FLAT-PLATE COLLECTORS

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Contents

Summary

Flat-plate collectors are a very useful tool for low to medium temperature heat collection from the sun. They can be used for many purposes including the various thermal desalination methods from low to medium capacities. Flat-plate collectors have simple characteristics: they are easily assembled, and easily operated. The aim of the detail analysis given here is to help create the best design and operational conditions with the best economic characteristics.

1. Introduction

The purpose of any system that converts solar radiant energy into thermal energy is the useful application of the thermal energy itself. The application can be direct as heat or indirect by using the heat to drive a heat engine to produce useful mechanical energy or to use the thermal energy for electricity production. For this purpose special devices are used called solar collectors. The purpose of a solar thermal collector is to absorb the radiant energy of the sun and to transfer the resultant heat to a fluid which in turn transfers the thermal energy to the site of application. In general, solar collectors are classified according to their thermal output temperature which determines also the field of their application.

This section deals only with low temperature solar collectors, the plane flat-plate collectors, which in general are simple devices easy to construct, to install and to operate. Flat-plate collectors are designed for applications requiring moderate temperatures usually up to 110°C above ambient temperatures.

The simplest flat plate collectors are the solar ponds and the solar stills which operate by direct utilization of the incident solar radiation acting simultaneously as solar energy converters. The importance of flat-plate collectors is that their thermal performance can be predicted and treated in considerable detail.

2. Solar Collector Applications

Solar collectors are very popular for installation in zones where there are high irradiation intensities and bright sunshine days. They can be installed easily in individual houses for household hot water, in hotel buildings and in municipal installations, such as athletic centres for hot water use and for heating swimming pools. Large commercial installations with high capacities are used in industry to produce process water or, in solar desalination plants to produce moderate temperature water, as feed to low or medium temperature distillation plants. In general they are useful tools for hot water production.

3. Definitions

It is important for the reader to be acquainted with some definitions concerning solar collectors as sometimes slightly and/or completely different definitions are used by various authors, depending on the source.

3.1. Solar Collectors

3.1.1. Solar Thermal Collector

Is a device where the solar radiant energy incident onto its surface is transformed into heat. The heat is transferred to a fluid circulating into the collector piping system.

3.1.2. Flat-Plate Collector

Is a device having an almost flat absorbing surface, with an area equal to the aperture of the collector. The solar radiation is collected on the absorbing surface of the collector.

3.2. Construction Elements of a Solar Collector

3.2.1. Absorber Plate or Selective Surface

Is a metal, glass or plastic surface, mostly black in color. It absorbs and converts radiation into thermal energy and then, by convection and conduction it is transferred to the circulating cold fluid.

3.2.2. The Transparent Cover

Is the upper part of the collector covering the tide absorber plate. It is made from glass or transparent plastic sheet to permit penetration of solar beams. It therefore protects the absorber from environmental damages and decreases thermal loss.

3.2.3. The Collector Insulation

Consists of a material with very low thermal conductivity. It is installed in the bottom and around the sides of the collector, in order to minimize heat loss.

3.2.4. The Heat Transfer Medium

Flowing through the collector to transfer the heat from the absorber to the utilization system. Can be either air or a liquid, usually water.

3.3. The Surface Areas

3.3.1. The Surface Area of the Absorber Plate

Is the available total heating surface.

3.3.2. The Transparent Cover Surface

Is the maximum projection area of the cover through which penetrates the global radiation.

3.3.3. Total Surface Area

Total surface area is described as the maximum projected area of the solar collector, excluding the enclosed supports and the connections to the fluid tubes. In the case of vacuum tube collectors, the total area is considered the maximum projected area of the tube band.

3.4. Operational Characteristics of the Collector

3.4.1. Collector efficiency (η)

Is the ratio of useful gained thermal energy for period of time *t* to the incident solar radiation onto the collector for the same time period.

3.4.2. Thermal Capacity of the Collector (C)

Is the amount of heat that can be stored per surface collector area and per unit of temperature change.

