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Research Paper

EFFECT OF DIVERSE STREAM PATTERNS ON THE PERFORMANCE OF SOLAR AIR HEATER

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This paper reports the results of a performance study in solar air heater subjected to single/double pass flow patterns. The effect of varied mass flow rate (24.84 kg/hr, 50.04 kg/hr and 75.05 kg/hr) at similar solar intensity is investigated on single/double pass solar air heater. Experimental findings show a better thermal efficiency for double pass conditions. In double pass air heater, the temperature of air at collector exit decreases at higher mass flow rate (75.05 kg/hr). The thermal efficiency of the collector increases due to reduced losses to ambience. Similar results were obtained for single pass (over flow and under flow) experimental conditions. Further the glass plate temperature and absorber plate temperature is found to be lower at high mass flow rate (75.05 kg/hr) employing double pass.

Keywords: Solar air heater, Under flow, Over flow, Single pass, Double pass

INTRODUCTION

Due to increase in conventional energy prices and environmental effects viz., air pollution, global heating, depletion of the ozone layer and green house effects, the application of solar energy enhanced significantly. A solar air heater finds extensive application such as domestic water heating, space heating, drying agricultural products and industrial processes. Solar collectors a special type of heat exchanger which transforms solar energy to internal energy of the transport medium. Flat plate solar air heater absorbs incoming solar radiation and converts it into heat and transfers to a fluid flowing through the collector (Kalogirou, 2004). The rate of heat transfer depends on various parameters such as properties of glazing materials, absorbing plate and working fluid. Researchers worldwide attempted various designs to enhance the thermal efficiency of a flat plate solar air heater (Gupta and Garg, 1967; Duffie and Beckman, 1980; Wijeydundera *et al.*, 1982; Hsieh, 1986; and Parker *et al.*, 1993). Bliss (1959) and Kovarik (1975) separately conducted economic analysis for the design and operation of solar collectors. Biondi et al. (1988) presented a diagram comparing

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different collector performance and is very helpful in construction and selecting operating parameters. Ong (1995) developed a theoretical model for predicting the thermal performance of flat plate solar air collectors using single pass configuration. An increase of thermal efficiency while employing wire mesh in the absorber plate during single pass flow was reported by Velmurugan and Ramesh (2011).

An attempt is made to fabricate single and double pass solar air heaters. Further overflow and under flow of the air in single pass air heater is also attempted. Nevertheless, double pass experimental condition, increases the contact area significantly and results in higher thermal efficiency than single pass and reduced heat losses to ambience.

EXPERIMENTAL SETUP

The experimental setup consists of upper and lower channel having two glass covers, bottom insulation and aluminum absorber plate painted with black as in Figure 1. The size of the collector is 700 mm in width and 1200 mm in length. The upper and lower channels having a depth of 63.5 mm each are separated by absorber plate. Air is sucked through the collector by a blower and the quantity of air flow is controlled by a gate valve. The flow channels (lower and upper) are covered by thermocole to minimize the heat losses to the surroundings. Air flow rate is measured using vane type anemometer. Calibrated k-type copper constantan thermocouples are employed for measuring, the average plate temperature, glass covers and inlet, outlet air temperatures. Solar intensity was measured by pyronometer.

Figure 1: Experimental Setup

Detailed specification of the each test collector is given below:

- Absorber material: Aluminum with black painted
- Plate type: Flat
- Dimensions of absorber plate: 1200 mm × 700 mm
- Absorber plate thickness: 1 mm
- Back insulation: Fiber glass wool (Thickness 40 mm)
- Glazing: Normal window glass (Thickness 4 mm)
- No. of glazing: 2
- Side insulation: Thermocole (Thickness 10 mm)
- Collector main frame material: Stainless steel (Thickness 2 mm)
- Collector tilt: 11° (North to South)

PROCEDURE

The solar air heater is designed to study the performance during single and double pass conditions. Experimental conditions employing single pass is of two types namely, over flow and under flow.

Overflow represents the passage of air through upper channel (over the absorber plate), while under flow indicates air is passing through the lower channel (under the absorber plate) of the collector. Double pass represents the recirculation of air from lower channel to upper channel. The over flow, under flow and double pass are schematically shown in Figures 2-4.

