

Survey of Solar Desalination Systems and System Selection

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September 21, 2017

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Abstract

Fresh water sources have significantly decreased since rapid industrialization, and the most practiced form for increasing fresh water supply is desalination. Desalination is the separation of the high quantities of salt and water, creating a new source of fresh water, but the necessary amounts of energy to conduct the process is high. Solar desalination is one of the ways to combat the extremely high burning of fossil fuels needed to conduct desalination, however solar desalination does not produce significantly high volumes of fresh water per day. There are two techniques: phase change using thermal processes, or membrane processes. Solar energy can be applied indirectly, using two sub-systems for energy collection and desalination, or directly, by using the solar energy to conduct a phase change. Factors have been added to direct processes to increase productivity, including dyeing the water black to attract more sun rays, adding charcoal to the edge of the water to reduce thermal inertia. Direct processes uses solar stills, which are expensive and not logical to use in underdeveloped countries, so researches have tried using plastic, instead of glass stills, to capture solar energy and make the stills more cost efficient. They have a shorter life span however, so finding a balance between cost effectiveness and longevity is a constant struggle in the construction and usage of solar stills. There are many types of indirect processes for solar desalination: multi-stage flash process, multiple-effect boiling process, vapor compression process, reverse osmosis, and electrodialysis. When considering which process will best suit the needs of each situation, designers must consider suitability, effectiveness, the range of applicability, seawater treatments, land, and cost.

Materials and Methods

Direct collection processes include a basin full of seawater and a glass roof overhead. Sun rays penetrate the glass and evaporate the water within the basin, while blocking infrared radiation from the water and causing the greenhouse effect. The evaporated water then condenses on the v-shaped glass roof and slides down the sides, where the droplets drip into fresh water basins, effectively separating the salt from the fresh water. These basins must be flushed recently, almost every day, to prevent salt water precipitation.

Indirect Collection:

Multi-stage flash: seawater flows through a heat-rejection area, where the temperature of the water and brine is lowered to the lowest level. The water is then mixed with a large basin of water, where it travels through heat exchangers to heat it to close to saturation temperature, then the water travels to another basin and the temperature is reduced. Due to the near saturation level, the water changes to steam and passes through a filter, where the brine is caught and then the process is repeated.

A multiple-effect boiling process uses steam to heat fluid and then while the vapor is condensing, evaporation of the seawater occurs. A similar process takes place here, where the water passes through a series of heaters, then is passed into a section, raising the temperature to almost saturation level. As the brine and water pass through the system, both “flash” due to differences in pressure.

Vapour compression: compressors are used to increase steam pressure to provide energy. As the vapor passes through different stages, or effects, it is used to heat more vapor, that will then pass through another compressor to reach saturation temperatures. The compressor acts as

the general energy source and the latent heat is recycled. This process has not been proven efficient unless modifications are made, or it is combined with other processes.

Analysis

Tables

Phase-change processes	Membrane processes
1. Multi-stage flash (MSF) 2. Multiple effect boiling (MEB) 3. Vapour compression (VC) 4. Freezing 5. Solar stills —conventional stills —special stills —wick-type stills —multiple-wick-type stills	1. Reverse osmosis (RO) —RO without energy recovery —RO with energy recovery (ER-RO) 2. Electrodialysis (ED)

Table 1: This table shows the difference desalination methods.

Process	Heat input (kJ/kg of product)	Mechanical power input (kWh/m ³ of product)	Prime energy consumption (kJ/kg of product)
MSF	294	3.7	338.4
MEB	123	2.2	149.4
VC	—	16	192
RO	—	12	144
ER-RO	—	7.9	94.8
ED	—	12	144
Solar still	2330	0.3	2333.6

Note: Assumed conversion efficiency of electricity generation of 30%.

Table 2: This table shows the energy consumption of desalination systems.

