UNIT 4 SOLAR AIR HEATERS

Structure

4.1 INTRODUCTION

A solar collector is basically a heat exchanger, which absorbs the incident solar radiation, convert it into heat and finally transfer this heat to a heat removal fluid (also called working fluid) for an end use system. If the working fluid is water, solar collector is called solar water collector or solar water heater. If the working fluid is air, solar collector is called solar air collector or solar air heater.

In contrast to solar water heaters which were introduced as early as 1837, solar air heaters were rather introduced recently.

Objectives

After studying this unit, you will be able to understand

- solar air heaters,
- classification of solar air heaters,
- natural type of solar air heaters,
- forced circulation type of solar air heaters, and
- various advantages of solar air heaters.

4.2 PRINCIPLES OF SOLAR AIR HEATING SYSTEMS

Solar air heaters can be broadly classified under two categories :

(1) First type has nonporous absorber in which air stream does not flow through the absorber plate. Air may flow above and/or below the absorber plate.

(2) Second type has a porous absorber in which air stream flows through the absorber plate.

4.1.1 Solar Air Collectors with a Nonporous Absorber

The simplest type of nonporous solar air heater is the one which consists of a bare metallic plate, the top of which is suitably blackened. Another plate, the rear of which is insulated, below the absorber plate is used to form the duct for air flow. The incident solar radiation on the blackened surface gets absorbed and the resulting heat is partially transferred to the flowing air within the duct. The schematic diagram of such a solar air heater is shown in Figure 4.1.

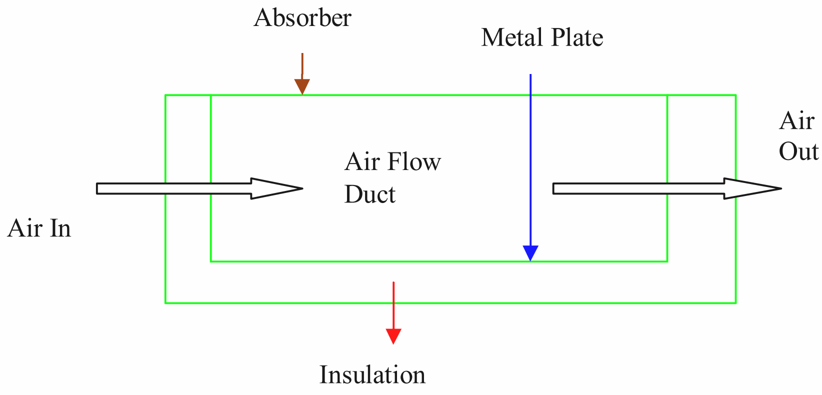

Figure 4.1 : Nonporous Type Solar Air Heater

The main disadvantage of this type of solar air collector is high thermal losses to the ambient due to convection and radiation. Therefore, the alternative designs have been developed where these type of thermal losses are reduced.

The convective losses can be reduced by covering the absorber plate with one or more transparent covers, usually called glazing. Such solar air heaters are shown in Figures 4.2 and 4.3. In the solar air heater shown in Figure 4.2, the air flow duct is between the glazing (glass cover) and the absorber. The flow of the air is above the absorber. On the other hand, the air flow is below the absorber in the solar air heater shown in Figure 4.3.

The selective coatings may be applied to the absorber to reduce the radiative losses.

