Mansoura Engineering Journal

Volume 27 | Issue 3 Article 6

1-25-2021

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Recommended Citation
Bayoumi Kabeel, Abdelnabi (2021) "Transient Model of the Performance of Solar Collector under Green House Effect.," *Mansoura Engineering Journal*: Vol. 27 : Iss. 3 , Article 6.
Available at: https://doi.org/10.21608/bfemu.2021.142978

TRANSIENT MODEL OF THE PERFORMANCE OF SOLAR COLLECTOR UNDER GREEN HOUSE EFFECT

النمزجة الوقتية لأداء المجمع الشمسى تحت تأثير ظاهرة الأحتباس الحرارى

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الخلاصة:

يعتمد أداء السخان الشمسي على درجة حرارة الهواء المحيط بالسخان. فكلما زادت تقل المفاقيد من السخان الشمسي. في هذا البحث تم وضع نموذج رياضى نظري لسخان شمسي داخل صوبة شفافة والأرضية المحيطة بالسخان من فرشة إسفلتية سمراء. تم دراسة تأثير كلا من سمك الفرشة الإسفلتية ونفاذية غطاء الصوبة وكذلك حجم الصوبة على أداء السخان الشمسي وقد تم دراسة تأثير كل متغير على حدة وحساب درجات الحرارة للفرشة الإسفلتية والهواء الداخلي وكذلك السخان الشمسي كما تم عمل مقارنة بين أداء السخان داخل الصوبة وفي الهواء الجوى.

وقد أظهرت النتائج تحسن أداء السخان الشمسي الموضوع داخل الصوبة عن السخان الموضوع خارج الصوبة.. فقد زادت الحرارة المكتسبة بنسبة تتراوح من 12-18%. وقد أظهرت النتائج أيضا زيادة درجة حرارة الهواء داخل الصوبة عن الهواء الجوى في حدود 14-20 درجة مئوية حيث تتوقف القيمة على الظروف المختلفة التي تم دراستها نظريا. وأوضحت النتائج قيمة الحرارة المخزنة في الصوبة حيث تم حساب قيمتها خلال فترات اليوم حتى منتصف الليل.

ABSTRACT

One of the important parameters that affect the performance of solar collector is the ambient air temperature around the collector. Increasing ambient air temperature around the collector reduces the losses from the collector, which enhance collector efficiency. In the present work, theoretical investigation on solar collector under green house effect is performed. The floor of transparent-wall enclosure is covered with a black pebbles bed as heat storage. From the theoretical model, the temperatures variation of air in enclosure, pebbles bed and collector during the day time for different values of enclosure transmissivity, bed thickness and enclosure volume, were evaluated. Also, the results for the collector performance in transparent-wall enclosure and that for the collector in the open-air condition are compared. From the theoretical model, it is observed that the air temperature rise in the green house reached 20 C above ambient temperature. A corresponding enhancement of useful heat gain of about 12-18 % for the collector in transparent enclosure can be reached. The system continued functioning several hours after the sunset due to the energy storage in the system.

Keywords: Solar collector, green house

NOMENCLATURE

A_a	enclosure surface area , m^2
A_c	collector surface area, m^2
A_b	pebbles bed surface area, m^2
A_1	enclosure surface area, m^2
B	duct width, m
c_p	specific heat of the water, kJ/kg. °C
C_b	conductance of the bond , W/m °C

Accepted September 22, 2002.

C_w	conductance of the tube wall, W/m.°C
D_h	hydraulic diameter of the duct.
F_s	shading factor
F_R	heat removal factor
F	collector Fin efficiency factor
F^-	collector efficiency factor
H	total solar radiation incident upon the plan of enclosure, W/m^2
h	hour angle, degree
h_{fi}	heat transfer coefficent, W/m^2 C
K	the thermal conductivity f the insulation, W/m °C
L	latitude angle
b	insulation thickness, m
L_1	enclosure length, m
L_2	collector plane length, m
L_3	shading area length, m
k	thermal conductivity of absorber plate, W/m °C.
k_b	total loss coefficient from the black pebbles to ground, W/m °C
Mc	collector mass, kg
$m^{\cdot}_w$	water flow rate passing in the collector, Kg/h
Nu	Nusselt number
Pr	prandtl number
q_1	heat transfer from the inside air to outside air, W
q_2	heat transfer from black pebbles to air in enclosure, W
q_3	total heat loss from the black pebbles to ground, W
q_{ca}	heat transfer from collector surface to air in enelosure, W
q_b	heat transfer from the bed to the ground, W
Q_u	useful heat gain, W/m^2
Re	Reynolds number
S	absorbed solar energy, W/m^2
T_a	ambient air temperature beside the collector, K
T_{wi}	water inlet temperature to the collector, K
T_{wo}	water outlet temperature from the collector, K
T_{ao}	ambient air temperature beside the collector, K
T_{ai}	air temperature inside green house, K
T_b	black pebbles bed temperature, K
T_c	collector surface temperature, K
T_{gr}	ground temperature, K
U_1	heat transfer coefficient from the inside air to outside air, W/m^2°C
U_2	heat transfer coefficient from black pebbles to air in enclosure, W/m^2°C
U_L	total loss coefficient from the collector, W/m^{2o} C
U_b	back loss coefficient from the collector, W/m^{2o} C
U_L	edge loss coefficient from the collector, W/m^{2o} C
U_{c-a}	heat transfer coefficient from the collector to ambient, W/m^2°C
U_{c-w}	heat transfer coefficient from the collector to water flow in collector, W/m^{2o} C
V_w	wind speed, m/s
w	distance between the tubes, m
y	bond average thiekness, m
yb	pebbles bed thickness, m
Z_0	flow channel height, m
δ_1	sheet thickness, m

δ declination angle

μ_f water viscosity at mean temperature between water and tube, kg/m.s

$\mu_{f,t}$ water viscosity at tube wall temperature, kg/m.s

τ transparent cover transmissivity.

