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The Influences of Surface Area on the Efficiency of a New Design of Solar Collector Suitable for Basrah City 30.5^0 N

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***Abstract**: In this work we try to acquire benefit of the climate behavior in Basra city 30.5^{0}N south of Iraq to design a new system of solar water heating. Two differences solar collectors are designs which are almost symmetrical in everything, with one main exception that is the dissimilarity in green house of the collectors. The dimension of the green house of first collector is (112 cm, 62 cm, 12 cm), whereas the dimension of the second green house is (112 cm, 27 cm, 12 cm). All data is recorded, during daylight hours between (8:00Am-13:00Pm). Experimental data from these solar collectors have been analysis. The result shows that the first collector is more efficiencies than the second collector, but the second collector are more suitable for our purpose.*

***Keywords**: Optical efficiency; ICSSWH; Thermal performance; Technological development*

I. Introduction

The device which is used to transform solar energy to heat is referred to as solar collector or SC. Depending on the temperatures gained by them, SC can be divided into low, middle and high temperature systems. Mid-temperature systems are applicable for refrigeration systems and industrial processes. Numerous theoretical and experimental research of solar collectors for the mid-temperature conversion of solar radiation into heat via a liquid water as a working fluid have been conducted see for example [1-5]. Flat plate solar collectors form a subset of devices that are sometime used to convert solar energy into heat and, as such, can be deployed for duties such as domestic water heating. The traditional flat plate solar collector consists of number of important functional components fabricated as a 'sandwich'. The integral collector/storage solar water heater (ICSSWH) is quite possibly the most well-known and simplest solar water heating system. It's developed from early systems often known as the "bread box" system; it was originally produced in the 1970's but is still in use now. It is simple, efficient and cheap to build. You simply paint a tank black, put it in a big crate, and insulate it all around except one side that needs to be covered by glass or plastic. To be viable economically, the system has evolved to incorporate new and novel methods of maximizing solar radiation collection whilst minimizing thermal loss. All it takes is a tank, insulation and sun. The water is collected, stored and warmed all in one container. Advances in ICS vessel design have included glazing system, methods of insulation, reflector configurations, use of evacuation, internal and external baffles and phase change materials.[6]. To understand the basic theory of the solar collector one should refers to the works of Hottel and Woertz [7-9], Bando[10], Hatfield [11], Zomorodian [12]. Fechner [13]. Minnerly [14], Bohn[15] and Duffie [16]. The advantages to the integral collector/storage system are low cost, no pumps or controls Simple, and Long-lasting. The large size of the tank helps to avoid freezing problems often seen in thermo-siphon units. The disadvantages **are** water doesn't get really hot, heat loss from the collector, and discontinuity of the optimal use of the hot water produced. In this paper we try to build an integral collector solar heater suitable for Basra city 30.5N south of Iraq. Our model has been tested in winter days where the outside temperatures fall below 5^0 C and it seem working wall. To generalized our model, a theoretical analysis has been carried out which allow us to predict the amount of hot water needed ant its temperature. The theoretical model shows a good agreement with our experimental data.

II. Experiments Requirement

We made some factors be fixed during all steps of this work, as follows:

1. Place of study: the experimental setup and carried out on the roof of a building of the department of physics, college of education for pure science at Basrah University. Basrah city located in southern of Iraq (latitude 30 ° 33 '56.55 "N, longitude 47 ° 45' 5.86" E).
2. Duration of record data: The data is recorded, during daylight hours between (8:00Am-2:00Pm).
3. Cold water tank: it made of galvanized iron material with (90 liter) capacity.
4. Inclination angle of the collectors: The angle of inclination of the collectors are 45^0 .

5. The direction of the collectors: All the collectors are installed 45^0 south–easts, in order to receive a large amount of solar radiation.
6. Fitting pipe: The pipes diameter is (1.25cm).

