Design of Solar Still Using Phase Change Material as Storage Medium with an Enhancement of Efficiency of Water Purification

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Abstract
Fresh water is becoming scarce with time, leading to severe water crisis in many parts of the world. Among the various methods of purification of water solar distillation is more prominent. Solar distillation has the inherent advantage of low energy consumption. Moreover it is simpler and more economical than other methods.

Keywords: Desalination, latent heat, PCM, Solar energy, Solar still, Thermal energy.

1. Introduction

This project focuses mainly on small-scale basin type solar stills as suppliers of potable water for families and other small users. In this study an attempt has been made to bring out a new kind of organic phase change material (Bitumen) for energy storage. The material used is refined bitumen of specific grade. In this work the system is fabricated using combination of PCM and water as the storage material. This system consists of solar still which is an equipment to perform the desalination (removing of salt form sea water) process and bitumen as phase change material.

A Solar Still is a device that produces clean, drinkable water from dirty water using the energy from the sun. This inexpensive device can easily be built using local materials. Presently, basin type solar still is the only device that is being used for water distillation applications. However leakage of water vapors through joints and glass ceiling of solar stills was found to be major reason for their limited use. Against this backdrop, research and development in the field of solar stills can be directed to obtain higher distillate yield of the required quality with maximum still efficiency by using advanced stepped type solar still. However, although solar thermal energy entering the still is the driving force of distillation process, its relation with production is not univocal, as one could initially suppose, because thermal energy used for evaporation does not come out directly together with produced water but it is recovered through condensation inside the still. Several efforts have been made in order to improve efficiency of the conventional solar still, concerning interventions in geometry (Satcunanathan and Hansen, 1973), materials (Bahadori and Edlin, 1973; Dhiman, 1990), or other operation parameters with more or less positive results In this efforts using Phase Change Material (PCM) in Solar still is found to be a best option to increase the efficiency of solar still not only at a day time but also at a night. In locations where there is plenty of solar energy and where sources of brackish water are available, supplies of small amounts of fresh water can be produced at reasonable cost by solar still with PCM which are relatively inexpensive to build and easy to maintain.

2. METHODOLOGY

In this present work comparative study is being made between solar still with and without PCM. The detail Methodology is as follows: - It requires simple technology and easy maintenance; hence it can be used at any place without much difficulty. Two single slope stepped solar still were constructed with and without phase change materials in order to compared the productivity of stills at day as well as night during sunny days. Paraffin wax was selected as Phase Change Material (PCM). It is found that the higher mass of latent heat thermal energy storage system with lower mass of water in solar still basin significantly increases the daily productivity and the efficiency. Therefore, the distillate productivity at night and a day for solar still with PCM increases by 127% and 30-35% respectively than the one without PCM.

3. Thermal Energy Storage Methods

Thermal energy storage (TES) method can be divided into three categories

- Sensible heat storage
- Latent heat storage
- Thermochemical storage

A. Sensible Heat Storage

Sensible heat storage is a heating of a material in which amount of heat stored depends on specific heat, amount of material and temperature difference between initial and final condition.

B. Latent Heat Storage

Latent heat storage (LHS) depends on phase change of material. In this method heating of material occurs until its phase changes. A lot of energy is absorbed inside the material due to phase change and it is known as the latent heat of vaporization or fusion. When temperature of phase change material increases, first its heat stored in its initial phase (solid) is released. After certain temperature, phase change occurs and transformation of solid into liquid takes place. Until all the solid material is converted into liquid state, temperature will be constant. In this transformation large amount of energy is absorbed in the material. After complete transformation again temperature of liquid material increases and energy is stored in sensible way.

C. Thermochemical Storage

Thermochemical storage depends on the concept of reversible endothermic chemical reactions. Chemical heat is the energy which is required to dissociate structures in a chemical compound and further energy will be recovered when a synthesis reaction takes place.

4. GENERAL CONSIDERATION

Selection of dimensions for stepped type solar still.

The outer tray of dimension1067mm x 686mm x 228mm is fabricated of GI sheet of 27 gauges by riveting it.

The inner tray of dimension991mm x 610mm x 191mm is fabricated of GI sheet of 27 gauges by riveting.

The 8 steps are made of aluminum sheet having the dimension of each is 98mm width, 36mm height and 610mm width. These steps are riveted to the inner tray such that the surface of basin makes an angle of 150 with the ground.

The aluminum trough is made of dimension 55cm X 5cm X 5cm and riveted to the lower end of the inner tray to collect the distilled water. The outlet is provided to the trough to take out the distilled water from the solar still.

The wooden frame is made of the dimension 139cm X 65cm X to cover the outer tray and glass of 4mm thickness is fixed to the wooden frame. The frame is hinged to the one longer end to the outer tray and the other longer end is free to open the frame whenever necessary to clean the bottom surface of the basin

The rubber gasket is fixed on the wooden frame to make it air tight and vapor tight when the cover is close.

The inlet water is provided at the top of the side face of the tray to provide the fresh water for distillation.

The thermocouples are attached at the various positions of the basin water and glass to measure the basin water temperature and glass temperature. The thermocouples are connected to the digital measuring instrument to get the temperature

The frame is made of steel to support the outer tray and completes unit at the given inclination.

