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Design and Fabrication of Solar Still

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ABSTRACT

The purpose of this project is to design a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable, and depends only on renewable solar energy. Distillation is one of many processes that can be used for water purification. This requires an energy input as heat, electricity and solar radiation can be the source of energy. When Solar energy is used for this purpose, it is known as Solar water Distillation. Solar Distillation is an attractive process to produce portable water using free of cost solar energy. This energy is used directly for evaporating water inside a device usually termed a "Solar Still". Solar stills are used in cases where rain, piped, or well water is impractical, such as in remote homes or during power outages. Different versions of a still are used to desalinate seawater, in desert survival kits and for home water Purification

Keywords – Purification, Convection, Distillation, Evaporation, Radiation.

I. INTRODUCTION

Due to environmental issues and limited fossil fuel resources, more and more attention is being given to renewable energy sources. In the recent years solar energy has been strongly promoted as a viable energy source. One of the simplest and most direct applications of this energy is the convergence of solar radiation into heat.

Solar radiation can be widely used for water heating in hot water systems, swimming pools as well as a supporting energy sources for central heating installations.

The energy of the solar radiation is in this case converted to heat with the use of solar panel. Using the sun's energy to heat water is not a new idea. More than one hundred years ago, black painted water tanks.

Water is a basic necessity of man along with food and air. Fresh water resources usually available are rivers, lakes and underground water reservoirs. About 71% of the planet is covered in water, yet of all of that 96.5% of the planet's water is found in oceans, 1.7% in groundwater,1.7% in glaciers and the ice caps and 0.001% in the air as vapor and clouds, Only2.5% of the Earth's water is fresh water and 98.8% of that water is in ice and groundwater. Less than 1% of all freshwater is in rivers, lakes and the atmosphere.

II. ABOUT SOLAR ENERGY

The sun radiates the energy uniformly in all direction in the form of electromagnetic waves. When absorbed by body, it increases its temperature. It is a clean, inexhaustible, abundantly and universally available renewable energy.

Solar energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy could be used, it will be one of the most important supplies of energy, especially when other sources in the country have depleted. This solution is solar water distillation. It is not a new process, but it has not received the attention that it deserves. Perhaps this is because it is such a low-tech and flexible solution to water problems. Nearly anyone is capable of building a still and providing themselves with completely pure water from very questionable sources. 3.8x1024 joules of solar radiation is absorbed by earth and atmosphere per year. Solar power where sun hits atmosphere is 1017 watts and the total demand is 1013 watts. Therefore, the sun gives us 1000 times more power than we need. If we can use 5% of this energy, it will be 50 times what the world will require. The energy radiated by the sun on a bright sunny day is 4 to 7 KWh per m^2.

III. INTRODUCTION TO SOLAR STILL

Solar distillation is a tried and true technology. The first known use of stills dates back to 1551 when it was used by Arab alchemists. Other scientists and naturalists used stills over the coming centuries including Della Porta (1589), Lavoisier(1862), and Mauchot (1869)[3]. The first "conventional" solar still plant was built in 1872 by the Swedish engineer Charles Wilson in the mining community of Las Salinas in what is now northern Chile (Region II). This still was a large basin-type still used for supplying fresh water using brackish feed water to a nitrate mining community. The plant used wooden bays which had blackened bottoms using logwood dye and alum. The total area of the distillation plant was 4,700 square meters. On a typical summer day this plant produced 4.9 kg of distilled water per square meter of still surface, or more than 23,000 litres per day. Solar water Distillation system also called "Solar Still". Solar Still can effectively purify seawater & even raw sewage. Solar Stills can effectively removing Salts/minerals {Na, Ca, As, Fe, Mn},Bacteria {Ecoli, Cholera, Botulinus}, Parasites ,Heavy Metals & TDS[2]. Basic principal of working of solar still is "Solar energy heats water, evaporates it (salts and microbes left behind), and condenses as clouds to return to earth as rainwater".

IV. LITERATURE REVIEW

Joel Gordes et.al Worked on "Basic studies on Solar Stills". Solar distillation uses the heat of the sun directly in a simple piece of equipment to purify water. The equipment, commonly called a solar still.

Arunkumar T et.al [1]Worked on the "Effect of air flow on tubular solar still efficiency". An experimental work was reported to estimate the increase in distillate yield for a tubular solar still. The experiment was carried out in two modes without and with air flow between inner and outer tubes. And they concluded that the rate of air flow was fixed throughout the experiment.

Arunkumar.T et.al [2]Worked on the "Experimental Study on a Compound Parabolic Concentrator Tubular Solar Still Tied".They found that the relative humid of the humid air was definitely not saturated and the hourly evaporation, condensation and production fluxes were proportional to the humid air temperature and relative humidity.

