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Efficiency Evaluation of Heat Exchanger Based Domestic Solar Water Heater - A Review

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Abstract

In this paper an attempt has been made to review the literature of performance improving techniques for solar water heater. In view of energy crisis, the application of solar energy in the form of solar water heater is most useful for domestic, commercial and industrial purpose but it is found that the application of its limited due to its demerits. Hence attempt to be made to find out the demerits of solar water heater and improve its performance so that it becomes more popular in domestic, commercial, as well as in industrial applications. The main objective of this research paper is to present the current status and future aspects of Solar water heater in the world by comprehensively reviewing various solar water heater related studies. This review paper shows comprehensive review and researches on solar water heater by various researchers of the world.

Keywords: Renewable energy, solar water heater, solar energy, domestic water heater, natural circulation.

Introduction

Solar radiation is an alternative energy source for numerous industrial and domestic applications. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Hence the domestic sector can lesson its impact on the environment is by the installation of solar flat collector for heating water. Conventional natural circulation flat plate solar water heaters are the most economical and large scale use of solar energy all over the world. Its thermal performance and efficiency which depends on its design parameters, thickness, type of insulation, number and type of glass covers, spacing between absorber and inner glass. Apart from these parameters its performance also depends on climatic and operational parameters.

The objective of the study is to conceive a cheap and efficient flat plate solar water heater. The work focuses mainly on the increasing the performance and efficiency of the solar water heater.

The circulation of the water in solar water heater is natural circulation due to the density differences between the hot water and cold water. The block diagram of solar water heater is shown in figure. Solar water heating systems use collector panels to capture the suns radiation and convert it into useful heat in the form of hot water. A solar collector coupled with solar water storage reduces the fuel needed for domestic hot water. Solar thermal systems could make a contribution to space heating as well as providing hot water. Water flows through tubes that are attached to a black metal absorber plate. The plate is enclosed in an insulated box with a transparent window to let in sunlight. The heated water is transferred to a tank where it is available for home, commercial or institutional use.

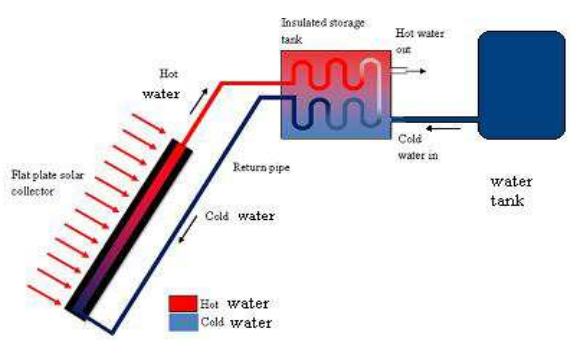

Figure: Block diagram of the heat exchanger based solar water heater

Literature Reviews

H.Y. andoh, et al [1]

In this research paper the thermal performance of the solar water heater designed with a local vegetable material as insulating material, coconut coir, widespread in tropical countries. The study focuses on the comparative thermal performance of this collector and

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another collector, identical in design, fabrication and operating under the same condition, using glass wool as heat insulation as well as with eight other design, chosen randomly using various materials as heat insulation with performance data from the literature, the material cost of the coconut coir collector is 25 % less than the glass wool one. The result of the study show very good thermal performance of the collector using coconut coir compared to the traditional ones.

Sumit ambade, et al [2]

This paper represents a simple method, low cost combined batch type solar water heater cum regenerative solar still. In this paper effort is being is made to integrate two different solar appliances so that they could work in much better way. Solar water heater cum distillation system is designed and fabricated to carry out two operations simultaneously heating of water and distillation. This composite unit performs more than one operation and converts solar energy into the thermal energy to make the devices more versatile and efficient.

Vimal dimri, etal [3]

This paper projects an attempt that has been made to evaluate inner and outer glass temperature and its effects on yield higher yield was observed for an active solar distillation system as compared to the passive mode due to higher operating temperature differences between water and inner glass cover. The parametric study has also been performed to find out the effects of various parameters, namely thickness of condensing cover, collector absorbing surface, wind velocity and water depth of the still. It is observed that there is significant effect on daily yield due to change in the values of collector absorbing surface, wind velocity and water depth.

