Analytical Comparison and Evaluation of Single Slope Single Basin Stepped Type Solar Still

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Abstract:

Concern for environment and ever increasing demand for energy, combined with relentless advancement in renewable energy innovations, are interested in the new opportunities to accomplish in the field of use of renewable energy resources. Till date, solar energy is the most clean, cheap and inexhaustible among all renewable resources. The power from the sun is many times larger than the present rate of energy consumption on the earth. Solar still is one of the finest ways to harness the solar power. A simple and effective device which is applied for obtain distilled water from the saline water with the solar desalination process is known as solar still. The conventional still produces 2–3 l fresh water per day (9AM to 5PM) but the output of stepped solar still is quite high compared to the conventional. There are various scientists and researchers who investigated the effect of design parameters, climate parameters and operational parameters to review the effect of these parameters with the yield of still. In this paper there are the various results and the comparison of the mathematical results with the experiment is being held and the final results have been conducted.

Key Words: Single Slope Solar Still, Mathematical Modeling, Comparison

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1. INTRODUCTION

Solar energy plays a very important role in producing distilled water from the saline water. From the sun, there are two things received by us, heat and light. Solar radiation produces the heat in the system; the system may be solar stills, solar water heater, solar cooker, solar pumps and many more. The percentage of saline water on the earth is 71%, but among that percentage, the fresh water available isnear about 2%, so, to produce distilled water to survive the life is a very important issue. In the rural areas of the India, there is a very hazardous condition, so, this kind of solar still plays a very important role in producing the distilled water as well as betterment of life. Solar still is the better option to produce fresh water from the saline water [1]. The implementation of the portable solar stills into the rural and remote areas is the beneficial aspects for the locality of that area as the fresh water availability is a concern. Solar still eliminates all the wastes which are dissolved into the saline water with the application of solar radiation energy. In solar distillation system, there are various parts which play important role in the desalination purpose, which are following:

1. Basin,
2. Glass cover, and
3. Frame etc.

Basin is filled with saline water according to water depth and then it will closed by the glass cover and system is made air tight with silicon or any other material. The whole system is put on a frame at an appropriate angle.

2. Working Principle of Solar Still

The solar still works on the principle of evaporation and condensation as shown in the Figure 1.

As mentioned earlier, that in the solar still system, solar radiation falls on the glass cover and is absorbed by black basin. Because of heat generation, the temperature of water will rise, at one stage the water will evaporate and change the phase into vapor form. The vapor will condense at the inner side of the glass cover, and because of the temperature difference between the water and glass, the vapor will converted into water form and this water will collect at one side of the output channel. So, this collected water, we can say, is the distill water. But we cannot use this kind of water for drinking purpose because there are no minerals in it, but after adding the minerals, we can say that it is fresh drinkable water.

There are various heat and mass transfer phenomena occurring at different stages:
There is a radiative heat transfer (h_r) which occurs at outer surface of glass and convective heat transfer also occurs at glass surface. Evaporative heat transfer occurs at water surface (h_{ev}) and convective heat transfer occurs at the wall and absorber plate as well. So, this is the whole system of the solar distillation system.

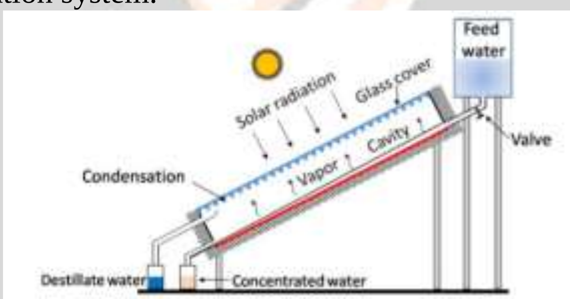

Figure 1: Single Slope Solar Still

3. Step Type Solar Still

There are various types of solar stills to generate the fresh water from the saline water. Single basin single slope solar still, Double basin single slope solar still, Single basin double slope solar still and single basin single slope stepped type solar still, etc.
Among the various types of solar still the discussion is being held for the single slope single basin stepped type solar still. This kind of solar still is shown in figure below.

