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IMPROVEMENT OF PYRAMID TYPE SOLAR STILL PERFORMANCE USING WAX LATENT HEAT MATERIAL

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ABSTRACT

Experimental measurements to determine conditions necessary for efficient solar desalination are given. The effects on performance of using wax latent haet material with storage system in pyramid type solar stills are investigated. Main objective of this present paper is to study the behavior of the still performance with latent heat material by analyzing the internal and external heat transfer modes and thermophysical properties of the pyramid type solar still.

Keywords: solar still; solar energy; distillation; distilled water.

INTRODUCTION

Distillation has long been considered a way of making salt water drinkable and purifying water in remote locations. As early as fourth century B.C., Aristotle described a method to evaporate impure water and then condense it for potable use. P.I.Cooper, in his efforts to document the development and use of solar stills, reports that Arabian alchemists were the earliest known people to use solar distillation to produce potable water in the sixteenth century. But the first documented reference for a device was made in 1742 by Nicolo Ghezzi of Italy, although it is not known whether he went beyond the conceptual stage and actually built it.

H.K.Gaur and G.N.Tiwari[1] (2010) optimized the number of collectors for PV/T hybrid active solar still. The number of PV/T collectors connected in series has been integrated with the basin of solar still. The optimization of number of collectors for different heat capacity of water has been carried out on the basis of energy and energy computed value of daily yield is approximately 7.9Kg for 50Kg water and 0.055 Kg/s, which is higher than that of the daily yield obtained from passive solar still by various researchers.

Thermal modeling of a double slope active solar still has been carried out by V.K.Dwivedi and G.N.Tiwari [2](2010) has been observed that the thermal efficiency of double slope active solar still is lower than the thermal efficiency of double slope passive solar still. However, the energy efficiency of double slope active solar still is higher than the energy efficiency of double slope passive solar still under natural modes gives 51% higher yield in comparison to the double slope passive solar still.

K.Kalidasa murugavel et al.,[3] (2010) developed a solar still which can convert available waste brackish water into potable water using solar energy. A single basin double slope solar still with an inner basin size, 2.08mx0.84mx0.075m and that of the outer basin size2.3mx1mx0.25m has been fabricated with mild steel plate and tested with a layer of water and different sensible heat storage materials like quartzite rock, red brick pieces and cement concrete pieces. The production rate depends on water-glass temperature difference and glass atmospheric temperature difference.

Farshad farshchi tabrizi et al.,[4] (2010) have demonstrated that solar sills were used for water desalination in arid lands with lack of water in the fair climatic conditions. Two cascade solar stills were constructed with and without latent heat thermal energy storage system (LHTESS) paraffin wax is selected as the phase change material (PCM) which acts as a LHTESS. Thermal performances of the stills were compared in typical sunny and partially cloudy days. However, foe a partially cloudy day, the still with LHTESS has a significantly higher productivity. The still without LHTESS is preferred for sunny areas because of its simplicity and low construction costs, while the still with LHTESS is proposed for partially cloudy areas due to the higher productivity.

Rocio Bayan A et al.,[5] (2010) have tested the latent heat thermal storage prototype under real working condition with steam produced by a parabolic-trough collector test facility at the plataforma solar de Almeria. The proto type contained KNO_3/$NaNO_3$ eutetic mixture as phase change material (PCM) and expanded graphite fins arranged in a sandwich configuration for improving thermal conductivity. Experimental data such as steam quality, PCM temperature distribution, stored energy and thermal power have been analyzed for a selected day. It has been noted that stored energy and the resulting thermal power are 40kwth and 50kwth respectively.

Al-Hinti et al.,[6] (2010) investigated on the uses of water-phase change material storage in conventional solar water heating system. Paraffin wax contained in small cylindrical aluminum containers is used as the PCM. The PCM storage advance is first demonstrated under controlled energy input experiments with the arid of an electrical heater on an isolated storage tank, with and without the PCM container. The storage performance was also investigated when connected to flat plate collectors in a closed-loop system with conventional natural circulation. Over a test period of 24h.The stored water temperature remained at least 30°c higher than the ambient temperature.

H.Shabgard et al.,[7](2010) developed a thermal network model and used to analyze heat transfer in a high temperature latent heat thermal energy storage unit for solar thermal electricity generation. Two storage configurations are considered: one with PCM surrounding a tube that conveys the heat transfer fluid, and the second with PCM contained within a tube over which the heat transfer fluid flows. Both melting and solidification are simulated. It is demonstrated that adding heat pipes enhance thermal performance, which is quantified in terms of dimensionless heat pipe effectiveness.

