DESIGN AND FABRICATION OF SOLAR DESALINATION WATER SYSTEM

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ABSTRACT

Extracting fresh water from seawater requires a great deal of energy, both thermal and mechanical. Renewable energy driven desalination is becoming more viable because it employs free natural energy sources and releases no harmful effluents to the environment. Solar radiation is usually chosen over other renewable energy sources because its thermal energy can be directly applied to drive desalination systems without the inevitable energy loss associated with energy conversion according to second law of thermodynamics. Solar desalination system is classified into direct and indirect process. In this work study Direct Method is used to purify and collect fresh water. Conventional Direct desalination method has been altered and different changes are done in the system. Here Stepped type solar still is used to achieve maximum efficiency of the system. Vacuum Pump is incorporated in the system to decrease and maintain the vapor pressure of the steam in the container so that evaporating temperature is also decreased which results in increase in evaporation rate.

Keywords: Solar radiation, Stepped type, Vacuum Pump, Solar Still.

1. INTRODUCTION

1.1 What is desalination process?

Desalination is a process that takes away mineral components from saline water. More generally Desalination refers to the removal of salts and minerals from a target substance. Salt water is desalinated to produce water suitable for human consumption or irrigation.

Desalination is used on many seagoing ships and submarines. According to the International Desalination Association, in June 2015, 18,426 desalination plants operated worldwide, producing 86.8 million cubic meters per day, providing water for 300 million people. This number increased from 78.4 million cubic meters in 2013, a 10.71% increase in 2 years.

1.2Types of Desalination:

(i) Direct Method
(ii) Indirect Method

(i) Direct Method:
In the direct method, a solar collector is coupled with a distilling mechanism and the process is carried out in one simple cycle. Solar Stills of this type are described in survival guides, provided in marine survival kits, and employed in many small desalination and distillation plants. Water production by direct method solar distillation is proportional to the area of the solar surface and incidence angle and has an average estimated value of 3-4 L/m^2/day.

(ii) Indirect Method
Indirect solar desalination employs two separate systems; a solar collection array, consisting of photovoltaic and/or fluid based thermal collectors, and a separate conventional desalination plant.

Production by indirect method is dependent on the efficiency of the plant and the cost per unit produced is generally reduced by an increase in scale. Many different plant arrangements have been theoretically analyzed, experimentally tested and in some cases installed. They include but are not limited to multiple-effect humidification (MEH), multi-stage flash distillation (MSF), multiple-effect distillation (MED), multiple-effect boiling (MEB), humidification.

1.3 What is the difference between 'Distillation' & 'Desalination'?

The difference between 'Distillation' and 'Desalination' is distillation is the action of separating a solution by heating or cooling and desalination is the removal of salt from salt water. That is the difference between distillation and desalination.

There is a significant similarity between the two, distillation involves heating the water so that only the pure water can be evaporated as steam hence leaving behind the solute. On the other hand, "desalination" can also be gotten from distillation in the sense that a salty water can also be heated to be distilled leaving behind the salt as a solute Distillation is the whole process whereas Desalination is the sub branch of the distillation process.

2. PROBLEM DEFINITION

Small desalination system using direct method are less efficient and unable to purify and collect pure water needed in particular area or place where it is placed. Direct method driven desalination plants requires more energy and result of water collection is not up to the mark.

3. OBJECTIVE

- To decrease the boiling point of water by incorporating vacuum pump in the system which will eventually result in increase of evaporating rate of water and increase the water collection in less amount of time.
- To make the system frugal and portable so that it can be transported and placed to remote places where there is scarcity of drinkable water.

4. COMPONENTS

The components used in the system are: -

(i) 12V Battery

- An battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smartphones, and electric cars.
- Here a Vacuum diaphragm pump is operated by a 12V battery.

(ii) Solar Still

- A solar still distills water, using the heat of the Sun to evaporate water so that it may be cooled and collected, thereby purifying it. They are used in areas where drinking water is unavailable, so that clean water is obtained from dirty water or from plants by exposing them to sunlight.
- There are many types of solar still, including large scale concentrated solar stills and condensation traps (better known as moisture traps amongst survivalists). In a solar still, impure water is contained outside the collector, where it is evaporated by sunlight shining through clear plastic or glass. The pure water vapor condenses on the cool inside surface and drips down, where it is collected and removed.
- Distillation replicates the way nature makes rain. The sun's energy heats water to the point of evaporation.
- As the water evaporates, water vapor rises, condensing into water again as it cools and can then be collected
- This process leaves behind impurities, such as salts and heavy metals, and eliminates microbiological organisms. The end result is pure distilled water.