Mattheus F.A. Goosen, et al [4]

This paper describes thermodynamic and economic considerations in solar desalination. This paper closes with a summary of key factors affecting system performance and recommendations for future areas of investigation and development. The thermodynamic efficiency of single basin and multiple effect solar water desalination systems was critically reviewed with special emphasis on humidification-dehumidification processes. Solar energy may be used either directly or indirectly to produce fresh water. System economics was also covered since it affects the final cost of produced water

Mohaned A. Eltawil, et al [5]

The objective of this paper is the development of technologies integrated with desalination systems. And a comparative study between different renewable energy technologies powered desalination system as well as economics have been done. The economic analyses carried out so far have not been able to provide a strong basis for comparing economic viability of each desalination technology. The economic performances expressed in terms of cost of water production have been based on different system capacity, system energy source, system component, and water source. These differences make it difficult, if not impossible, to assess the economic performance of a particular technology and compare it with others, reverse osmosis is becoming the technology of choice with continued advances being made to reduce the total energy consumption and lower the cost of water produced.

Zhang tao, et al [6]

Zhang tao experimentally investigated the performance of the two sets of collectors which were applied separately when the collector are mounted in 90^o and 15^o of ground, and found that the latent heat can be used effectively to increase the heat storage when the collectors have the right installing angle.

G.N. Tiwari, et al [7]

This paper presented the parametric study of passive and active solar stills integrated with a flat plate collector based on the computer based thermal models. These models are developed based on mass and energy balance equations. The effect of inner and outer glass cover temperatures on the performance of the solar stills is studied which lacks in this literature. The comparison is made between active and passive solar stills based on the hourly yield values for the two assumptions. The thermal performance of the active solar still is affected by design parameters like water depth, thickness of glass cover, insulation thickness, condensing cover material, type of solar collector, number of collectors, and also affected by a change in climatic parameters like ambient air temperature, solar intensity and wind velocity. The effect of design parameters and wind velocity on the daily yield of both passive and active solar stills is presented in this paper

Ruchi shukla, et al [8]

This paper concerns with the recent advances in the solar water heating system. Recent developments in heat pump based solar collector technology exhibit a promising design to utilize solar energy as a reliable heating source for water heating applications in solar adverse regions. Heat pump based solar water heating is influenced by many factors including the nature of the refrigerant. Due to the environmental concerns, the refrigerants with high global warming potential have come under scrutiny and several have already been phased out. Driven in part by these concerns, new refrigerants are being sought out and ‘‘old’’ refrigerants such as carbon dioxide, ammonia and propane are being investigated. Apart from the choice of working fluid, there has been a major research focus in improving the performance of various components of the SWH system.

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Nay Zar Aung, et al [9]

This paper numerically investigated the effect of riser diameter and inclination on system parameters in a two phase closed loop thermosyphon solar water heater the effect of riser diameter and its inclination angle on system parameters in a two-phase closed loop thermosyphon solar water heater has been numerically investigated. Here, receivable heat flux by the collector, circulating mass flow rate, driving pressure, total pressure drop, heat transfer coefficient in risers and collector efficiency are defined as system parameters. For this aim, a model of two-phase thermosyphon solar water heater that is acceptable for various inclinations is presented and variations of riser diameter and inclination are considered and water is chosen as working fluid. The results show that higher inclination angle is required for higher latitude location to obtain maximum solar heat flux. The longer two-phase heat transfer characteristics can be obtained at smaller inclination angles and mass flow rate for all riser tube sizes. Therefore, it is observed that the optimum inclination angles and diameters for solar heat flux, circulating mass flow rate and heat transfer coefficient in two-phase thermosyphon system do not coincide. From this work, better understanding and useful information are provided for constructing two-phase thermosyphon solar heaters.

Abmed safwat nafey etal [10]

This paper concerns about the simulation of the solar water heater. Simulation has become an accepted tool for the performance, design, and optimization of thermal processes. Solving the mathematical models representing solar heating process units and systems is one of the most tedious and repetitive problems. Nested iterative procedures are usually needed to solve these models. To tackle these problems, several researchers have developed different methods, techniques, and computer programs for the simulation of very wide verity of solar heating process units and systems.

Lebanon's market for domestic solar water heaters: Achievements and barriers. [11]

This research paper discussed about the domestic solar water heater's achievements and its barriers. Domestic solar water heating systems are a cost effective and mature technology that enjoys increasing popularity around the world yet in many countries the penetration rates are still low. The recent growth in Lebanon's solar water heater market reflects tremendous efforts on the legislative, financial, and awareness level. This paper analyzes the developments in this market and highlights persisting barriers. Our scenario analysis presents a baseline scenario and two different renewable energy scenarios.

