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An Experimental Investigation Of A Novel Design Of A Double Pass Solar Air Heater

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Abstract: An experimental Investigation has been carried out on a Double pass Solar Air Heater. The first passage having its duct packed with blackened wire screen matrices is formed between the upper glass cover and the array of outer blackened surface of Aluminium pipes. Flow in reverse direction takes place in the Blackened Aluminium pipes (8 identical pipes of 6 cm diameter each). The main idea of using double pass arrangement is to minimize the heat loss to the ambient from the front cover of the collector and thus improving the thermal performance of the system. Porous absorber can absorb the solar radiation in depth thus heat exchange between absorber and flowing air can be enhanced. It is concluded that the double pass solar air heater is thermally more efficient than the conventional one and that the double pass solar air heater with porous material as packing is further more efficient that the simple double pass solar air heater.
Keywords: Novel Design Of A Double Pass Solar Air Heater, Experimental Investigation.

1. Introduction

Solar air heating is a renewable energy heating technology in which the energy from the sun is captured by an absorbing medium and used to heat air. A Conventional Solar Air Heater is essentially a flat plate collector with an absorber plate, a transparent cover at the top and insulation at the bottom. It has many applications in drying agricultural products, such as seeds, fruits and vegetables, and as a low-temperature energy source. Also, solar air heaters are utilized for heating buildings with auxiliary heaters to save energy in winter-time. Due to the heat losses to the ambient from the front cover of the collector, the thermal efficiency of the conventional solar air heater is low. It can be improved by using a double pass solar air heater. Over the years, many suggestions have been provided to improve the existing Solar Air Heaters. The idea of double pass solar air heater is studied in[1]. The study of thermo hydraulic performance of solar air heaters with roughened absorber plates was done in[2]. The investigation of thermo hydraulic performance on a packed bed solar air heater having its duct packed with blackened wire screen matrices of different geometrical parameters was done in[3].

As stated above, there are many studies on the solar air heater. However, the presented work deals with the study of a novel design of a double pass solar air heater, where the first passage is packed with blackened wire screen matrices and is formed between the upper glass cover and the array of outer blackened surface of

Aluminium pipes. Flow in reverse direction takes place in the Blackened Aluminium pipes (8 identical pipes of 6 cm diameter each). In conventional double pass air heaters the first passage is formed between the two glass cover and the second passage is formed between the bottom glass cover and absorber plate. Thus, in the design proposed in this work, the heat lost from the absorber plate to the insulation is also utilised.

2. Experimental Set up

The experiment Setup used in the present investigation has been shown in the figure 2.1. It mainly consists of two air collectors (1m in length and cross sectional area of 200 cm^2). The first passage having its duct packed with blackened wire screen matrices is formed between the upper glass cover and the array of outer blackened surface of Aluminium pipes. Flow in reverse direction takes place in the Blackened Aluminium pipes (8 identical pipes of 6 cm diameter each). These collectors were south facing and kept at an angle inclined of 15 degree with respect to the horizontal to maximize the solar radiation intensity in the collector all year round. The absorber pipes are made of 1mm thin Aluminium sheet blackened with paint on the upper side facing solar radiation. Below the absorber pipes, a ply wood of 5mm thickness is placed as insulation.

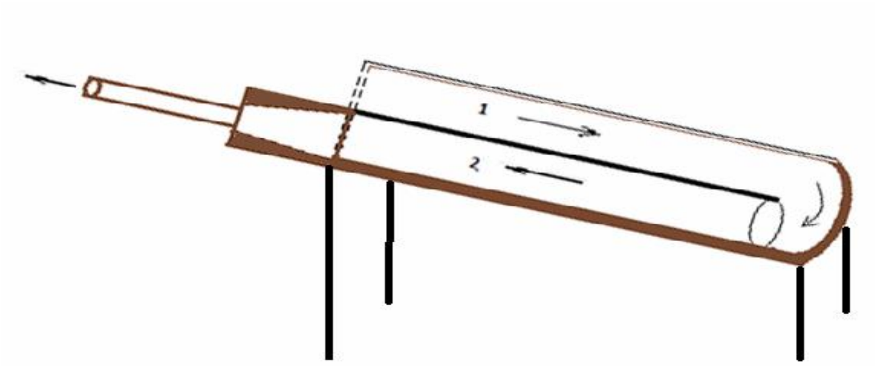

Fig. 2.1 Proposed Experimental Setup of Double pass Solar Air Heater

Fig. 2.2 Actual Experimental Setup of Double pass Solar Air Heater

3. Mathematical Modeling

The mathematical model describing the heat transfer characteristics for each passage of air is derived from the conservation of energy.