The following materials were used in the manufacture of solar collectors:

1. Iron galvanized materials which are available in the local market to fabricate the tube. This is the main component in all models of solar collectors used in this work as well as for the manufacture of cold water tank.
2. Wooden staves used to make the rectangles "greenhouse" that reserved all components of the solar collector inside it.
3. Glass plates with a thickness (4 mm) used to make the cover of the front side of greenhouse; the glasses are manufactured in Iraq and available in local markets.
4. Rubber silicon which is inorganic polymer compound used to fix the glass plates tightly so as to avoid the air circulation to and out of the greenhouse.
5. Sheets of copper used as a good reflective material to reflect the solar radiation.
6. Pieces of glass wool thickness (7 cm), a thermally insulating material to minimize heat losses out of the greenhouse.
7. Black stain used to paint the main tubes.
8. Transparent plastic tube in different lengths is used for draining and supply water.
9. Water taps to control the amount of the input and output water of the solar collector

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III. Theory

To allow the solar radiation transmitted through the glazing propagates onto the absorber plate. The absorber plate must absorb an optimum amount of solar radiation whilst minimizing thermal re-radiation. Typically, the absorber is painted with black. Based on this experiment set up the general conservation equation of this model can be written as :

$$\rho c\frac{\partial T}{\partial t}=\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\mathrm{S} \qquad (1)$$

This equation is one dimensional unsteady heat equation with source term S, ρ is the density , c is the specific heat, and k stand for conductivity. For convenient we shall assume the terms ρc and k are constant. According to the above set up this equation seem to be one way coordinates in term of spatial and time coordinates, one can obtained the solution by marching in time from a given initial distribution of the temperature. The discretization equation can be derived by integrating equation (1) over a convenient control volume and over the time interval from t to $t+\Delta t$ thus:

$$\rho c\int_{x_{i-1}}^{x_{i+1}}\int_{t}^{t+\Delta t}\frac{\partial T}{\partial t}dtdx=\int_{x_{i-1}}^{x_{i+1}}\int_{t}^{t+\Delta t}\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)dt\,dx+\int_{x_{i-1}}^{x_{i+1}}\int_{t}^{t+\Delta t}Sdtdx \qquad (2)$$

where the order of integrations are chosen according to the nature of the term. By employing the Crank-Nicolson scheme, the result is

$$a_i^kT_i^k=a_{i+1}^{k-1}\left[T_{i+1}^k-T_{l+1}^{k-1}\right]+a_{i-1}^k\left[T_{i-1}^k-T_{l-1}^{k-1}\right]+\left[a_i^{k-1}-a_{i+1}^{k-1}-a_{i-1}^k\right]T_i^{k-1}+S_0 \qquad (3)$$

For first approximation assume

$$a_{i+1}^{k-1}=a_{i-1}^k=\frac{\boldsymbol{\rho c}}{\boldsymbol{2\delta x}},\quad a_i^{k-1}=\frac{\boldsymbol{ps\Delta x}}{\boldsymbol{\Delta t}},\quad a_i^k=\boldsymbol{2}a_{i-1}^k+a_i^{k-1} \qquad (4)$$

The solution shown in Eq. (3) and the linearization used in this solution "the nonlinearity in this set of equations results from the quadratic temperature terms" allowed this problem to formulated as a linear system of algebraic equations, shown in vector form in Eq. (5); the solution to each iteration of this linear system therefore became the solution to a matrix inversion problem:

$$\mathbf{T}=\mathbf{M}^{-1}\mathbf{C} \qquad (5)$$

Here M is a square matrix, which contains all the coefficients of the temperature dependencies that result from the energy balance equations. The boundary conditions for the solution domain were specified temperatures at the solar collector inlets and out let only. The initial condition for the temperature field was that all nodes were specified to be a known, and uniform, temperature.

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IV. Result and Discussion

In this work we design laboratory models of two sympathetic of solar collectors shown in figure (1). The common properties of these collectors are:

1) They consist both of collector tube made from iron with dimension of 80 cm in length and 5 cm in diameter.
2) The total amount of water inside the tube is 1570 cm^3
3) The tube is closed tightly from both ends.
4) The collector tube is fitted 5 cm away from the upper and lower basses.

5) The inlet and outlet pipes are fitted in opposite side of the green house with 25 cm in length and 1,25 cm in diameters. The inlet cold water enters the collector from bottom and exit from top of the collector.
6) A copper plate was used as reflector material for solar radiation.