ITEM	MSF	MEB	VC	RO	Solar still
Scale of application	Medium-large	Small-medium	Small	Small-large	Small
Sea water treatment	Scale inhibitor Anti foam chemical	Scale inhibitor	Scale inhibitor	Sterilizer Coagulant Acid Deoxidiser	—
Equipment price (C£/m ³) (1993 prices)	1200-2000	1250-1900	1800-2900	2000-2550 Membrane replacement every 3-4 years	900-1000

Table 3: This table depicts the comparison of desalination plants.

Table 1 pertains to the article as it presenting the different methods of distillation before going into the actual study of them. This pertains to our project as we need to decide which process we are going to use, so it is helpful to know what options there are. Table 2 pertains to the article as it gives some general information on the energy consumption on the different desalination systems. This is relevant to our project since we want to pick the most efficient method, and the amount of energy that is required will be a major factor in which one we choose. If it requires a lot of energy, then it will probably not be a good method to go with. Table 3 pertains to the article as it seeks to compare the different desalination systems. This is helpful for our project because we can see the strengths and weaknesses of the different desalination methods.

Figures

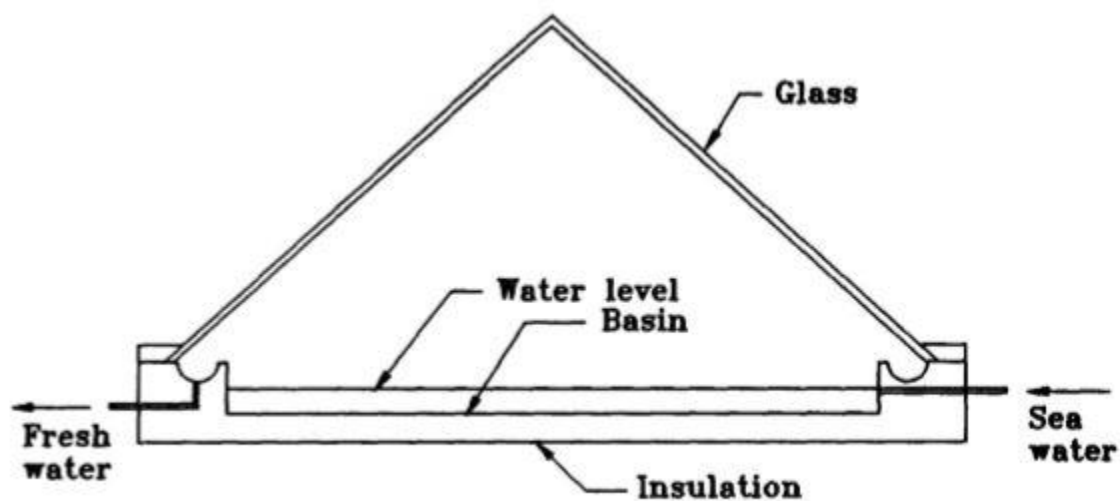


Fig. 1. Schematic of a solar still.

Figure 1: This figure depicts one of the many design implementing the desalination processes, using the greenhouse effect, known as a solar still.

