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Numerical Analysis of Return-Flow Solar Air Heater with V-Staggered-Discrete Baffle as Artificial Roughness Using Matlab Equations

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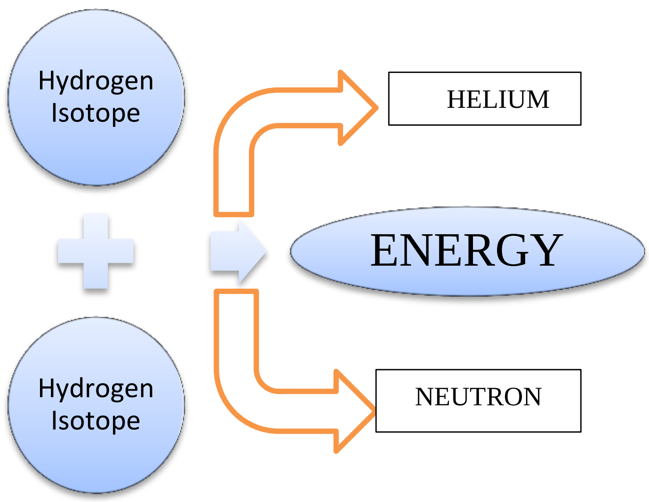
ABSTRACT

Conventional solar air heaters generally consists of an absorber plate with a parallel plate below it forming a small passage through which the air to be heated flows. Due to low value of heat transfer coefficient between absorber plate and air and thus low efficiency, surfaces are either provided with roughened or longitudinal fins or use of v-shaped or corrugated absorber plate. Further in case dealing with flat plate type sun oriented heater with one-pass, the losses are relatively high also resulting to low efficiency, to overcome this parallel or sometimes return flow arrangement of flow system is used In this work a thermal characteristic performance of a return flow solar air heater with v-staggered discrete baffles as an artificial roughness has been studied. It has been found that use of v-staggered-discrete baffles increases efficiency by 5% to 10% compared to v-baffles. Finally, it was found that for very small value of mass flow rate the efficiency of proposed work was similar to that obtained by Return flow solar air heater with v- baffles, but with increase in mass flow rate after 0.03 kg/sec there was a significant improvement in the value of efficiency which varied from 8% to 10%.

1. INTRODUCTION

SOLAR ENERGY

The enormously huge and large sum energy radiated from sun each and every day is referred to as what we call as solar energy. This so called process namely nuclear fusion includes the hydrogen isotopes getting combined to synthesis a helium atom and of energy as radiations.



The thermal efficiency of solar air heater is less due to low heat transfer capability between absorber plate and fluid flowing in the duct. To make solar air heater more efficient solar energy utilization system, thermal efficiency needs to be improved by enhancing heat transfer rate. The heat transfer rate can be exaggerated by the following:

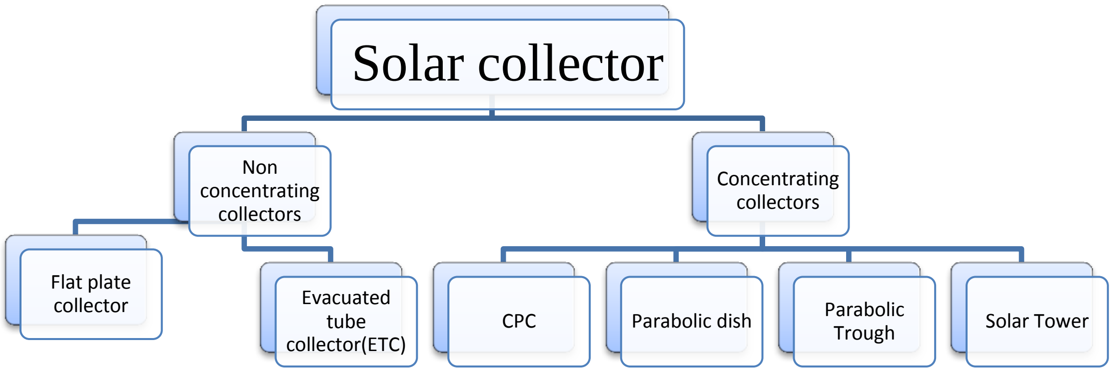
(a) Use of a secondary heat transfer surface,

