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A Comprehensive Review of Solar Air Heaters

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Abstract: Solar energy is a renewable form of energy which is emitted from the sun. This energy is further utilized in several ways by human beings. This paper study includes an overview of solar air heater technology, a detailed explanation of several solar air heater types, and information on solar air heaters that use alternative absorber plate surface geometries to speed up heat transmission. Different designs of solar air heaters, notably those using phase change materials as heat storage, are also explained. The absorber plate's surface design and usage of fins improve the rate of heat transfer while it is sunny, and PCM (phase change material) is used to deliver heat energy when it is cloudy. The popularity of solar air heaters increases as a consequence of a variety of applications.

***Keywords* – Solar air heater, Phase change materials, thermal efficiency.**

1. INTRODUCTION

Our society's need for energy is expanding in order to maintain the standard of living and the smooth operation of the other sectors of our economy. But the consumption or utilization of conventional fossil fuels such as coal, oil and natural gases produces harmful pollutants and emissions. The consumption of fossil fuels by the world is shown in fig.1 [1]. Therefore, the adoption of renewable energy is important to fulfil our energy needs. Although there are numerous renewable energy technologies in use today, many of them are still in the early stages of development. Solar air heaters (SAHs) are frequently utilized as heat exchangers in solar energy applications. One of the main solar thermal uses is air heating, which is used for both space heating and process heating, such as drying crops, desalinating water, and heating water for washing. The use of conventional energy for this procedure will raise the cost and cause environmental pollution. Utilizing solar energy for air heating will lower system operating costs and conventional energy usage. The goal of this review is to combine the efforts of the SAH researchers and identify methods for presenting their findings through reliable applications, improving performance for use in current design and development. Due to the large variety of designs and empirical constructions, classifying solar air heaters is quite difficult.

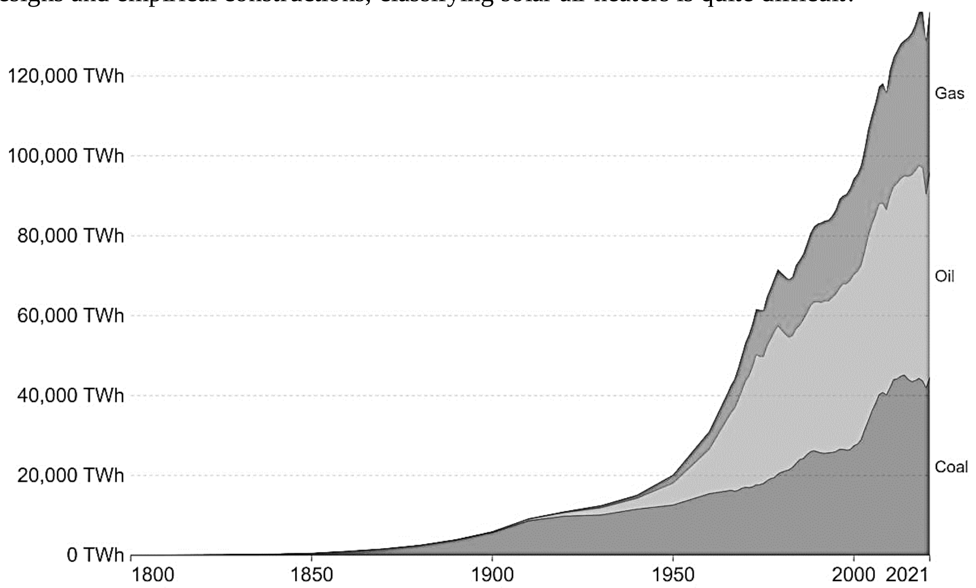

Fig1. Fossil fuel consumption by the world till 2021.