Figure 2: Over Flow

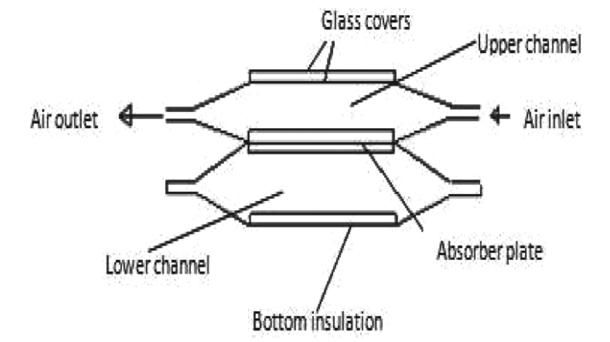


Figure 3: Under Flow

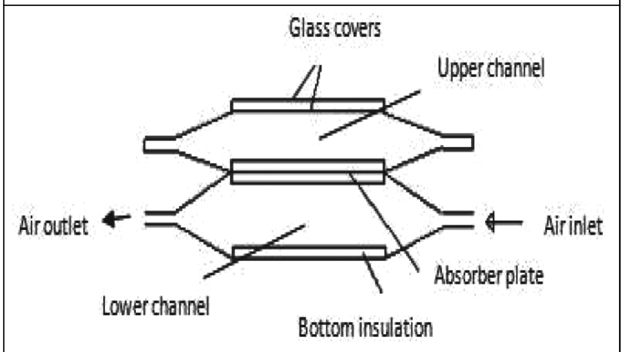
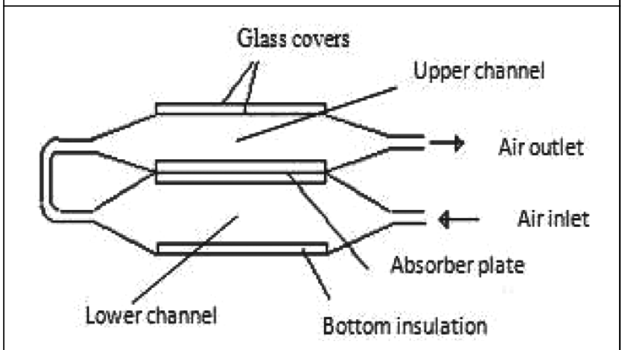


Figure 4: Double Pass



Three sets of solar air heater having under flow, over flow and double pass were fabricated and tested at uniform solar intensity. Performance of the solar air heater at various mass flow rates (28.84 kg/hr, 50.04 kg/hr and 75.05 kg/hr) is studied. Further, the rise in temperature, absorber plate temperature and glass plate temperature of double pass solar air heater with similar solar intensity subjected to different mass flow rates are reported.

PRIMARY DATA

The useful gain (Q_u) by the solar collector exposed to solar radiation with measured values of fluid inlet (T_1) and outlet temperature (T_2) and the mass flow rate (m) is given as follows (Duffie and Beckman, 1980).

$$Q_u = mC_p(T_2 - T_1) \quad ...(1)$$

where C_p is the specific heat of the fluid. The thermal efficiency of the collector is given by Duffie and Beckman (1980).

$$\eta_{th} = Q_u/A_cS \quad ...(2)$$

where A_c is the area of the collector and S is the global solar radiation incident on the collector.

RESULTS AND DISCUSSION

The heat gained by the air increases with increase in mass flow rate. In addition, the thermal efficiency and heat gained is found to be maximum at higher mass flow rate (75.05 kg/hr). Experimental conditions having double pass shows a higher thermal efficiency than single pass condition. Outlet air temperature decreases with increase in mass flow rate. The results of varied mass flow rate, it is observed that the thermal efficiency of double pass solar air heater is higher than single pass (over flow/

under flow) air heater (Figures 5-7). The convective heat transfer coefficient between air and absorber plate was significantly lower resulting in maximum thermal losses to atmosphere. Double pass solar air heater increases heat transfer area and restricts the heat loss to ambience leading to enhanced thermal performance. The thermal efficiency of over flow condition is higher than under flow as a consequence of heat transfer from absorber plate and glass plate. In under flow, heat is transferred only by the absorber plate as the bottom surface is insulated.

Figure 5: Time vs. Thermal Efficiency (m = 24.84 kg/hr)

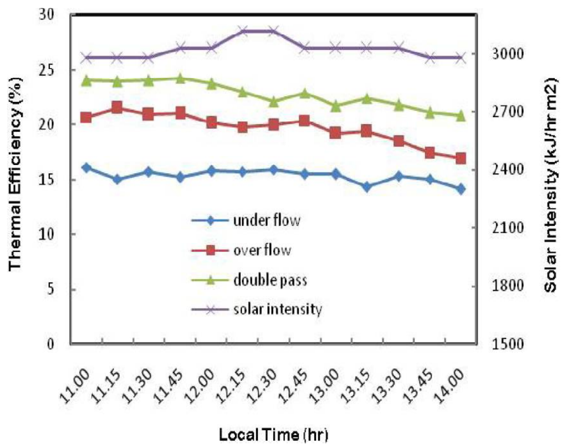


Figure 6: Time vs. Thermal Efficiency (m = 50.04 kg/hr)

