

Floating "green" desalination plant

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Abstract

Author proposed to build an autonomous floating desalination plant in the Mediterranean Sea (with a 600 million m³ per year of the fresh water capacity), which uses wave float generators as a green energy source.

State of the art

For many years, scientific, governmental and public organizations in Israel have been working on water balance issues in Israel. Many projects have been proposed and implemented to improve water supply in Israel, and many are currently under consideration. Some of them propose, for example, to build islands in the Mediterranean to house the DU and power plant, or add desalinated water to Lake Kinneret (government agencies are considering this in 2019). [1]

Years without rain and a continuous increase in water consumption in the country's economy demanded that the production of desalinated water be increased to 700 million cubic meters per year. Reverse osmosis desalination plants require coastal areas and electrical power. The cost of electricity mainly determines the price of the received water. Desalination plants consume electricity mainly for the high pressure pumps operation. For some desalination plants, separate thermal power plants are being built using hydrocarbon fuels. Renewable ("green" energy) sources - save hydrocarbon fuels and do not pollute the atmosphere.

Proposal brief description and technical approach

Sea waves Float Generators, located on Mediterranean Sea, will use the sea waves energy directly for water desalination.

Generators consists of reciprocating water pumps that pumping water as the floats move up and down by the waves. Pumps are capable to create water pressure of 2MPa, which is enough for the reverse osmosis filters operation and fresh water poroduction.

Economic sense

Desalination of sea water will be drive by sea waves energy only. That is why the cost of the desalinated water is determined exclusively by the equipment's depreciation, the cost of consumables and labor remuneration. This will bring profit, increase the level of the country's energy supply and increase its defense invulnerability.

Description of the structures that make up the proposed complex

- Description of the wave piston generator

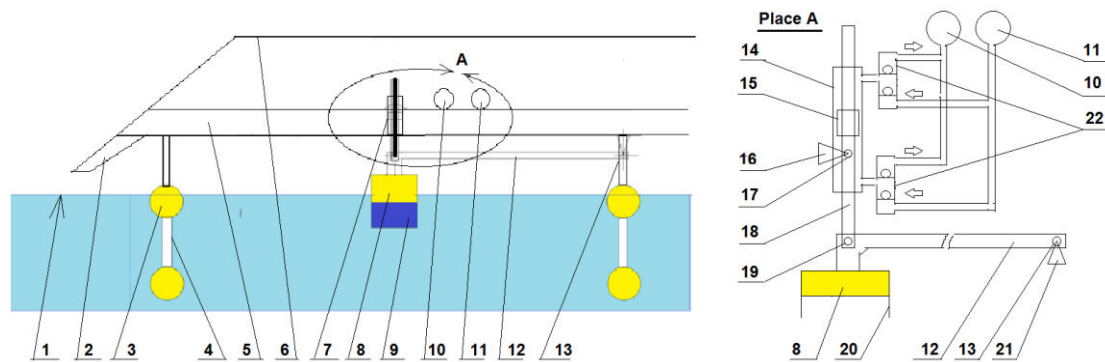


Figure: 1 Diagram of a wave piston generator

Figure 1 shows a schematic of a wave reciprocating power generator that converts wave energy into water energy under high pressure, sufficient for reverse osmosis desalination.

Legend in the diagram Fig. 1: 1- sea level, 2- pontoon visor, 3- farm of pontoon, 4- rack on truss, 5- pontoon deck, 6- pontoon roof, 7- high-pressure piston pump, 8- light filler float, 9- hollow float, 10- high pressure pipeline, 11- low pressure pipeline, 12- float suspension arm, 13- arm support point, 14- pump cylinder, 15- pump piston, 16- pump strut on deck, 17- pump trunnion, 18- pump rod, 19- trunnion on the rod, 20- float body, 21- lever post on deck, 22- check valve.

Wave pumps, valves and piping are located on the deck of the pontoon, not underwater. This arrangement of equipment greatly facilitates the operation of the equipment and its maintenance.

In Fig. 1 we have sea level 1, on the sea surface a hollow float 9 floats and sways on the waves, inside which there is a light filler 8. The hollow float is connected to the rod 18, on which we have a piston 15. The piston moves in the cylinder 14, on the cylinder we have a journal 17, on which the cylinder is mounted on the rack 16. The float is swinging on the lever 12, which is mounted on the post 21. The post 16 and the pivot point of the lever 13 on the post 21 are mounted on the deck 5 of the pontoon. The outlets of the cylinders are connected via check valves 22 to a high-pressure pipeline 10 and to a low-pressure pipeline 11. In pipeline 11, seawater comes from a desalination plant, in which all the stages of conventional preliminary treatment are carried out. From pipeline 10, water flows directly into the reverse osmosis filter.

