Research Paper on Enhancing Solar Still Productivity by Optimizing Angle of PCM Embedded Absorber Surface

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Abstract

Desalination is a process in which saline water is separated in two parts using different forms of energy. Here we are going to discuss desalination of saline water using solar energy. The solar distiller purifies water by first evaporating and then condensing it. Distilled water contains no salts, minerals or any organic impurities. This distilled water can be used for drinking purposes, applications in hospitals, replenishing batteries, and so on. Our try here is to enhance the solar still productivity using PCM and by varying the angle of the solar still from ground surface. Phase change materials are the thermal energy storage materials. They store energy in the process of changing their aggregate state from solid to liquid. PCM starts melting whenever temperature goes beyond its melting point. The experimental results illustrated that the use of PCM and angle variation with solar still is cost effective and viable in enhancing the evaporation rate as well as thermal conductivity hence freshwater production. Based on the performance evaluation, the daily productivity of freshwater was increased compared to conventional solar still.
Keywords: Distillation, Desalination, PCM, Solar Energy, Solar Still, Thermal Energy, Water

I. INTRODUCTION

A. Desalination Technology:

Common process of desalination consumes large amount of energy to remove a portion of pure water from salt water .The size and desalination process is derived from availability of the source of water , volume of portable water needed An important physical principle is that when water vapour is condenses, it 'gives back' the heat used to vaporize it. Desalination is a process that removes dissolved minerals from feed water sources such as sea water, brackish water, ground water.

B. Basic Principle of Solar Distillation:

A solar still operates using the basic principal of evaporation and condensation. The impure saline feed water goes into solar still and the sun's rays penetrate a glass surface causing the water to heat up through the greenhouse effect and, consequently, evaporate. When the water evaporates inside the solar still, it leaves all contaminants behind in the basin. The evaporated and now purified water condenses on the underside of the glass and runs into a collection trough and then into an enclosed container. In this method the salts and microbes that were present in the original feed water to the solar still, are left behind.

II. METHODOLOGY

A. PCM (Phase Change Material):

Phase change material is a material which conserves available energy and improving its utilization with the help of many sources available in nature .Solar energy is available only during the day, and hence, its application requires efficient thermal energy storage so that the excess heat collected during sunshine hours may be stored for later use during the night. A phase-change material is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing

and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. In this experiment honey bee wax is used as PCM due to well property and available cheaply.

B. Solar Model Using PCM:

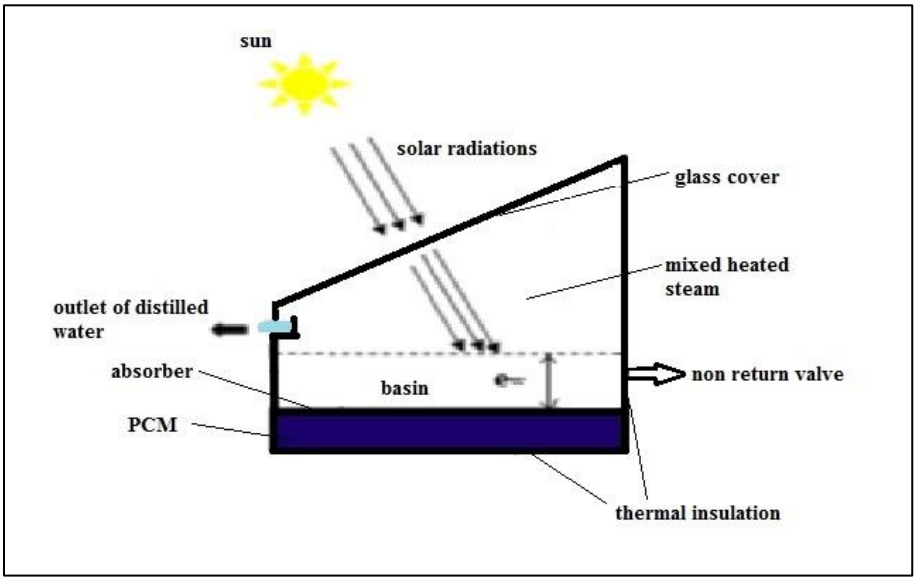

Fig. 1: Solar model using PCM.

Phase change material (PCM) shown in fig.1 the system of one square meter of surface area, is consisted of several element in the figure. Thus, the basin of this desalination device is fed by a brackish water reservoir through a non-return valve and this water is heated by solar radiations received by the solar still through the condensing glass cover. A large temperature difference between the salt water surface and the inner glass cover surface causes an increase in water evaporation process, hence the water gets condensed at the inner surface of the glass cover and it is collected by the outlet put at the base of the condensing cover of the solar still. A storage medium with PCM thickness is incorporated under the absorber and it is filled by a type of paraffin as a phase change material (PCM) that serves as a latent heat thermal energy storage system. The still is insulated to minimize any heat loss from the bottom and sides of the unit.

