Scientific Journal of Impact Factor (SJIF): 4.14

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 3, Issue 5, May -2016

A review to optimize the parameter of solar air heater

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Abstract: Solar air heater is the best alternative solution for heating and drying application in the industries. But, because of its low efficiency and low temperature output it is not commercially in the market. This research study carried out to optimize the double pass solar air heater parameters and focused on the design of experiment for different applications. It concludes that the DOE gives the best effective and economic output for the designed parameter of an experiment from the responses.

Key words: Double pass, solar air heater, DOE, Taguchi, solar radiation

Introduction:

A typical solar air heating collector is made up of wood, galvanized iron sheet, or concrete. Inclination is provided to receive maximum solar radiation, glass is put on the top for allowing the maximum solar radiation inside the solar air collector, inner surface is blackened coating to absorb the maximum solar radiation during the day period. Outer side walls is insulated with different insulation materials such as puff, thermocol, wood, fiber glass wool, etc. this collector put at the northern facing to collect the maximum solar radiation.

Solar air heating is an essential component of any effective climate change toolkit, as it targets one of the largest single usage of energy in the building sector – and corresponding CO2 emissions – at the lowest capital cost of any renewable energy option. The technology has been used successfully around the world for several decades and is now poised to offer a large-scale contribution to global climate change mandates.

Solar thermal air heater system has a myriad of uses and applications. It is ranging from solar process drying of crops such as coffee and nuts, to solar space heating and fresh air ventilation for industrial, commercial, institutional and multi-residential buildings. View examples of Solar Wall applications below:

Figure 1 Solar air Heating Application

Problem definition:

There are lots of work has been already done to improve the efficiency of the solar air heater but due to its lower efficiency and higher installation cost for same capacity, it is not commercialize global in the market. The double pass solar air heater gives more efficiency as compared to the single pass solar air heater. So, it is necessary to reduce the cost of solar air heater and increase the efficiency of the DPSAH with optimizing the parameter with the help of DOE.

Objectives and goal:

The main objective of this Research study is to make the solar air heater commercially applicable and in low cost. By this concept combine effect of metallic wiry sponge and DOE Method applying for going to optimize the parameter and increase the efficiency of the double pass solar collector in the same absorber plate area. Reduce the cost of active solar air heater by using the inexpensive and easily available material and also reduce the complexity with for less skill operation.

For this review the following research study has been observed and reviewed: Review on literature on experimental investigation on solar air heater and DOE to find the Thermal efficiency and heat transfer enhancement used different porous media, thermal energy storage material, obstacles etc. So many researchers were finding different review give us below.

[1] **Aldabbagh, L. B. Y., F. Egelioglu et al.** (2010) investigated on **experimentally performed a thermal analysis of single and double pass solar air heaters with steel wire mesh layers are used instead of a flat absorber plate**. 10 steel wire mesh layers were fixed in second duct parallel to the glazing. They studied an effect of mass flow rate of air on the outlet temperature and thermal efficiency. This researcher fount that the efficiency with increase with increasing the mass flow rate for the range of the flow rate used in this study between 0.012 and 0.038 kg/s. And for the same flow rate, the efficiency of the double pass is found to be higher than the single pass by 34 to 45%. So proven that double pass solar air heater was more efficient compare that single pass solar air heater. Moreover, the maximum efficiencies obtained for single pass and double pass air collector are 45.93% and 83.65%. Shown Figure below simple diagram and arrangement of steel wire mesh layers inside the air channel.

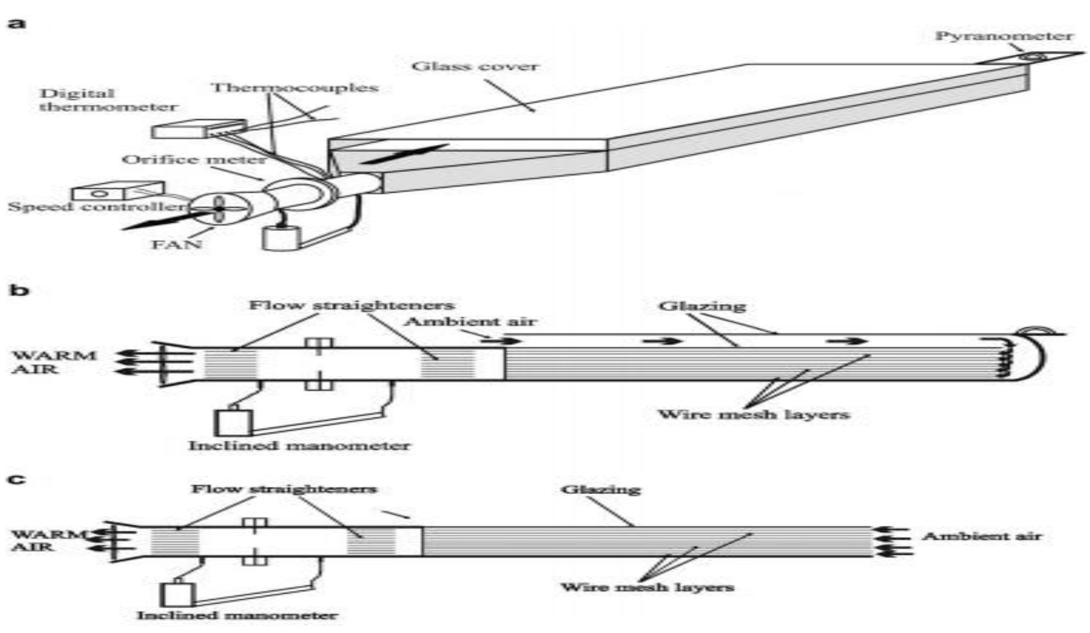

Figure 1 Schematic view of an Experimental Setup [1]

[2] **S. S Krishnananth et al.** (2013) work on **Experimental analysis on double pass solar air heater with thermal energy storage.** Double pass solar air heater was fabricated and integrated with thermal storage system. Paraffin wax used as thermal energy storage system and this paraffin wax placed inside the aluminum capsules was used phase changing energy material. These capsules placed inside the channel at different location. So they was study of experimental analysis at different configuration such as 1) flat absorber plate 2) capsules above the absorber plate 3) capsules below the absorber plate 4) capsules above the back plate. (Fig. 2.2) This four configuration used on double pass solar air heater and they was find that capsules placed above the absorber plate was more efficient compare to other configuration. They was also observed that, the solar air heater with paraffin wax as energy storage material delivers comparatively high temperature air throughout the day. The efficiency is also higher during evening hours.