- Description of the desalination plant

Let us take as a basis the proposed desalination plant, for example, the AIST-100.0 reverse osmosis unit, which has a capacity of $100 \text{ m}^3 / \text{h}$, a nominal input water flow rate of $117 \text{ m}^3 / \text{h}$, an operating pressure of $7 \dots 16 \text{ kg} / \text{cm}^2$ and an installed power of 110 kW . [2] The industry produces several more types of similar desalination plants, for example, PETSEA RO SW-RE or PVO-RO-200.

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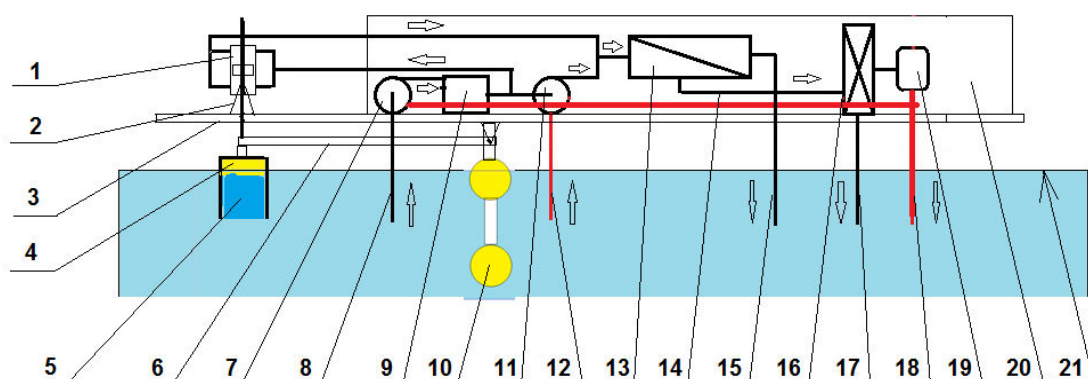


Figure: 2. Wiring diagram of a desalination plant with a piston pump and a float

Legend in the diagram Fig. 2: 1 - wave high pressure piston pump, 2 - pump stand, 3 - pontoon deck, 4 - hollow float, 5 - sea water in the float, 6 - float lever, 7 - low pressure booster pump, 8 - suction line, 9 - equipment for preliminary treatment of source water, 10 - pontoon farm, 11 - high pressure electric pump, 12 - external power supply line for high pressure pump, 13 - reverse osmosis filters, 14 - line of high pressure of concentrate, 15 - desalinated water outlet line, 16 - high pressure turbine, 17 - concentrate discharge line, 18 - power output line, 19 - electric generator, 20 - service rooms on the pontoon, 21 - sea level.

The piston of the high pressure wave pump 1 receives energy from the floats 4, which the waves move up and down. The electric booster pump 7 through the suction line 8 receives seawater and supplies it to the equipment 9 for preliminary preparation of the source water. The treated water enters a high pressure wave piston pump 1 or a high pressure electric pump 11. Water from pumps 1 or 11 is supplied under a pressure of 2 MPa to reverse osmosis filters 13. Desalinated water goes into line 15 and enters the 1st pumping station on the ascending water conduit and to other consumers.

Through line 14, the concentrate comes out of the reverse osmosis filter 13. The concentrate has almost full initial pressure, its amount is approximately equal to 10 ... 20% of the amount of desalinated water in reverse osmosis units AIST-100.0. For energy recuperation, the concentrate transfers energy through a turbine 16 to an electric generator 19. After the turbine, the concentrate is discharged into the sea through line 17. The electric generator 19 feeds the low pressure booster pump 7, as well as other equipment.

For a more rational use of desalination equipment at low wave heights, the high-pressure electric pump 11 can receive energy from the country's electricity grid. Desalinated water produced by the power of the network goes to the country's economy. The power consumption from the network is about 1 kWh / m³ of desalinated water.

The floating power truss of the pontoon is made, for example, of steel pipes (see Fig. 4), the pipes are filled with a light material such as expanded polyethylene to obtain the buoyancy of the pontoon. The steel truss is strong enough to withstand storm loads. On the pontoon, visor 3 is 0.6 m above the water level, so that waves above 1.2 m run onto the pontoon roof and penetrate under the pontoon minimally.

Pontoons are installed at a distance of 500 ... 1000 m from the coast. The relative position of the pontoons is shown in Fig. 6. To protect the coast and pontoons from storm waves and winds, separate structures are required, which are not considered in this article.