Ajeet Kumar Rai et.al [3]Investigated on the "Experimental Study of Double Slope Solar Still with Energy Storage Medium". Andthey conducted an experiment to enhance the productivity of double slope solar still by storage of thermal energy in day time with the help of phase change materials (PCM). Overall 23% gain was observed when paraffin wax was used in solar still.

Ajeet Kumar Rai et.al [4]Observed on "Experimental Study of a Tubular Solar Still with Phase Change Material". Experiments were carried out on tubular solar still in Allahabad climate conditions. And it was concluded that the productivity of solar still increase by 20% when energy storage medium is used.

AmimulAhasanet .al [5]Worked on "Production Model of Tubular Solar Still Based on Condensation Theory". A production model based on a film-wise condensation theory for a Tubular Solar Still taking account of the thermal resistance of the unsaturated humid air inside the still was developed in this study. And it was found that the thermal resistance coefficient was reversely proportional to the dry air pressure fraction.

V. OBJECTIVES

For high efficiency the solar still should maintain high feed (undistilled) water temperature A large temperature difference between feed water and condensing surface Low vapour leakage. A high feed water temperature can be achieved if a high proportion of incoming radiation is absorbed by the feed water as heat. Hence low absorption glazing and a good radiation absorbing surface are required. Heat losses from the floor and walls are kept low. The water is shallow so there is not so much to heat.

A large temperature difference can be achieved if the condensing surface absorbs little or none of the incoming radiation condensing water dissipates heat which must be removed rapidly from the condensing surface.

VI. FABRICATION

The methodology of the work consists of following stages:

STILL BASIN

It is the part of the system in which the water to be distilled is kept. It is therefore essential that it must absorb solar energy. Hence it is necessary that the material have high absorbtivity or very less reflectivity and very less transmitivity. These are the criteria's for selecting the basin materials. Kinds of the basin materials that can be used are as follows: 1. Leather sheet, 2. Ge silicon, 3. Mild steel plate, 4. RPF (reinforced platic) 5. G.I. (galvanised iron). We have used blackened mild steel sheet(K= thermal conductivity= 300W/m0C) (3mm thick).

Outer tank is of size (400*305*h1=150mm,h2=250mm), and painted with black color to absorb heat from the sun light and outer layer is painted with grey color .

Inner tank is of size (350*200*10mm), and painted with non-corrosive paint and black paint inside the tank

Fig. 1Outer and inner tank made by bending and arc welding

Fig. 2 Painted Outer and inner tank

TOP COVER

The passage from where irradiation occurs on the surface of the basin is top cover. Also it is the surface where condensate collects. So the features of the top cover are: 1) Transparent to solar radiation, 2) Non absorbent and Non-adsorbent of water ,3) Clean and smooth surface. The Materials Can Be Used Are: 1) Glass, 2) Polythene. We have used glass (3mm)

Fig.3 Top Cover with Glass

CHANNEL

The condensate that is formed slides over the inclined top cover and falls in the passage, this passage which fetches out the pure water is called channel. The materials that can be used are: P.V.C., 2) G.I. , 3) RPF . We used V-shaped mild steel channel .

Fig. 4 Channel

SUPPORTS FOR TOP COVER

The frame provided for supporting the top cover is an optional thing. I.e. it can be used if required. We have used fiber stick as a support to hold glass (size :: 5 mm X 5mm). The only change in our model is that we have to make the model as vacuumed as possible. So we have tried to make it airtight by sticking tape on the corners of the glass and at the edges of the box from where the possibility of the leakage of inside hot air is maximum.

Fig. 5 Fabricated Model

INLET PIPE FITTINGS

Inlet pipe is made up of mild steel and is of 2mm diameter and brass pipe of 2mm diameter is connected to inlet pipe to inner tank. Ball type gate valve is connected to the inlet valve.

Fig.6 Pipe Fittings

OUTLET PIPE CONNECTIONS

Outlet pipe is made up o mild steel and it is of 2mm diameter .water collector is connected to the outlet pipe.

Fig. 7 Pipe Connections

V. OPERATION

Solar panels use light energy (photons) from the sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most solar panels are rigid, but semi- flexible ones are available, based on thin-film cells. Electrical connections are made in series to achieve a desired output voltage and/or in parallel to provide a desired current capability. The conducting wires that take the current off the panels may contain silver, copper or other non-magnetic conductive transition metals. The cells must be connected electrically to one another and to the rest of the system. Externally, popular terrestrial usage photovoltaic panels use MC3 (older) or MC4 connectors to facilitate easy weatherproof connections to the rest of the system. Bypass diodes may be incorporated or used externally, in case of partial panel shading, to maximize the output of panel sections still illuminated. Solar cells become less efficient at higher temperatures and installers try to provide good ventilation behind solar panels.