3.4.3. Pressure Drop (Δp)

Is the difference in pressure between the inlet to the collector and the outlet due to circulation friction.

3.4.4. Stagnant Conditions

The stagnant condition is characterized by no fluid circulation inside the collector during the period in which the absorbing surface area receives a considerable incident radiation.

3.4.5. Incidence Angle Coefficient (kθ)

The ratio of the optical efficiency of a solar collector with a fixed beam angle of incidence to the optical efficiency of the collector at its normal.

3.5. The Characteristic Parameters of the Collector

3.5.1. The cover reflectance (ρ_c)

As cover reflectance is considered the ratio of reflected solar radiation from the cover to the environment to the incidence solar radiation.

3.5.2. Cover Transmittance (τ_c)

Is the ratio of the solar radiation passing through the transparent cover to the incident irradiation.

3.5.3. Cover Absorptance (α_c)

Is the ratio of the absorbed solar radiation in the absorber to the incident radiation.

3.5.4. Coefficient of cover Emissivit (ε_c)

The coefficient of cover emittance is the ratio of the intensity emitted by the cover, for a fixed temperature, to the intensity of a blackbody irradiance, of exactly the same shape and same temperature.

3.5.5. Coefficient of Absorber Emissivity

Is the ratio of emitted radiation from the absorber, for a fixed temperature, to the intensity of a black body irradiance of the exactly same shape and same temperature.

3.5.6. Selective Surface

Is a solid surface covered by a selective coat**.** A selective surface identifies the highest possible absorptivity of the incident solar radiation. The plate surface of the collector is treated with a suitable material with high selectivity of the solar radiation.

3.5.7. Selective Coat

Selective coats are materials that possess high solar radiation absorptance ($\lambda \leq 3$ μm) and simultaneously low emittance for wavelengths larger that three μm ($\lambda \geq 3$ μm).

3.5.8. Collector Efficiency Factor (F')

Is the ratio of the real energy output of the collector to the energy output in the case when the total absorber area was at the average fluid temperature with the same fluid quantity of flowing water.

3.5.9. Collector Flow Factor (F'')

Is the ratio of the energy that the collector can deliver at the average temperature of the fluid to the energy that the collector can supply at the inlet collector temperature. For a certain collector the flow factor is a function of the flowing water quantity.

3.5.10. Collector Heat Removal Factor (F_R)

Is the ratio of the energy collector output to the energy output of the collector in temperature of the inlet fluid. It is temperature dependent. The thermal output factor is connected to the flow factor and to efficiency factor by the relationship: $F_R = F' \times F''$.

3.5.11. Collector Heat Loss Coefficient (U_L)

The coefficient of thermal loss of a collector is defined as the ratio of the temperature difference per unit area of the cover to the ambient temperature.