M.Medrano A et al.,(8) (2009) made a study on the phase change material (PCM) possess a great capacity of accumulation of energy in their temperature of fusion thanks to the latent heat. These materials are used in applications where it is necessary to store energy due to the temporary phase shift between the offer and demand of thermal energy. Possible applications are the solar system as well as the recovery of residual heat for its posterior use in other processes. The thermal storage technology based on the use phase change materials (PCM) has recently raised an important practical interest.

Yibing Cai et al.,[9] (2009) have presented work the thermal energy storage phase change materials (PCM) based on paraffin/high density polyethylene (HDPE) composites were prepared by using twin-screw extruder technique. Therefore, considering applications in low-temperature heat storage of paraffin, the HDPE still can acts as supporting materials and prevent the phase change from solid to liquid.

Humid EL Qarnia [10] (2009) presented the theoretical model based on the energy equations was developed to predict the thermal behavior and performance of a solar latent heat storage unit (LHSU) consisting of a series of identical tubes embedded in the phase change material (PCM). A series of numerical simulations were conducted for three kinds of PCM to find the optimum design for a given summer climatic conditions.

N.Nallusamy and R.Velraj[11] (2009) have studied the experimental apparatus utilizing paraffin as PCM, which is filled in high-density polyethylene spherical capsules, is constructed and integrated with a solar flat plate collector to conduct the exprements. The water used as HTF to transfer heat from the solar collector to the storage tank also acts as sensible heat storage (SHS) material. It is found that the results of the numerical model are in good agreement with the experimental results.

Frederic Kuzhik et al., [12] (2008) have constructed the use of phase change materials (PCM) allows storage of energy from the solar radiation. The application of such possible to improve thermal comport and reduce energy consumption

B.B.Sahoo et al.,[13] (2008) made a performance study on the assessment of a solar still using blackened surface and thermocol insulation. The present work is aimed at utilizing solar energy for removal of fluoride from drinking water by using a solar energy. Also test have been conducted with the solar still to find out hourly output rate and still efficiencies with various test matrices.

Cemil Alkan[14] (2007) investigated paraffin's are used as phase change material (PCM) for latent heat thermal storage (LHTES). The efficiency of a PCM is dependent on the encapsulated quantity and energy storage capacity per unit mass during its melting and solidifying. Two different kinds of paraffin were sulfonated at three different mole percentages to increase the LHTES efficiency for this purpose.

Rustum mamlook & Omar Badran[15] (2007) have made an attempt to find out the effect of different parameters on the solar still output using a fuzzy set technique. The study reveals that the major factors that affect yield are: wind speed(WS),ambient temperature(AT),solar intensity(SI),sprinklers(SPR),coupled with collector(CC),salt concentration(SC),water depth(WD)

Hiroshi Tanaka and yasuhito nakatake[16] (2006) presented a theoretical analysis of a basin types still with internal and external reflectors. The numerical analysis of heat and mass transfer in the still, and found that the internal and the external reflectors can remarkably increase the distillate productivity throughout the year except for the summer season.

W.Saman et al., [17] (2005) analyzed and discussed the thermal performance of a phase change storage unit. The storage unit is a component of a roof integrated solar heating system being developed for space heating of a home. The unit consists of several layers of phase change material (PCM) slabs with a melting temperature of 29^{o}C.The effects of sensible heat which exists when the initial temperature of the PCM is well below or above the melting point during melting were taken in to account.

Abdulhaiy M.Radhwan[18] (2005) made an attempt to find out the still was designed for heating and humidification of agriculture green houses (GH) in remote areas. The basin was placed on a slab filled with a layer of paraffin wax that acts as a latent heat thermal energy storage system (LHTESS).The still performance parameters investigated were analyzed and the results compare d with the case of a still with LHTESS has an efficiency of 57% and the total daily yield is about 4.6 L/m^2.