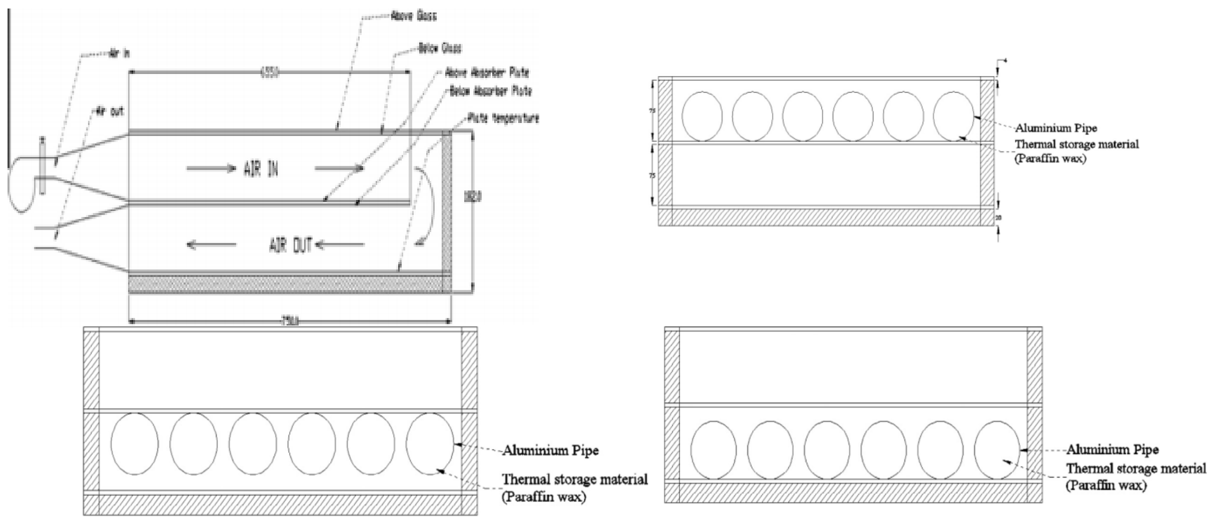

Figure 2 Thermocouples Arrangement of an Experimental Setup and different configuration of double pass solar air heater [2]

[3]Abdallah Salah et al. (2009) presented on **effect of various absorbing materials on the thermal performance of solar stills.** They used Different types of absorbing materials to examine their effect on the yield of solar stills. These absorbing materials are of two types: coated and uncoated porous media (called metallic wiry sponges) and black volcanic rocks (Fig. 2.3). This solar steel contains black coated and uncoated metallic wiry sponge made from steel quality AISI 430. This researcher found that an uncoated metallic wiry sponge has the highest collection during day time compare to metallic wiry sponge and black volcanic rocks. They found that the overall average gain in the collected distilled water taking into the consideration the overnight water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively.

Figure 3 Photograph of different absorbing porous media (a) uncoated & (b) coated metallic wiry sponge, (c) black volcanic rocks [3]

[4] **RahelehNowzari, L.B.Y. Aldabbagh at al.**(2014) represented an **experimentally performed a thermal analysis of single and double pass solar air heaters with partially perforated cover**. They studied on the thermal performance of the single and double pass solar air heaters with normal glazing and with quarter perforated cover experimentally (Fig. 2.4). The solar air collector was tested with two different perforated covers in which the holes made on one cover had the center-to-center distance of 20D (6 cm) and on the other cover it was 10D (3 cm), where D (0.3 cm) was the hole diameter. Simple they was finding that thermal efficiency of the double pass always more than single pass solar air heater by 5-22.7% for the 0.037 kg/s mass flow rate. At the same mass flow rate they were found maximum thermal efficiency of the single and double pass solar air heaters with normal glazing are 55.52% and 60.18%.While the double pass solar air heaters have 60.49% and 57.60% maximum thermal efficiency with 10D and 20D perforated covers, respectively. So this researcher fount that, the efficiency of the solar air heater with 10D perforated cover is slightly higher than one with 20D perforated cover for both single and double pass.