(b) Disruption of the unenhanced fluid velocity,

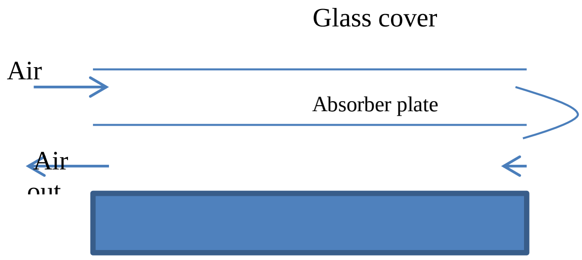
(c) Disruption of the laminar sub layer in the turbulent boundary layer\

Further in case of flat plate solar air heater with single pass, the losses are relatively high also resulting to low efficiency, to overcome this parallel or return flow arrangement of flow system is used.

SOLAR COLLECTORS



Conventional solar energy air heaters generally contains a absorber plate along with parallel plate beneath it forming a small passage through which the air which is being heated flows. The twofold pass sun oriented air warmers are essentially of two kinds on basis of direction in which fluid flows, these are counter or sometimes called return flow 2-pass sun oriented air heater and parallel pass 2-channel solar oriented air heater.



1. Counter flow DPSAH

2. Parallel flow DPSAH

MATHEMATICAL MODELS

a. Parallel pass solar air heater

b. Counter flow solar air heater

c. Double pass flat plate solar air heater with porous media

d. Double pass flat plate solar air heater with longitudinal fins

e. Multi pass flat plate solar air heaters with external recycle

f. Double pass solar air heater with packed bed

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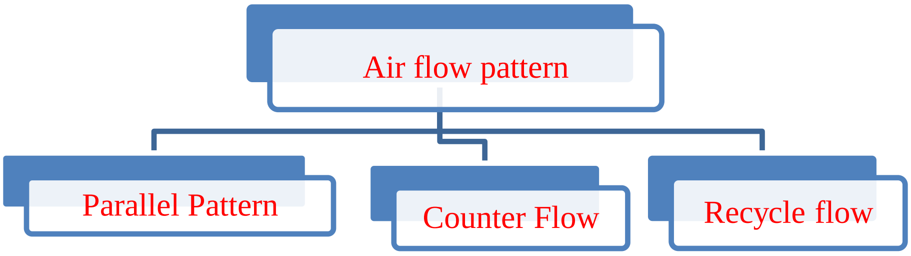


2. LITERATURE SURVEY

Satcunathan & Deonarine[1] have suggested the utility of 2-pass air solar heater in order so as to reduce losses from top. The air flows first in the space made in between the glass cover and the absorber plate, further it is induced through the duct. The thermal losses from one or many covers glass can suppress by using such systems. Such systems are 10–15% more efficient then single pass system.

Wijey sundera et al [2] subsequently studied two pass concept both experimentally and also analytically using 2 types of arrangements. First he studied the arrangement of Satchunathan and Denarine .While in other, the inlet air followed first above the absorber and then under it. It was encountered that the open systems, with inlet fluid at ambient temperature, the double exposure systems are 10–15% more efficient then the single exposure for a vast range of working conditions. It is eloquent that the temperature of outer cover is sharing the same boundary with ambient temperature compared to the single glass cover operated system.

Karim & Hawlader [3] reported the achievements of single cover air heater while operated as single pass and also double pass mode. The 3 kinds of absorber plates i.e. Flat type, flat plate with fins and v-shaped were tested. It was established that v- shaped absorber plate collector was most efficient of the 3 types.

