Principles and Performance of Solar Energy Thermal Systems: *A Web Course by V.V.Satyamurty*

MODULE 12 Lecture No: 12

Solar Flat Plate Collectors

This Module 12 comprising of Lectures 12 to 13 deals with

Lecture 12

12.1 INTRODUCTION

12.2 FORMAL EXPRESSION FOR USEFUL ENERGY GAIN AND DIFFERENT FACTORS ASSOCIATED

12.3 THE ASSUMPTIONS

Lecture 12

12.1 INTRODUCTION

A commonly used fin and tube type of absorber for liquid heating is shown in Fig. 12.1. The temperature variations at a fixed x and fixed y are also shown in Fig. 12.2.

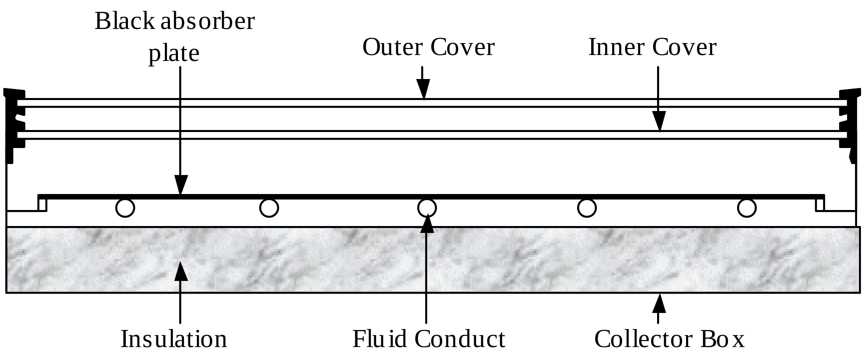
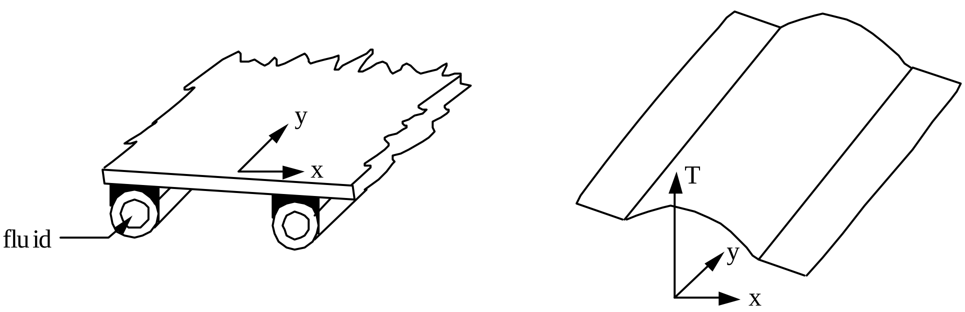
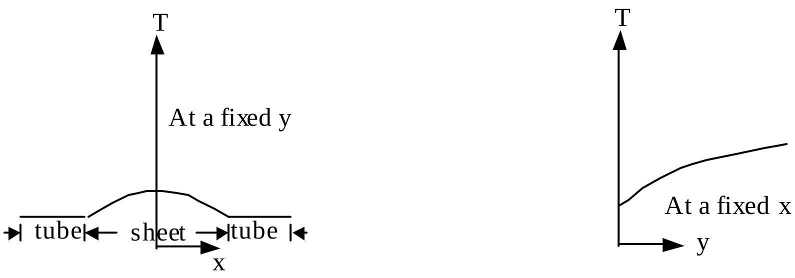


Fig. 12.1 Sheet and tube solar collector absorber



(a) (b)



(b) (d)

Fig. 12.2 Temperature variation on an absorber plate

The absorbed energy, conducted from the fin region to the base of the tube is further conducted through the material of the tube. From the inside surface of the tube heat is transferred to the working fluid by convection. Thus the overall performance of this type of solar flat plate collector depends on the temperature gradient required to transfer energy at a given rate, from the fin to the tube, (which shall be characterized by fin efficiency) and the bond conductance between the tube and the plate. Finally, heat transferred to the working fluid depends on the convective heat transfer coefficient inside the tube.

These heat transfer parameters decide essentially the temperature difference between the plate and the working fluid. Smaller the difference, more efficient is the difference. In other words, for a desired temperature of the working fluid, the plate temperature can be close (though necessarily higher) to the working fluid, thereby losing minimum possible heat to the surroundings.

12.2 FORMAL EXPRESSION FOR USEFUL ENERGY GAIN AND DIFFERENT FACTORS ASSOCIATED

Energy balance on a solar collector yields,

$$Q_u = A_C\left[(\tau\alpha)I_T - U_L\left(T_{p,m} - T_a\right)\right] \qquad (12.1)$$

$$= A_C F'\left[(\tau\alpha)I_T - U_L\left(T_{f,m} - T_a\right)\right] \qquad (12.2)$$

$$= A_C F_R\left[(\tau\alpha)I_T - U_L\left(T_{f,i} - T_a\right)\right] \qquad (12.3)$$

In Eqs.(12.1) to (12.3), A_c is the collector area, $(\tau\alpha)$ is the effective transmittance-absorptance product, discussed in Module 9, I_T is the solar radiation falling on the tilted collector surface, (see, Module 7) U_L is the overall heat loss coefficient, T_{pm},*and* T_{fm} are the mean absorber (plate) temperature and the mean fluid temperature. $T_{f,i}$ is the fluid inlet temperature. F' is the collector efficiency factor and F_R is the collector heat removal factor. Eqs. (12.1) to (12.3) become available to estimate the useful energy gain when $(\tau\alpha)$, U_L, $T_{p,m}$ or F' and $T_{f,m}$ or F_R and T_i are known. Necessary analysis to obtain these parameters is presented here..

12.3 THE ASSUMPTIONS

The following analysis is subject to a number of assumptions listed as under.

1. Performance is steady state.
2. Construction is of sheet and parallel tube type.
3. The headers cover a small area and can be neglected.
4. There is no absorption of solar energy by covers insofar as it affects losses.
5. The headers provide uniform flow to the collector tubes.
6. There is one dimensional heat flow from the covers.
7. There is one dimensional heat flow from the back insulation.
8. The covers are opaque to infrared radiation.
9. There is negligible temperature drop through a cover.
11. The sky can be considered as a blackbody for long wavelength radiation at an equivalent sky temperature.
12. Temperature gradients around the tubes can be neglected.
13. The temperature gradients in the direction of flow and between the tubes can be treated independently.
14. Properties are independent of temperature.
15. Loss through front and back are to same ambient temperature
16. Dust and dirt on the collector are negligible.
17. Shading on the collector absorber plate is negligible