Tyagi et al. [2] divided solar air heaters into categories based on their energy storage, expanded surface, and several covers. Hot air is produced in various locations and is channelled to the intended use in passive solar air heating systems. In order to provide hot air during the night and on the weekends, active SAH frequently uses heat-storing materials. However, passive SAHs are typically used during the day. From another perspective, SAHs can be divided into single-pass and multiple-pass categories based on the number of air passes. Air travels in one direction from the air input to the air exit in a single-pass air solar heater, either above the absorber plate or below it. Air passes through two passageways in a double-pass air solar heater, which can be either parallel or anticlockwise. Air flow ducts and absorber plates make up the majority of SAHs. Low thermal conductivity thermal insulation is used to decrease heat loss from the bottom and sides. To explore the impact of potential changes to the SAH's primary components, many researchers have built their experimental test rigs. As a result, the major goal of the current research is to identify the scope and examine the various design options for SAHs.

2. LITERATURE REVIEW

Ramani et al. examined the efficiency of a double pass solar air heater and discovered that it is 35% more efficient than a single pass collector and 25% more efficient than a collector without porous absorbing materials [3].
Bayrak et al. examined the effectiveness of five collectors utilizing baffles formed of closed-cell aluminium foams and also, above the absorber plate, the baffles were arranged both sequentially and staggered [4].
Solmus and Yamali created a double pass solar air heater. The major component of the solar air heater is a duct constructed of iron sheets that have been dyed a matte black finish. The copper absorber plate used for the absorber plate was coated matte black and positioned horizontally on the duct's centerline. Two glass coverings were used to cover the SAH [5].
Gao et al. built a recycling baffled double-pass SAH. For both above and below the absorber plate, five stainless steel fins with baffles were joined to them. The airflow from the lower channel was combined with the controlled airflow for the recycling process using an adjustable valve that was already present at the upper channel endplate [6].
Monem et al. designed and operated a double-pass solar air heater that used black-coated wire mesh as the packed bed on the absorber plate. The temperature difference between the intake and output is substantial when the mass flow rate is low, yet the thermal efficiency is lower than it would be at larger mass flow rates. This experiment's maximum and minimum efficiencies are 79.30% and 67.98%, respectively, with a mass flow rate of 0.0323 kg/sec. Thermal efficiency has been improved by using porous materials with high conductivity. To prevent heat loss to the environment, higher insulating materials have been used [7].
Jouybari et al. investigated the effect of thin porous media with higher heat conductivity on the absorber plate of a solar collector. It has been shown that applying thin porous layers over the absorber plate significantly boosted the thermal and thermo-hydraulic efficiency of the solar collector. However, the average increase in friction factor for sun heaters with porous media is two times that of solar heaters without porous media. The average increase in thermal efficiency and thermohydraulic efficiency is higher than five times that of a solar air collector without a porous medium [8].
Luan et al. evaluated solar air collectors in order to get the highest efficiency and the lowest costs. They looked at numerous arrangements and evaluated their consequences. The air channel depths ranged from 15 to 30 mm, the flow rates were between 0.01 and 0.02 kg/s, and the collector lengths were between 1.5 and 2.5 m. According to the parametric analysis's findings, the triple-pass SAC was the most effective while the single pass SAC was the least effective [9].

3. SOLAR AIR HEATER AND ITS CLASSIFICATION

A solar air heater is a device that transfers energy from a distant radiant energy source to air. Solar air heaters may be used for a variety of things, including drying crops, heating rooms, and keeping indoor temperatures acceptable all year round. Classifications of solar air heaters are shown below in fig.2 [10].