(iii) Water Cooled Condenser

- A water-cooled condenser is a heat exchanger that removes heat from refrigerant vapor and transfers it to the water running through it. Having the refrigerant vapor condensed on the outside of a tube does this. In doing so, the vapor condenses and gives up heat to the water running inside the tube.
- Here the steam sucked by the vacuum pump is passed onto to the condenser and then water is condensed, pure water is collected.

(iv) Vacuum Pump

- Pump, a device that expends energy in order to raise, transport, or compress fluids.
- We have used a Vacuum diaphragm pump
- It performs 2 functions i.e.
- reduce the vapor pressure in the system and maintain pressure of 0.2-0.3 bar in the system which yields in decrease in boiling point of water according to the steam table.
- To Suck vapor produced in the system and supply it to the condenser for condensation.

(v) Thermocouple

- thermocouple is an electrical device consisting of two dissimilar electrical conductors forming electrical junctions at different temperatures.
- A thermocouple produces a temperature dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature.
- Thermocouples are a widely used type of temperature sensor.

(vi) Absorber Plate

- The absorber plate is the main element of a flat-plate collector. It covers the full aperture area of the collector and is usually made out of metal materials such as copper, steel or aluminum which have a high thermal conductivity.
- The absorber plate is usually a black surfaces demonstrate a particularly high degree of sunlight absorption. It's purposes are:-

(i) To take up the maximum possible amount of the solar irradiance , which means it should have high absorptivity. The absorptance value depends upon the material.

(ii) To conduct heat into the working fluid with a minimum temperature difference, which means it should exhibit high thermal conductivity.

(iii) To lose a minimum amount of heat back to the surroundings . This loss mechanism is a function of the emittance of the surface.

(vii) Stepped basin

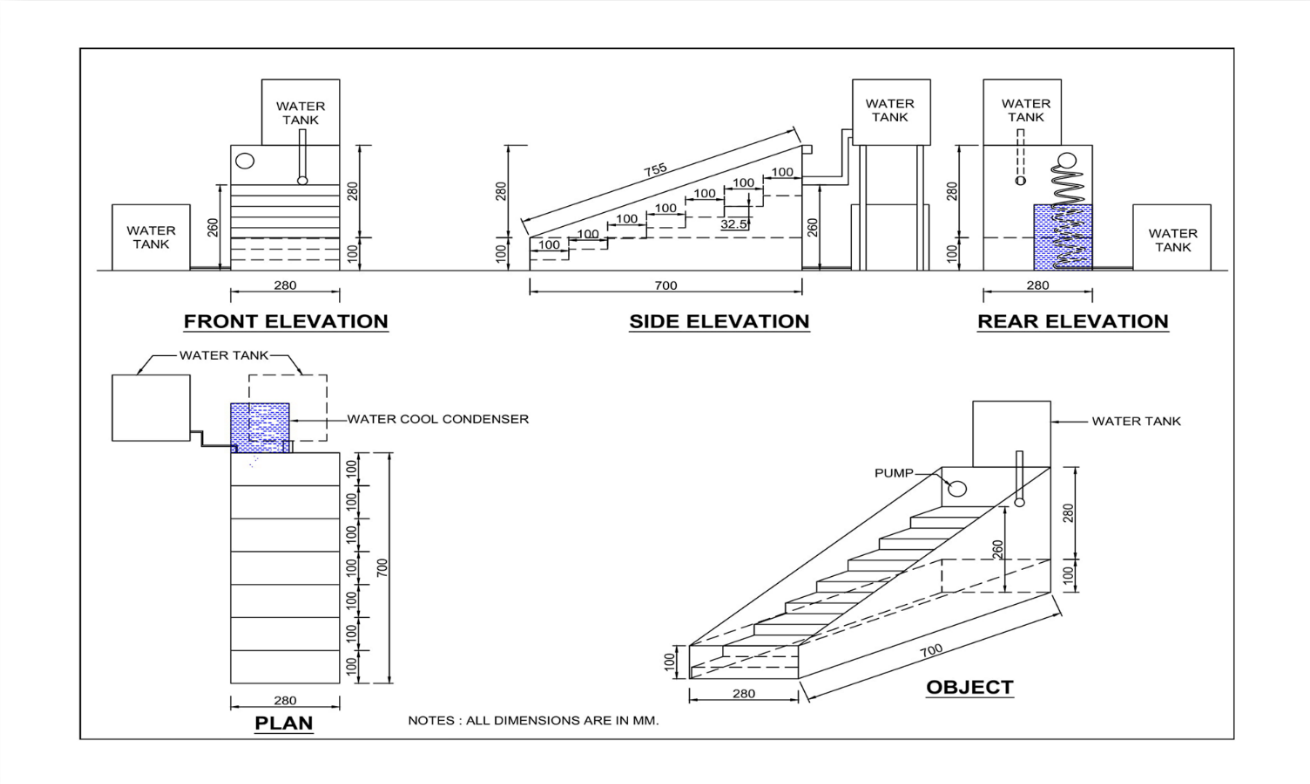
- It is the constructional setup that has been used in our system
- It is in the form of steps of equal sizes acting as an absorber plate.
- Its function is to provide surface area for water so that it can be evaporated with greater ease.