τ_g glass cover transmissivity.

α_a absorbitivity of air in enclosure.

α_b absorbitivity of pebbles bed.

α_g absorbitivity of glass cover.

α azimuth angle, degree

β collector tilt angle, degrr

INTRODUCTION

Water heating for domestic uses is the most up to date widespread application among active solar systems. The performance of a solar water collector is highly influenced by solar radiation reached its surface and the overall loss from the collector to ambient air. Many researches were carried out to study the performance of solar collector configuration similar to that proposed by Hottel and Willier (1977), bliss (1959) and Matrawy anf Farkas (1997). The operation of most solar energy system is inherently transient. Klein et al (1974) and wijeysundera (1978) studied the effects of collector heat capacity on collector performance. The effects can be regarded in two distinct parts. One part is due to the heating of the collector from its early morning low temperature to its final operating temperature afternoon. The second part is due intermittent behavior during the day whenever the driving forces such solar radiation, and wind speed change rapidly. Klein et al (1974) showed that the daily morning heating of the collector results in a loss that can be significant but is negligible for many situations. The performance of a built-in-storage system is strongly affected by night cooling due to ambient factors via the collector cover. It is proposed in the literature that the collector heat losses can be minimized by the application of a second cover surface [6], the use of an insulating baffle within the collector, night covering with an insulating material [6,7], and by using a selective coating on the absorber surface [8]. Field [9] and smith et al [10] tested flat plate collectors with semitransparent slab placed to fin -tube absorber plate. These experimental results show that collector performance improvement is possible with thermal trap collector. The use of a polymer absorber has been studied by Van Niekerk et al (1996). Cristofari et al (2002) illustrated the thermal behavior of solar collector using a copolymer material in regard to radiative and wind conditions. It was developed a nodal model for the solar water heating installation and studied the influence of various parameters; thickness of insulation, fluid flow rate, fluid layer thickness and wind speed.

A lot of attention has been paid to reduce top heat losses from collector system. The use of a transparent insulation material in solar energy has attracted wide attention in recent years(Wittwer et al., (1986); Goetzberger et al., (1984); Twidell et al 1994; Lien et al., (1997); Clarke et al (1998); Peuporitier and Michel, (1995); Chaurasia (2000). The advantage of transparent material is that it is favorable in the range of solar radiation and at the same time it reduces the top losses from the solar system. The scope of this transparent insulation can also be extended for solar collector storage water heaters to prevent top heat losses during the night and thus elimunate the necessity of extra insulating cover after sunset. This transparent insulation can be filled up the space between the glass and absorbing plate of the solar collector to insulate the top-absorbing surface to reduce heat losses. Goetzberger et all 1987 have attempted to work on transparent insulation for solar water collectors. A comprehensive studies by Chaurasia et al. (2001) for the effective use of transparent insulation in solar water collector to evaluate its role in reducing comparative heat losses enabling the provision of hot water the next morning with and without transparent insulation. It has found that the storage efficiency of such solar water system is increased to 39% compared to 15.1 % without transparent insulation material.

The main objective of the present work is to minimize the energy losses from the collector. For this purpose, the collector is put in a transparent-wall enclosure. The floor around the collector is coated with black pebbles bed. It is interested to evaluate the combined effect on the collector performance inside transparent-wall enclosure compared with the performance of the same solar collector in open air. The analysis depends on the variation of different parameters such as the bed thickness, transparent-wall transmissivity and enclosure size.

THEORETICAL MODEL

Based on the physical model illustrated in Fig. 1, a theoretical model for the analysis of the system performance is developed. In the theoretical model the following assumptions are considered for each run of the daily performance:

1- constant value of transparent-wall transmissivity .
2- constant value of pebbles bed absorbativity.
3- The water inlet temperature to the collector is kept constant

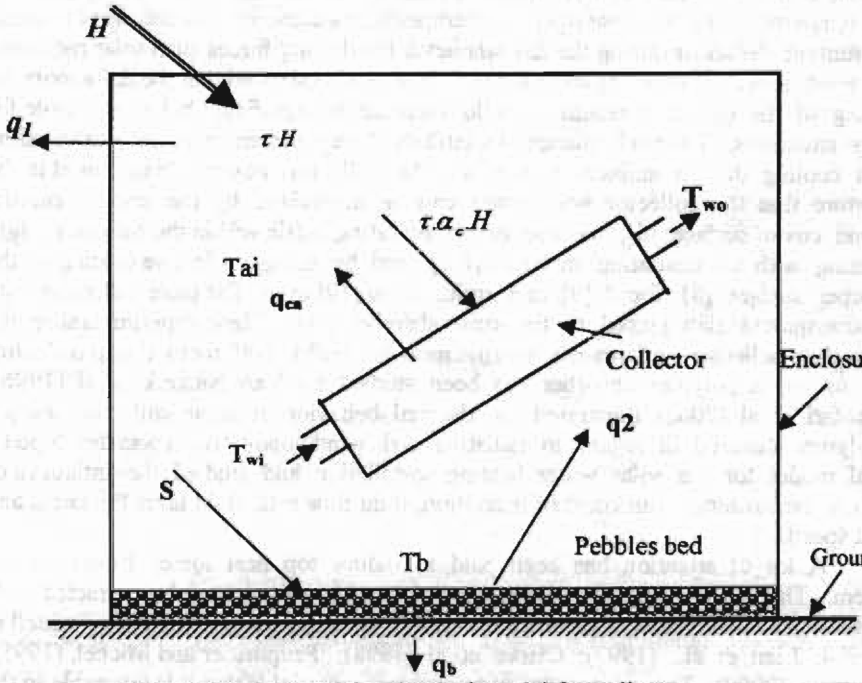


Fig. 1: Schematic of the physical model for collector in transparent-wall enclosure.