Figure 2: Stepped Type Solar Still

In this type of solar still there are six types of steps which is shown in the figure.in this single basin single slope stepped type solar still, the still is placed at the 20^0 at south facing of the direction. And the still is placed on the stand which is shown in the figure.

Now, the whole procedure of the solar still which is converted the saline water into fresh water is following:

The tap water which is shown in the figure, in the blue bucket is feed into the still from the nozzle. The sun radiation is placed on to the glass of the solar still and it gets heated. Because of the transmissivity property of the glass, the sun radiation transmits from the glass to water and as the radiation increase the heat also will increase and the water temperature also will rises. At one point or we can say that at the saturation temperature, the water will change the face and the liquid water will converted into the vapor form so we can say that the evaporation process is held. The vapor is placed onto the inner surface of the glass and because of the temperature difference the vapor get condense and change the face from gas to liquid.

The condensed water is free from the all kind of water impurities solid, liquid or gaseous.

Now the condensed water is flow from the inner surface of the glass to the downcammer and it will get collected into the bucket as shown in the figure.

So this is the whole phenomena of the single slope solar still. Here we have six steps is define in to the geometry because the evaporative surface area of the still is getting higher than the single steps and hence the output of water also gets improved.

There are three types of water impurities like solid (e.g. dust, sand particles, solid chemical waste, salt particles, etc.) liquid, (e.g. chemical wastes, solvents, etc.) gases, (e.g. chlorine, or etc.) will removed from the solar still by evaporation- condensation processes.

4. Materials

- There are various materials can be used in the solar still.
- In metal stainless steel is the best suitable for the basin material.
- We have to use SS 316 because the following property:
- It is highly corrosive resistance then SS 304.
- In SS 316 it implies 0.08% C, 16% Cr, 10% Ni and 2% Mn
- We have to choose the material, which is cost effective and sustainable for the saline water.
- Non corrosive materials have to be chosen for the solar still.
- For insulating material, black paint.

5. Application of Solar Still:

1. Produces pure water
2. No prime movers required
3. No conventional energy required
4. No skilled operator required
5. Local manufacturing/repairing
6. Low investment
7. Can purify highly saline water (even sea water)

Solar stills is an useful devise to get fresh/ distilled water which is required in sanitization

Table 1: Applications for Solar Still

Industries	for industrial processes
Hospitals and Dispensaries	Fresh water
Garages and Automobile Workshop	for analytic work
Telephone Exchange	for radiator and battery maintenance
Marshy and costal area	To get fresh potable water

6. Experimental Data:

Experimental Data: Experimental Data of Solar Still on 20th January, 2017Data which is shown in following table (2)

Parameter/Time	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
Water Temperature (^{0}C)	20	24.5	32	43.3	49.3	54.7	55.8	53	47
Glass Temperature inner (^{0}C)	21.4	27	30	41	47	49	53	51	45
Glass Temperature outer (^{0}C)	20.7	26	27	35.3	35.3	44.3	47.3	45	38
Horizontal Intensity (W/m2)	226	387	559	677	849	634	516	355	194
Inclined Intensity (W/m2)	301	527	720	860	1000	785	720	505	312
wind velocity (m/s)	0.1	0	0	0.2	0.1	0.1	0	0	0.1
Ambient Temperature (^{0}C)	20.1	21.9	24.4	26	27.7	29.1	30	29.8	27.7
Water production (ml/h)	20	30	105	304	490	700	590	550	450