5. WORKING

As the solar desalination plant by direct method concentrates the solar heat in the system by the help of solar stills, the temperature starts to increase inside the system. Here the water is exposed to a considerably large surface area so that it can absorb heat with ease As this happens, water will start evaporating at 100°C at atmospheric pressure but to increase the efficiency of the system we have decreased the system pressure to 0.2 bar and therefore it brings the absolute boiling point of the water down to 60.9°C and therefore the water evaporation rate increases. Then the evaporated vapor is collected into the condenser and cooled down to get fresh potable water.

6. DESIGN

- Design has been made in Auto-cad. Proper dimension are taken to achieve maximum efficiency in the system
- The length to breadth dimension ratio is kept at 1:4 to achieve maximum result.
- Solar still inclination angle is kept at 22 degree to achieve optimum efficiency of the still.
- In the system total there are 7 steps in which water is poured also in each step 3cm depth of water is maintained to achieve maximum result.



7. CALCULATION AND OBSERVATION TABLE:

7.1 Nomenclature.

- **A_w = Area(m^2)**
- **(M_w)=Mass of water(kg)**
- **L=Latent heat of water**
- **Q_{cw-g} = convective heat from water to glass(W/m^2)**
- **h_{cw-g} = convective heat transfer coefficient between water glass**
- **T_w = Water temperature(°C)**
- **T_g= glass temperature(°C)**
- **P_W= pressure of steam at water temperature(Pa)(taken from steam Table)**
- **P_{g-} = pressure of steam at glass temperature(Pa)(Taken from steam Table)**
- **h_{ew} = Evaporative heat transfer coefficient between water and glass**
- **I(t)= solar irradiation(W/m^2)**
- **Solar still inclination = 22°**
- **1.)MASS OF DISTILLED WATER (M_w)= Q_{cw-g} /L**
- **2.)$Q_{cw-g} = h_{cw-g} A_w(T_w-T_g)$**
- **3.)h_{cw-g} =0.884 $\{ (T_w-T_g)+[(p_w-p_g)(Tw+273.15)]/ (268.9*10^3-P_w) \}^{1\backslash 3}$**