C.R. Lloyd, et al [12]

In this research paper the performance of commercially available solar water heaters. This paper includes the policies incentives to adoption of energy efficient hot water heating as a means of reducing greenhouse gas emissions. Such policies rely heavily on assumed performance factors for such systems. This paper also found that the performance of solar system can be markedly improved through the use of auxiliary controllers to prevent the non environmental energy source coming on during daytime.

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S. no. [1]	Author [2]	Parameters [3]	Specification [4]	Formula [5]	Result [6]
1.	H.Y. Andoh	1) Insulation 2) Insulation thermal conductivity 3) insulation thickness 4) fluid flow rate	Insulation material: Coconut coir / Glass wool Insulation thermal conductivity: 0.074 / 0.040 Insulation thickness: 50 / 50 Fluid flow rate: 0.0085 / 0.0085	Energy gain :(Q_u)=m c_p(T_{fo}-T_{fi}) Heat loss :(Q_L)=A_C U_L(T_{abs}-T_a) Collector efficiency (ή)=Q_u/$A_c I_t (\tau\alpha)$ Thermal conductivity $\frac{dQ}{dt} = -kdS\,\frac{\partial t}{\partial n}$	1) The result obtained after 10hr. of maintaining the device in a steady state is k=0.074 w/m k, with result precision = ±5%, 2) efficiency= 52% 3) thermal conductivity= 0.0828 w/m k
2.	A. Sumit ambade	1)water depth 2)thickness of glass 3)insulation thickness 4)condensing cover material 5)types and no. Of collector 6)ambient air temperature 7) wind velocity	Mass of water=100kg Initial temperature=20°c Specific heat of water=4.19KJ Heat required per day=16748KJ Overall collector efficiency=40% Collector area=2 m^2 Slope of collector=42°	Solar water heater efficiency ή = ms (Tf − Ta) / (∑IA_pΔt) distillation efficiency $ή_{dist}$ = Q_e/Q_t Slop of the collector (β)=(Q-δ) Angle of inclination (δ)= 23.45 sin[0.9863(284+n)]	1) max. Temp. Of water in storage tank=55°c 2) thermal efficiency=55% 3) distillate output=556ml/day 4) the result of PH and total dissolved solid measurement of distilled water and normal water were 7.1, 7.9, 30ppm. The distilled water can be used for its low dissolved solid.
[1]	[2]	[3]	[4]	[5]	[6]
3.	Vimal dimri	1)thickness of condensing cover 2)collector 3)absorbing surface 4)wind velocity 5)water depth.	Design parameter of flat plate collector effective area of the collector=4m^2 Specific heat of working fluid=4190 J/kg°c collector efficiency factor=0.8 mass flow rate=0.035kg/s overall heat transfer coefficient of the collector=6w/m^2°c depth of water in the basin=0.05m.	Outer glass temperature (T_{go})=[α'$_g$ $I_{effs}h_k$+$U_{wo}T_w$+$h_{1g}T_a$]/[h_{1g}+U_{wo}] Hourly output is given by (m_{ew})=[h_{ew}(T_w-T_g)3600]/L	It is clearly indicated that yield decreases with the increase of glass cover thickness due to reduction in the top loss coefficient, yield decreases with increase of water mass from 20 to 150kg
4.	Mattheus	1)mass of water 2)heat exchanger length 3)mass flow rate	1)the total area of the solar absorber =966m^2 2)surface area of the solar pond=1700m^2 3)surface area of the flat plate collector=81m^2	Hourly productivity of the still (P_h)=3600h_{ewg}(T_w-T_g)/L_w Daily efficiency of the still ($ή_d$)=[100$P_d L_{av}$]/[A_pΔt∑I_g] Daily thermal efficiency ($ή_d$)=∑m_{pwL}/[∑I(t)A_{st}+∑ I'(t)A_c]3600	The paper closes with a summary of key factors affecting system performance and recommendations for future areas of investigation and development.
5.	Mohammad Ali fazilati	1) Effect of phase change material as storage medium.		Storing sensible heat (Q_s)=msΔT Stored energy(Q)=$\sum_j m_c$(T_{ij}-T_{aj})Δt_j Total exergy entered/exited from/to the tank during charge/discharge is determined by Δx=$\sum_j m_c$ (T_e-T_i)-$T_o I_n$(t_e/T_i)	Energy storage density increased by 39% and exergy efficiency is enhanced by 16%.