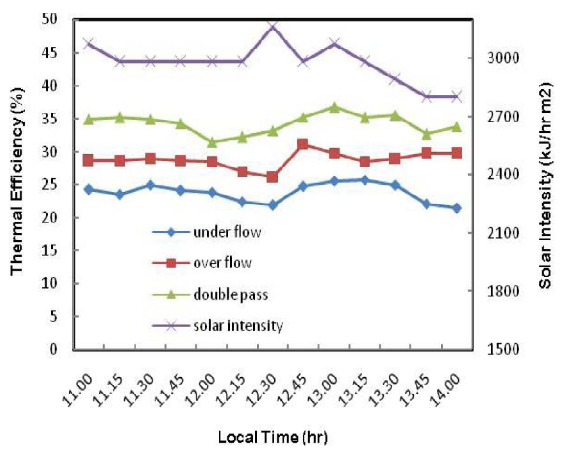
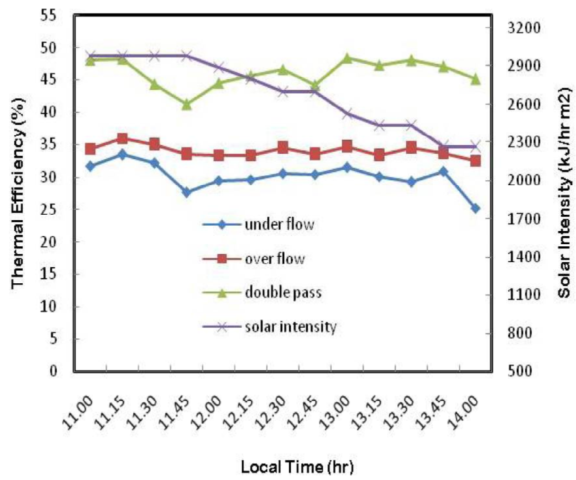


Figure 7: Time vs. Thermal Efficiency (m = 75.05 kg/hr)



The heat gained by air is maximum during double pass due to enhanced surface area for all mass flow rates (Figures 8-10). In single pass flow, heat gained by air during over flow is higher than heat gained during under flow. Mass flow rate of air significantly influences the amount of heat gained. During higher mass flow rate, heat transfer to air is more as a result of reduced losses to ambience. The outlet temperature of air is higher during lower mass flow rate (Figure 11). At lower mass flow rate,

Figure 8: Time vs. Heat Gained by the Air (m = 24.84 kg/hr)

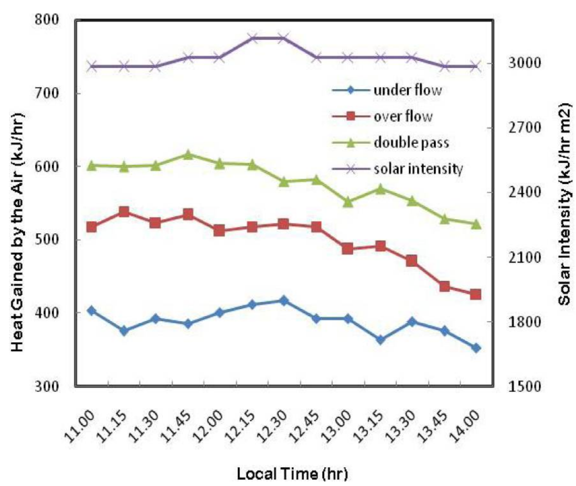


Figure 9: Time vs. Heat Gained by the Air (m = 50.04 kg/hr)

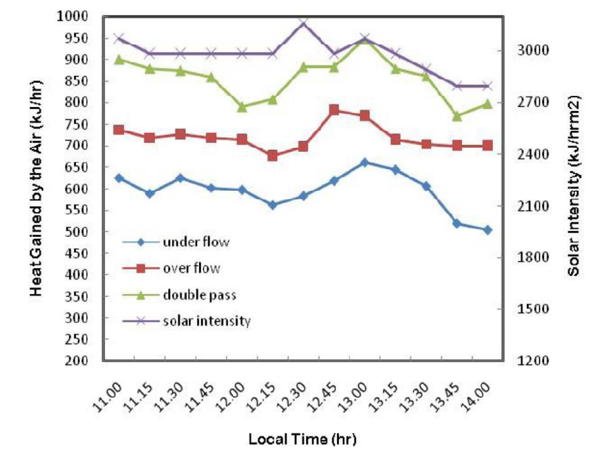


Figure 10: Time vs. Heat Gained by the Air (m = 75.05 kg/hr)