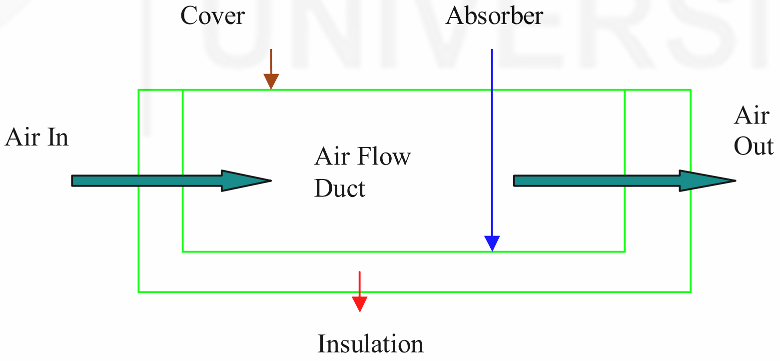

Figure 4.2 : Nonporous Type Solar Air Heater with Glazing

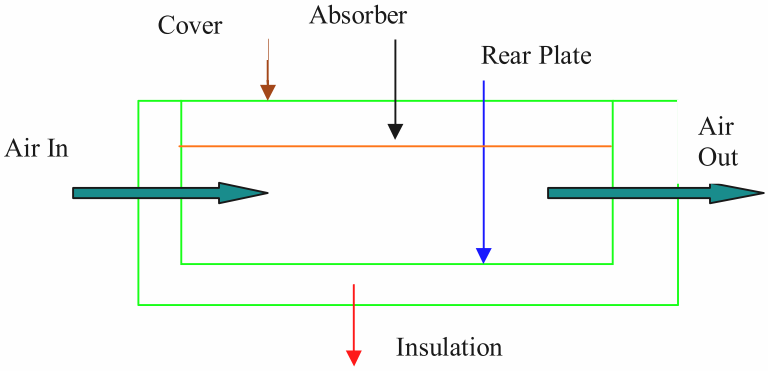

Figure 4.3 : Nonporous Type Solar Air Heater with Glazing

4.3 THERMAL EFFICIENCY OF SOLAR AIR HEATERS

The thermal efficiency of a solar air collector is given by the following relation:

$$\eta = F_R[(\tau\alpha)_e - U_L(\frac{T_i - T_a}{I})] \qquad \ldots (4.1)$$

here η = Thermal efficiency of the collector,

F_R = Heat removal factor of the collector,

U_L = Collector heat loss coefficient between absorber plate and ambient, W/m^2 ºC,

τ = Transmissivity,

α = Absorbtivity,

T_i = Inlet air temperature, ºC,

T_a = Ambient air temperature, ºC, and

I = Solar radiation incident on collector, W/m^2.

$(\tau\ \alpha)_e$ is referred to as the effective transmissivity-absorbtivity product.

The heat removal factor, F_R, is defined as follows :

$$F_R = \frac{\text{Useul collected energy}}{\text{Useful collected energy if the absorber plate were at the inlet air temperature}}$$

The maximum value of F_R can be unity. The efficiency can be increased by increasing heat removal factor and by reducing heat loss coefficient.

The other parameters for increasing thermal efficiency are :

- increasing the mass flow rate per unit area.
- increasing the convective heat transfer coefficient between the air stream and the absorber plate.
- increasing the surface area to transfer heat from the absorber plate to the air stream using fins, etc.

Variation in the method of blowing air and the position of the absorber with respect to the cover leads to different designs with varying thermal efficiencies.

The number of transparent covers over the absorber is an important factor influencing the collector's performance. With increasing number of covers, the overall thermal losses from the absorber plate to the ambient decrease but simultaneously, the effective transmittivity-absorptivity product of the system also decreases. There is thus a balance between solar gain and heat loss. The use of one or more covers usually depends on the range of temperatures for which the collector is designed. The final selection of the number of covers has to be based on the economic performance criterion which aims to minimize the life-cycle cost of the thermal energy collected by the solar air heater.

The main disadvantage of nonporous solar air heater is the low transfer between air and the absorber plate. The heat transfer can be increased by roughing the surface of the absorber at the rear, by adding fins or by making the absorber plate vee corrugated. The designs of nonporous absorber air heaters with such design variations are given in Figures 4.4 and 4.5.

SAQ 1

(a) Explain the purpose of glazing in solar air heaters.

(b) State the main disadvantage of nonporous type of solar air heaters.

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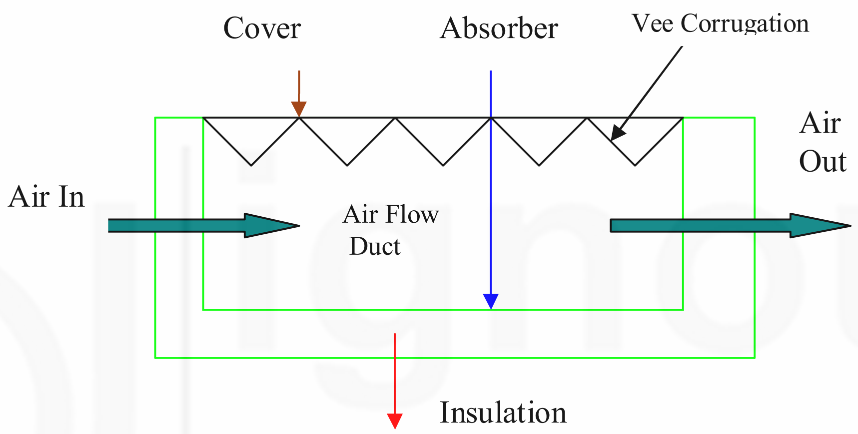