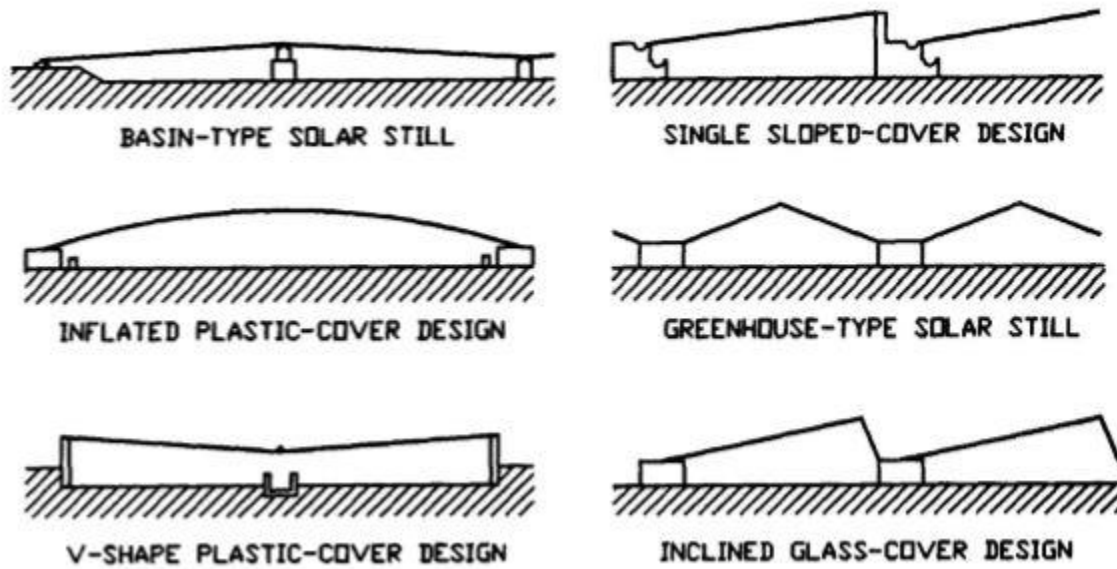


Figure 2: This figure depicts common designs of solar stills.

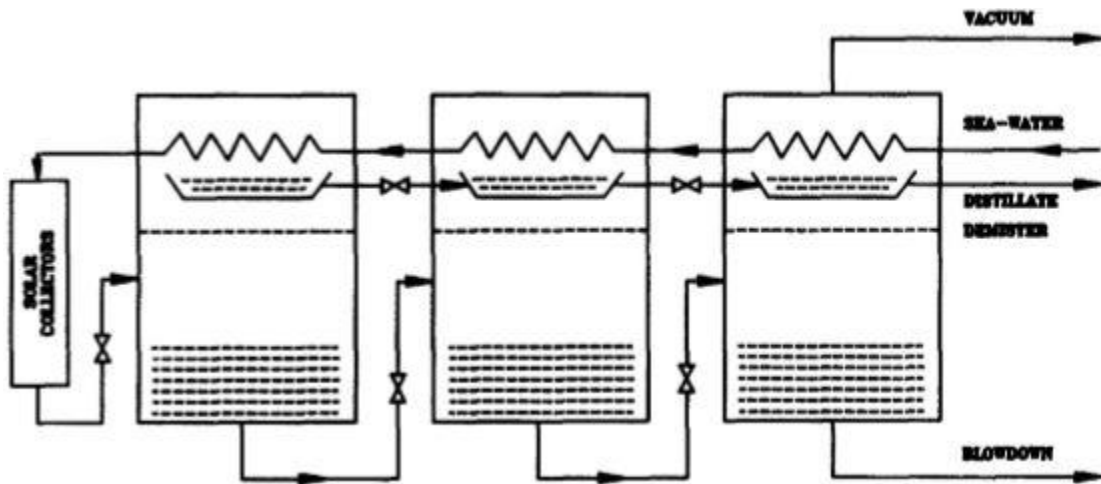


Figure 3: This figure shows the principle of operation of the multi-stage flash system.

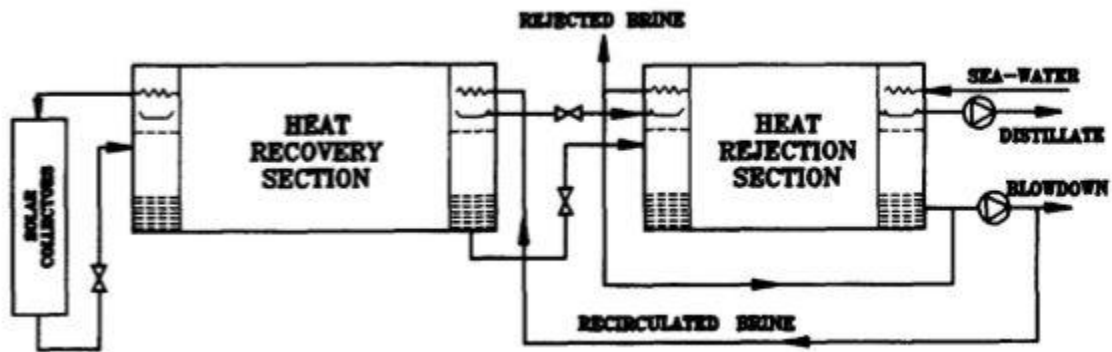


Figure 4: This figure depicts the multi-stage flash plant process.