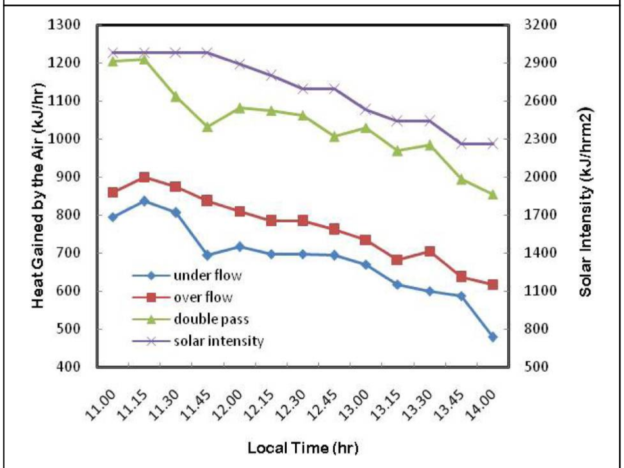
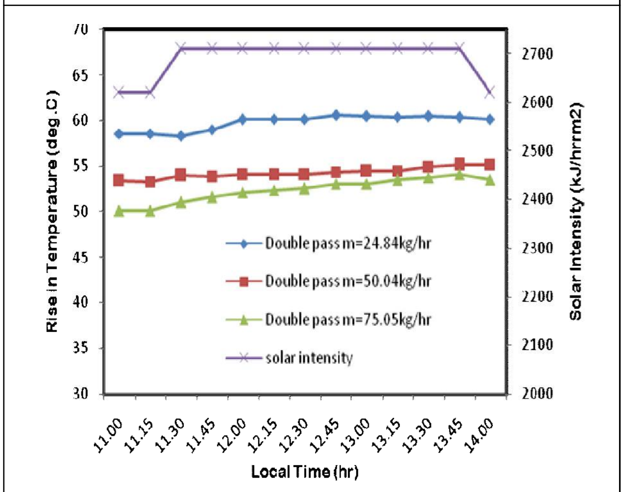


Figure 11: Time vs. Rise in Temperature



the contact duration, of air with absorber plate increases resulting in higher outlet temperature. The absorber plate temperature is lower at higher mass flow rate (Figure 12). During higher mass flow rate, the available air is sufficient to remove the heat stored in the absorber plate. Glass plate temperature is inversely proportional to mass flow rate (Figure 13). The heat loss to ambience is reduced, as flowing medium removes the available heat at higher mass flow rate.

Figure 12: Time vs. Absorber Plate Temperature

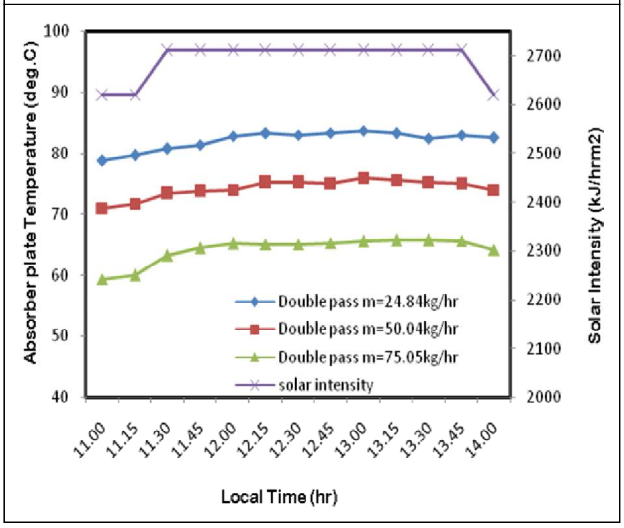
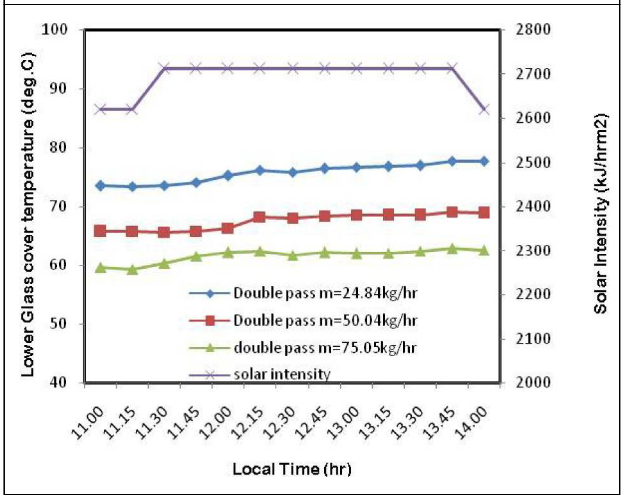


Figure 13: Time vs. Lower Glass Cover Temperature



CONCLUSION

The performance studies of solar air heater with single and double pass at similar solar intensity was conducted and the following conclusions were drawn.

- Higher thermal efficiency and heat transfer rate was obtained during double pass.
- Mass flow rate influences the thermal performance for all experimental conditions.
- In single pass solar air heater, higher efficiency was obtained during over flow than under flow.
- Absorber plate temperature and glass plate temperature is lower during double pass conditions.

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