Figure 4.4 : Nonporous Type Solar Air Heater with Vee Corrugation

An important drawback of the nonporous absorber plate is the necessity of absorbing all incoming solar radiation over the projected area from a thin layer over the surface, which is of the order of few microns. Unless selective coatings are used, radiation losses from the absorber plate are excessive, and therefore the collection efficiency is difficult to be improved.

The pressure drop along the duct formed between the absorber plate and the rear insulation is also prohibitive in nonporous absorbers. Any effort to increase the heat transfer between the absorber and flowing air stream such as adding fins or enlarged corrugations results in increased pressure drop across the collector. More fan power is therefore required to maintain the same air flow rate through the heater.

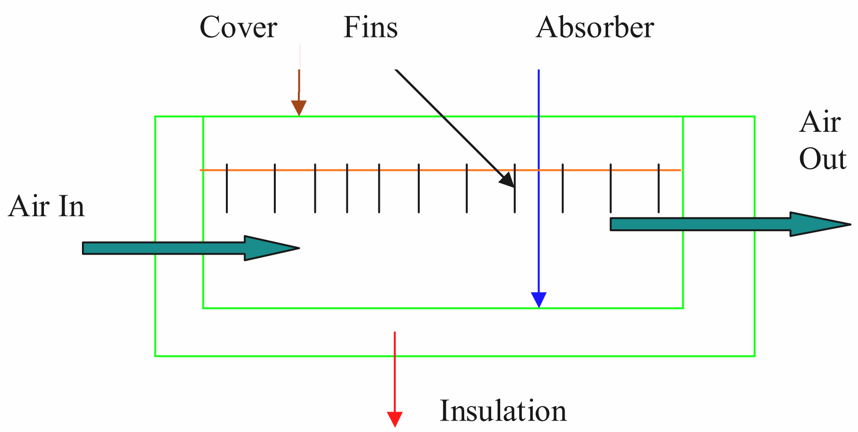

Figure 4.5 : Nonporous Type Solar Air Heater with Fins

SAQ 2

What are the different designs of nonporous type of solar air heaters?

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4.4 SOLAR AIR COLLECTORS WITH A POROUS ABSORBER

You have seen some of the problems with nonporous type of solar air heaters. A porous absorber shown in Figure 4.6 overcomes some of these problems in following way :

(a) The solar radiation penetrates to greater depths and is absorbed gradually depending upon the porosity of the absorber. The incoming air introduced from the upper surface of the matrix is first heated by the upper layers. The air stream gets heated while traveling through the matrix layers. The lower matrix layers are hotter than the upper ones resulting into better heat transfer from the matrix.

(b) The pressure drop for the porous matrix is usually much lower than the nonporous absorber.

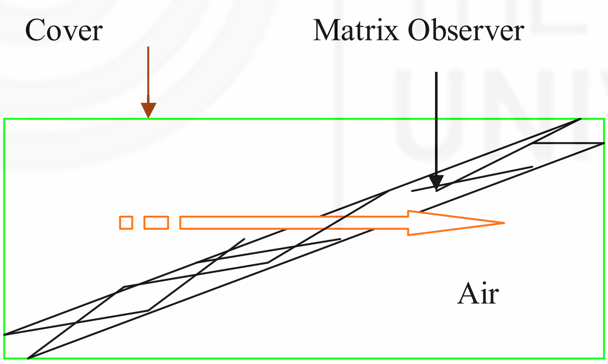

Figure 4.6 : Porous Type Solar Air Heater

4.5 APPLICATIONS OF SOLAR AIR HEATING SYSTEMS

The air heated by solar collectors can be used in the following applications :

(a) Space heating

(b) Solar drying

(c) Solar water heating

The application of solar air heaters for drying purposes will be discussed in Block 4. We will briefly discuss applications for space heating and hot water.