1-Heat balance of the air in enclosure

The heat balance for the air in enclosure can be expressed by the following equation:

$$\rho_a c_a V \frac{dT_{ai}}{dt} = \tau.\alpha_a.A_a H + q_{ca} + q_2 - q_1 \qquad (1)$$

Where:

q_1, q_2 and q_{ca} are the heat transfer from the inside air to outside air, the heat transfer from black pebbles to air in enclosure and the heat transfer from collector surface to air in enclosure respectively. It can be calculated from the following equations:

$$q_1 = U_1 A_1 (T_{ai} - T_{ao}) \qquad (2)$$

$$q_2 = U_2 A_b (T_b - T_{ai}) \qquad (3)$$

$$q_{ca} = U3\, Ac(T_c - T_{ai}) \qquad (4)$$

$$U_1 = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}} \qquad (5)$$

U_2, U_3 are the heat transfer coefficient from pebbles bed to air in enclosure and the heat transfer coefficient from the collector surface to the air in enclosure respectively.

h_i, h_o are the convection heat transfer coefficient inside and outside the enclosure respectively.

H is the total solar radiation falling upon the enclosure surface. It is calculated by using the procedure outlined in reference [8].

2-Heat balance of the collector

To evaluate the body temperature T_c of the solar collector a heat balance is carried out for the collector as given by:

$$M_c c_c \frac{dT_c}{dt} = \tau\alpha_c H.A_c - q_{ca} - m_w.c_p(T_{wo} - T_{wi}) \qquad (6)$$

Where:

c_c is the specific heat of collector material

T_{wi} is the water inlet temperature to the collector

T_{wo} is the water exit temperature from the collector and calculated from the following relation [8]:

$$Tw_o = Ta_i + S/UL + (Tw_i - Ta_i - S/UL)\exp(-A_c\, UL.F'/mw.C_p) \qquad (7)$$

Where, U_L is the collector overall losses coefficient which can be calculated using the relation given in reference, [3], as:

$$U_L = U_t + U_b \qquad (8)$$

$$U_T=\left[\frac{N}{\frac{C}{Tc}\left(\frac{Tc-Ta}{N+f}\right)^{e}}\right]^{-1}+\left[\frac{\sigma(Tc+Ta)(Tc^2+Ta^2)}{\left(\frac{1}{d}+\frac{2N+f-1+0.133\varepsilon_p}{\varepsilon_g}\right)-N}\right]$$

Where:

$C=520(1-0.00051\beta^2$

$e=0.43(1-100/T_c)$

$d=\varepsilon_p+0.00591N.hw$

$f=(1+0.089hw-0.1166hw\varepsilon_p)(1+0.0786N)$

$$hw=5.7+3.8Vw \tag{9}$$

The back loss coefficient U_b can be calculated from the following relation

$$U_b=K_1/b \tag{10}$$

where, K_1, b are the thermal conductivity and thickness of the insulation respectively.

3-Heat balance of pebbles bed

The bed temperature T_b can be calculated from the heat balance of the bed as:

$$\rho c_p V_b \frac{\partial T_b}{\partial t}=\tau\alpha_b H.A_b.F-q_2-q_b \tag{11}$$

Where, q_b and F_s are the heat transfer from the bed to the ground and the shading factor, respectively. The heat transfer from the bed to ground is calculated as follows:

$$q_b=k_b A_b (T_b-T_{gr}) \tag{12}$$

The amount of solar radiation incident on the pebbles bed is less than the amount reached the enclosure due to the shading effect. The following analysis used to evaluate the value of the shading factor F. Figure 2 shows a simple schematic diagram for calculating shading factor.

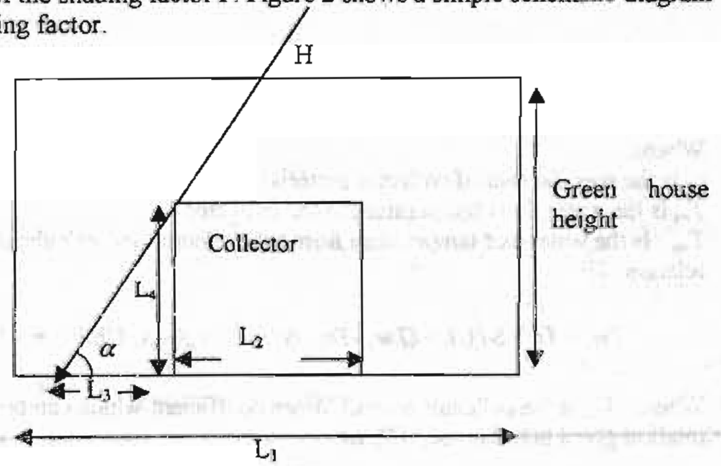


Fig. 2: Schematic diagram for calculating shading factor

$$F_s = \frac{L_1 - L_2 - L_3}{L_1} \tag{13}$$

where:
L_1, L_2 are the enclosure and collector plane length respectively.

The shaded length L_3 is calculated from the following relation:

$$L_3 = L_4 / \tan \alpha \tag{14}$$

where L_4 is the collector height from the ground surface and altitude angle α depends on the time of day, location and day. It is calculated using the following relation:

$$\sin(\alpha) = \cos(L).\cos(\delta).\cos(h) + \sin(L).\sin(\delta) \tag{15}$$

where:
α, L, δ *and* h are ,azimuth, latitude, declination and hour angles respectively and calculated as given in reference [8].

4-Ambient air temperature

Ambient air temperature T_a is simulated by the sine function [24]:

$$Ta = Ta_1 + (Ta_2 - Ta_1)\sin(\frac{\pi t}{2t^*}) \tag{16}$$

where, Ta_1, Ta_2 are the minimum and maximum ambient air temperatures respectively and t^* corresponds to the time at Ta_2, its known from weather data.

5-Useful heat gain from the solar collector

Useful heat gain from the solar collector depends on different parameters such as solar radiation intensity, ambient air temperature around the collector and collector specifications. In the following analysis the effect of these parameters is studied. All the solar radiation that is absorbed by a glass cover is not lost, since this absorbed energy tends to increase the cover temperature and consequently reduce the thermal losses from the plate. In the following analysis two cases are studied; The collector in ambient air and the collector is inside green house enclosure with pebbles bed on the ground around the collector.