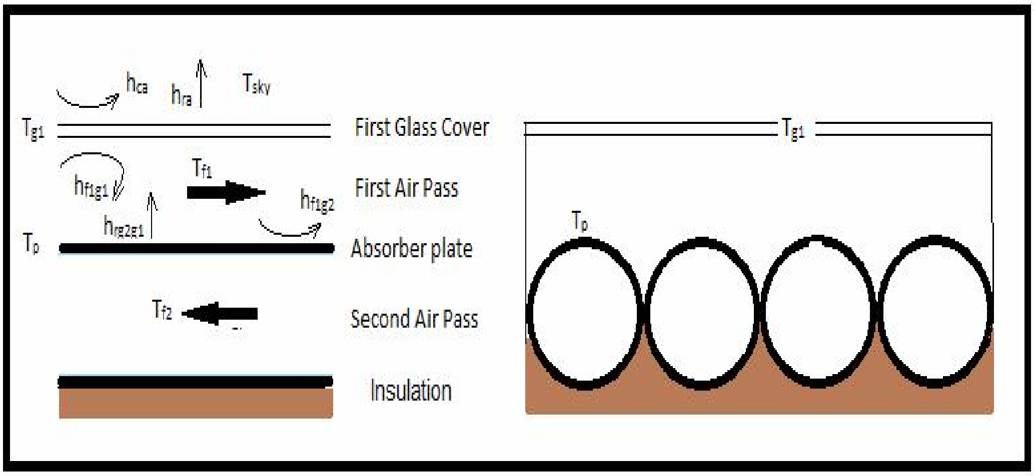

Fig. 3.1. System components of double pass solar air collector

The following assumptions are made in the mathematical modelling.

- The flow of air is steady, one dimensional and the thermo physical properties of the air are independent of temperatures.
- Temperature drop across the glass is negligible.
- The inside and outside convective heat transfer coefficients are constant along the length of solar collector.
- The heat loss from the sides and bottom of the rectangular duct is very small and hence neglected.

Energy balance for each component can be expressed as-

For Absorber plate

$I\tau_1\alpha_p = h_{f1p}(T_p-T_{f1}) + \sigma\varepsilon_{pg}(T_p^{\,4} - T_{g1}^{\,4})+U_A(T_p- T_a)$………………………………………(1)

For First Glass Cover

$I\alpha_1 = h_{f1g1}(T_{g1}-T_{f1}) + h_{ca}(T_{g1}-T_{sky}) + \sigma\varepsilon_{g1}(T_{g1}^{\,4} - T_{sky}^{\,4}) + \sigma\varepsilon_{pg1}(T_{g1}^{\,4} - T_p^{\,4})$ …………… ….(2)

$h_{ca} = 5.7 + 3.8\ V$, (V is the wind speed)……………………………………………… (3)

For First Air Pass

$mC_p(dT_{f1}/ dx) = h_{f1g1}(T_{g1}-T_{f1}) + h_{f1p}(T_p- T_{f1})$……………………………………………(4)

For Second Air Pass

Considering Forced Convection,

$Re = \rho UD/\mu$………………………………………………………………………… .(5)

$Pr =\mu C_p/ k$………………………………………………………………………… (6)

$Nu =hD/k = 0.023\ (Re)^{0.8}(Pr)^{0.4}$ ………………………………………………………… (7)

From above equations, the value of h can be calculated. Heat transfer per unit length of the tube,

$Q = h(\pi D)\Delta t$

Now bulk temperature (ΔT_{f2}), over a 1 m length of the tube is calculated from the given equation.

$$Q = (\rho AU)c_p(\Delta T_{f2})$$

Using the values of the properties of air and putting them in above equations, overall temperature rise can be calculated.

3. Results & Discussion

The collectors were warmed up for over an hour before the start of observations. This duration ensures that the quasi steady state condition has almost been established. After quasi-steady state condition is established, readings of the temperature of the outside and inside surfaces of Absorber pipes, Inlet and outlet temperature of the air, temperature of each wire mesh screen layers and temperature of upper transparent sheet were recorded.