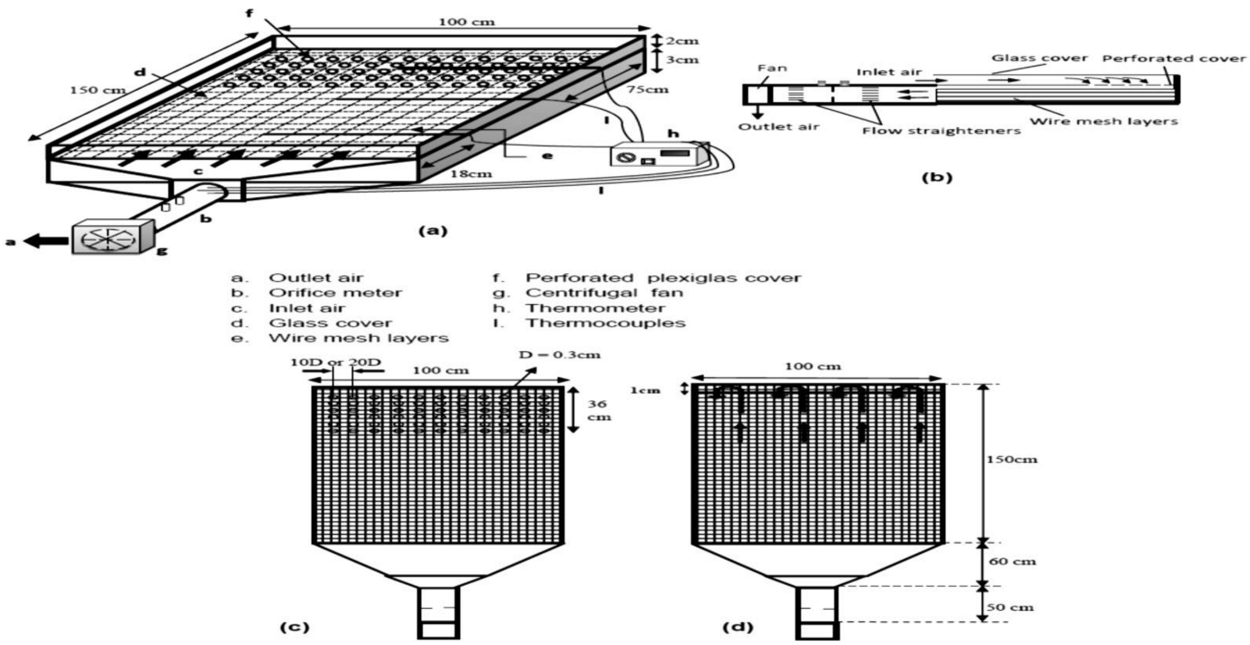

Figure 4 Schematic assembly of the manufactured solar air heater (a) schematic of solar collector (b) side view (c) Top view Perforated cover (d) Top view with normal glass cover

[5] Paisarn Naphon et al. (2005) worked on **numerically analysis of heat characteristics and performance of double pass flat plate solar air heater with and without porous media** (Fig. 2.5).They develop mathematical models which describe the heat transfer characteristics of the double-pass flat plate solar air heater and these are derived from the energy conservation. They found thermal conductivity of porous media has significant effect on the thermal performance of the solar air heater. They found that porous material used high thermal conductivity because the heat transfer rate depends directly on the thermal conductivity. And also they observed that, they found thermal conductivity of porous media has significant effect on the thermal performance of the solar air heater.

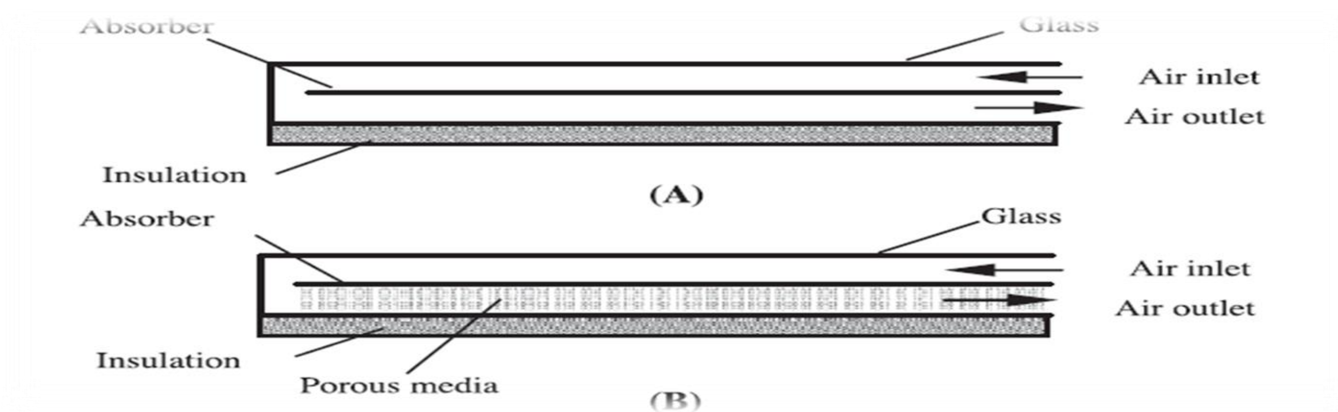

Figure 5 Schematic diagrams the solar air heater without (A) and (B) porous media [5]

[6] **P. T. Saravanakumar at el.** (2012) presented **Numerical study and thermal performance of the Flat plate solar air heaters with and without Thermal storage system** (Fig. 2.6).The mathematical models described that the heat transfer of the plate solar air heater are derived from the energy equation. The results obtained from the model are validated by comparison with experimental data. They found that the thermal conductivity of thermal storage material has significant effect of thermal performance of the solar air heater. And also they observed that the solar air heater with the thermal storage material gives 5 - 10% higher collector efficiency than that of without thermal storage material.

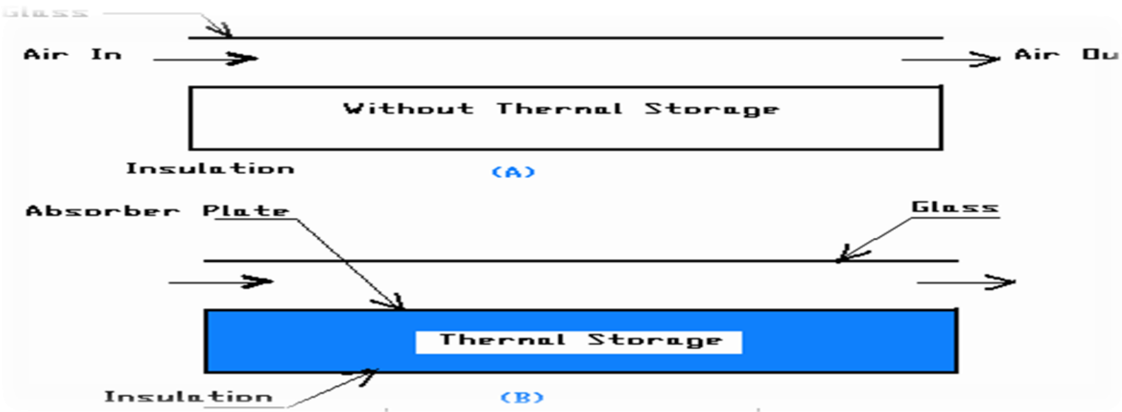

Figure 6 Solar air heaters (A) without (B) with thermal storage. [6]