4.5.1 Space Heating

Solar air heating systems consist of an array of solar heating collectors along with a storage facility (pebble bed). There may be four possible modes of operation :

(1) If the solar radiation is available and the heating load is there, the room air is circulated through the solar collectors and returned back to the room

(2) When there is no space heating load, the air heated by the collectors is sent through the pebble bed storage where the thermal energy carried by the hot air is absorbed by the pebble bed for later use.

(3) When there is no sunlight but the space requires heating, the room air is circulated through the pebble bed to meet the required heating load.

(4) When there is no sunlight or the stored energy is not sufficient to meet the required heating load, then some auxiliary energy source is used to meet the extra heating demand.

4.5.2 Solar Water Heating

Most of the solar air heating systems designed for space heating also provide the need for domestic hot water requirements by using air/water heat exchanger and a water storage tank.

4.6 LET US SUM UP

We have discussed various types of solar air collectors.

A solar collector is basically a heat exchanger, which absorbs the incident solar radiation, convert it into heat and finally transfer this heat to a heat removal fluid (also called working fluid) for an end use system. When the working fluid is air, solar collector is called solar air collector or solar air heater.

Solar air heaters can be broadly classified under two categories:

(1) First having nonporous absorber in which air stream does not flow through the absorber plate. Air may flow above and/or below the absorber plate.

(2) Second hacing a porous absorber in which air stream does flow through the absorber plate.

The number of transparent covers over the absorber is an important factor influencing the collector's performance. With increasing number of covers, the overall thermal losses from the absorber plate to the ambient decrease but simultaneously, the effective transmittivity-absorptivity product of the system also decreases.

There is thus a balance between solar gain and heat loss. The use of one or more covers usually depends on the range of temperatures for which the collector is designed.

The final selection of the number of covers has to be based on the economic performance criterion which aims to minimize the life-cycle cost of the thermal energy collected by the solar air heater.

The main disadvantage of nonporous solar air heater is the low transfer between air and the absorber plate. The heat transfer can be increased by roughing the surface of the absorber at the rear, by adding fins or by making the absorber plate vee corrugated.

A major drawback of the nonporous absorber plate is the necessity of absorbing all incoming solar radiation over the projected area from a thin layer over the surface, which is of the order of few microns. Unless selective coatings are used, radiation losses from the absorber plate are excessive, and therefore the collection efficiency is difficult to be improved.

4.7 KEY WORDS

Absorptivity

A property of a material; fraction of solar radiation falling on a material gets absorbed by the material, its value is less than unity.

Absorptance

The ratio of the radiation absorbed by a surface to the total solar energy falling on that surface; given in percentage.

Collector

A device to capture solar radiations like glazed device, wall or window.

Conduction

The direct transfer of heat energy through a material.

Conductivity

The rate at which heat is transmitted through a material.

Convection

The transfer of heat by movement of a fluid, like air or water.

Emissivity

The property of emitting radiation.

Emittance

The emissivity of a material, expressed as a fraction; range from 0.05 for brightly polished metals to 0.96 for flat black paint.

Flat Plate

A device used to collect solar energy.

Heat Loss

The rate at which a building or a collector lose heat.

Thermal Efficiency

$$\frac{\text{Useful work and energy out}}{\text{Higher heating value of input fuel}} \times 100$$

U-value (coefficient of heat loss)

The rate of heat loss, W/m^{2o}C.

4.8 ANSWERS TO SAQS

SAQ 1

(a) The glazing (transparent cover) reduces the thermal losses from the solar air heaters. The number of transparent covers (one or two) over the absorber helps in reducing the overall thermal losses from the absorber plate to the ambient. The use of one or more covers usually depends on the range of temperatures for which the collector is designed.

(b) The main disadvantage of nonporous solar air heater is the low transfer between air and the absorber plate.

SAQ 2

The different designs of nonporous type of solar air heaters are :

- Solar air heaters with Vee Corrugated absorber.
- Solar air heaters with Fins attached to absorber.
- Solar air heaters with air flow duct having absorber at the top of the duct or at the bottom of the duct.