MATERIALS AND METHODS

Fresh water is the essence of life and it is an urgent need for human life. Fresh water is the most important constituent of the environment brackish water contains harmful bacteria and therefore cannot be used for drinking. About 97% of available water source are saline or include harmful bacteria and 2% is frozen in glaciers and polar ice caps. Hence, only 1% of the world's water is usable for drinking and domestic usage (Farshad Farshchi Tabrizi et al., 2010).Solar distillation is one of the many processes that can be used for water purification. Solar stills can provide a solution for those areas where solar energy is available in plenty but water quality is not good. This device can be used for producing drinking water. Solar stills are cheap and having low maintenance cost. Solar radiation can be the source of heat energy where brackish or sea water is evaporated and is then condensed as pure water. **(A.A.EI-Sebaii et al., 2009)**

Construction of Pyramid Solar Still

General Setup of the Still

Pyramid solar still of base area 0.85m x 0.85m is designed. The still is filled with the water to a height of 0.05m. Top of the system is covered by a 3 mm transparent glass pyramid cover with a height of 0.30m at the middle. It is air tightened using the cushion supports at the interface between the top cover and the sides of sliding support for uniform landing. Bottom of the still is insulated using sawdust.

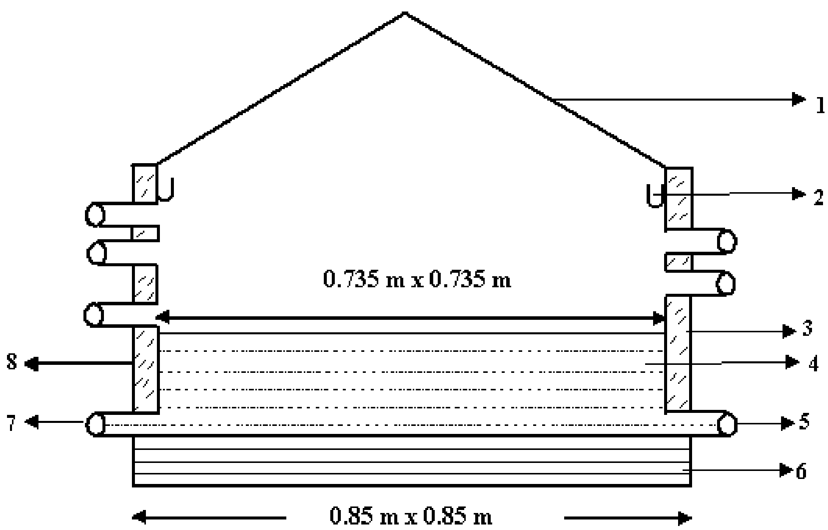

Figure (3.2) Cross sectional view of pyramid solar still

1.	Top cover	5.	Still outlet
2.	Water collection segment	6.	Sawdust insulation
3.	Glass Wool Insulation	7.	Still inlet
4.	Water storage basin	8.	Wooden box

PCM STORAGE MATERIAL

The PCM storage material used for the performance study of both the pyramid type solar still and single solar still is the pure wax, uniformly chopped of almost uniform size. The Wax pieces were spread to a uniform thickness of 0.025 mm in the Aluminum blackened box. The area of the aluminum box is 24 gauge mild steel. The Wax storage material can store more amount of heat energy and increase the heat capacity of the basin. Paraffin wax is an attractive material for heat storage application. Phase change materials (PCMs) are latent thermal storage materials. They use chemical bonds to store and release heat. The thermal energy transfer occurs when a material changes from a solid to a liquid or from a liquid to a solid form. This is called a change in state or phase initially these solid-liquid PCMs perform like conventional storage materials: their temperature rises as they absorb solar heat. Unlike conventional heat storage materials, when PCMs reach the temperature at which they change phase (their melting point), they absorb large amounts of heat without getting hotter. When the ambient temperature in the space around the PCM material drops, the phase change material solidifies, releasing its stored latent heat.PCMs absorb and emit heat while maintaining a nearly constant temperature. Within the human comfort and electronic-equipment tolerance range of 20°c to 35°c, latent thermal storage materials are very effective. They are also useful for equalization of day night temperature and for transport of refrigerated products.