[7] **Hikmet Esen** et al. (2008) work on **experimentally investigated the energy and exergy analysis for a double-flow flat plate solar air heater with and without obstacles.** Four types of absorber plates made of stainless steel with black chrome selective coatings were used (Fig. 2.7). The dimensions and plate thickness for all four collectors were 1250 x 800 mm and 1mm, respectively. Single glazing with 5 mm thickness was used. It was observed that the obstacles created the turbulence and reduced the dead zones. The shapes of tested obstacles were presented in the study. The measured parameters were the inlet and outlet temperatures, the absorbing plate temperatures, the ambient temperature, and the solar radiation. Following analysis of the results, optimal value of efficiency was found to be when the absorbing plate was in the middle level of flow channel for all operating conditions. It was also found that the double-flow collector equipped with obstacles appeared significantly better than that without obstacles. It was shown that the Type III (the one which was staggered with leaf shaped obstacles) absorber plate always yielded higher efficiency than the Type I (flat plate) (Figure 8). An exergy analysis for the experimented collector was also performed. The results showed that the largest irreversibility occurred at the flat plate (without obstacles) collector in which collector efficiency is the smallest.

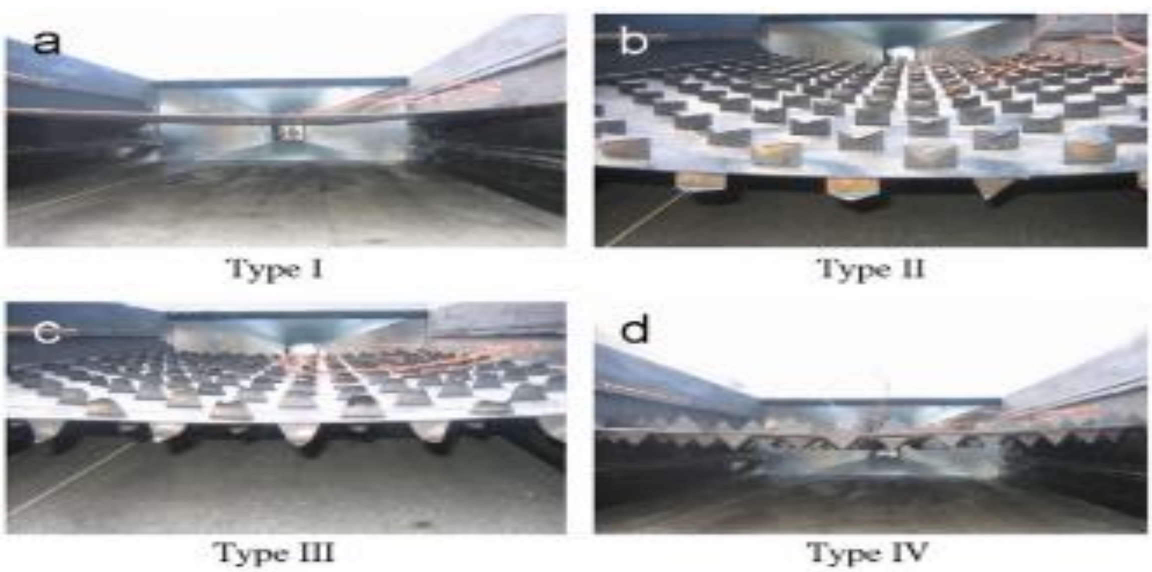

Figure 7 Photograph of obstacles on absorber plate. [7]

[8] A. J. Mahmood, L. B. Y. Aldabbagh at el. (2015) represent on **experimentally Investigation of single and double pass solar air heater with transverse fins and a package wire mesh layer** (Fig. 2.8). Four transverse fins painted dark black and place transversely to create four equal-spaced sections. Sixteen steel wire layers were located between these fins as an alternatively of an absorber plate. It was single and double pass SAH with wire mesh used as an absorber plate was constructed and tested for different air mass flow rate and different height of the lower channel in case of double pass. And also thermal efficiency and outlet temperature were studied. They were found that thermal efficiency increase as the air mass flow rate (0.0011-0.0032) kg/s. The maximum efficiency obtained using the 7.5-cm high collector was 62.50% for the double-pass SAH and 55% for the single-pass SAH at an air flow rate of 0.032 kg/s. moreover they were find that further increase the efficiency by decreasing the height of lower air pass of the double pass solar air heater. Maximum solar intensity during middle of the day they observed maximum temperature different 45.30K of double pass SAH and 39.9K of single pass SAH