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<table>
<tr><th>[1]</th><th>[2]</th><th>[3]</th><th>[4]</th><th>[5]</th><th>[6]</th></tr>
<tr>
<td>6.</td>
<td>Zhang tao</td>
<td>1)angle of the collector
2)water depth
3)thickness of glass
4)insulation thickness
5)condensing cover material
6)types of solar collector
7) no. Of collector</td>
<td>1)Area of the collector= $1.45m^2$
2)no. Of tubes=12(Φ58-1800mm.)</td>
<td>Solar radiant energy per unit time
$q=E*s*\sin(\delta+v)$
$\sin\lambda=\sin\lambda_o*\sin_{wt}$
Solar energy received by the solar panels
$Q=\int_0^t q.dt$
$Q_1=P*Q-k*\Delta t*q_1*t$
$\delta=90°-\lambda_\circ=|\alpha-\beta|$
thermal discharge of the heat transfer fluid
$Q=\sum_{n=2}^{i/2} 2C*m*(t_{out}-t_{in})$
$Q_1=P*E*S*2/w*\sin(\delta+\lambda_\circ)-(k*\Delta t*q_1*t)$</td>
<td>1)outlet temp.=38^0c-40^0c
<table>
<tr><td>Tilt angle</td><td>90°</td><td>15°</td></tr>
<tr><td>The average temp. Of hot water</td><td>35.6°c</td><td>40.3 °c</td></tr>
</table>
</td>
</tr>
<tr>
<td>7.</td>
<td>G.N. tiwari</td>
<td>1)water depth
2)water depth
3)thickness of glass
4)insulation thickness
5)condensing cover material
6)types of solar collector</td>
<td>1)Area of the collector=$2m^2$
2)specific heat of water=4190
3)collector efficiency factor=0.8
4)mass flow rate=$0.035kgs^{-1}$
5)overall heat transfer coefficient=$6wm^{-2}c^{-1}$
Effective-absorptance transmittance product</td>
<td>Thermal efficiency of solar still:
Passive solar still
$(\acute{\eta}_{passive})=\sum(m_{ew}L)/\sum[I(t)_s*A_s*(3600sh^{-1})]$
Daily yield
$(M_{ew})=\sum_{i=1}^{24} m_{ew}$
Hourly yield
$(M_{ew})=A_s h_{ew}(T_w-T_{gi})3600sh^{-1}/L$</td>
<td>1)the optimum depth for the highest yield from the active solar still is 0.11m water depth.
2)thickness of insulation is 0.1m for 0.03m. water depth.
3)The optimum no. of collectors for max. Yield for 0.15m water depth was found to be 3.</td>
</tr>
</table>

Nomenclature

Q_{u} = useful energy gain
m = working fluid rate
C_p = specific heat of water
T_{fo} = final temp. Of the fluid
T_{fi} = initial temp. Of the fluid
Q_L= heat loss
A_C = collector area
U_L = collector overall heat loss coefficient
T_{abs} = absorber temp.
T_a = ambient temp.
ή = efficiency
I_t = radiation intensity
Tα = fraction of the solar radiation absorbed by the collector
A_P = aperture area
Δt = time
$\acute{\eta}_{dist.}$= distillation efficiency
T_{go} = outer glass temp.
α'_g = fraction of energy absorbed
I_{effs} = effective solar intensity w/m^2
h_k = heat transfer coefficient
U_{LC} = overall heat transfer coefficient for collector.
T_i = average of water and inner glass temp.
h_{1w} = total heat transfer coefficients from water surface to glass cover, w/m^2
T_{go} = outer glass temp.
h_{1g} = total heat transfer coefficients from water surface to glass cover w/m^2
U_l = overall top loss coefficient from water surface to ambient air, w/m^2
β = slope of the collector
Q = latitude of the test site
δ = angle of the inclination
n = no. of days
m_{ew} = daily output of still kg/m^2
L_g = thickness of glass
P_h = hourly productivity of the still
h_{ewg} = evaporative heat coefficient
T_w = temp. of the water
T_g = temp. of the glass
L_w = latent heat of vaporization of water
$\acute{\eta}_d$ = overall daily thermal efficiency
P_d = daily productivity
L_{av} = average latent heat
I_g = solar radiation intensity incidental on the glass

Conclusion

At Present, Solar water heating systems are installed with different configurations and arrangements. The basic technology concrete of these systems are studied and it is found that there is a need to work on the generated design procedure to select, install and monitor the solar water heating system as per the availability of solar radiation and local geographical condition. Hence need to find out the demerits of solar water heater and improve its performance so that it becomes more popular in domestic, commercial, as well as in industrial applications.

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