4. Main Collector Components

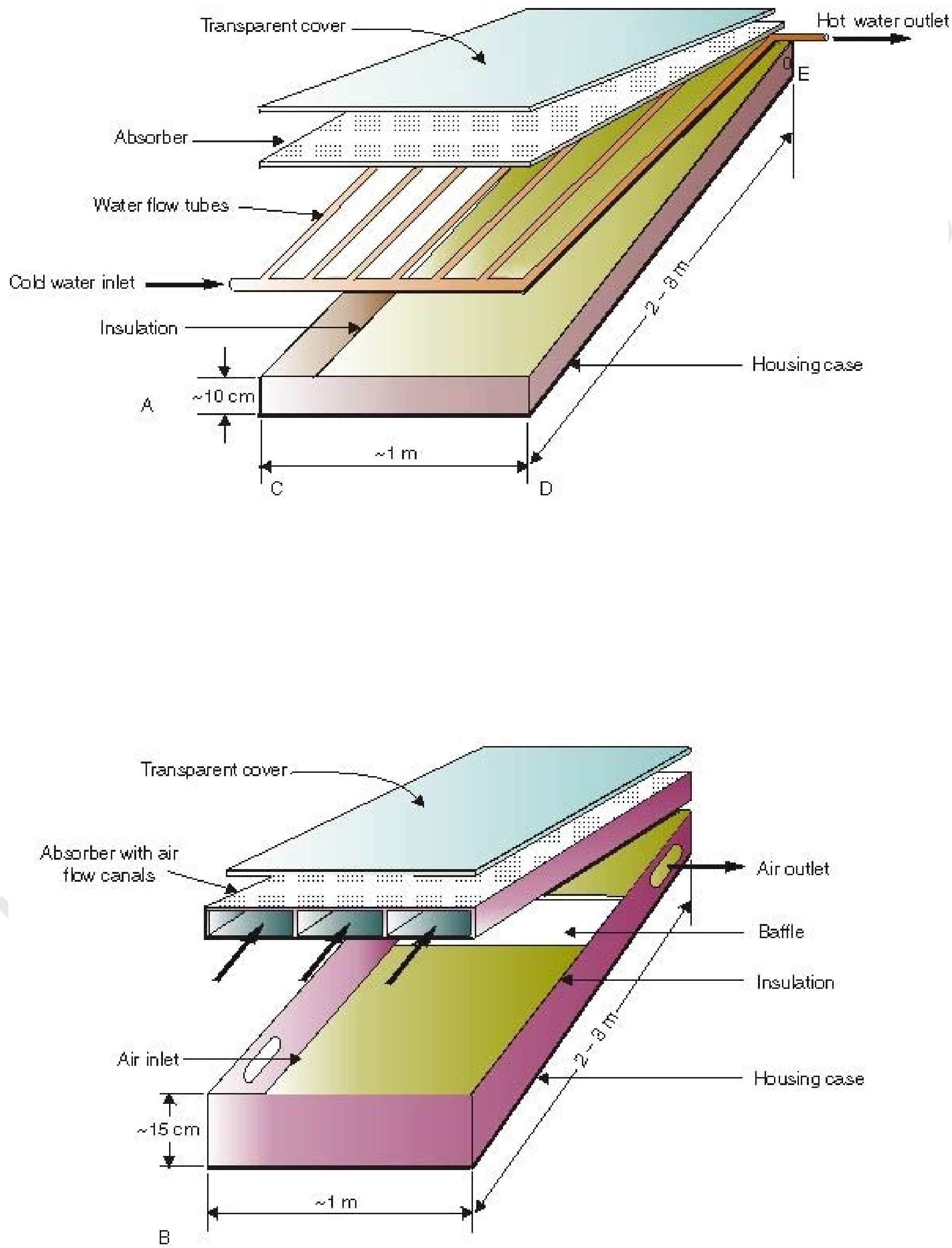
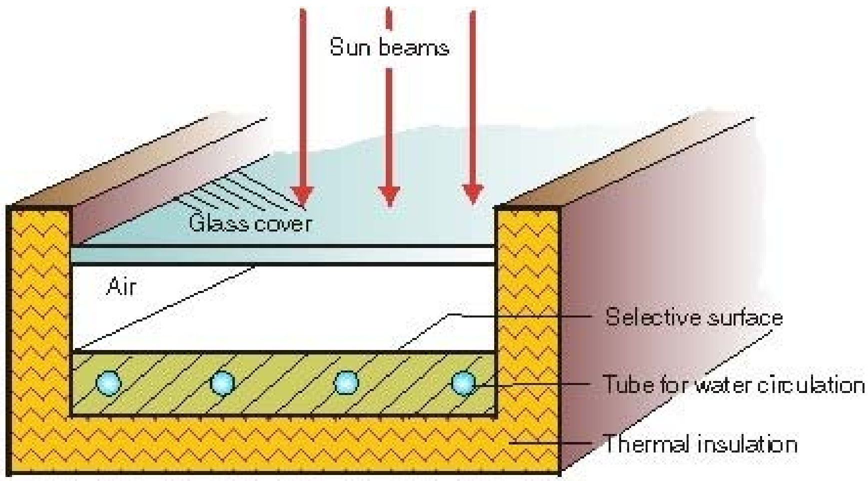


Figure 1. The absorber plate, the transparent cover and the insulation material bound together.