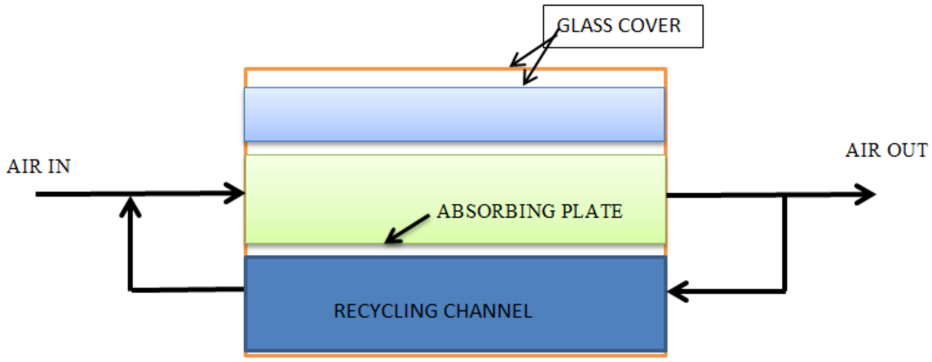
Ho et al. [4] developed a mathematical based model of e counter flow sun oriented air heater. In such type of collectors, flowing air is made to move faster than the simple collectors. The following assumptions were considered:

a) Temperatures of insulated bottom plate, absorbing plate and that of fluid are elements of only direction of air flows.

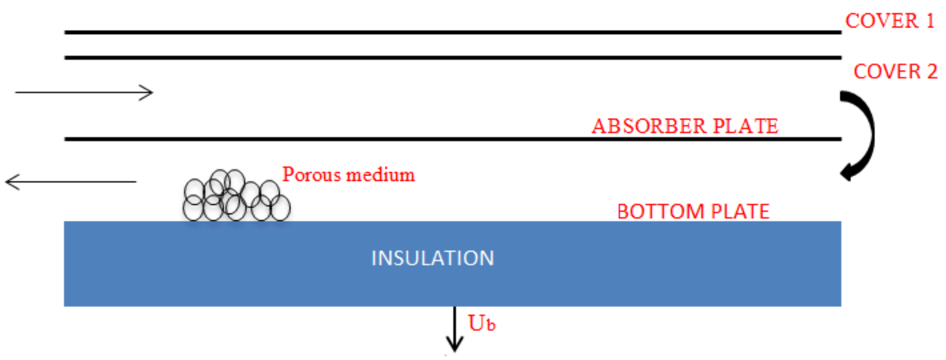
b) Radiant energy is not absorbed in by absorber plate and Glass.

c) The quantity of radiant energy as absorbed in by outlet cover remains negligible.

He showed that if we mix part of warm air leaving a 2-pass air heater with inlet externally and it is recycled , the efficiency associated with collector increases.

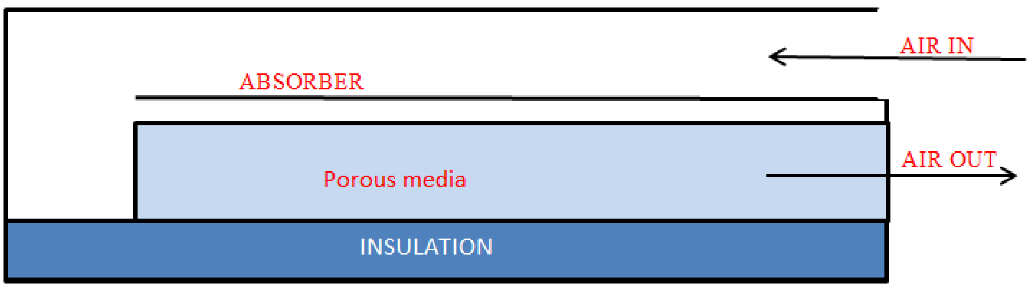


Sopian et al. [5] used a heater based on sun with some porous medium in second channel. He conducted indoor experiments and deduced that 2-pass solar heater for air with some porous medium in second channel has thermal efficiency ranging 60% to 70% i.e. about 10% to 20% excessive than that one without any porous medium



Naphon[6] examined theoretically the characteristics of heat transfer and performance associated with 2-pass flat sun oriented air heater both with and also without any porous media. The mathematical model presented in this examination of designed 2-pass single solar air collector along with some porous media is established from model presented by researchers Naphon and Wijeysundera

Yeh et al. [7] examined a parallel Two-pass SAH accompanied by fins adhered under and also over the proposed absorber plate. A considerable advancement with efficiency was noted for the Two-pass SAH as compared to a One-pass variety of SAH while using same dimensions and type of flow conditions. It was moreover viewed that OFR (optimum flow ratio) in upper pass w.r.t lower pass was 0.5, exhibited maximum enrichment in efficiency for Two pass SAH.

