Desalination Using Solar Energy

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Abstract- *The purpose of this project is to fabricate a solar water distillation system that can purify the water, which is impure by using a systematic arrangement must have low cost for manufacturing and works based on renewable energy of solar. There is less amount of water only left on earth that is safe to drink without purification after 20-25 years from today. 99% of Earth's water is in a solid state and other impure form and the remaining is in liquid form. Due to this reason, water purification is necessary. Because of this, purposes the solar still is constructed which will convert the impure water into pure water using the renewable solar energy. The incoming solar radiation from the sun is heating the water, which placed in the basin in impure form, and this water gets evaporated and condensed into pure drinkable water.*

I. INTRODUCTION

The different sources from which energy can be drawn is be broadly categorized into conventional and non-conventional energy resources with conventional energy based production dominate over non-conventional energy resource based production. The energy scenario and export-import statistics in India show that the economy of the country has direct relation with energy generation and consumption of these energy sources. The country inhabits close to 18% of the global population with a primary energy consumption of 6% of the total worldwide energy spent. The rapid pace of development in the country since the year 2000 , has witnessed doubling in energy consumption rate within a short span of 15 years. The growth trend in Indian economy foresees it to emerge as an important energy consumer aggregating to 35% of the energy demand addition to global level by the year 2050. The country mainly depends on imported fossil fuels for energy generation which has necessitated considerations of other alternative forms of energy to reduce economic burden. The estimates indicated that renewable energy component in the energy mix that currently hovers at 13% would grow to 60% of total energy by the year 2040. India government now looks forward to meet energy demand through higher volume of renewable energy systems.

1.1 Desalination

Desalination is a process that extracts mineral components from saline water. More generally, desalination refers to the removal of salts and minerals from a target substance, as in soil desalination, which is an issue for agriculture.

Saltwater is desalinated to produce water suitable for human consumption or irrigation. One by-product of desalination is salt. Desalination is used on many seagoing ships and submarines. Most of the modern interest in desalination is focused on cost-effective provision of fresh water for human use. Along with recycled wastewater, it is one of the few rainfall-independent water sources.

1.2 Methodology

The proposed project is to harness the solar energy to convert salt water to distilled water. Here we use a solar concentrator to achieve our objective. Solar concentrator is a device that concentrates all the incoming solar radiations at one point thus leading to the generation of heat. There are three types of solar concentrators namely dish type, solar still and parabolic trough. The solar concentrator that has been used in this project is a parabolic trough. We have used mirrors attached on a body frame with epoxy resin to prepare the solar concentrator. The solar concentrators focal point was calculated to be at a distance of 0.448m from its centre. A copper tube has been used to carry the water from inlet which then gets converted to steam when exiting the outlet. The copper tube has been placed along the focal axis Of the parabolic trough concentrator.

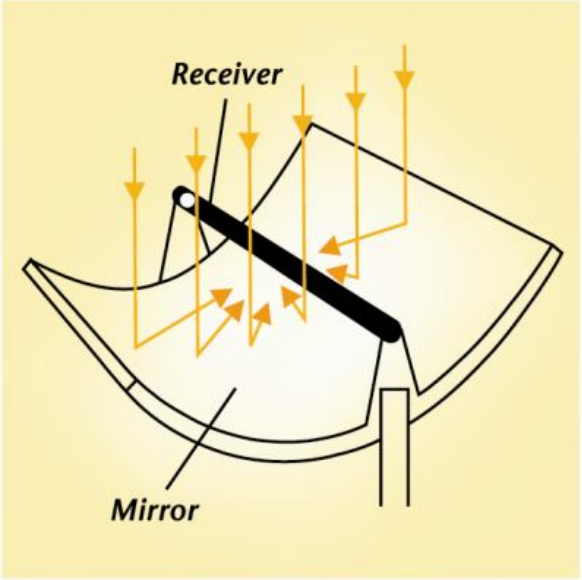

Fig1.1.Parabolic Trough Concentrator

Copper has been chosen for this as it has the third highest thermal conductivity among all the metals with gold and silver being its predecessors which are not economical. Another reason why copper has been used is due to its non corrosive properties. This tube has been painted black so as to increase its thermal conductivity even more. There is one inlet tank and one outlet tank. The inlet tank consists of salt water which flows into the copper tube due to difference in head. Due to heat concentration the water gets evaporated inside the copper tube and flows into the outlet tank as steam which then condenses to give clean distilled water. The salt that is collected is cleaned from the copper tube by rinsing it in freshwater and the copper tube has to be cleaned with vinegar every 10 days.

1.3 Results and Discussions

Angle of incidence on aperture plane

$$\delta = 23.45\sin[360/365(284+n)]$$

δ is the declination and is the angle made by the line joining the centers of the sun and the earth with the projection of this line on the equatorial plane. It arises by the virtue of the fact that earth rotates about an axis which makes an angle of approximately 66.5^o with the plane of its rotation around the sun. The declination angle varies from a maximum value of +23.45^o on December 21. It is zero on the two equinox days of March 21 and September 22.

n is the day of the year.(For April 5th it is 94)

Therefore,

$$\delta=23.45\sin[360/365(284+94)] = 5.204^o$$

$$\tan(\phi-\beta) = [\tan\delta/\cos\omega]$$

ω is known as the hour angle and is an angular measurement of time and is equivalent to 15^o per hour. It also varies from -180 to +180. We adopt the convention of measuring it from noon based on local apparent time, being positive in the morning and negative in the afternoon. Sine the peak temperature is achieved in this project at 12:30. (ω=7.5^o)
ϕ is the latitude of a location is the angle made by the radial line joining the location to the centre of the earth with the projection of the line on the equatorial plane. By convention, the latitude is measured as positive for the northern hemisphere. It varies from -90^o and +90^o . For Bangalore it is19.12^o.