The main differences of the our two models are

1) The dimensions of the green house of the first model are (62 cm, 12 cm, and 112 cm) as shown in figure (1a), whereas the dimensions of the second model are (27 cm, 12 cm, and 112 cm) figure (1b).
2) The dimensions of the reflector of the first model are (50 cm, 95.5 cm), whereas the dimensions of the reflector plate for the second model is (25 cm, 95.5 cm).

In order to preserve the thermal energy from losses from the hot space inside the green house to the cold weather outside through its sides and its lower base, we have situate an glass wool layer as a thermal insulation material inside the house specifically on its sides and lower base; The insulation was used adjacent to the black paint and the reflector material to enriched the collector efficiency . The real setup of our two laboratories model is shown in figures (2). Table (1) shows the recorded data on Sunday (8-12-2013), the weather that day was totally clear, the recorded data started at 8:00 am and end at 13:00 pm. It was found that model no. (1) is more effective than model No.(2). The highest temperatures were recorded at 13:00 pm by model No. (1) is 89.5^0, and by model No.(2) is 80^0. On Monday (9-12-2013) the weather was totally cloudy and is a chance to test our two models. The performance of our two models was dropped dramatically as shown in table (2). The highest temperature recorded is 29^0 for the collector No. (1) at 13:00 pm, and the highest temperature recorded for collector No.(2), was 26^0. The temperatures shown in table (1) and table (2) are as follow:

T_{air} represents the air temperatures outside the collectors; T_{cw} represents the cold water temperatures; T_1 and T_2 represent the temperature of collectors No.(1) and No.(2) respectively; $\Delta T_{1\text{-}cw}$ and $\Delta T_{2\text{-}cw}$ represent the gain in temperatures for the two collectors respectively. Figure (3a) shows the temperatures as a function of daylight hours for totally clear day, whereas figure (3b) plotted for totally cloud day. Figures (4) show the amount of gain in temperature for the two collectors aimed at totally clear and totally cloud day. To explain why collector no.(1) is more effective than collector no.(2), one can be argued that the relatively large space of greenhouse means that there is more air molecules in space of model no.(1); and when the air molecules increase, the amount of radiation absorbed by these molecules increases too, and the amounts of radiation reflected by these molecules are increase also in the space of greenhouse. As a conclusion one can recommend model no.(2) as a heat water suppliers for the domestic use although that model no.(1) is more efficient than model no.(2) because the fitted space of model no.(2) about half that for model no.(1). And for multiple component used of model no.(2) one can supply more hot water by using this model for same fitting space.

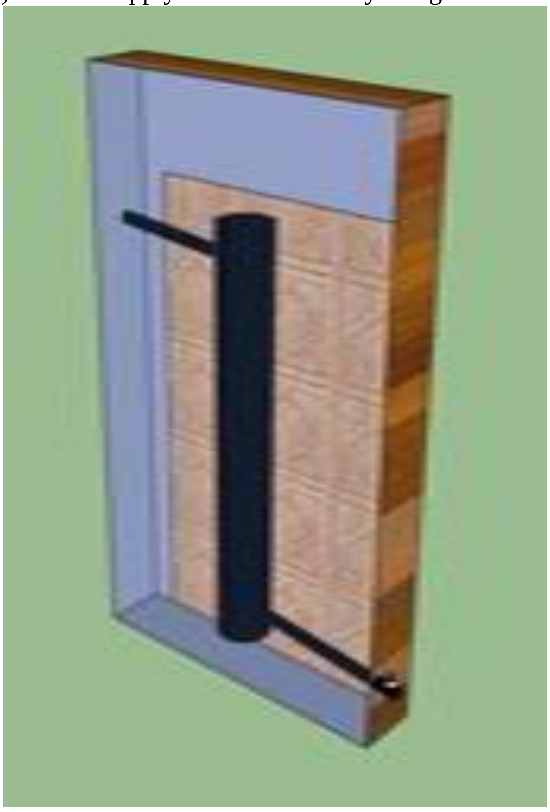

Figure (1) Schematic diagram of Model No. (1a)