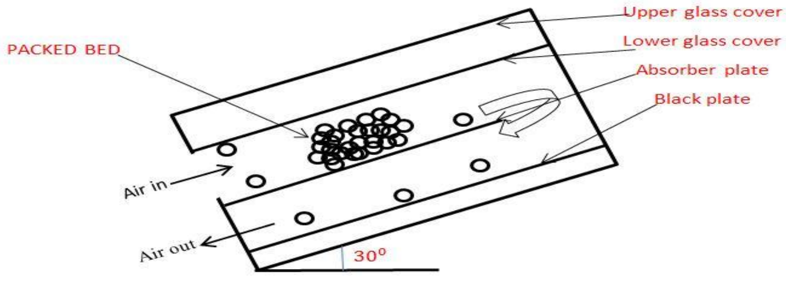


Some designs involved porous matrix.

Hamid and Beckman[8] have studied the absorption characteristics and temperature profiles in matrices made by stacking copper wire screens while **kays and London[9]** gave characteristics for pressure drop of such matrices. Based on their studies , it was deduced that a matrix depth of 4cm is adequate. With 20^0 temperature of inlet air, it was estimated that an efficiency of 75% would be obtained with matrix using air heater compared to 58% of conventional variety of air heaters based on sun. Further the pressure fall was estimated to be 200 times less compared to conventional variety of air heater based on sun's energy.

Sharma et al. [9] experimentally probed artificial roughness by utilizing circular wires adhered to some absorber plate in the channel of a two-pass SAH. The wires used were positioned in form of V-shape with height relative roughness and R_e(Reynolds numbers) related to ranges of about 0.022–0.044 and 4900 to 12000, respectively. The estimations of the Nusselt number and friction element for the roughened gatherer were contrasted and the comparing estimations of smooth channel.Considerable enrichment with Nusselt number along with friction factor was outlined.

Ramadan et al. [10] studied effects of mass and porosity of packing materials, and mass flow rate of air. It was stated that low porosity material with an expanding mass stream rate of air was favorable for accomplishing better thermo-water powered performance .However; flow rates beyond 0.05 kg/s were established to be insignificant.



3. OBJECTIVES

Due to low value of heat transfer coefficient between absorber plate and air and thus leading to Low efficiency. To solve this problem surfaces are either provided with roughened or longitudinal fins or use of V-shaped or corrugated absorber plate. Further in case of flat plate solar air heater with single pass, the losses are relatively high also resulting to low efficiency, to overcome this parallel or return flow arrangement of flow system is used.

Thus, the main objectives of the proposed work are:-

a. Thermal analysis of return flow solar air heater.
b. Investigation of effect of geometry of baffles on the absorber plate efficiency.
c. Comparison of arrangement system using V-corrugated absorber plate on return flow solar air heater with arrangement using V-staggered discrete corrugated absorber plate on return flow solar air heater.

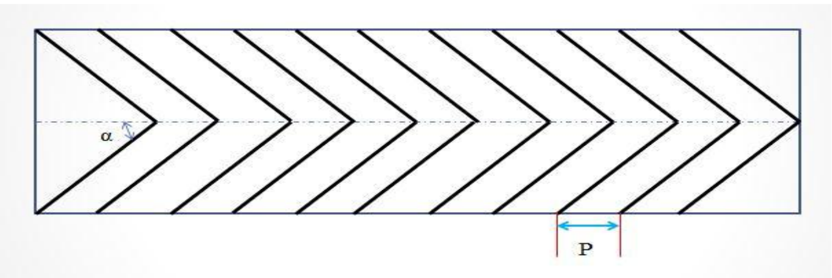
Conventional solar air heaters generally consists of an absorber plate with a parallel plate below it forming a small passage through which the air to be heated flows . The double pass solar air heater are of mainly two types depending on the fluid flow direction namely counter or return flow double pass solar air heater and parallel pass double duct solar air heater.