INTERNAL HEAT TRANSFER

Internal heat transfer occurs within the solar still. The internal heat transfer modes are due to convection, evaporation and radiation.

a) Convection:

The convective heat transfer is conveniently considered in terms of dimensionless parameters namely Nusselt number (Nu), Grashof number (Gr), Prandtl number (Pr) and Reynolds (Re). The expressions for these numbers are

Nusselt number (Nu) = $(h_{cw}X/K)$ .... (9)

Grashof number (Gr) = $(X^3\rho^{2g}\beta T/\mu^2)$ .... (10)

Prandtl number (Pr) = $(C\rho\mu/K)$ .... (11)

b) Evaporation:

Dunkle (1961) connects convective and evaporation heat transfer coeffients as

H_{ew} = 16.273 x 10-3 h_{cw} .R_1W/m2 .... (18)

c) Radiation:

In the usual analyses of solar stills, the water surface and the glass cover are considered as infinite parallel planes. Using Stefan Boltzmann's constant, the heat transfer coefficient is given by,

$q_{rw}=h_{rw}(T_w-T_g)$ .... (21)

EXTERNAL HEAT TRANSFER

The external heat transfer modes are due to convection, radiation, and conduction.

a) onvection:

The external Convention loss from glass cover to the outside atmosphere is,

$q_{ca}= h_{ca} (T_g-T_{amb})$ .... (22)

h_{ca} is a function of wind velocity and is given by,

$h_{ca} = (5.7 + 3.8 V)$

b) Radiation:

The external radiation loss from the glass cover to the atmosphere is given by,

$q_{ra} = \varepsilon\sigma[(T_g + 273)^4 - (T_{sky} + 273)^4]$ .... (23)

c) Conduction:

External heat transfer due to conduction through the bas is found using the formula

$q_b = h_b (T_w-T_{amb})$ .... (26)

EXPERIMENTAL STUDY

The performance of the still has been studied on clear sunshine for a no of days during the period December to march, 2010-2011. The following observations are taken for analyzing the performance of square trough solar still with pyramid shaped top cover & sloped sheet made of glass. The observations carried out are measurement of temperature profiles, total solar insulations measurement and distillate water output measurement, including nocturnal output. These observations are made from 9 am to 5:30 pm for every half an hour intervals on selected clear shiny days.

DISCUSSION

The performance of the pyramid cover solar still and single slope solar still is analyzed in this study for normal sunny days. Temperature profiles of water, ambient, cover and amount of distillate output were observed, including nocturnal output along with the measurement of solar radiation for every half an hour interval. The performance of a pyramid cover solar still and single slope solar still is analyzed with PCM storage material of wax were augmenting the productivity . The instantaneous and daily efficiency were calculated along with the computation of heat transfer coefficients. Numerical calculations are carried out for comparing the observed values of heat transference with theoretical simulation values for the same. The system reliability and viability are estimated by a techno economic analysis. The standard and quality of distilled water yield is examined for physical and chemical properties in the regional laboratory, Tamil Nadu supply and drainage board, Coimbatore.

Graphical Analysis

The pyramid cover solar still and single slope solar still graphs are plotted for various observed parameters such as solar insolation, efficiency, distillate output, temperature profile of various junctions etc., during selected sunny days of experimentations with heat absorbing PCM storages materials.

Typical results of variation of the temperature profile with respect to time, with PCM storage material are shown in fig(5.1).The cover temperature of the still increases as the day progresses because of the increased evaporation of water from basin and consequent condensation of water vapour at the bottom surface of the top cover. Ambient temperature variation depends on atmospheric conditions. The temperature of water and glass cover have similar trends and increases in the morning hours to maximum values and decreases Late in the afternoon.

Instantaneous efficiency as a function of time with PCM storage in both the stills fig (5.3). Instantaneous efficiency of pyramid cover solar still and single slope solar still was in the range of 0-44 and 0-49 respectively observed with PCM storage material. It is found that the efficiency of single slope solar still with PCM storage material is more than the pyramid type solar still.

Fig (5.2) & Fig (5.4) water temperature and distillate output with respect to time observed with PCM storage material in pyramid type solar still and single solar still respectively. The water collection from pyramid cover solar still and single slope solar still was 1876ml and 1726ml respectively.

The pyramid cover solar still performance is reasonably good compared to sinsgle slope solar still in daily output with nocturnal output. The addition of sensible heat absorbing materials were capable of enhancing the productivity with heat retention causing continued evaporation.