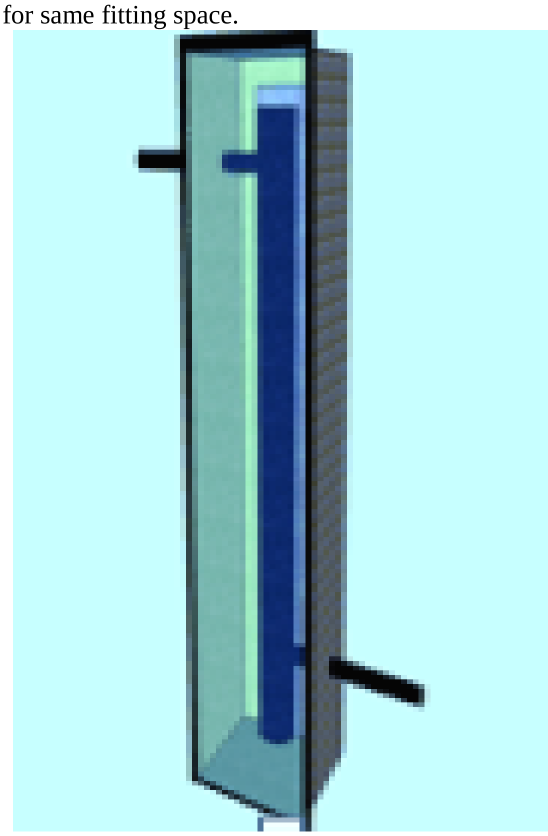

Figure (1) Schematic diagramof Model No. (1b)

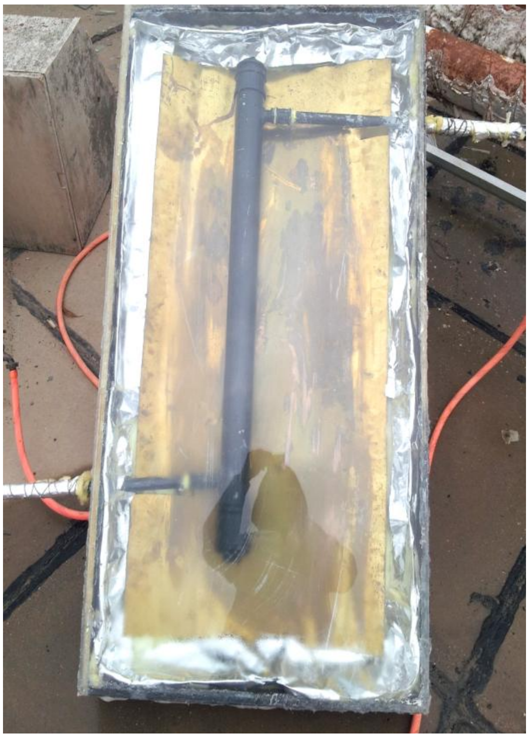

Figure (1) Real of Model No. (2a)

Figure (1) Real of Model No. (2b)

The day light (hour)	T_{air}	T_{cw}	T_2	T_1	ΔT_{1-cw}	ΔT_{2-cw}
8AM	16.4	15.8	**24**	**26**	10.2	8.2
9AM	17	16.6	**38**	**43**	26.4	21.4
10AM	19.5	18	**55**	**64**	46	37
11AM	22	19.5	**72**	**82**	62.5	52.5
12AM	22	20	**75**	**88**	68	55
13PM	22	21.5	**80**	**89.5**	68	58.5

Table (1) Temperatures at Sunday on (8/12/2013) the weather are clear.

The day light (hour)	T_{air}	T_{cw}	T_2	T_1	ΔT_{1-cw}	ΔT_{2-cw}
8AM	17	18	**18**	**18**	0	0
9AM	18	18	**22**	**24**	6	4
10AM	19	18.9	**27**	**30**	11.1	8.1
11AM	19	19	**29**	**32**	13	10
12AM	18	19	**26**	**29**	10	7
13PM	18	19	**27**	**30**	11	8

Table (2) Temperatures at Monday on (9/12/2013) the weather are Totally Cloudy.