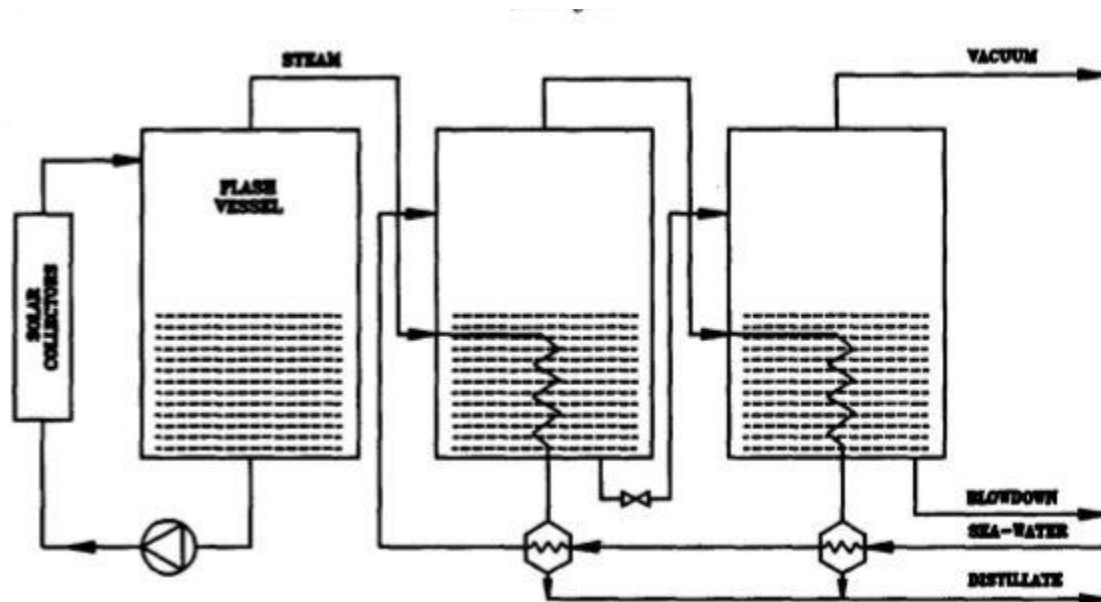


Figure 5: This figure shows the principle of operation of a multi-effect boiling system.