The collector useful heat gain Q_u can be evaluated from the following relation [8]:

$$Q_u = A_c F_R \left[S + \frac{I_t U_t (1 - \tau_g \alpha_g)}{U_{c-a}} - U_L (T_{wi} - T_a) \right] \tag{17}$$

where :

$$D = \frac{I_t U_t (1 - \tau_g \alpha_g)}{U_{c-a}} \tag{18}$$

The quantity D represents the reduction in collector losses due to absorption in the cover but can be considered an additional input in the collector equation [8].
As seen from the equation (18) the reduction term D depends on the total solar radiation and losses from the collector to ambient. This term is higher in collector inside green house enclosure due lower value of U_{c-a} compared with the value for the collector in open air. This value may be enhance the reduction of the total incident radiation on a collector in enclosure.

The ambient air in enclosure and collector temperature are higher than the water temperature enters to the collector. This means that there are same heat transferred from the collector to the flowing water. The value of heat transfer is higher for the collector in enelosure compared to that in open air. This term is added as useful heat to equation (18) to take the following form:

$$Q_u = A_c F_R \left[S + \frac{I_t U_t (1-\tau_g \alpha_g)}{U_{c-a}} + U_{c-w}(T_c - Tw_m) - U_L (T_{wi} - T_a) \right] \quad (19)$$

where:
U_{c-w} is the heat transfer coefficient between collector and water in tubes
T_{wm} is the mean value of the water flow rate temperature.

The collector heat removal factor can be calculated as follows [8]:

$$F_R = \frac{m' c_p}{A_c U_L} \left[1 - e^{-\frac{A_c U_L F'}{m' C_p}} \right] \quad (20)$$

The collector efficiency factor F' is calculated from the following relation [8]:

$$F^{-} = \frac{\frac{1}{U_L}}{w \left[\frac{1}{U_L [D_h + (w - D_h) F]} + \frac{1}{C_b} + \frac{1}{C_w} + \frac{1}{\pi D_h h_{fi}} \right]} \quad (21)$$

D_h is the hydraulic diamter of the absorber duct. The cross section of collector is shown in Fig. 3

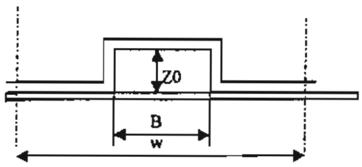


Fig. (3): Cross-section of absorber flow duct

The convective heat transfer coefficent between the duct wall and the fluid h_{fl} can be obtained for liquid collectors from the following relations [25] :

For laminar flow (Re<2300)

$$Nu = 1.86(\mathrm{Re}\ \mathrm{Pr})^{1/3}\left(\frac{\mu_f}{\mu_{fs}}\right) \quad (22)$$

For turbulent flow (Re >2300)

$$Nu = 0.0155\,\mathrm{Re}^{0.83}\,\mathrm{Pr}^{0.5} \quad (23)$$

Where:

$$Nu = \frac{h_{fl}\ D_h}{K_f} \quad (24)$$

where K_f is the thermal conductivity of water.

The plate-fin efficiency factor F can be written as [25]:

$$F = \frac{\tanh\left(m(W - D_h)/2\right)}{\left(m(W - D_h)/2\right)} \quad (25)$$

where:

$$m = \sqrt{\frac{U_L}{k\ \delta}} \quad (26)$$

Calculation Procedure

Since T_b, T_c, T_{al}, T_a, H, T_{wo} and Q_u vary with time, the numerical solution of the problem is the most suitable. In this calculation the time interval has been taken as 1 sec. The following procedure has been used for calculation.

(1) The solar radiation H is calculated from the given data according to location, time and number of the day in years

(2) The ambient air temperature during the day time is calculated using the climatic table of the minimum and the maximum ambient temperatures using equation 16.

(3) The heat transfer coefficients are calculated using the initial values of Tc, Tb, Tai and system specification.
(4) Knowing the heat transfer coefficients, T_c, T_b and *Tai* at the end of first time interval are calculated using equations 1, 6 and 12
(5)Using the new values of Tc, Tb and Tai, heat transfer coefficients are recalculated and step 4 is repeated for another time interval.
(6)For each time interval, T_{wo} and Q_u are calculated based on Tai for the collector in transparent-wall enclosure and Ta for the collector in open air.

RESULTS AND DISSCUSSIONS

The solar radiation incident on the system depends on the day number of the year, the time of the day, and the location expressed by latitude. The calculated solar radiation for day 21/4 at 31^0 N latitude is shown in Fig. 4. These values of solar radiation and ambient temperature calculated from equation (16) during this day are used to calculate other parameters in the theoretical model. The system specifications, which are used in the theoretical model, are shown in table 1 and the following initial conditions are assumed:
Initial collector temperature is 300 K.
Initial ambient air temperature is 300 K.
Initial air temperature in transparent-wall enclosure is 300 K.
Ground temperature is constant with time and equals 290 K
Wind speed is 5m/s.