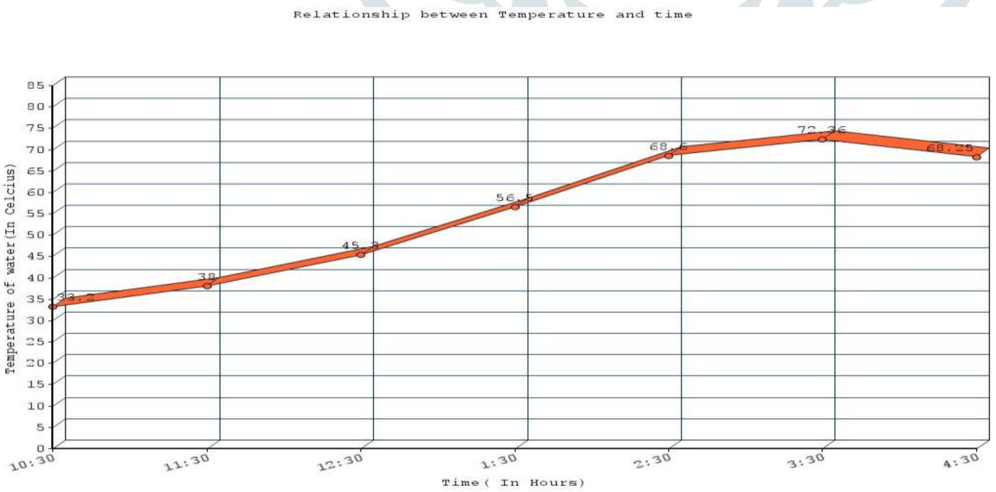
- **4.)** $h_{ew} = [(16.273*10^{-3})\ h_{cw}\ (p_w - p_g)]/T_w$
- **5.)The thermal instantaneous efficiency and performance of solar still is given as**
- $\eta_i = q/\ I(t)$
- $h_{ew}\ (Tw-T_g)/\ I(t)$**………………………..(1)**

Which is the ratio of evaporative heat transfer rate from water surface to glass cover in W/m² to the instantaneous solar radiation intensity (I(t)) in W/m² . In the equation h_{ew} is the evaporative heat transfer coefficient, T_w and T_g are the average water temperature, and the average glass temperature respectively.

7.2 Observation Table.

DATE: 29TH MAR							
WATER IN SYSTEM:2.02 Litres							
SALT COMPOSITION IN WATER: 70 gms							
hew = Evaporative heat transfer coefficient between water and glass, hcw-g = convective heat transfer coefficient between water glass							
Qcw-g = convective heat from water to glass(W/m2), ηi (Efficiency)= q/ I(t)							
TIME	**TEMPERATURE OF WATER(C*)**	**TEMPARATURE OF GLASS (C*)**	**WATER COLLECTED IN ml**	**Hcw**	**n**	**Qcw**	**Hew**
10:30	33.2	31	-	1.23	7.7	0.54	0.075
11:30	38	35.2	-	1.36	9.23	0.86	0.15
12:30	45.3	40.3	225	2.27	26.7	2.02	0.26
13:30	56.2	44	-	2.68	28.9	2.72	0.34
14:30	68.6	56	650	3.56	31.5	3.12	0.49
15:30	72.36	63	850	3.95	36.5	3.56	0.59
16:30	68.25	62.7	900	3.86	39.1	3.64	0.69

7.3 GRAPH ANALYSIS



8. TECHNICAL SPECIFICATION

SR NO.	COMPONENT	MATERIALS AND COMPONENTS
1	SOLAR STILL	ACRYLIC GLASS.
2	VACUUM PUMP	0.2 -0.3 BAR Vacuum pressure inlet 110 psi Blowing pressure outlet
3	SALT COMPOSITE WATER TANK	2.02 litres capacity
4	Connecting Tubes	Pvc material

9. Experimental Setup

Experimental setup is as follows,

Fig 9.1

Fig 9.2

10. Conclusion:

- In our system vacuum pressure of 150 mm/hg to 200 mm/hg is maintained in the system which is equivalent to 0.2 and 0.3 bar ,Which results in decrease of vapor pressure in the system. Decrease in the vapor pressure in the system decreases the boiling point of water and yields in increasing evaporating rate of water. So instead of water boiling at 100 Celsius it start evaporating at lower temperature which results more drinkable water collection.
- In desalination direct method system water collection is directly proportional to basin Area of the still .
- The amount of drinking water produced in a direct desalination unit is proportional to the surface area of the device. The daily freshwater output per square metre of area is typically 2 to3 litres (about 0.5 to 0.8 gallon).
- Compare to the direct method desalination system water collection for 1meter square= 2.5 litres (Approx. taken). For conventional system having area of basin of our system that is 0.196 meter square water collection is of 0.5 litres.
- Compare to conventional system having area of 0.196 water collection is of 0.5 litres whereas in our system decreasing vapor pressure , increases the evaporating rate and results in more water collection of 0.8 to 0.9 litre in 5-6 hours of duration.

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