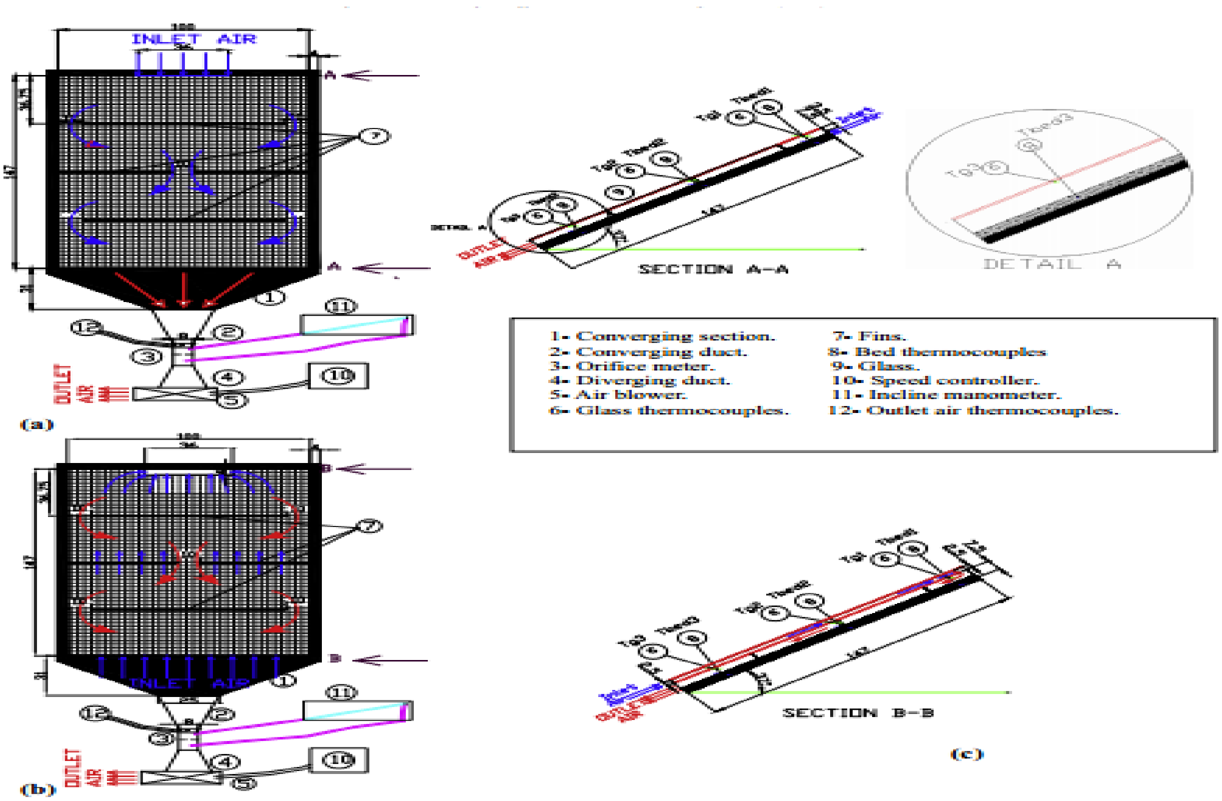

Figure 8 (a) Schematic assembly of the single-pass solar air heater system, (b) section A-A, side view of single - pass solar air heater, and (c) schematic assembly of the double pass solar air heater. [8]

[9] Chii-Dong Ho, Hsuan Chang at el. (2015) worked on **Analytical and experimental studies of wire mesh packed double-pass solar air heaters under recycling operation** (Fig. 2.9).Twenty pieces of wire mesh were welded in to lower sub channel using mesh interval of 0.015 m and mesh pitch of 0.003 m Comparisons were made among different the single-pass, flat plate double-pass and recycling wire mesh packed double pass operations. The application of steel wire mesh layers and recycling effect of new concept to present study and it was aiming to strengthen the convective heat transfer coefficient due to the turbulence enlargement. This researcher found that collector efficiency of the recycling wire mesh packed double pass operation is much higher than the other configurations under various recycle ratios and mass flow rates. Also they found collector efficiency increase with increase recycle ratio and mass flow rate due to air velocity enlargement and resulting convective heat transfer enhancement.

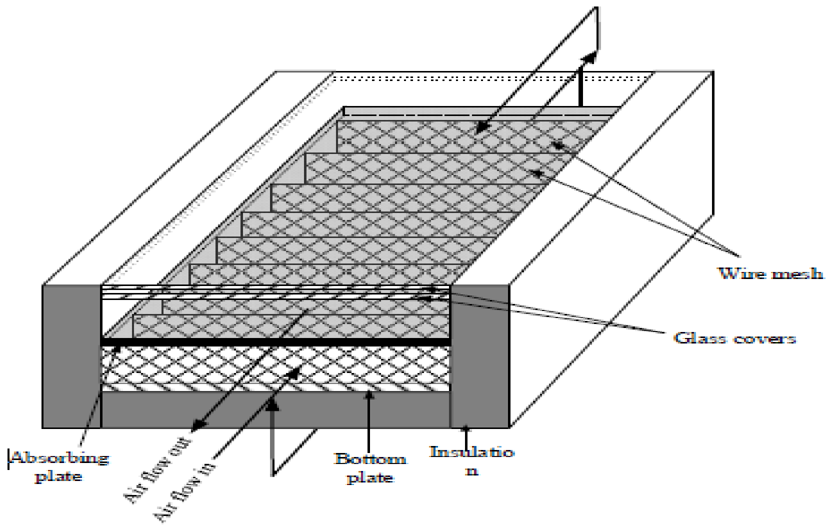

Figure 9 Double pass solar air heater with recycle

[10] Ming Yang worked with **Design and optimization of a solar air heater with offset strip fin absorber plate.** They Presented the design and optimization of a solar air heater with offset strip fin on absorber plate. The offset strip fins, which form the core of the heater, are mounted staggerly on the absorber plate and parallel to the airflow direction, as fig 2.9 Presents. Based on the empirical data, the instantaneous thermal efficiency could exceed 0.40 under the typical heating condition even at the low airflow rate (100 m^3 h^{-1}), where solar irradiance on the collecting area is 600 W/m^2, indoor air temperature 14 $^{\circ}$C, outdoor air temperature -5 $^{\circ}$C, and incident angle 0–30°. The according required fan power could be as low as 20 W.