4. ANALYSIS

A. <u>For smooth surfaces following two equations are given:</u>

$$N_u = 0.0158Re^{0.8}$$

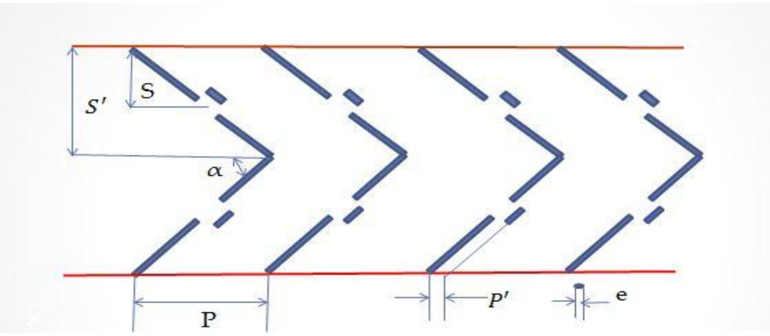
B. <u>For V-corrugated absorber plate following equation is given:</u>



$$N_u = 0.005344Re^{0.815}\left[\left(\frac{e}{H}\right)^{-0.1215}\right]\left[\left(\frac{p}{e}\right)^{1.8368}\right](\beta^{-0.2345})\left[\left(\frac{\alpha}{60}\right)^{-0.0244}\right](\psi^{-0.6379})\exp\left[-0.910\left\{\ln\left(\frac{e}{H}\right)^2\right\}\right]$$

$$\left[exp\left[-0.4555\left\{ln\left(\frac{p}{e}\right)^2\right\}\right]\right] exp[-0.0714\{ln\beta^2\}]\, exp\left[-0.2761\left\{ln\left(\frac{\alpha}{60}\right)^2\right\}\right] exp[-0.9680\{ln(\psi)^2\}]$$

C. For staggered discrete v-corrugated absorber plate following equation is given:



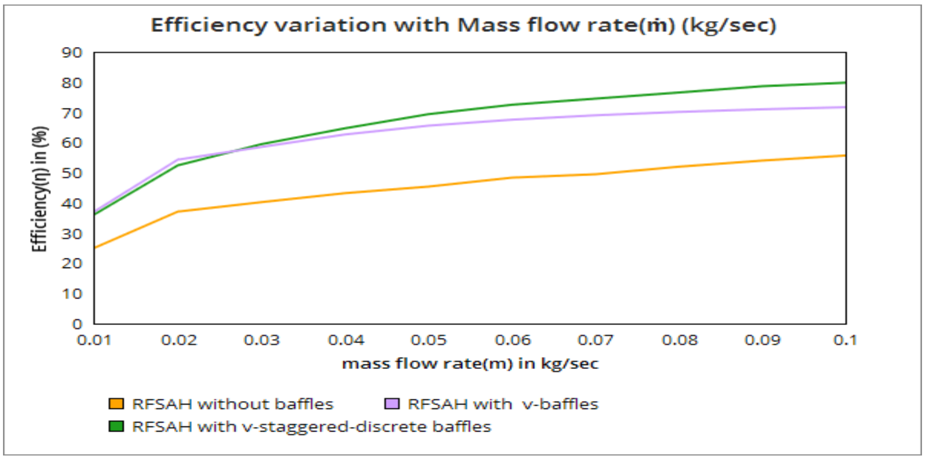
$$N_{ur} = 0.005344(Re^{1.299})\left(\frac{B}{S}\right)^{1.346}\left(\frac{S'}{S}\right)^{1.112}\left(\frac{e}{D}\right)^{0.270} * \exp\left[-2.25\ln\left(\frac{P'}{2}\right)^2\right] * \exp\left[-0.376L\ln\left(1-\frac{\propto}{60}\right)\right]$$

