the condensate will be larger, at a water temperature in the lower bath above 80 ° C, then too, the temperature drops will be higher, the condensate will be more.

The calculation of the evaporator, which has 6 stages of water condensation, showed that the evaporator output - the sum of the condensate from all the baths is 23.4 kg / h * m^2.

The external energy consumption is 70 W / m^2 of the bath area, the specific external energy consumption is 3 kWh / ton (=70 W / m^2 / 23.4 kg /h* m^2 =3 Wh / kg). Specific consumption of thermal solar energy is 111 kWh / ton (=2600 W * h / m^2 / 23.4 kg / h * m^2 = 96 kcal / kg).

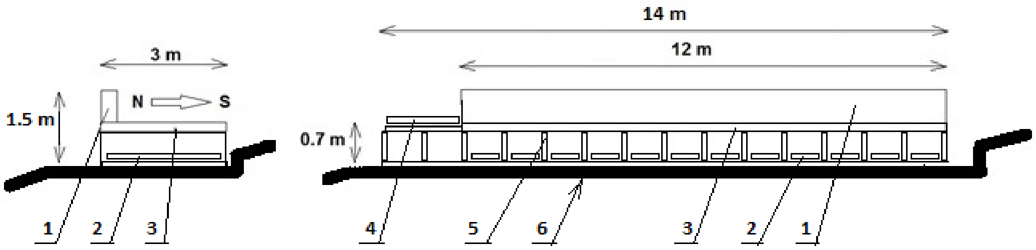
The author also made and explored a model of a flat horizontal solar collector. Such a collector is simpler, it is easier to heat-insulate it. The model had a surface area irradiated by the sun, 0.192 m^2, was installed on the balcony in the author's apartment and was irradiated by the sun for 5 hours 40 minutes (from 14 hours on a June sunny day).

The amount of energy received by the collector was measured by the amount of evaporated water and by the increase in the water temperature. During the entire solar day this energy would be 6 kWh / m^2. Let us assume that in Lod, the energy of solar irradiation in June is the same as at the Dead Sea, i.e. 7.5 kWh / m^2. Perhaps then we had a horizontal collector efficiency of at least 80% (= 6 / 7.5).

The average annual average daily energy in hot countries is 4 ... 6 kWh / m^2. For example, in Israel in the Dead Sea region, the average annual average daily energy is 5 ... 5.5 kWh / m^2. The daily average in January is 2.5 kWh / m^2 and in June 7.5 kWh / m^2 (we mean the surface area of the Earth, that is, the horizontal surface).

It was shown above that the horizontal collector has an efficiency of at least 80%. We assume that the average annual average daily irradiation energy is 5 kWh / m^2. The horizontal collector of 1 m^2 has an average annual average daily power N = 0.43 kW / m^2 (= 5 * 1 * 0.8 / 14 * 2/3). The area of each bath (per 1 m^2 of the collector) is therefore S = N / p1 = 430 W / 2600 W / m^2 = 0.165 m^2.

The condensate mass average annual daily average is M = 36 kg / m^2 of the collector (= 5 kWh / m^2 * 0.8 / 0.111 kWh / kg). To produce 1 ton of condensate per day, collectors are required, with an area of 28 m^2 (= 1000 kg / 36 kg / m^2) and each bath area 5 m^2 (=28*0.165).
The external energy consumption for obtaining 1 ton of condensate is 3 kWh, the power consumption is 350 W (= 70 W / m^2 * 5 m^2). Solar photovoltaic panels have a power of 200 W / m^2, the panel has an area of 2 m^2, i.e. power is 400 watts.
Thus, to get 1 ton of condensate per day, enough one solar photovoltaic panel, collectors of 36 m^2 and a bath of an evaporator of 5 m ^{2} (= 36 m^2 * 0.128). To accommodate these collectors and a solar photovoltaic panel, an area of about 41 m^2 (= 36 + 5 + 2) = 0.000041 km^2 is sufficient.
For example, the scheme of such a block-module is shown in Fig.5. A block of such collectors will produce 360 cubic meters of condensate per year from the territory of 0.000042 km^2, i.e. 8.6 million m^3 / km^2 * year (= 360 / 0.000042= 8.6 m^3 / m^2 * year).



1-evaporaive baths, 2-complete evaporation baths, 3-solar collectors, 4-photovoltaic panels, 5-foam board, 6-ground

Fig. 5

The resulting water is either dew or rainwater, but only cleaner, because do not collect dust and other contaminants from the surrounding atmosphere.
All equipment are powered only from photovoltaic panels. The such a block-module is completely autonomous: the Sun appeared, voltage appeared on the panels, inverters converted the voltage, in the collectors the water under the Sun warmed, the vapor condenses on the bottoms, the condensate flows into the fresh water network. The sun went down, the processes stopped (no batteries needed).

Sources of raw water for processing with the use of solar energy and evaporators for the proposed environmentally friendly technology may be substandard groundwater from wells, salt lakes and seawater. The brine after water treatment is of the order of 10…15%. The brine can be drained to baths for complete evaporation (position 2 on Fig.5) or drained back into the sea (by separate pipes). On the basis of reverse osmosis technology, the brine is 50 ... 100%.
Solar energy is an excellent gift of Nature, but equipment, construction of roads and pipelines networks will naturally require financial investments.

Conclusion

In Israel, despite the nearly 700 million cubic meters of water desalted by reverse osmosis, the use of solar energy to produce fresh water remains relevant for agricultural and industrial enterprises that consume a lot of water. The water received from the energy of the Sun is **cleaner and unlimited!**

Mass use of the proposed technology will give a positive "side effect", because will reduce, and then stop, the withdrawal of water from the Lake Kinneret and from the Jordan River. The restored level of the Lake Kinneret and the full-flowing Jordan River will solve environmental problems and the lakes of the Kinneret and the Dead Sea. The Jordanian kingdom can also use the water of the Red Sea and not use water from the Jordan River.

We hope that there will be a group of enthusiasts who, for the benefit of themselves and countries with a hot climate, as well as Lake Kinneret and the Dead Sea, will create a start-up that will develop the necessary documentation and patents for environmentally friendly solar technology for obtaining fresh water.