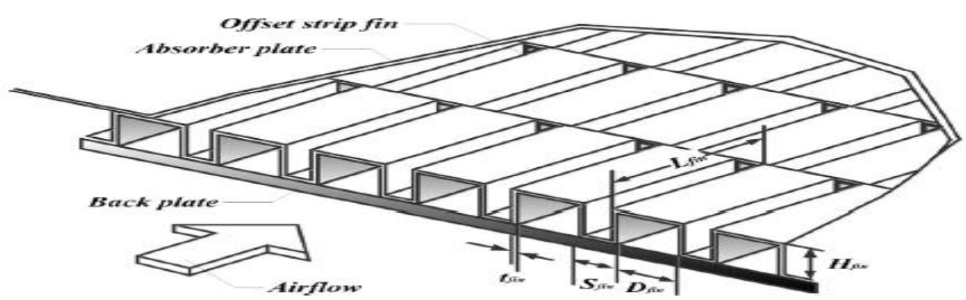

Figure 10 Offset strip fins in the airflow pass

[11] K. Mohammadi at el. (2013) worked with **Comprehensive performance evaluation and parametric studies of single pass solar air heater with fins and baffles attached over the absorber plate.** The performance of upward type single pass solar air heater with fins and baffles attached over the absorber plate is investigated by them. The parametric study of the fins and baffles is the main focus; also effect mass flow rate and solar intensity were studied. With increasing mass flow rate, the rate of enhancement outlet temperature reduces sharply. They were studied of variation number of fins and distance between baffles length and width. So with increasing number of fins and baffles width, the outlet air temperature, heat transfer and h increases, but this effect reduces with further increasing the number of fins and baffles width. Since Increasing the baffle width in comparison with the number of fins and distance between baffles results in higher increment of pressure drop especially in turbulent flow regime, the baffle width is a crucial parameter particularly at high mass flow rate. The Maximum efficiency 73.04% obtained single pass single air heater, where mass flow rate 0.05 kg/s, number of fins 7, width and length of baffle 0.05 m.

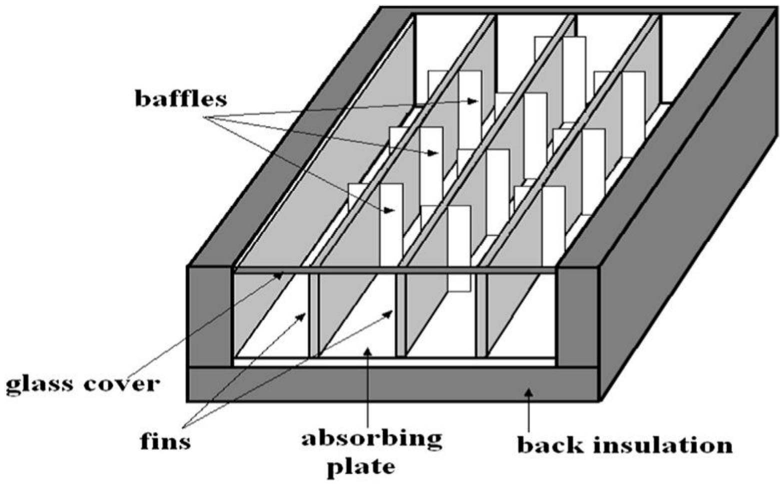

Figure 11 Schematic diagram of a single pass upward type solar air heater with fins and baffles attached over the absorber plate [10]

[12] Messaoud Badacha, Stephane halle at al. (2012) worked on "**A full 34 factorial experimental design for efficiency optimization of an unglazed transpired solar collector prototype"(Fig. 12)** This study was carried out for optimize the thermal performance of an unglazed transpired solar collector (UTC) prototype using a full factorial experiment with four factors (hole diameter, absorber coating, irradiation and mass flow rate) at three levels. A quadratic polynomial model for efficiency was shown to explain 95.47% of the variance of thermal output. They found that changing the absorber coating from low level (1) to medium level (0) with high-level (1) air flow increased the efficiency from 18% to 90% (top curve).

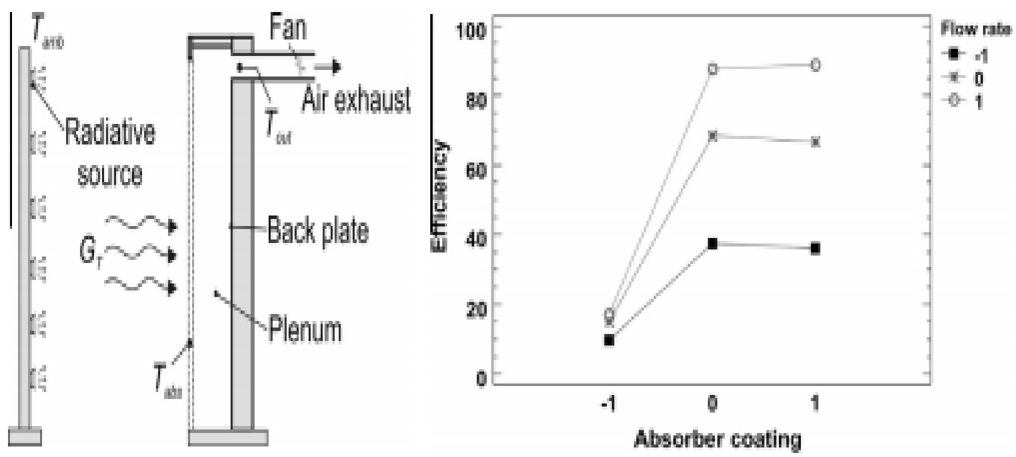

Figure 12 Schematic representations of the experimental apparatus and Chart of Variation of the efficiency with the type of coating for the three mass flow rates

[13] Sunil CHAMOLI work on design of experiment "**ANN and RSM approach for modeling and optimization of designing parameters for a V down perforated baffle roughened rectangular channel" (Fig. 13)** In this present study, the influence of design parameters of the V down perforated baffle roughened rectangular channel on the heat transfer and friction factor was investigated using RSM and ANN. The quadratic model generated by RSM is used to predict the performance parameters, i.e. Nusselt number and friction factor with reasonably good accuracy. The training of the experimental data is carried out using 4-10-2 neural network and the predicted values are compared with the experimental values and found deviation in the range of ±10% among predicted and experimental values. The comparison of predicted values by RSM and ANN with the experimental values was carried out for each run of experiment and it was observed that the RSM predicted values are in accord with the experimental values in the uncertainty range of ±5%.