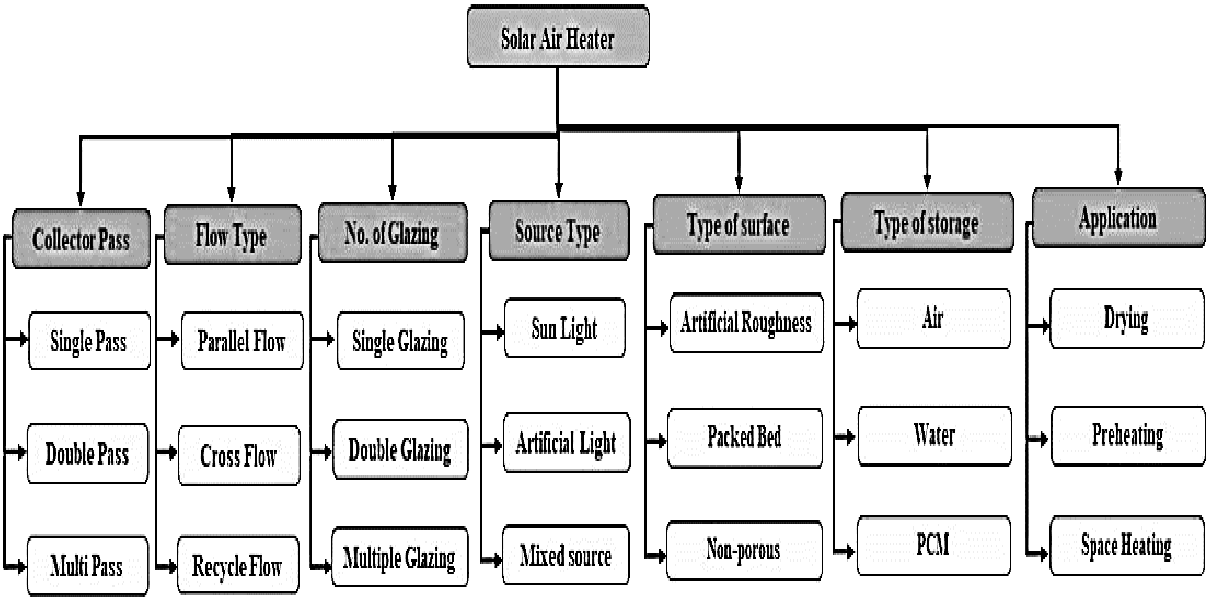

Fig 2. Classification of SAH

3.1 SINGLE PASS SAH

In single pass SAH, air passes through a single passage whether above or below the absorbing plate. The diagram of a single pass SAH is shown below in fig.3 [11].

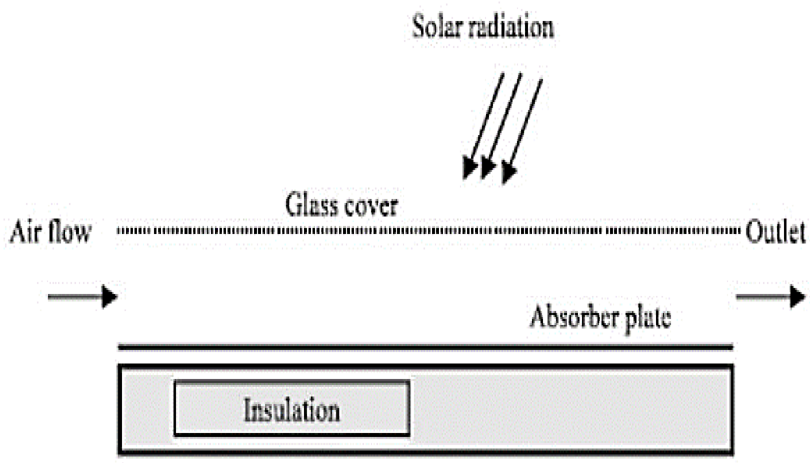

Fig 3. View of single pass SAH

3.2 DOUBLE PASS SAH

Double pass solar air heater delivers a significant efficacy in comparison to single pass SAH. In double pass SAH, incoming air passes along both sides of the absorbing plate during this operation air takes the useful heat from a plate. Once again double pass SAH is further bifurcated i.e., parallel flow double pass solar air heater and counter flow double pass solar air heater. The pictorial view of both types of solar air heaters is shown below in fig.4 and fig.5 respectively [12-13].