Water to be cleaned is poured into the still to partially fill the basin. The glass cover allows the solar radiation to pass into the still, which is mostly absorbed by the blackened base. This interior surface uses a blackened material to improve absorption of the sunrays. The water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The heated water vapor evaporates from the basin and condenses on the inside of the glass cover. In this process, the salts and microbes that were in the original water are left behind. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle. Feed water should be added each day that roughly exceeds the distillate production to provide proper flushing of the basin water and to clean out excess salts left behind during the evaporation process. If the still produced 3 litres of water, 9 litres of make-up water should be added, of which 6 litres leaves the still as excess to flush the basin.

VI. CALCULATIONS

Sl.no.	Parameters	Symbol	Design parameter of solar still
1	Solar declination	Δ	$\delta = 23.45 \sin [0.9863(284 + n)]$
2	Angle	B	$\delta = -23.3$ $\beta = (\Phi - \delta)$
3	Slope of collector	Ic	$\beta = 40^{o}\ 48'$ $I_c = I_h \times \text{Cos}$
4	Intensity of insolation on horizontal	Is	θ $I_c = 450$ W/m2
5	Intensity of insolation on sloping surface	θh	$I_s = I_h \times \text{Cos}\,\theta / \text{Cos}\,\theta h$ $I_s = 594.5$ W/m2
6	Cosine of θh		$\theta h = 40^{o}.8'$

Table 1. Solar Radiation Data

Angle of declination of flat plate

$\delta = 23.45\ \text{Sin}[360/365(284/n)]$

Where n=day of the year

$= 23.45\text{Sin}[360/365(284/122)]$

$\boldsymbol{\delta = 15.21^{\circ}}$

$\text{Cos}\Theta = \text{Sin}\phi\text{Sin}\delta + \text{Cos}\phi\text{Cos}\delta\text{Cos}\omega$

$= \text{Sin}\ (15.21)\ \text{Sin}\ (12.58\text{-}10) + \text{Cos}\ (15.21)\ \text{Cos}\ (45)\ \text{Cos}(12.58\text{-}10)$

$\boldsymbol{\Theta = 46.095^{\circ}}$

Zenith angle

$\text{Cos}\Theta = \text{Sin}\ (12.58)\ \text{Sin}\ (15.21) + \text{Cos}\ (12.58)\ \text{Cos}\ (15.21)\ \text{Cos}45$

$\boldsymbol{\Theta = 43.689^{\circ}}$

Azimuth angle

$\text{Cos}\gamma = \text{Cos}\Theta\text{Sin}\phi - \text{Sin}\delta / \text{Sin}\Theta\text{Cos}\phi$

$= \text{Cos}\ (43.689)\ \text{Sin}\ (12.58) - \text{Sin}\ (15.21) / \text{Sin}\ (43.689)\ \text{Cos}\ (12.58)$

$\boldsymbol{\gamma = 62.72^{\circ}}$

Global Radiation I_g reaching a horizontal surface on the earth is given by

$$I_g = I_b + I_d$$

$$I_g = I_{bn}\text{Cos}\Theta + I_d$$

$$I_{bn} = A \exp(-B/\cos\Theta)$$

I_{bn} = 865.86 w/m²

$I_d = c\, I_{bn}$

I_d = 112.56 w/m²

Global Radiation**I_g= 978.42 w/m²**

Efficiency

$\eta = APh_{fg} / 3600 I_g$

where

A= Collecting area in m²

P = Daily productionin kg

h_{fg} = latent heatKJ/kg

η = 22.94% ≈ 23%

VII CONCLUSIONS

Distillation is a method where water is removed from the contaminations rather than to remove contaminants from the water. Solar energy is a promising source to achieve this. This is due to various advantages involved in solar distillation. The Solar distillation involves zero maintenance cost and no energy costs as it involves only solar energy which is free of cost.

It was found from the experimental analysis that increasing the ambient temperature from 32°C to 47°C will increase the productivity by approx. 12 to 23%, which shows that the system performed more distillation at higher ambient temperatures. When inverted type absorber plate was used thermal efficiency of single slope solar still was increased by 7 %.

It was observed that when the water depth increases from 0.01m to 0.03m the productivity decreased by 5%.These results show that the water mass (water depth) has an intense effect on the distillate output of the solar still system.

Solar still productivity can also increase by use of reflector by 3%. The use of the mirror reflector will increase the temperature of the solar still basin; such an increase in the temperature is because of the improvement in solar radiation concentration.

The solar radiation increase from 0 MJ/m2 /h to 6 MJ/m2 /h has increased the productivity of the still by 15 to 32%. However the increase of the solar radiation parameter will increase the solar energy absorbed by the basin liner.

The main disadvantage of this solar still is the low productivity or high capital cost per unit output of distillate. This could be improved by a number of actions, e.g. injecting black dye in the seawater, using internal and external mirror, using wick, reducing heat conduction through basin walls and top cover or reusing the latent heat emitted from the condensing vapour on the glass cover. Capital cost can be reduced by using different designs and new materials for construction of solar stills.

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