A collector is an independent unit which consists of: the absorber plate, the transparent cover and the insulation material bound together by a case that houses the collector components, as presented in Figures 1 and 2.



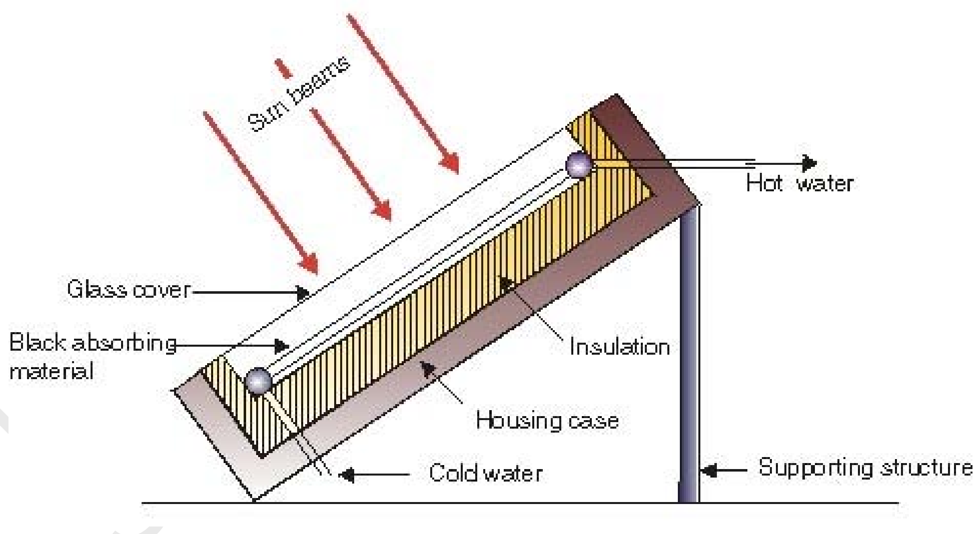


Figure 2. Flat-plate collector.

4.1. The Solar Radiation Absorber

An absorber is characterized by the type of material, the form of tube fins and the type of absorption coat. The most usual materials of construction are: steel, aluminum, copper, and a combination of copper tube with aluminium fins. The area of the metallic surface that is loaded with solar radiation is painted either with a black paint or coated with a selective surface material. For the coating of a metallic surface with a selective material high precise technology is applied to avoid corrosion phenomena. Corrosion phenomena can also occur in the metallic feedings of the absorber and the connecting tubes. Electrolytic phenomena can occur resulting in the corrosion of the metals.

4.2. The Transparent Cover

The collector cover is usually glass but can also be a special plastic material, weather proofed and not easily deteriorated by solar radiation. Glass, containing low iron concentrations, is a proved transparent material, with high weather durability, good mechanical characteristics and very high solar radiation permeability. Its only disadvantage is its fragility.

Plastic materials are not fragile but they are vulnerable to weather changes and UV deterioration which easily decreases their transparency and their mechanical resistance properties.

4.3. Thermal Insulation

Insulation materials usually used are polyurethane, glasswool and rockwool. Glass- and rock wool have to be applied in air- and water tide appliances due to their physical nature. For other insulation materials it is of importance to have high heat loss resistance to stagnant temperatures.

4.4. The Casing of the Collector

The frame or shell is the most important part because it houses all other collector components. It is constructed usually from aluminum or plastic material having high resistivity to all weather conditions, and to solar radiation intensity. The geometric design and the construction of the shell needs special attention in order to provide high collector stability during the installation, tightness, and a perfect fit between the cover and the shell.

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