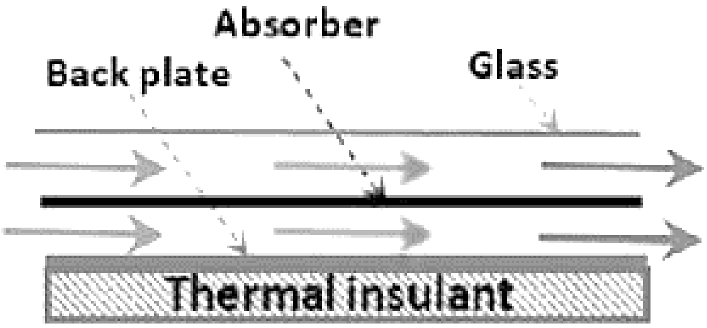

Fig 4. View of parallel flow double pass SAH

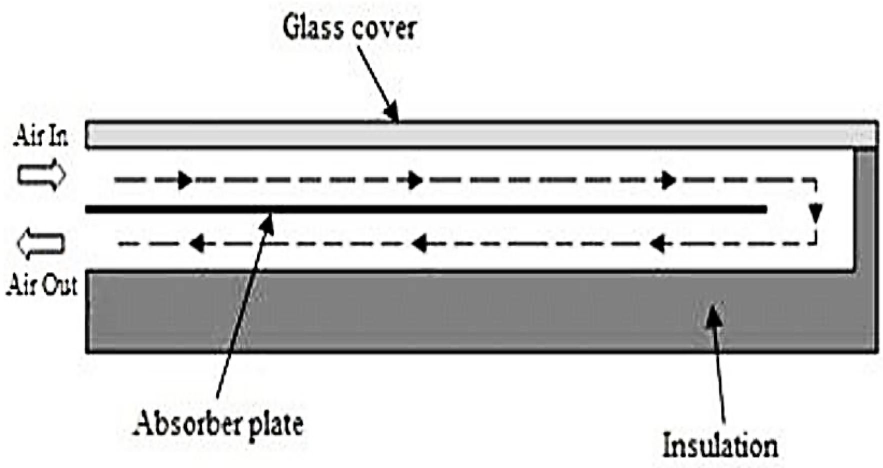

Fig 5. View of counter flow double pass SAH

3.3 MULTI-PASS SAH

This type of SAH contains several flow passages for the single incoming air. This air takes over the heat from the absorbing plates and an insulating material is also provided below the lower portion to reduce heat losses which are shown in fig.6 [14].

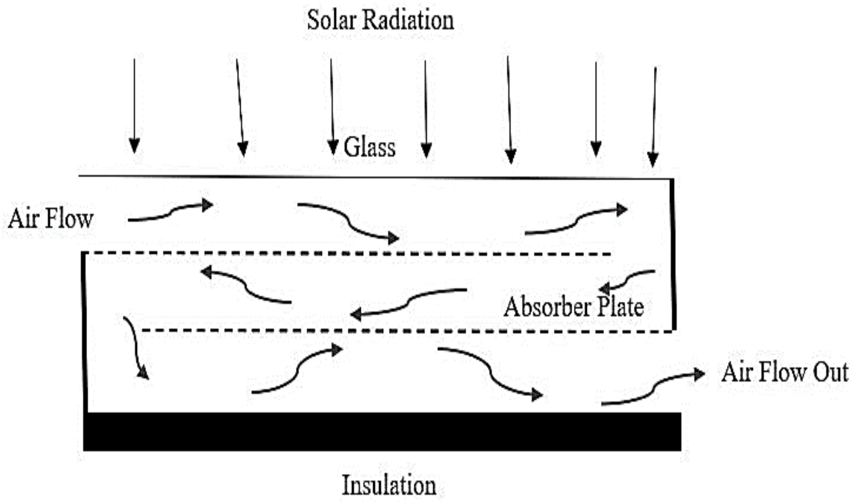

Fig 6. View of multi-pass solar air heater

3.4 RECYCLING FLOW SAH

This solar air heater enhances the heat transfer between the plate and the air. A small portion of the outlet air is mixed with incoming air for better efficiency. Figure 7 shows the working of the recycling flow solar air heater [15].