D. RESULTS AND DISCUSSIONS

Based on the results of the program a comparison has been drawn graphically with variations in parameters. These parameters are of two types i.e. Design parameters and Baffle parameters.

a. Efficiency(η) vs mass flow rate($\dot{m}$)

Mass flow rate($\dot{m}$) (kg/sec)	Efficiency of Return flow solar air heater without baffles (%)	Efficiency of Return flow solar air heater with v-baffles (%)	Efficiency of Return flow solar air heater with v-staggered-discrete baffles (%)
0.01	25.029	37.0701	36.0937
0.02	37.07	54.2775	52.3837
0.03	40.2098	58.4922	59.4066
0.04	43.1890	62.6241	64.6636
0.05	45.3653	65.5490	69.3522
0.06	48.33	67.5268	72.4806
0.07	49.4602	68.9874	74.5037
0.08	51.9621	70.1029	76.5350
0.09	53.9972	70.9769	78.6257
0.1	55.6731	71.67	79.79

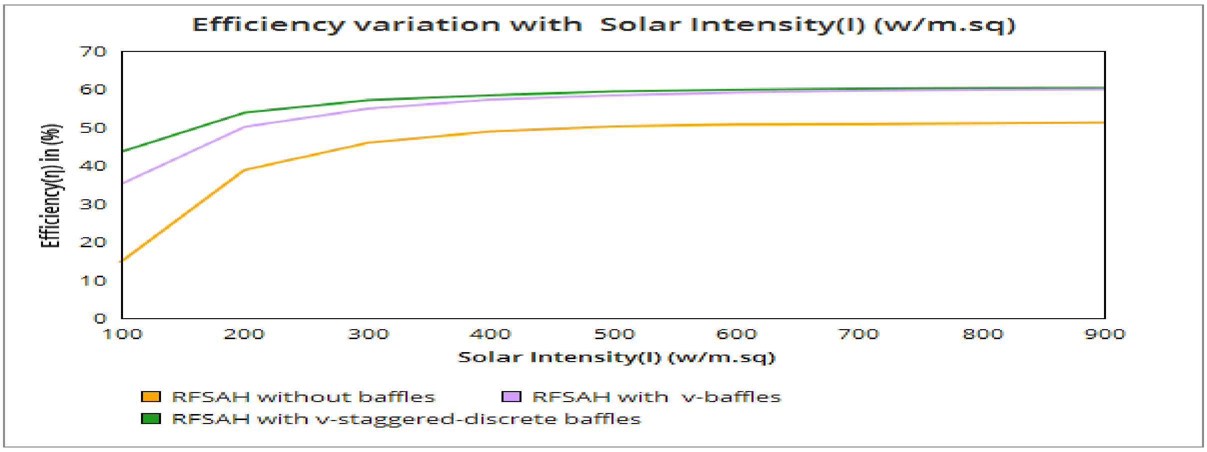


From the above graph we can see the variation of efficiency with change in mass flow rate for different arrangements of return flow solar air heater. It is clearly visible that efficiency increases significantly on application of baffles on absorber plate. For both flat plate return flow solar air heater and Return flow solar air heater with v-baffles the efficiency increases with mass flow rate to certain point and then becomes nearly constant.

Furthermore with application of Return flow solar air heater with v-staggered-discrete baffles, the efficiency for mass flow rate of 0.1kg/sec reaches to a maximum value of 79.79% compared to the maximum value of 71.67% in case of Return flow solar air heater with v-baffles, which is almost 10% increase.

b. Efficiency(η) vs Solar Intensity(I)