C. System Development:

System development is mainly concern with the design of the experiment, in system development various factors or components are assembled together .And the components which are not properly working are replaced with the new parameter . The testing is done after full assembly of the experiment, trail is done on 5 mock up and the result obtained depends on the energy available and the output at that time. Assembly contains following components,

1) Aluminium box with honey bee wax (as PCM)
2) Stainless steel box
3) Water tank
4) Glass covering
5) Screw jack
6) Pipe and collector assembly
7) Support stand

The complete setup was then air tightened and a collecting container was provided at the still output outlet. The still was then exposed to the sun for experimentations. The important factor or innovation part of the experiment is honey bee wax as PCM and screw jack used for angle variation of glass surface of the solar still from which we can understand at what angle the maximum solar radiation will incident on the glass surface.

In the experiment the change in the process or its output is measured by the following parameters,

1) Pyranometer:

It is used to measure broadband solar irradiance on a planar surface and is a sensor that is designed to measure the solar radiation flux density (in watts per meter square) from a field of view of 180 degrees. to attain the proper directional and spectral characteristics, a pyrometer's main components are thermopile sensor with black coating and a glass dome. The black coating on thermopile sensor absorbs the solar radiation, this radiation converted to heat ,the heat flows through the sensors to pyranometer housing .The thermopile generates a voltage output signal that is proportional to the radiation.

2) Animometer:
It is used for measuring wind speed
3) Thermocouple Temperature Indicator:
It is a temperature measuring device used consisting of two dissimilar conductors that contact with each other with one or more spots, it converts temperature gradient into electricity.
4) Inclinometer:
It is used to measure angle of slope.

III. CALCULATION

A. Numerical Approach:

Volume of aluminium plate = L x W x H
= 0.775 x 0.850 x 10
= 6.587 mm³.
= 0.006587 m³.
Required mass of PCM,
Density of PCM = 950 kg/m³.
Mass of PCM = volume x density
= 0.006587 x 950
= 6.25 kg
Allowing 10% volume expansion,
Mass of PCM = 6.25 - 0.625
= 5.62kg
Standard available radiations = 907 W/m^2
Radiation Absorbed by Aluminium (AL) sheet =178W
Radiation available Al sheet in peak hour (10am-3pm) = 10680KJ
Total radiation absorbed by AL in peak hour (10am-3pm) = 3204KJ
Energy stored in the aluminium plate is ,
$Q = \sigma*(T_f^4 - T_i^4).A$ = 1693.11 KJ

B. Specifications:

- Thickness of glass : 6mm
- Area of aperture : 0.658 m^2
- Thickness of Al sheet : 2mm
- Mass of PCM : 5.62 Kg
- Thickness of PCM slab : 10mm
- Solar panel Angle : 31°

C. Experimental Methodology:

The solar still is compared with conventional still in order to improve the in performance due to modification. The observations were recorded for the output in ml of water of both still for same conditions for each modification. Both stills were supplied with 15 lit of water at same initial temperature and quality. In conventional still, water is filled in basin trough during the start of experiments. In modified still, water is supplied to box through pipe. Jute is kept inside the box for equal distribution of water. Thermocouples are provided on set up to measure temperature. By using thermocouples, temperatures were noted down for 24 hrs cycle.

D. Result Table:

The measurements are tabulated in the table below:

Table – 1
Result Table of Experiment 1

Time	Distillate collected from conventional still (ml)	Distilled collected from modified solar still without PCM (ml)
10.00-12.00	150	230
12.00-14.00	160	270

14.00-16.00	163	264
16.00-18.00	140	250
18.00-8.00	850	1321
8.00-10.00	160	222
24hrs	1623	2557