Table 1: System specifications

Absorber plate dimensions	1.5 x 0.8 m
Absorber duct width B	0.05 m
Absorber duct height Z_o	0.02 m
Green house length	3 m
Green house width	3 m
Green house height	2.0-3.0m
Bed thickness	0.15-0.03 m
Bed absorbitivity	0.95
Collector material absorbtivity	0.8
Collector weight	50 kg
Wind speed	5 m/s
Thermal conductivity of insulation	0.05 W/m. C.
Insulation thickness	0.05 m

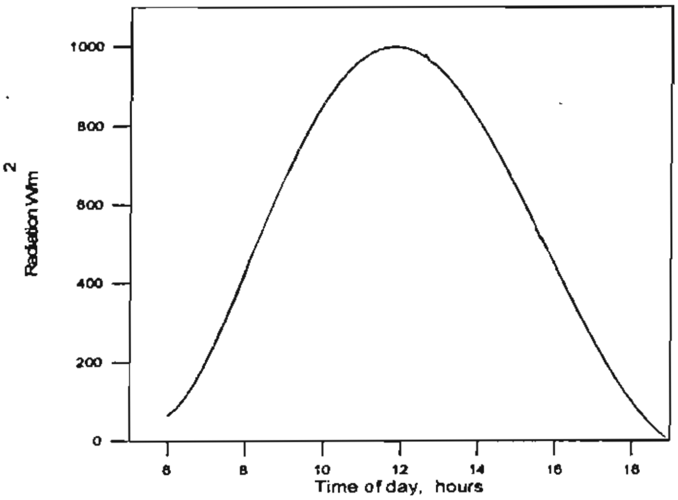


Fig. 4: Variation of solar radiation intensity during the day.

From the theoretical analysis, the temperatures of the bed, collector and ambient air as well as the collector performance are evaluated for the different values of the following factors:

1- transparent-wall transmissivity.
2- pebbles bed thickness
3- green house size

1- Effect of transparent-wall transmissivity

Figure 5 shows the variation of collector, ambient temperatures in transparent-wall enclosure and pebbles bed during the day for different values of transmassivities 0.8, 0.85, 0.9 and 0.95. It is observed that the temperatures increase with the increase of the transmissivity. Also, it can be seen that the bed temperature increases with time increase and reaches maximum value at 3 A.M The maximum pebbles bed temperature increase from 61, 63, 66, 68 C at transmissivity equals 0.8, 0.85, 0.9 ,0.95 respectively. The maximum difference between the ambient temperature in enclosure and outside it, which represents the energy losses from the collector increases with the increase of enclosure transmissivity.The maximum difference increase from 15 C to 16 C to 18 C to 20 C at transmissivity equals 0.8, 0.85, 0.9, 0.95 respectively. These results are a good agreement to that given experimentally by the Kabeel [12]. The maximum collector temperature occurs between 2 and 3 P.M. It increases with the increase of transmissivity from 51 C to 52 C to 54 C to 55.5 C at transmissivity equals 0.8, 0.85, 0.9 and 0.95 respectively.

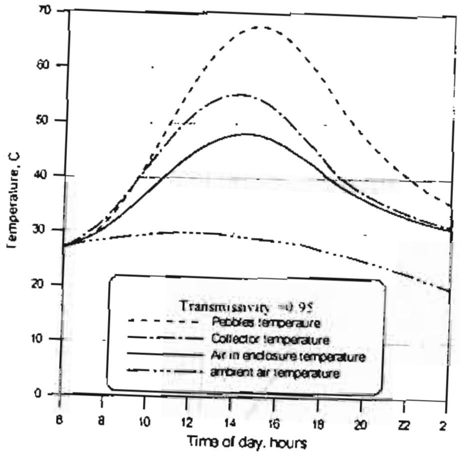


Fig. (5 –a)

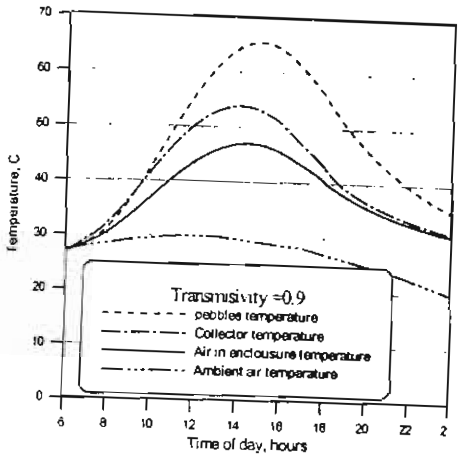


Fig. (5-b)

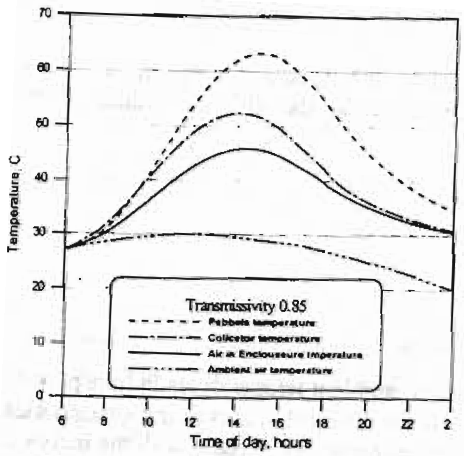


Fig. (5-c)

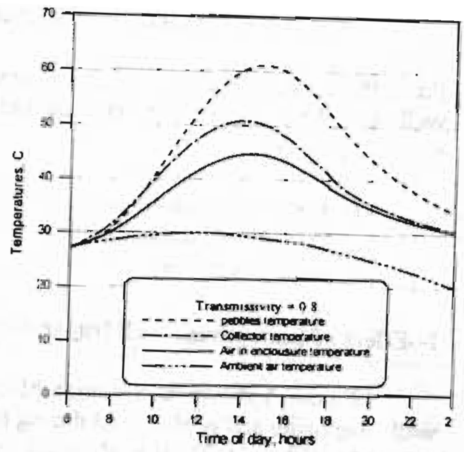


Fig. (5-d)

Fig. 5: Variation of bed, air in enclosure and collector temperatures at different values of transmissivity.

2-Effect of pebbles bed thickness

The effect of pebbles bed thickness its temperatures, collector and ambient air in transparent-wall enclosure was evaluated for three different bed thickness, 0.02 m, 0.025m and 0.03 m. Figure 6 shows the variation of pebbles bed temperature during the day time. With the increase of the pebbles bed thickness, the maximum bed temperature decreases.. It decreses from nearly 78 C to 60 C when bed thickness increases from s 0.02 to 0.03 m respectively. The time of this maximum is shifted from 3 A.M to 4 A.M. with the increase of bed thickness from 0.02 to 0.03 m respectively, which gives that the energy stored in the bed for longer period and the energy emitted from the bed to the system takes longer time after sunset. These can be also shown by the higher value of the bed temperature at 12 A.M. for the larger value of the bed thickness. The maximum ambient temperature inside the enclosure decreases from 61 C to 56 C when the bed thickness increases from 0.025 m to 0.015m. Also, the enclosure air temperature is kept at higher values for longer period during the time after sunset, which increases the useful heat gain from the collector.