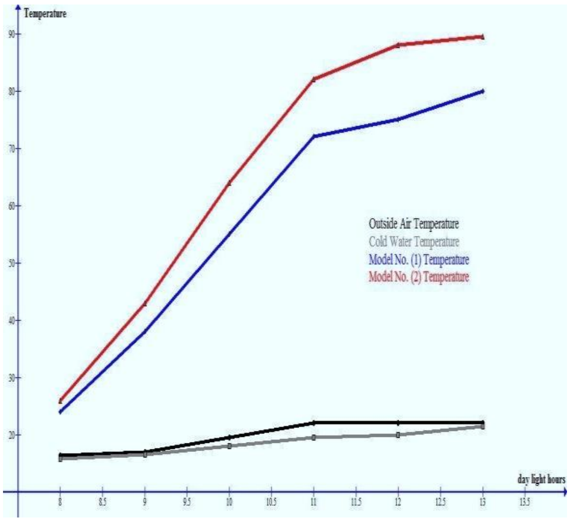

Figure (3a) Temperatures at Sunday on (8/12/2013) The Sky Are Totally Clear.

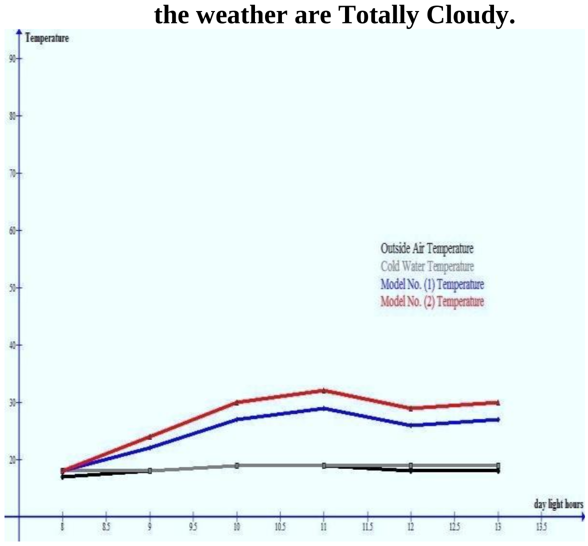

Figure (3b) Temperatures at Monday on (9/12/2013) The Sky Are Totally Cloudy

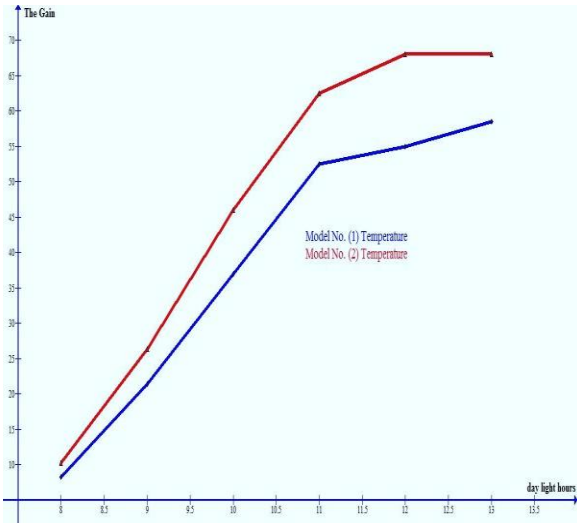

Figure (4a) The Gain in Temperatures at Sunday on (8/12/2013) The Sky Are Totally Clear.

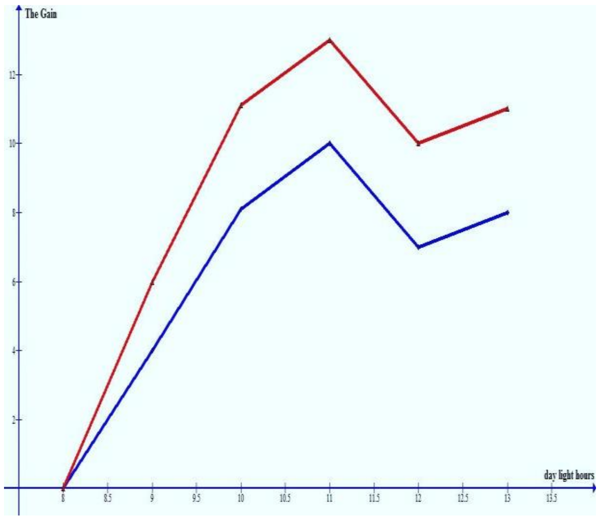

Figure (4b) The Gain in Temperatures at Monday on (9/12/2013) The Sky Are Totally Cloudy.

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