The distance between the rows of floats is 15 m so that the rows have minimal influence on each other. Each float takes a volume of 0.25 m^3 ($= 0.125 \text{ m} * 2 \text{ m}^2$) from each wave with a height of more than 0.25 m. These 250 liters spread over a surface area of 45 m^2 ($= 1.5 \text{ m} * 30 \text{ m}$) in a layer 0.000555 m thick ($= 0.25 \text{ m}^3 / 45 \text{ m}^2$), i.e. at a distance of 15 m from the float in the adjacent row, the water level changes by only 0.6 mm.

- Energy indicators

In the Mediterranean Sea near the coast of Israel, the wave height reaches 1.5 m in non-stormy weather, but during a storm it can be 3 m, and waves up to 6.5 m are noted. For our Mediterranean coast, it can be taken for energy calculations that the average annual wave height is 0.8 m.

In this proposal, we propose to use a wave piston pump with a piston stroke of 1.2 m. At higher wave heights, the water flow is limited by the piston stroke.

Let us consider what water flow rate can be obtained with a wave with a height of $H = 0.8 \text{ m}$. For such a wave with a wind speed of at least 5 m/s , the period t is no more than 4 s, according to the graph in [3].

For the operation of the reverse osmosis desalination plant AIST-100.0, the pump delivers source water under a pressure of $P = 2 \text{ MPa}$. We assume that the rectangular float has an area of 2 m^2 . When the wave descends, the floats also descend. When the wave descends, the floats begin to descend only after a height of 0.125 m below the top of the wave, because piston locked with check valves. In this case, the downward movement begins when the force on the piston and the weight of the water in the hollow float are balanced. This mass of water in a hollow float is $b = 0.125 * S * \rho = 0.125 * 2 * 1000 = 250 \text{ kg}$, presses on the rod with a force of $B = 2500 \text{ N}$ and supplies the initial water under a pressure of $P = 2 \text{ MPa}$. At a distance of 0.125 m from the base of the wave, the floats do not move further downward, because the piston is again locked with a non-return valve. The float stroke is $H_1 = H - 0.125 \text{ m} = 0.8 - 0.125 = 0.55 \text{ m}$.

The mass of water in the hollow float $b = 250 \text{ kg}$ generates energy $A = b * H_1$. This energy is received through the piston to water $A = P * s * H_1 = B * H_1 = 2500 * 0.55 = 1375 \text{ J}$. The pump piston has an area of $s = B / P = 2500 / 200000 = 12.5 \text{ cm}^2$. At a wave height of 0.25 m (or less), the H_1 piston stroke becomes zero and the water supply stops.

The flow rate of water during the downward movement of the piston in half the cycle $t_1 = t / 2 = 2 \text{ seconds}$ is equal to $q / 2 = s * H_1 / t_1 = 12.5 * 10^{-4} * 0.55 / 2 = 0.000344 \text{ m}^3 / \text{s}$. The floats and the piston give the same flow rate both during the rise and fall of the wave, therefore the water flow per cycle $t = 4 \text{ s}$ (during the rise and fall of the wave) is $q = 2 * 0.000344 \text{ m}^3 / \text{s} = 0.000688 \text{ m}^3 / \text{s}$.

The power generated by the pump in each stroke is $N [\text{W}] = g * \rho [\text{kg} / \text{m}^3] * q [\text{m}^3 / \text{s}] * H [\text{m}] = 9.81 * 1000 * 0.000688 * 200 = 1350 \text{ W}$. Here ρ is the density of water, H is the head $2 \text{ MPa} = 200 \text{ m}$. The float through the pump piston gives off 1.35 kW in the form of feed water with a pressure of 2 MPa and a flow rate of $0.000688 \text{ m}^3 / \text{s} = 688 \text{ ml} / \text{s}$ at a wave height of 0.8 m. In an hour we have source water (under a pressure of 2 MPa) $2.48 \text{ m}^3 / \text{h}$ ($= 0.000688 * 3600$), 59.4 m^3 per day ($= 0.612 * 24$), and $59.4 * 365 = 21700 \text{ m}^3$ per year from each float.

All water entering the wave pumps is supplied by booster pumps and is pretreated.

- Overall performance of the pontoons.

With an average sea state and wave height $H = 0.8$ m, we have the productivity of the 1st float $2.48 \text{ m}^3 / \text{h}$ ($= 21700 \text{ m}^3$ per year) of the initial input water for desalination.

In the AIST-100.0 reverse osmosis desalination plant adopted as a basis, we have a capacity of $100 \text{ m}^3 / \text{h}$ and a nominal flow rate of inlet water of $117 \text{ m}^3 / \text{h}$.

We propose to install 400 floats on 1 pontoon, it will be $1000 \text{ m}^3 / \text{h}$ ($= 2.5 * 400$) initial, i.e. input water. The total productivity of desalinated water on 1 pontoon will be $855 \text{ m}^3 / \text{h}$ ($= 1000 * 100/117$). The average performance of one pontoon per year will be amount to 7.5 million m^3 ($= 855 * 24 * 365$) of desalinated water.