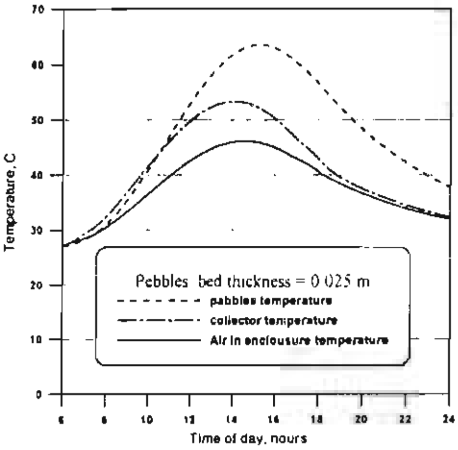


Fig. (6-a)

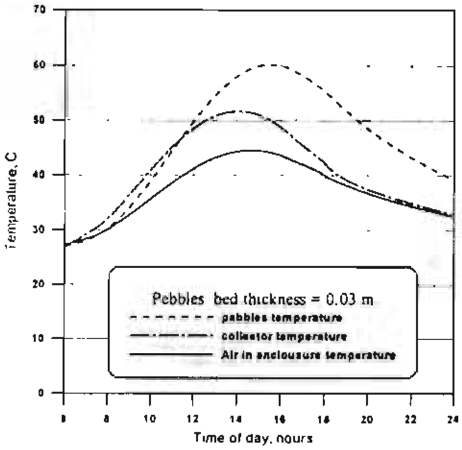


Fig. (6-b)

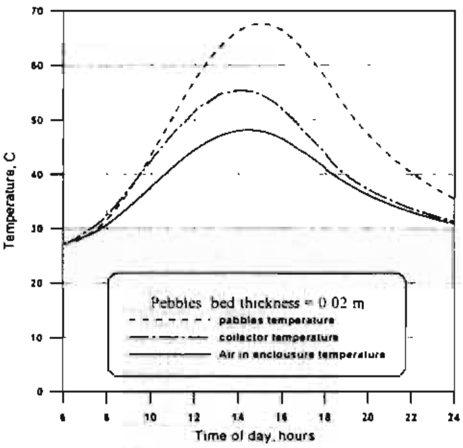


Fig. (6-c)

Fig. 6: Variation of pebbles bed, collector and enclosure air temperatures with different bed thickness during the daytime

3-Effect of green house size

The increase of transparent-wall enclosure height will increase the air volume in enclosure, which will affect the other parameters.

Figure 7 shows the variation of collector, bed and ambient temperatures along the day time at three different heights 1.5, 2 and 2.5 m. With the increase of height from 1.5 to 2.5 m, the maximum pebbles bed temperature decreases from 67 C to 60 C, the collector temperature decreases from 61 to 54 and the ambient temperature inside the enclosure decreases from 53 C to 47 C respectively. Also, the period of energy emitted from the system increases with the enclosure size, which increases on the increase of the pebbles bed temperature at the reset of the daytime. At 12 AM the bed temperature equals 35 for height 1.5 m and equals 39.2 C at height 2.5 m.

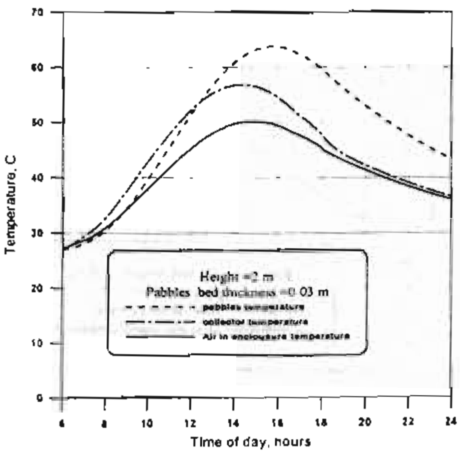


Fig (7-a)

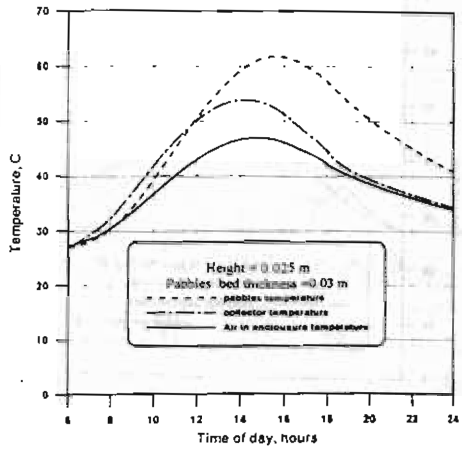
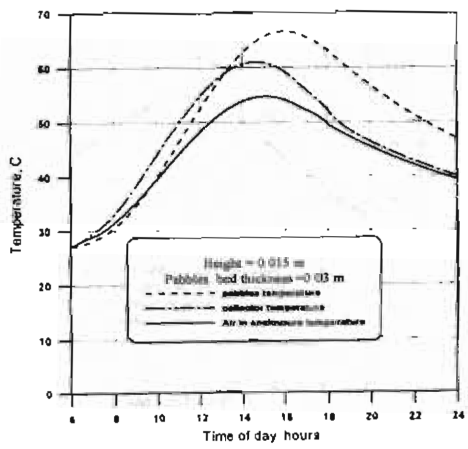


Fig. (7-b)



(7-c)

Fig. 7: Variation of temperatures of pebbles bed, collector and air in enclosure during the daytimc for different enclosure size