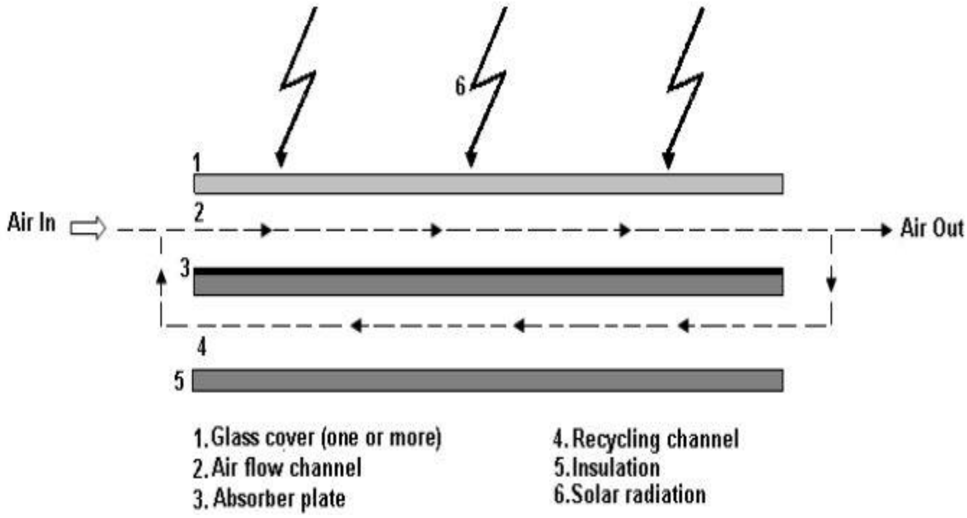

Fig 7. View of recycling flow solar air heater

4. MATHEMATICAL MODELLING

- Mass flow rate = Density x Area of outlet x Velocity

Or, $\dot{m} = \rho \times A_o \times v$

- The equations for the useful heat gain and thermal efficiency of the collector are:

$Qu = \dot{m}\ Cp\ (To - Ti)$

where, Cp = specific heat.

To = outlet temperature.

Ti = inlet temperature.

- Solar radiation incident on the collector surface = $I \times A_c$

where, A_c is the area of the collector.

- Thermal efficiency of the collector i.e.,

$$\eta_{th} = \frac{Q_u}{I \times A_c}$$

5. ADVANTAGES OF SOLAR AIR HEATER

- Better solar energy absorption compared to traditional passive solar technology, without the limitations of benefits from direct sunshine.
- Solar air heaters reduce the price of energy use.
- Solar heat may be utilised more effectively with the usage of a thermal wall since heat is discharged from the wall when the sun isn't shining [16].

- To pre-heat air, solar air heaters may be used in conjunction with HVAC systems [17].

6. DISADVANTAGES OF SOLAR AIR HEATER

- If a proper design is not adopted, the cost of solar air heaters might be significant [18].
- The ineffectiveness of air at transferring heat. Therefore, optimizing heat transfer from the absorber to the air requires careful consideration.
- The air is not a good choice for use as a storage fluid due to its limited thermal capacity [19].
- Because of the low density of air, it needs to be moved about in enormous volumes [20].

7. CONCLUSIONS

The paper proposes different types of solar air heaters which help to obtain better thermal performance. An overview of solar air heater technology and information on solar air heaters that use alternative absorber plate surface geometries to boost heat transfer comes under this study. Various researcher's work upon novel design of solar air heater to achieve better thermal efficiency with low cost. Also, the advantages and disadvantages of solar air heaters are discussed. Furthermore, solar air heater can be used for various purposes such as space heating, crop drying etc.

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