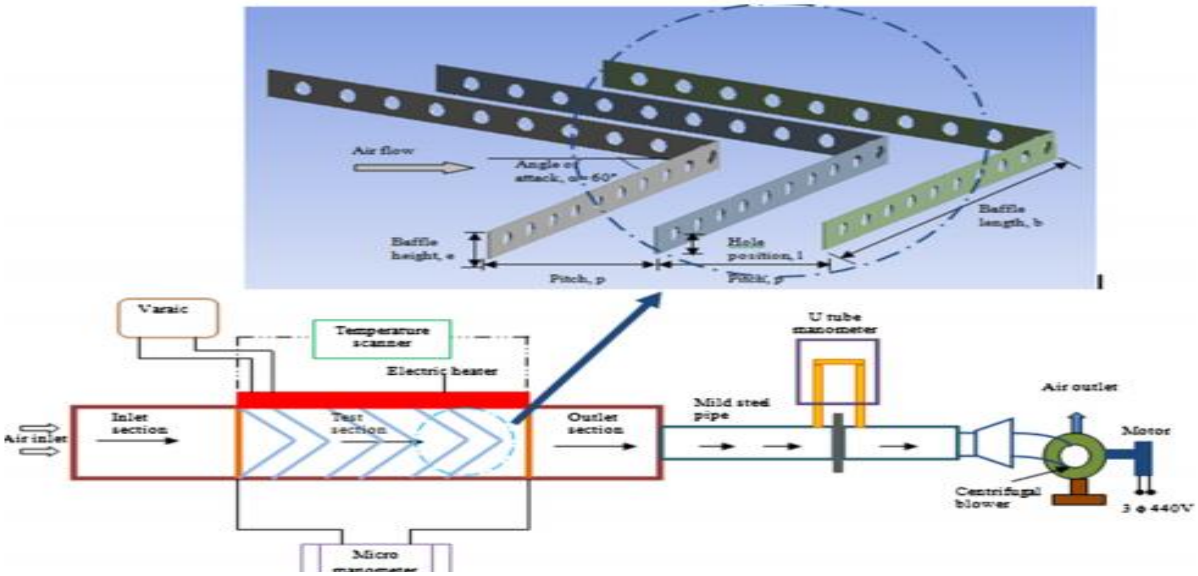

Figure 13 Schematic diagram of the experimental test rig

[14] Nikhil Singh, Vishal Francis at al. represent on "**Investigating the Effect of Water Temperature and Inclination Angle on the Performance of Single Slope Solar Still: A Taguchi Approach" (Fig. 14)** The effect of temperature and inclination angle on the performance of the single slope solar stills inclined at The inclination are 15°, 30° & 45° and the operational temperature range is from 60˚ to 70˚ at intervals of 5°C. L9 orthogonal array was employed for the experiment. They conclude that optimal parameters for Productivity are Inclination angle with 45℃ and 70℃ Temperature. Also both inclination angle and water temperature are found to significant factor but water temperature is found to be significant factor.

Exp. No.	Inclination angle (°)	Temp. (°C)	Productivity (ml)	SNR (Signal to Noise Ratio)
1	15	60	40.4	32.1276
2	15	65	54.4	34.712
3	15	70	67.2	36.5474
4	30	60	44.4	32.9477
5	30	65	65	36.2583
6	30	70	81.8	38.2551
7	45	60	53.6	34.5833
8	45	65	66.8	36.4955
9	45	70	97	39.7354

Figure 14 Results For Experimental Trial Runs

[15] T. Morimoto, W. Purwanto at al. work on "**Optimization of heat treatment for fruit during storage using neural networks and genetic algorithms" (Fig. 15)** In this study, an optimal pattern of the heat treatment for tomatoes was investigated based on their surface color, using a DOE technique consisting of neural networks and genetic algorithms. First, the time-history change in the surface color, as affected by temperature, was identified using neural networks. Two types of

optimal heat treatments were obtained. The result showed that they gave better They found that the three-layer neural network was effective for identifying the cumulative responses in the color change, as affected by temperature, including heat treatment.

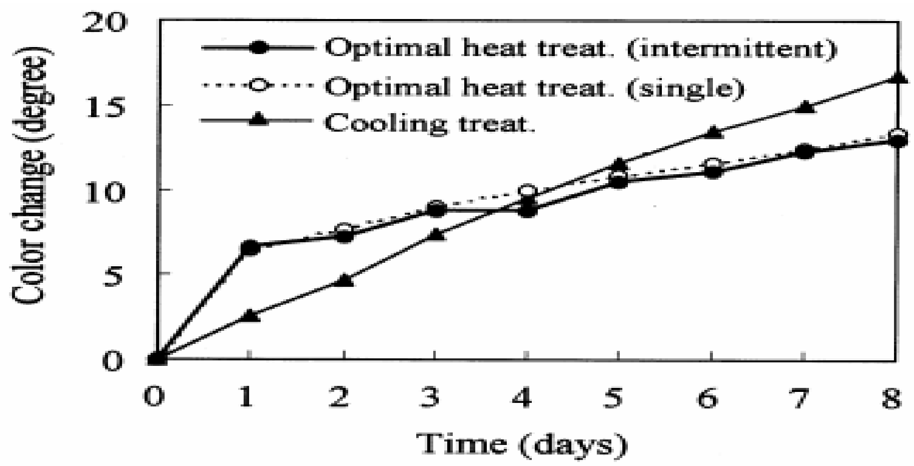

Figure 15 Actual control performances of the color change as affected by two types of optimal heat treatments and cooling treatment

[16] Abd El-Wahab S.Kassem, Mohammed A. Al-Sulaiman at al. work on "**Predicting Drying Efficiency during Solar Drying Process of Grapes Clusters in a Box Dryer using Artificial Neural Network" (Fig. 16)** In this study, modeling of various parameters with drying efficiency of grapes clusters dried in the solar box dryer have been investigated using multiple linear regression (MLR) analysis and artificial neural networks (ANN). R2, RMSE and MAE have been determined for drying efficiency as 0.7068, 2.9227%, 2.1748%, respectively when using ANN model in testing phase.The predictive neural network model showed better predictions than regression model for drying efficiency.