The PUF (poly urethane foam) is filled up in the space between the outer tray to provide the insulation

5. EXPERIMENTAL SETUP

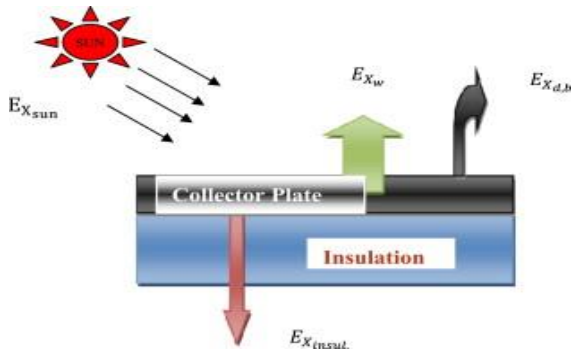

Fig .1

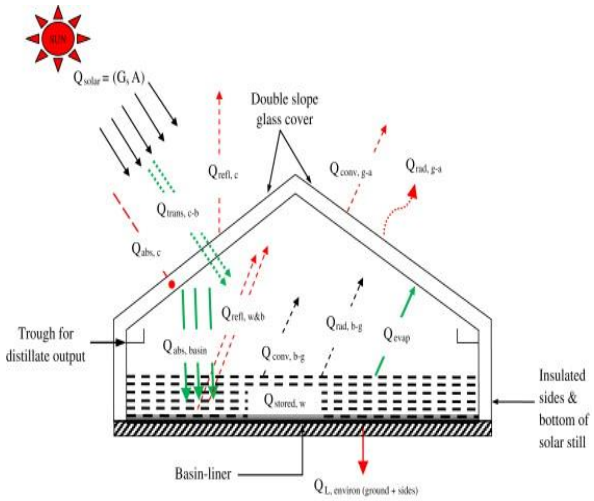

Fig .2

i. Outer Tray:

It is made up of GI sheet of 24 gauges. It has a dimension of 1067mm x 686mm x 228mm. The main function of outer tray is to provide the space for insulation and to support wooden frame and glass.

ii. Inner Tray:

It is made up of GI sheet of 24 gauges and its dimension is 991mm x 610mm x 191mm. It encloses the various steps, which contain the water. The inner tray is placed below the outer tray and the space between inner tray and outer tray is filled up with glass wool for insulation. Below the inner tray, glass wool is provided to prevent the heat losses. At the lower end of the inner tray, the distilled water collecting trough is provided to collect the distillate. On the upper side of inner tray glass cover is provided.

iii. Steps:

There are 8 numbers of steps each of 40mm height and base is 98mm. The steps are coated with lamb black so that maximum of the solar energy could be absorbed.

iv. Distillate collecting trough:

It is made up of aluminum sheet of dimension 550mm x 50mm x 50mm. The trough is placed lowermost part of the glass cover so as to collect the condensate. One tap is connected with the trough with a pipe to get the distillate output

v. Glass:

Glasses used in these solar stills are 3.5 mm thick. The dimension of the glass is same as that of inner tray. It allows the radiation to enter the basin containing water. It also helps the evaporated water to condense when vapor come in contact of it and get it collected in the trough. The glass is provided with the metallic frame with hinges at the one side to open the basin for cleaning when the salt is deposited on the surface of the basin.

B. Performance Studies

Experimental validation of Solar Still is briefly discussed along with their performance in day as well as night time.

i. Experimental Procedure: Experiments done on the fixed conventional design of the solar still were carried out on successive days during the period March 2013- April 2013. Each experiment started from 9:00 am in the morning to 8:00 pm in the evening. The electrical and electronic parts were tested and calibrated before being used on the various designs of the solar stills. The first part of this research work was to test the stepped type solar still in a fixed position towards the south. Thermocouples were installed on the solar still system at different locations. These locations were: (a) A basin base to measure the temperature of the plate, (b) Inner surface of the glass, (c) Outer surface of the glass, (d) Water temperature in the basin, and (e) Water vapor. The most important factor that affects level of production of the solar still is the amount of solar radiation on the glass cover, called irradiance. Not allof the solar energy that contacts the glass will actually be used for evaporation of the water in the basin because it gets reflected and absorbed by anything it passes through. If the still is not perfectly sealed and insulated there will be heat losses to the surroundings.

6. CONCLUSION

Thermal energy storage is known as one of the best solutions for tackling cooling and heating issues in narrow temperature range, as well as one of the most environment friendly technologies.

This study shows the potential of integration of phase change material with solar still system for producing potable water in rural, semi urban and urban areas throughout the day and night.
The preliminary results show that the system dramatically increases the productivity of 35-40% as compared to conventional solar stills.

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Nomenclature

- Tpcm- temperature of Phase change material, [^{o}C]
- Tb- temperature of base plate, [^{o}C]
- Tgi- temperature of inside glass cover, [^{o}C]
- Tgo- temperature of outside glass cover, [^{o}C]
- T- ambient temperature, [^{o}C]
- Tw- temperature of water, [^{o}C]
- t- time
- W- Distillate

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