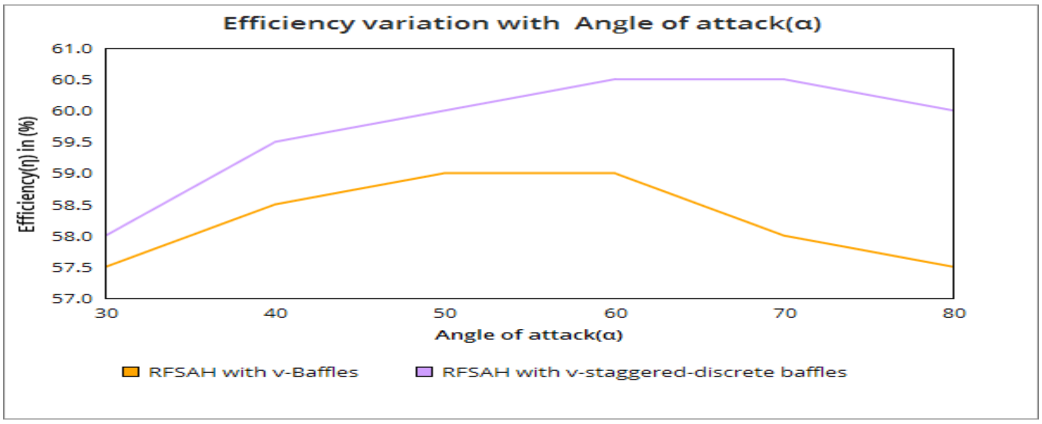
Solar Intensity(I) (w/m.sq)	Efficiency of Return flow solar air heater without baffles (%)	Efficiency of Return flow solar air heater with v-baffles(%)	Efficiency of Return flow solar air heater with v-staggered-discrete baffles(%)
100	14.8654	35.2022	43.6322
200	38.8113	50.1055	53.8451
300	45.9451	54.8889	57.0928
400	48.9087	57.2454	58.3984
500	50.2298	58.3820	59.4066
600	50.7503	59.1159	59.8655
700	50.8306	59.5600	60.1245
800	51.0201	59.8231	60.2583
900	51.2085	59.9653	60.3084



The above graph shows that the efficiency varies with solar intensity (I) only up to 400(w/m.sq.) , and after this the efficiency becomes almost asymptote for all three types of variations in Return flow solar air heater. For Return flow solar air heater with v-staggered-discrete baffles the maximum efficiency is nearly 60% for a mass flow rate of 0.03kg/sec compared to 59% for Return flow solar air heater with v- baffles for same mass flow rate

c. Efficiency(η) vs angle of attack(∝)

angle of attack(∝) (degree)	Efficiency of Return flow solar air heater with v-baffles(%)	Efficiency of Return flow solar air heater with v-staggered-discrete baffles(%)
30	57.5	58
40	58.5	59.5
50	59	60
60	59	60.5
70	58	60.5
80	57.5	60



It is clearly visible from the graph that efficiency of return flow solar air heater with baffles first increase and then starts to decrease after reaching a maximum value. This decrease is more significant in Return flow solar air heater with v-baffles as we compare it with the decrease as in case of Return flow solar air heater with v-staggered-discrete baffles. The efficiency in case of Return flow solar air heater with v-staggered-discrete baffles reaches to a maximum value of 60.5% at fixed values of mass flow rate of 0.03 kg/sec, and solar intensity of 500 (W/m sq).

5. CONCLUSION

Here the present work objective is to investigate the effect of use of v-staggered discrete baffles on both sides of absorber plate of a Return flow solar air Heater using a MATLAB program .The analysis shows the effect of various parameters and comparison of v-staggered discrete baffles on return flow w.r.t a Return flow solar air Heater using v-baffles .

Some conclusions associated with the present work are:

1. There is a significant enhancement in performance of a Return flow solar air Heater when we use a Return flow arrangement of solar air Heater.
2. A significant variation in efficiency of a v-staggered-discrete baffle solar air heater is observed with variation in baffle parameters. Maximum efficiency values are obtained corresponding to angle is attack values of 60-70^0 i.e. about 60.5%.
3. The use of v-staggered discrete b-baffles shows better performance for a Return flow solar air heater when compared with using a v-baffle. The rise in efficiency is nearly 5 to 10% compared to that of v-baffle

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