Figure 16 The solar box dryer

[17] Deepak Baburao Jadhav, Ganesh Lotanrao Visavale at al. represent on "**Solar Cabinet Drying of Bitter Gourd: Optimization of Pretreatments and Quality Evaluation" (Fig. 17)** Response surface methodology was used to optimize the pretreatments before solar cabinet drying of bitter gourd slices (6-7 mm thick). Central composite design (CCD) was used to conduct the experiments which consisted thirteen experiments with two variables, viz., blanching time (1-5 min) and potassium metabisulfite (KMS) (0.2-0.5 %). The numerical optimization was carried out using the developed models and the optimum conditions were found by researchers with 345.38 g hardness and 19.92 mg/100g chlorophyll retention at 4.24 min blanching time and 0.49 % KMS concentration.

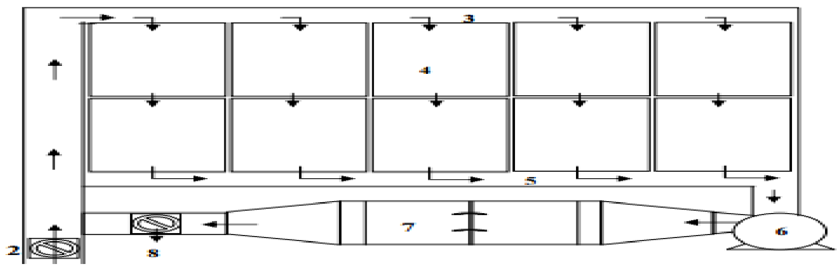

Figure 17 Schematic diagram of a solar cabinet dryer

[18] Medugu, D. W work on "**Performance study of two designs of solar dryers"** Two solar dryers (chimney and cabinet) were fabricated and tested in Mubi, Adamawa State, Nigeria with same basin area. Both dryers were used to perform experimental test in drying 50kg of tomatoes, pepper and bitter leaves. With solar chimney dryer, results reveal that these quantities of tomatoes, pepper and bitter leaves can be dried within 129, 105 and 84h, respectively giving an average 51% of the time spent for the natural sun drying. With solar cabinet dryer, the same quantities of tomatoes, pepper and bitter leaves can be dried within 138, 129 and 90h, respectively with an average 79% of the time spent for the natural sun drying. It was finally observed that solar chimney dryer yields the best result.

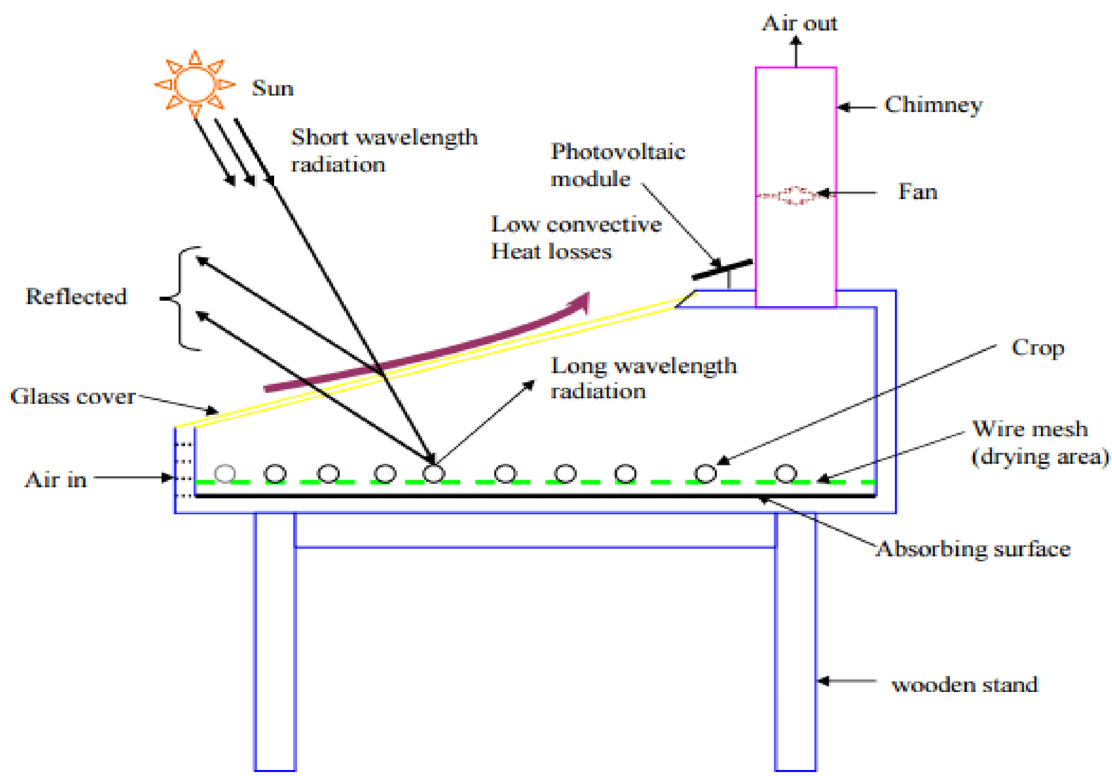

Figure 18 Schematic of Solar Chimney Drier

Conclusion:

From the above literature work it has been observed that so many works have been carried out on the double pass solar air heater. The metallic wiry sponge is more effective proven in the solar air heater and same DOE also plays an effective role to optimize the parameter of solar air heater. So, from the above study it has been conclude that the effect of metallic wiry sponge gives the batter efficiency in the double pass solar air heater and it will optimize with the help of DOE.

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