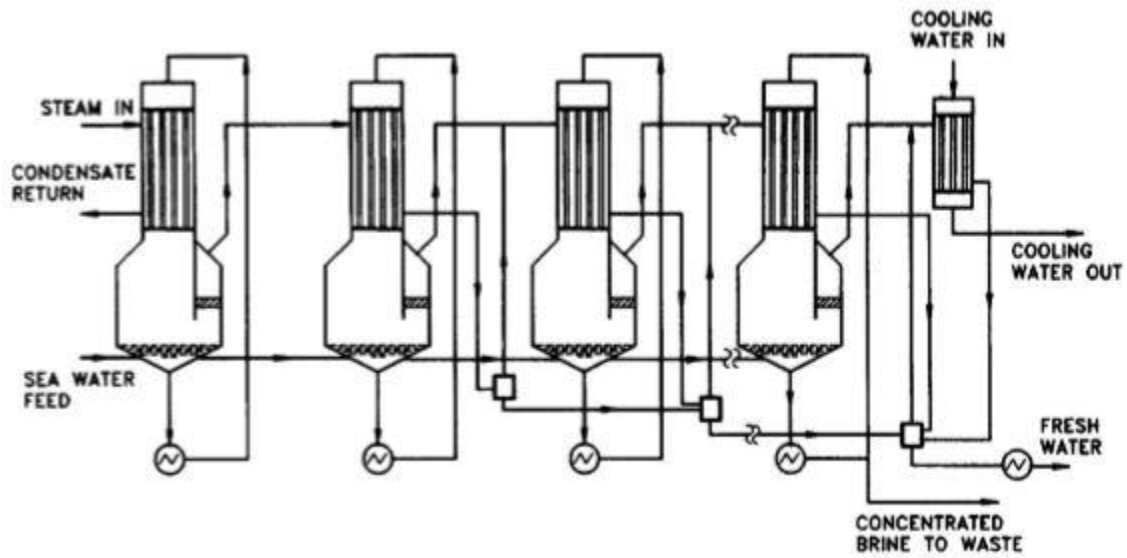


Figure 6: The figure above depicts long tube vertical multi-effect boiling system.

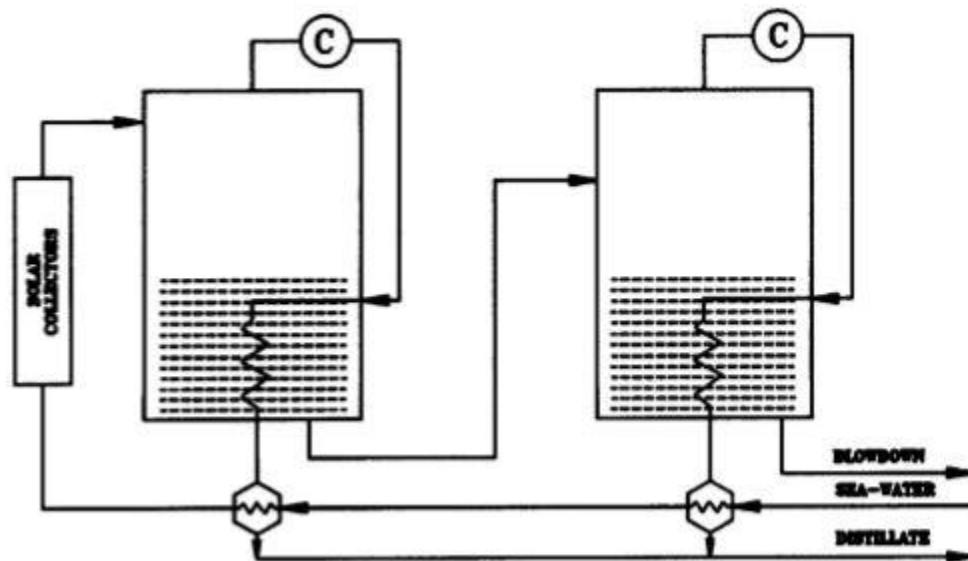


Figure 7: This figure shows the principle of operation of a vapour-compression system.

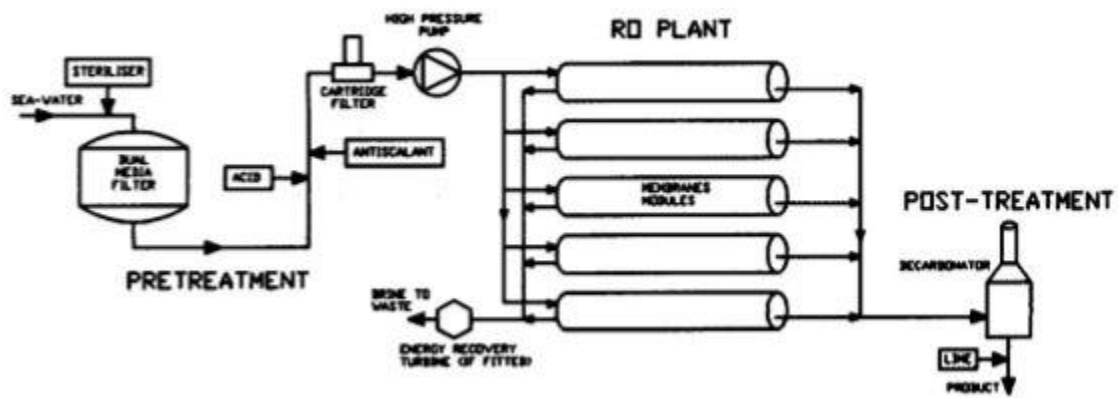


Figure 8: This figure depicts the principle of operation of a reverse osmosis system.