4-Collector performance

The water outlet temperature and the useful heat gain were calculated from equations (7), (17) and (19) for the collector in transparent-wall enclosure and in open air. It is expected that the temperature of the surrounding air directly affect the system performance. The difference between the two conditions for the collector is that, when green house is applied, the air temperature around the collector is higher than that of the ambient air. Accordingly, in the theoretical model the temperature in enclosure is evaluated from the heat balance then the collector performance is carried out. The effect of wind speed for the collector in the enclosure is neglected during the calculation of the top losses in equation (9)

5-Variation of useful heat gain

The variation of useful heat gain from the collector in open air and that in transparent-wall enclosure at different values of transmissivity is shown in Fig. 8. It can be seen from the figure that the useful heat gain from the collector in transparent-wall enclosure is higher than that the collector in open air. For a constant value of bed thickness of 0.02 m , the heat gain increases by 16% at transmissivity of 0.85 and 19% at transmissivity of 0.95%. Figure shows also that the useful heat gain from the collector in enclosure increases with the increase of transmissivity. The increasing value between transmissivity 0.95, 0.80 is about 3%.

The effect of pebbles bed thickness at transmissivity 0.85 on the useful heat gain from the collector in open air and in transparent-wall enclosure is presented in Fig 9. The pebbles bed thickness is varied from a minimum value of 0.02 m to a maximum value of 0.05 m with a step of 0.005. It can be observed that the useful heat gain increases with the decreases in the bed thickness. The enhancement in the heat gain is about 15 % at bed thickness of 0.02m. Also, the figure shows that the maximum useful heat gain for thickness 0.05 m is about 104% compared with that of collector in open air

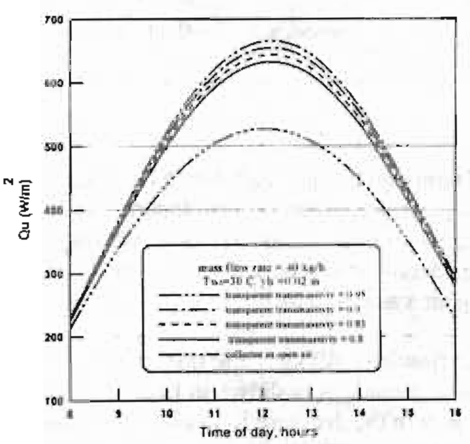


Fig. 8: Variation of useful heat gain for at different values of transmissivity.

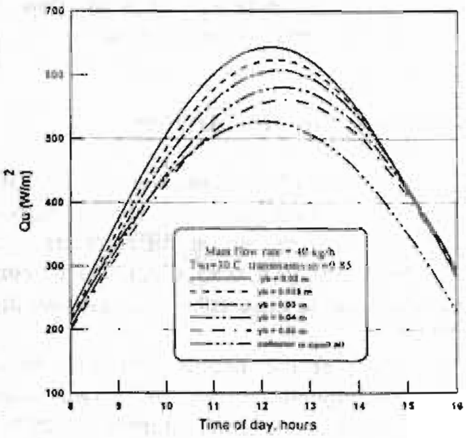


Fig. 9: Variation of useful heat gain for at different pebbles bed thickness

The effect of water flow rate on the useful heat gain for the two situations (collector in open air and collector in transparent wall enclosure) is shown in Fig 10. It can be observed that the useful heat gain increases with the increase in the flow rate. The figure shows also that the enhancement in the useful heat gain from the collector in transparent-wall enclosure is about 13 % at flow rate of 25 kg/h. This value shows a good agreement with the values given experimentally [12].

Figure. 11 shows the effect of the variation of collector inlet temperature on the useful heat gain for the two cases. It can be seen that the useful heat gain is higher for the collector in transparent-wall than that in open air for all values of water inlet temperatures.

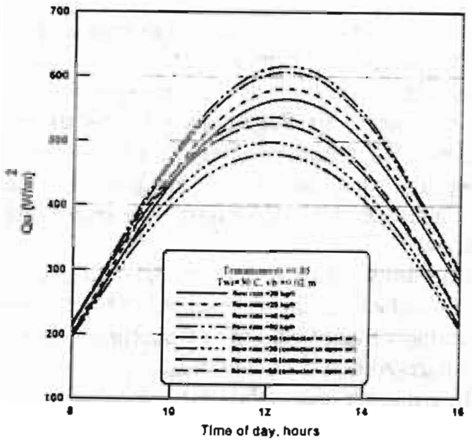


Fig. 10: Variation of useful heat gain for different values of flow rates for the two cases.

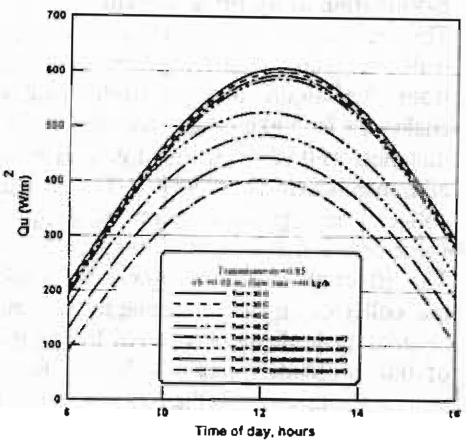


Fig. 11: Variation of useful heat gain for different values of inlet water temperature for the two cases

6-Temperature rise variation

Figure (12) shows the variation of temperature rise (difference between water exit and inlet temperatures) for the collector in transparent-wall enclosure and for the collector in open air at different transparent-wall transmissivities Four values of transmissivity (0.8, 0.85, 0.9, 0.95) are considered. It can be seen from the figure that the temperature difference iincreases for higher value of tansmissivity.

The effect of the pebbles bed thickness at flow rate 40 kg/h and transmissivity 0.85 on the temperature rise for the two collector situations is shown in Fig. 13. It can be observed that the temperature rise increases with the decrease in thickness. It reached 12.4 C for the collector in open air and reached 17.2 C for the collector in transparent-wall enclosure.