The data pertaining to a given specific mass flow rate corresponding to a clear sky day were recorded between 11:00 A.M. to 04:00 P.M in the month of March, 2011 near Allahabad City. The readings are listed in Table 3.1.

Table 3.1 shows the comparison between the temperature rise of air recorded in the double pass solar air heater with and without the meshes during the course of a day.

Table 3.1 Record of Temperature

				Without Meshes		With Meshes	
Time (hr)	Absorber plate temp (°C)		Air Inlet Temp (°C)	Air Outlet Temp (°C)	Temperature Rise (°C)	Air Outlet Temp (°C)	Temperature Rise (°C)
	(Outside)	(Inside)					
11:00	59.7	54	35	54	19	59	24
12:00	69.4	67.2	34	52	18	67	33
13:00	73.0	68.1	39	61	22	70	31
14:15	71.7	68.4	42	65	23	72	30
15:45	50.2	48.3	38	53	15	61	23
16:45	44.2	43.1	36	47	11	51	15

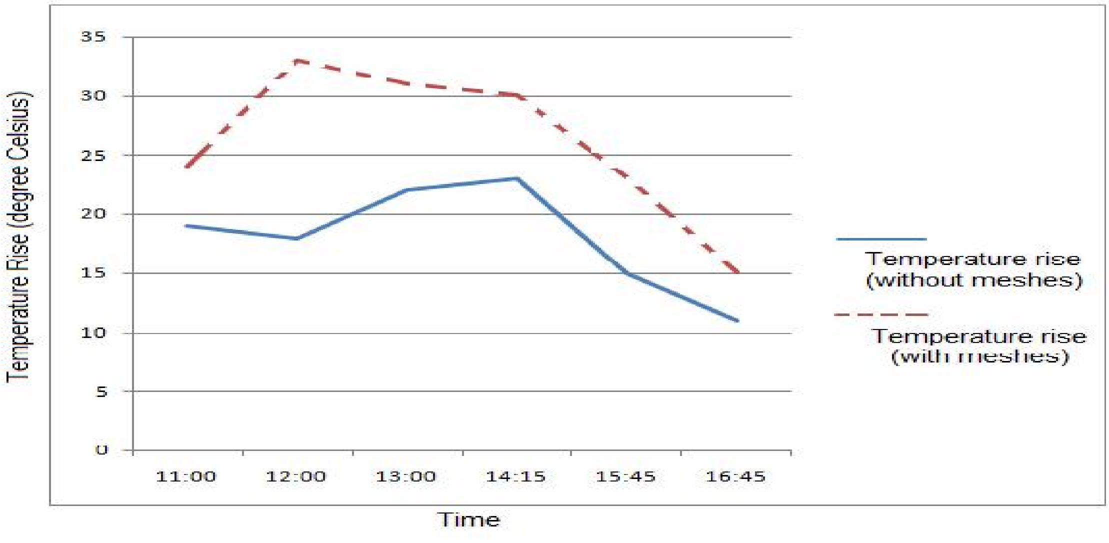

Fig. 3.2 Temperature rise of air recorded in the double pass solar air heater with and without the meshes.

In case of heater with meshes, temperature rises as sun intensity falling on earth increases with time reaching to maximum at 12:00 noon. Temperature rise falls slowly after reaching its peak as sun rays intensity decreases later and as a result face steep fall in evening time.

In case of heater without meshes, temperature rise reaches its peak at about 14:15 P.M after which temperature rise starts to fall due to aforementioned reason. The reason for achieving peak value at later time of 14:15 P.M. as compared to heater with meshes which reaches its peak value at 12:00 noon may be attributed to heat transfer media, which is only blackened aluminium pipe in present case, whereas it were heated meshes and blackened aluminium pipe, both, in the aforementioned case.
It is concluded from the observation table and from the figure 3.2 that the temperature rise is more in case of heater with meshes. This can be attributed to increased residence time of air with the heated meshes and blackened aluminium pipe.

4. Conclusion

The performance of counter flow air heater is compared with the conventional solar air heater. The heat loss from the top cover is reduced in case of counter flow solar air heater for the entire range of mass flow rate. The efficiency of counter flow solar air heater is further increased by adding porous matrix to the air heater in second air pass. The path of the air travel is increased in case of counter flow solar air heater resulting higher outlet temperature of the same mass flow rate.

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