The pontoon must have at least 10 installations similar to the AIST-100.0 ($= 1000/117$). The dimensions of the unit are $600 \times 4500 \times 2000$. [2] For 10 the installations an area of no more than 100 m^2 is required. The area of the pontoon deck is not less than 7000 m^2 . When the sea is rough with a wave height of less than 0.8 m, for part of the desalination modules (out of 10), the water from the wave pumps will not be enough. In this case, the modules begin to receive water from the high-pressure electric pump at the expense of the network energy. The energy consumption of the modules is about $1 \text{ kWh} / \text{m}^3$. Desalinated water, obtained from the network energy, becomes an energy storage for the network, because through the ascending conduit it enters the energy storage device - the upper reservoir. See Fig. 8.

When the sea is rough with a wave height of 1.2 m and more, the pump capacity will be one and a half times higher than with a wave of 0.8 m and will be $1500 \text{ m}^3 / \text{h}$ (limited by the piston stroke). To use this excess water of $500 \text{ m}^3 / \text{h}$ obtained on the pontoon from the pumps, it is sent to high-pressure turbines 17 and through the generator 19 the resulting electricity is returned to the network. The excess water flow through the turbines is $0.139 \text{ m}^3 / \text{s}$ ($= 500/3600$). Pontoon generators in total have a capacity of up to 237 kW: $N [\text{W}] = g * p [\text{kg} / \text{m}^3] * q [\text{m}^3 / \text{s}] * H [\text{m}] * k = 9.81 * 1000 * 0.139 * 200 * 0.87 = 237 \text{ kW}$. The amount of energy transmitted to the network is determined by the duration of waves with a height of more than 0.8 m. Desalinated water obtained in the desalination plant both from the energy of the waves and from the energy of the network is used for supply to the pumped storage complex. For example, 80 pontoons each with 400 floats give 600 million m^3 of water per year ($= 7.5 * 80$).

Each pontoon is independent from the others and can be installed anywhere in the sea, near any shore and supply it with desalinated water. Pontoons take energy from waves and protect the shores from wave destruction. Because the pontoons are the floating structure, then they cannot have a negative impact on marine life and other environmental processes and issues. The brine after desalination must be returned to the sea in accordance with the standards for operating desalination plants.

To locate the proposed desalination plants at sea, an area of, for example, 0.2 km by 10 km is required. Israel's coastline is 165 km. The desalination plants are completely autonomous and have their own rather powerful source of "renewable" electricity.

Their performance is determined by the wave height and the capabilities of the equipment used. To protect against storm effects and destruction, devices that are not considered in this article should be used.

- Economic indicators of desalination

Estimated cost of the necessary equipment for 1 pontoon:

- A modular seawater desalination unit of the AIST-100.0 type costs 26 million rubles, i.e. \$ 350,000 ($= 26,000,000 / 80$), 10 modules cost \$ 3,500,000. [2]
- Piston pumps 400 units cost \$ 80,000.
- Steel pipes of different diameters 3 km cost \$ 300,000 ($= 100 \$ / m * 3,000 m$) [4]
- The volume and mass of polyethylene foam - we can use polyethylene foam with a mass of 35 kg / m³ and a volume of 180 m³, for 1 pontoon we have 6,000 kg, cost \$ 6,000.

The total cost of equipment for 1 pontoon is about \$ 4,000,000, and 80 pontoons cost \$ 320,000,000.

- The cost of the rest of the equipment and labor costs for the construction of a floating desalination plant were not considered here due to the lack of reliable information at the authors.

The costs of construction and equipment of desalination plants in world practice are relative to the annual productivity, for example,

- in Oman 2.4 \$ / m³ * year [5],
- in Iran 2.5 \$ / m³ * year [6],
- in Crimea 6 \$ / m³ * year [7].

In our case (based on the average sea state), the cost of equipping desalination plants on pontoons is no more than 0.6 \$ / m³ * year ($= 320,000,000 / 600,000,000$), i.e. significantly lower than in world practice.

The cost of electricity mainly determines the cost of routine maintenance of installations. Floating "green" desalination plants are powered by sea waves only, so there are no electricity bills.

For desalination plants on pontoons, coastal areas and the construction of large capital structures are not needed.

The tariff for water for consumers is 6 ... 9 shekels per cubic meter of water. In a year, 80 pontoons will produce 600 million m³ of desalinated water (based on average sea waves), which costs 3,000 ... 5,000 million shekels, i.e. about \$ 1,000,000,000.

Conclusion

Send this proposal to the Minister of Energy for consideration by the Ministry's specialists and holding tenders between companies for the construction of the proposed facilities.

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