7. Mathematical Calculation:

Table 3: Calculations

h_{cw}	q_{cw}	h_{rw}	q_{rw}	h_{ew}	q_{ew}	M_{ew}
-1.07739	1.616082	7.339927	-11.0099	-3.2406628	4.860994	0.014609
1.634768	8.173842	7.658671	38.29336	6.1026785	30.51339	0.091702
1.999794	15.99835	8.4282	67.4256	11.974749	95.79799	0.287902
2.139865	19.0448	8.885858	79.08414	16.503496	146.8811	0.441422
2.291524	22.68608	9.303546	92.10511	21.933415	217.1408	0.652573
2.204435	18.7377	9.459473	80.40552	22.753789	193.4072	0.581247
2.120947	16.96758	9.238091	73.90473	19.609281	156.8743	0.471454
2.117887	19.06098	8.690286	78.21257	14.70025	132.3023	0.397608

Here the comparison of the Experimental data with mathematical model

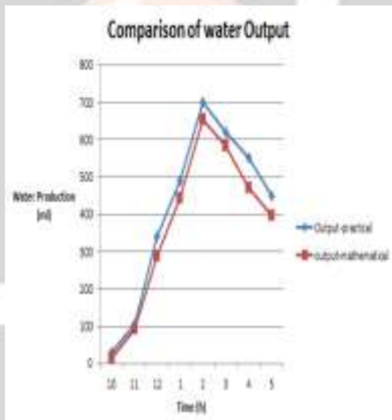

Figure 3: Comparison

Comparison of Practical and Theoretical Model is shown in upon figure

8. Mathematical Expressions for the comparison of the experimental data and mathematical model

Convective Heat Transfer:

$h_{cw} = 0.884\{\frac{[(Tw-Tg)+(Pw-Pg)(Tw+273)]}{268900-Pw}\}$^0.33

$P_w = \exp((25.317 - 5144)/T_w)$

$P_g = \exp((25.317 - 5144)/T_g)$

$q_{cw} = h_{cw}$ x $(T_w - T_g)$

Radiative Heat Transfer:

$h_{rw} = E_{ff} * \sigma * [(273+T_w)^2 + (273+T_g)^2]$

Evaporative Heat transfer:

$h_{ew} = 16.27 x 10^{(-3)} x\ h_{cw}\ x\ \frac{Pw - Pg}{Tw - Tg}$

$q_{ew} = h_{ew}$ x $(T_w - T_g)$

Mass Transf$M_{ew} = \frac{qew\ x\ Aw\ x\ t}{hfg}$

Calculations for 11 AM:

$h_{cw} = 0.884\{\frac{(305-300)+(4681.74-3534.52)(305)}{268900-4681.74}\}$^0.33

$h_{cw} = 1.634768\ W/m^2K$

$q_{cw} = h_{cw} (T_w - T_g)$

$q_{cw} = 1.6347 (305-300)$

$q_{cw} = 8.173842\ W$

$h_{rw} = 1.222 * 5.66E\text{-}08\{(305)^2 + (300)^2\} = 7.658671 W/m^2K$

$q_{rw} = h_{rw} (T_w - T_g)$

$q_{rw} = 7.65 (305-300) = 38.29W$

$h_{ew} = 16.27*10^{-3} *1.634768 * \frac{(4681-3534)}{(305-300)} = 6.1026$

$q_{ew} = h_{ew} (T_w - T_g)$

$q_{ew} = 6.1026 (305-300) = 30.5133$

$M_{ew} = (30.51*1.89*3600) / 2264000$

$M_{ew} = 0.09170\ l = 91ml$

Efficiency of the Solar Still

The overall Thermal Efficiency of still is given by the following equations:

$$\eta = (\Sigma m_w \cdot h_{fg}) / \Sigma(A_s.I)$$

Where,

w = mass of the distilled water collected as output in kg/s. *m*

A = Area of the basin in m^2

I (t) = Solar radiation with respect to time W/m^2 and

L= Latent heat of vaporization (h_{fg}) in KJ/s:

From the above equation the efficiency is 30% of the still.

9. Conclusion:

From the comparison with the mathematical modeling of the still the system is proved and it gives the minimum percentages of error.

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