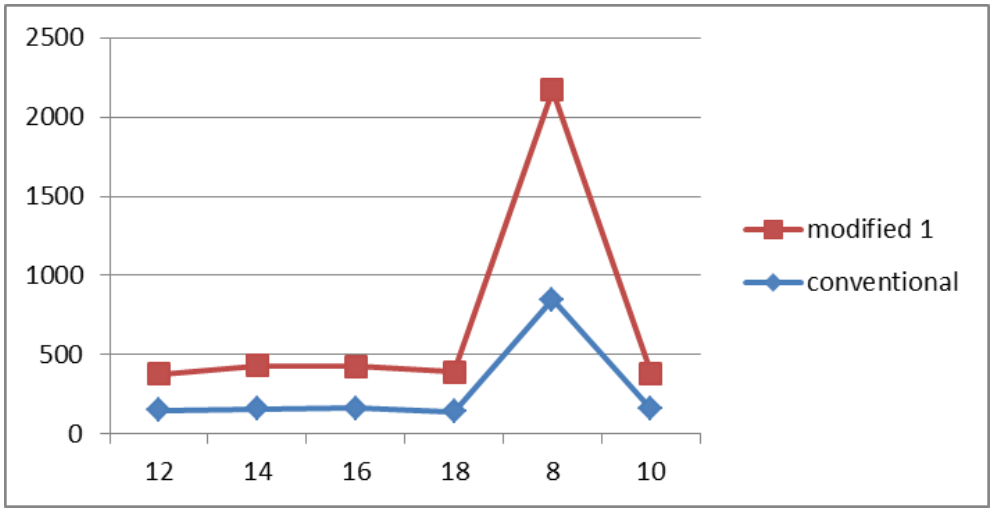

Chart 1: Result Graph of Experiment 1

Table - 2
Result Table of Experiment 2

Time	*Distillate collected from conventional still (ml)*	*Distilled collected from modified solar still with PCM (ml)*
10.00-12.00	*160*	*265*
12.00-14.00	*170*	*300*
14.00-16.00	*170*	*300*
16.00-18.00	*153*	*282*
18.00-8.00	*950*	*1430*
8.00-10.00	*145*	*250*
24hrs	*1748*	*2827*

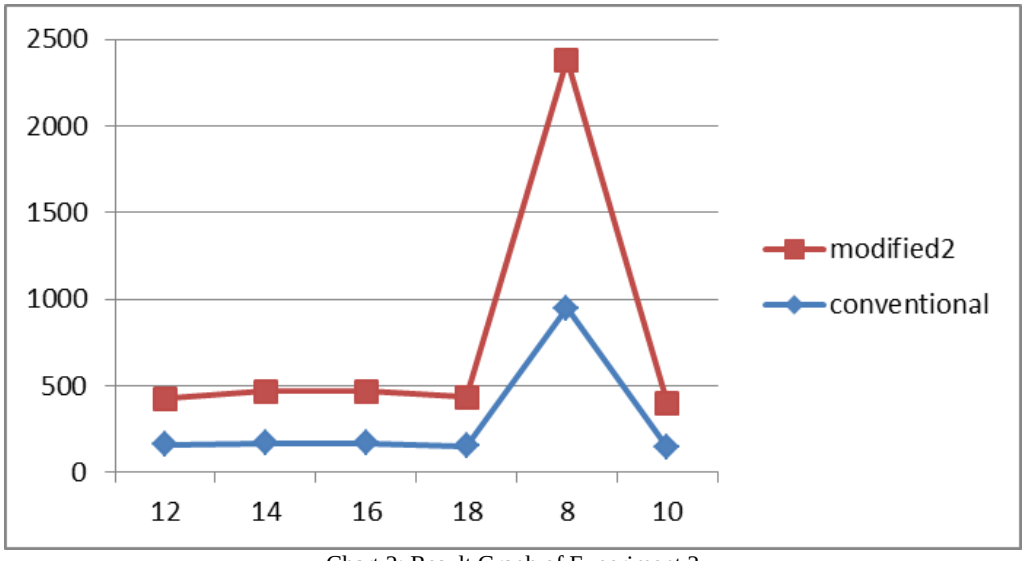

Chart 2: Result Graph of Experiment 2

Table – 3
Temperature Table

Time	*Temperature (degree celsius)*				
	T1	*T2*	*T3*	*T4*	*T5*
10.00	*30*	*46*	*49*	*43*	*46*
11.00	*38*	*59*	*64*	*58*	*54*
12.00	*38*	*59*	*64*	*58*	*54*
1.00	*40*	*56*	*59*	*52*	*56*
2.00	*41*	*60*	*64*	*65*	*58*
3.00	*41*	*58*	*57*	*64*	*58*
4.00	*37*	*54*	*55*	*63*	*58*
5.00	*37*	*54*	*56*	*64*	*56*
6.00	*30*	*50*	*52*	*50*	*48*
8.00	*26*	*43*	*45*	*40*	*43*
9.00	*28*	*45*	*47*	*42*	*45*

Where,
For Modified Solar still,
T1 = Inlet water temperature.
T2 = Glass surface temperature.
T3 = Inside Jute Material temperature.
For conventional still,
T4 = Inside Water temperature.
T5 = Upper Glass surface temperature.

IV. CONCLUSION

In this work, we have considered the solar still for water desalination principle containing PCM material. This material acts as heat source during day hrs and heat sink during night hrs. Hence we have made this process continuously available throughout the day. The use of steel box is to seal the PCM within it. The jute is placed to maintain uniform flow of water over steal plate. This has further improved the system performance. Experimental results of modified still were compared with conventional still. It was found that distillate output increased by 62% in modified still when compared with conventional still and the maximum output of water obtained at 34° when compared with other angles. The solar radiation during the test was of varying intensity due to a cloudy sky.

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