Figure 14 shows the variation of temperature rise at different flow rates of the two collector situations. The solid line represents the variation of the collector in transparent wall enclosure and the dashed lines represents the variation for the collector in open air. It can be seen that the value of temperature rise at flow rate 20 kg/h reached 32 C for the collector in transparent wall enclosure and 23 C for the collector in open air.

The variation of the temperature rise with different values of inlet temperature for the two collector configuration is represented in Fig.15. It can be observed that the temperature rise for the collector decreases with the increase in the water inlet temperature.

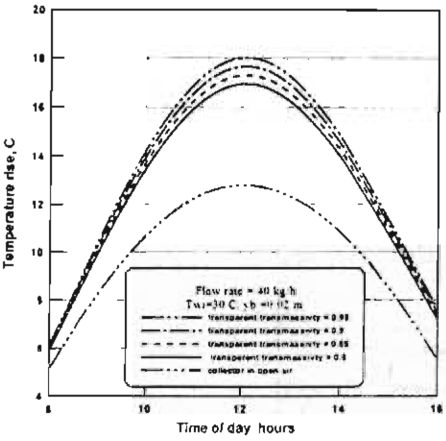


Fig. 12: Variation of water temperature rise at different values of transmissivity.

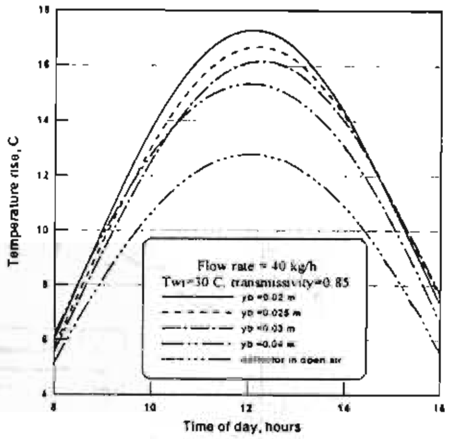


Fig. 13: Variation of water temperature rise at different values of pebbles bed thickness

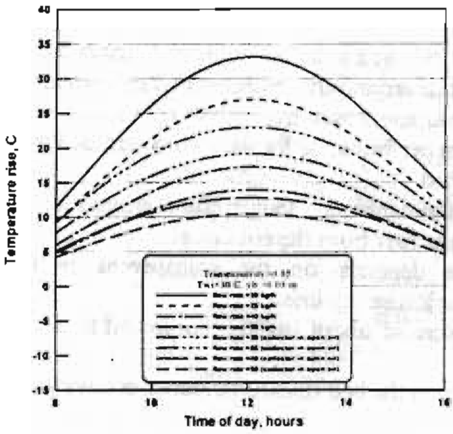


Fig. 14: Variation of water temperature rise at different flow rate for the two cases.

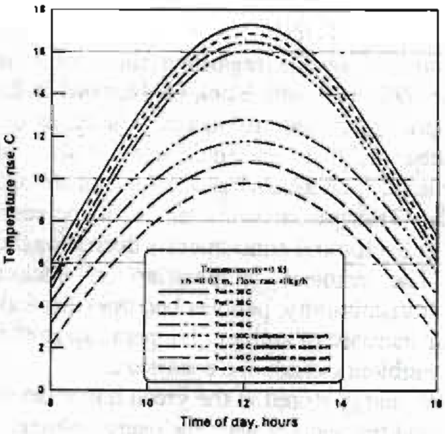


Fig. 15: Variation of water temperature rise at different inlet water temperature for two cases.

Comparison with the previous experimental work [12]

Figure 16 shows the variation of the air temperature rise in enclosure (difference between temperatures of air in enclosure and ambient) for the previous experimental work [12] and the present work at the same conditions of flow rate. The figure shows a good agreement between the previous experimental work and the present theoretical work. Because the conditions such as variation of the wind speed, variation of the ground temperature involved in the theoretical work, some deviation of experimental data can be observed in Fig. 14.

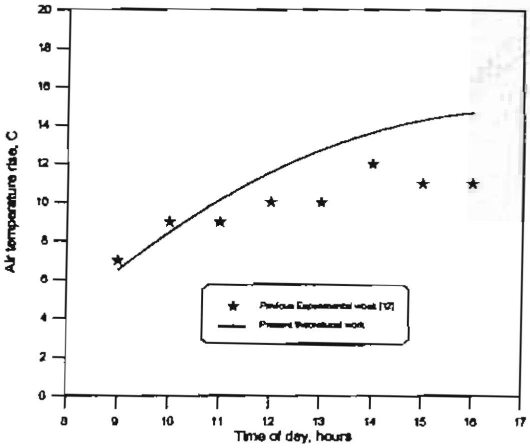


Fig. 14: Comparison between theoretical and experimental air temperature rise

CONCLUSIONS

Theoretical results regarding the useful heat gain of a solar collector in transparent-wall enclosure with black pebbles bed in its floor around the collector and in open air are presented and discussed. The effect of transparent wall transmissivity, enclosure volume, pebbles bed thickness on the system performance for the two conditions is discussed. The following conclusions are obtained.

1-The Transparent-wall enclosure increases the ambient temperature around the collector and consequently decreases the heat loss from the collector.

2- The ambient temperature in enclosure depends on the transparent wall transmissivity, pebbles bed thickens and enelosure volume.

3-An increase of ambient temperature in enclosure of about 14-20 C compared to the ambient outside the enclosure.

4-The energy stored in the green house depends on the bed thickness, transmisssivity and transparent wall enclosure volume..

5- Water temperature rise is higher for the collector in enclosure, it reached 32 C for the collector in enclosure compared to 23 C for the collector in open air at the same conditions.

6- An increase in the useful heat gain of 13 % for the collector in transparent-wall enclosure at transmissivity 0.8 and 17% at transmissivity 0.95 can be obtained..

7-The stored heat in the system is used to keep the collector functioning for a long period after sunset.

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