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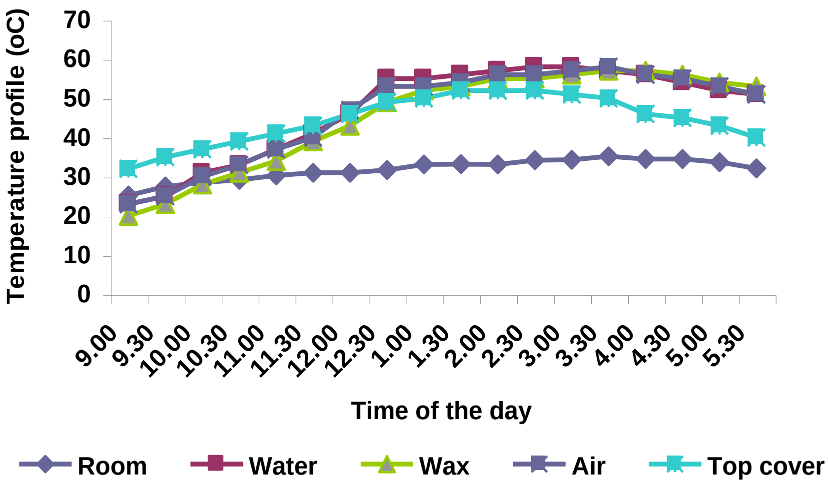

Figure. (5.1) Time Vs. Temperature Profiles for single slope solar still

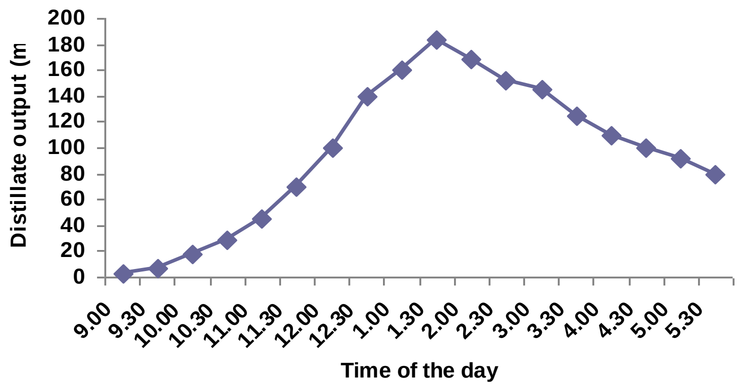

Figure. (5.2) Distillate Output Vs. Time for single slope solar still

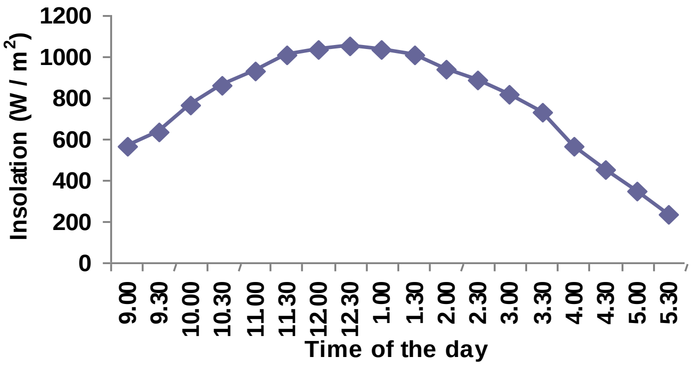

Figure. (5.3) Insolation Vs. Time for single slope solar still

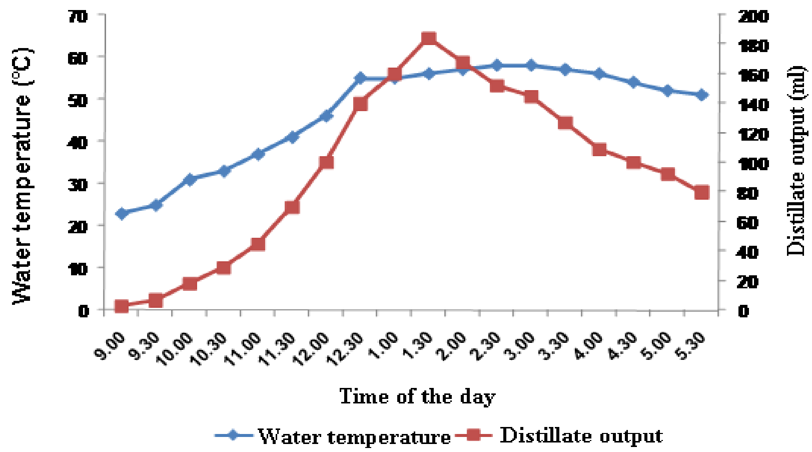

Figure (5.4) Water Temperature / Distillate Output Vs. Time for single slope solar still