β is the angle made by the plane surface with the horizontal. It can vary from 0^o to 180^o.

tan (19.12-β) = [tan 5.204/cos(-7.5)]
β=13.711^o.

$$\cos\theta = \sqrt{(1-\cos^2\delta\sin^2\omega)}$$

θ is called the solar altitude angle.
θ = 7.4607^o

Absorbed flux

$$r_b = [\sin\delta\sin(\phi-\beta)+\cos\delta\cos\omega\cos(\phi-\beta)]/[\sin\phi\sin\delta+\cos\phi\cos\delta\cos\omega]$$

r_b is the ratio of the beam radiation flux falling on a tilted surface to that falling on a horizontal surface and hence known as the tilt factor.

Therefore, r_b = 0.9913/0.96244

r_b = 1.0299
Absorbed flux is denoted as **S**

$$S = I_b r_b \rho\gamma(\tau\alpha)_b + I_b r_b (\tau\alpha)_b [D_o/W - D_o]$$

ρ is the specular reflectivity of the concentrator surface.(0.85)
γ is the intercept factor i.e., the fraction of the reflected radiation intercepted by the absorber pipe.(0.95)
$(\tau\alpha)_b$ is the average value of the transmissivity - absorptivity product for beam radiation

W is the aperture of the solar concentrator

D_o is the outer diameter of the copper pipe.

S = 705 x 1.0299 [(0.85x0.95x0.85x0.95)+{(0.85x0.95x0.05)/(1.69-0.05)}]

S = 491.2459 W/m^2

Convective Heat Transfer Coefficient h_f

The various properties of the fluid can be determined keeping in mind that the rise of temperature of the fluid will only be a few degrees and in this case, properties will be taken at a mean fluid temperature of 152^{o}C.

Thus, ρ = 750.3 kg/m^3, c_p = 2.449 kJ/kg-K
v = 2.42 x 10^{-6} m^2/s , k = 0.119 W/m-K

Average Velocity,

$$V = \dot{m}/(\pi / 4D_i^2 \rho)$$

V = 0.0075 m/s

Reynolds Number,

$$R_e = VD_i / v$$

R_e=140

Prandtl Number,

$$\Pr = c_p v\rho / k$$

Pr = 37.37

Nusselt number,

$$N_U = 5.172[1 + .005484\{\Pr(R_e / X)^{1.78}\}^{0.7}]^{0.5}$$

N_U = 13.49

Convective heat transfer coefficient,

$$h_f = N_U k / D_i$$

h_f = 35.6 W/m^2-K

Collector Heat-Removal Factor.

$$F' = 1/U_l[(1/U_l) + (D_o / D_i h_f)]$$

F’ is the collector efficiency factor.
F_R is the heat removal factor.
U_l is the overall loss coefficient.
Since the F_R and U_L cannot be directly determined and the value of one depends on the other, we assume U_l =3.28 W/m^2-K.
Therefore,

F’ = 0.90713

$$F_R = \dot{m} C_p / \pi D_o L U_l [1 - \exp\{-(F' \pi D_o U_l L / \dot{m} C_p)\}]$$

F_R = 35.0915[1 - exp(-0.9071/35.0915)]

F_R = 0.8954

REFERENCES

[1] Mohamed A. Dawoud - Environmental Impacts of Seawater , 2012, (Vol. 1)ISSN 1927-9566

[2] Chennan Li - Solar assisted sea water desalination, Reviews 19 (2013) 136–163.

[3] Khalifa Zhani - Solar desalination based on multiple effect humidification process: Thermal performance and experimental validation Reviews 24 (2013)406–417.

[4] H.M.N. Al-Madani - Water desalination by solar powered electro-dialysis process, Renewable Energy 28 (2003) 1915–1924.

[5] Elias Stefanakos - Solar assisted sea water desalination. Renewable and Sustainable Energy Reviews 19 (2013) 136–166.

[6] Ashutosh Chakraborty- Adsorption desalination: An emerging low-cost thermal desalination method. Desalination 308 (2013), 161-179.

[7] Wenbo Chen - Thermal and economic analyses of solar desalination system with evacuated pipe collectors .Solar Energy 93 (2013) 144–150.

[8] Edward K. Summers - Air Heating Solar Collectors for Humidification-Dehumidification Desalination Systems. Journal of Solar Energy Engineering, FEBRUARY 2011, Vol. 133 / 011016-1.

[9] D. Yogi Goswami - Solar Flash Desalination Under Hydrostatically Sustained Vacuum. Journal of Solar Energy Engineering , AUGUST 2009, Vol. 131 / 031016-1.

[10] C. Fritzmann - Reverse Osmosis Desalination

[11] John H. Lienhard- Solar powered Multi-stage Flash Distillation (MSF). ISSN: 2278-0181/ Vol. 4 Issue 03,(March-2015).

[12] Mark Worall - Economic study for an affordable small scale solar water desalination system in remote and semi-arid region. Renewable and Sustainable Energy Reviews 25 (2013) 543–551.

[13] S. Nandakumar - Fabrication of Solar Water Distillation ystem,Volume 2,Issue 1,April 2015.

[14] Ravindra Kumar Jain- Study of Water Distillation by Solar Energy in India. Volume 3, Issue 2, ISSN 2348-196x.

[15] Trivedi Hetal K- Renewable Resources Used for Seawater Desalination. ISSN 2249-8974