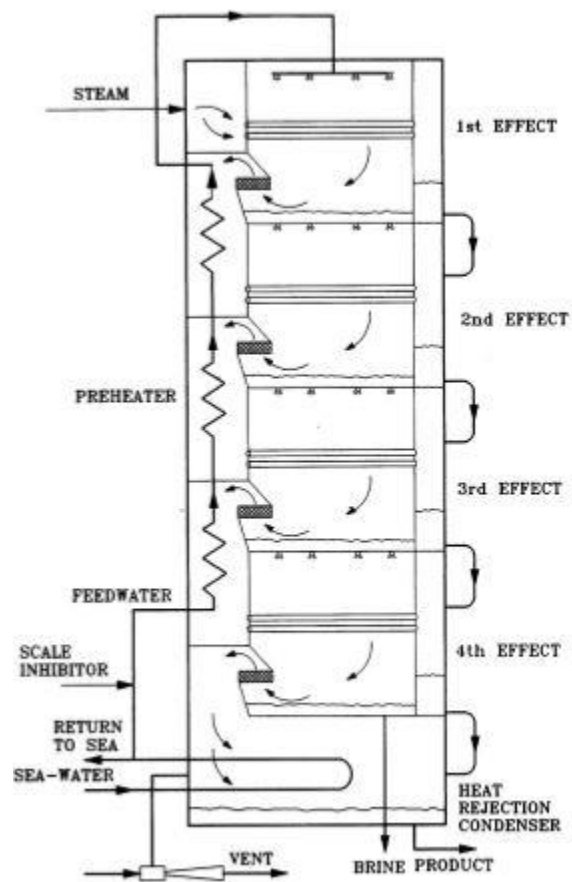


Figure 9: The figure above shows the schematic of the multiple effect stack evaporator.

Figure 1 pertains to the article as it shows a basic design of a desalination system, known as a solar still. This is relevant to our project as we need to get an idea how different desalination systems are constructed, and we could use it as inspiration for our own design. Figure 2 pertains to the article as it expands on the basic design of the solar still and shows the different designs that have been done so far to run the process of desalination. These will prove useful in our project as we need inspiration for the design we will be making, so these are a good starting point of some we might be interested in trying. Figure 3 shows the multi-stage flash process of distillation. This pertains to the article as the theme of the article is analyzing different distillation processes and designs, and this is one of multiple complex designs. This is relevant to our project because we want to make an effective, but not too complex of a distiller. This gives us some understanding of what an intense but efficient desalinators look like. Figure 4 shows the actual process of a multi-stage flash plant. This is relevant to the article as it follows the idea of the construction of the plant and goes into more detail about how it actually functions. This gives us an idea about how a multi-stage flash plant works and what components we would need to get it to operate correctly. Figure 5 is relevant to the article as it introduces the operation of a multi-effect boiling system to the readers. This will be helpful for our project as it gives us yet another option to distill unclean water. Figure 6 is relevant to the article as it presents yet another way of desalination to the readers. This pertains to our project as we can use this for more inspiration for our design of a distillation system. Figure 7 pertains to the article depicts the principle of operation of a vapour compression system and helps the reader understand how this desalination system works. This will prove to be helpful for our project as we are trying to do something similar by condensing the water vapour from boiling water. Figure 8 has to do with the article since it presents the principle of a reverse osmosis system, another desalination plant. This can

be useful information for our project because we can take some of the concepts in this design and include them in the system we will be constructing. Lastly, Figure 9 is important to the article as it shows the schematic of the multiple effect stack evaporator and helps the reader understand this process. This pertains to our project as we can use the image that is given to help us figure out how to implement a similar process in our distillation system.

References

- Kalogirou, S. (1997). Survey of Solar Desalination Systems and System Selection. *Fuel and Energy Abstracts*. Retrieved September 20, 2017, from <http://www.sciencedirect.com/science/article/pii/S0360544296001004>.