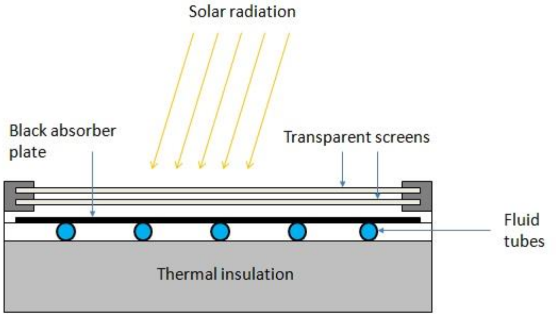
Chapter 3
Solar Heating & Storage system

Energy flow of flat-plate collectors

- The flat-plate solar collectors are probably the most fundamental and most studied technology for solar-powered domestic hot water systems.
- The overall idea behind this technology is pretty simple.
- The Sun heats a dark flat surface, which collect as much energy as possible, and then the energy is transferred to water, air, or other fluid for further use.



Dr. A.T.M. Saiful Islam
Assistant Professor
BSMRSTU

Energy flow of flat-plate collectors

- These are the main components of a typical flat-plate solar collector:
- ✓ Black surface - absorbent of the incident solar energy
- ✓ Glazing cover - a transparent layer that transmits radiation to the absorber, but prevents radiative and convective heat loss from the surface
- ✓ Tubes containing heating fluid to transfer the heat from the collector
- ✓ Support structure to protect the components and hold them in place
- ✓ Insulation covering sides and bottom of the collector to reduce heat losses

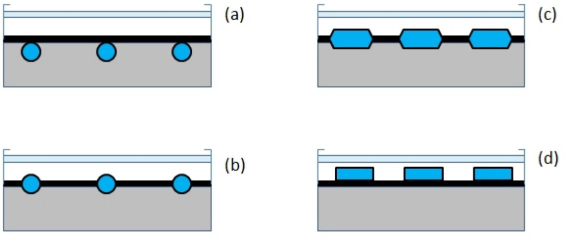
Energy flow of flat-plate collectors

- The flat-plate systems normally operate and reach the maximum efficiency within the temperature range from 30 to 80 ^{o}C
- However, some new types of collectors that employ vacuum insulation can achieve higher temperatures (up to 100 ^{o}C).
- Due to the introduction of selective coatings, the stagnant fluid temperature in flat-plate collectors has been shown to reach 200 ^{o}C.

**Advantages and Disadvantages of the* flat-plate collectors

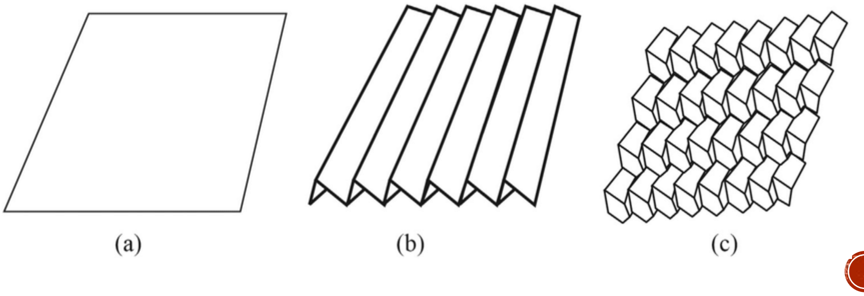
Flat-plate collectors

- ✓ The key considerations in flat plate collector design are maximizing absorption, minimizing reflection and radiation losses, and effective heat transfer from the collector plate to the fluids.
- ✓ One of the important issues is obtaining a good thermal bond between the absorber plate and changes (tubes or ducts containing the heat-transfer fluids).
- ✓ Different construction designs (shown below) try to address this issue.
- ✓ One of the considerations in choosing the assembly method is cost of labor and materials.



Absorber plates

- ❑ The absorber coating is typically a selective coating.
- ❑ Selective stands for having the special optical property to combine high absorption in the visible part of the electromagnetic spectrum coupled to low emittance in the infrared one.
- ❑ This creates a selective surface, which reduces black body energy emission from the absorber and improves performance.



Dr. A.T.M. Saiful Islam
Assistant Professor
BSMRSTU

Heat-transfer fluids

- The flat plate collectors can involve liquid or air heat transport.
- Water is one of the common options as liquid fluid due to its accessibility and good thermal properties:
  - It has a relatively high volumetric heat capacity
  - It is incompressible (or almost incompressible)
  - It has a high mass density (which allows using small tubes and pipes for transport)
- One disadvantage of water is that it freezes during winter, which can damage the collector or piping system.
- This can be managed by draining down the collector at low solar inputs.
- Drain down sensors are often employed to monitor the system and to ensure complete draining, as pocket water freezing can cause damage.
- Refilling the system with water on the next morning also is not perfect.
- Possible air pockets in the collector can be a problem, blocking water flow and decreasing system efficiency.

Heat-transfer fluids

- Antifreeze mixtures can be used instead of pure water to alleviate the above-said problems.
  - ✓ The common antifreeze components are ethylene glycol or propylene glycol.
  - ✓ Those chemicals are mixed with water require closed-loop systems and proper disposal due to toxicity.
  - ✓ Nominal antifreeze service like is about 5 years, after which it needs to be replaced.
- Air can be used as transport fluid in some designs of flat -plate collectors.
  - ✓ This option is better suited to space heating applications or crop drying.
  - ✓ A fan is usually required to facilitate air flow in the system and efficient heat transport.
  - ✓ Certain designs can provide passive (no fan) movement of air due to thermal buoyancy.

Heat-transfer fluids

- Phase-change liquids can also be used with flat-plate collectors.
  - ✓ Some refrigerants are included in this group of fluids.
  - ✓ They do not freeze, which eliminates troubles explained above for water, and, due to their low boiling point can change from liquid to gas as temperature increases.
  - ✓ Those fluids can be practical in settings where quick response to rapid temperature fluctuation is needed.

Efficiency of flat-plate collectors

- In steady state, the useful energy output of the collector is the difference between the absorbed solar radiation and the total thermal losses from the collector

Useful energy = Absorbed solar energy - Thermal losses

Obviously, the higher the useful energy output from a particular design, the higher the expected efficiency.

$$\eta = \frac{Q_u}{A_c G_T}$$

where Q_u is the useful energy output from a collector, G_T is the incident solar radiation flux (irradiance), and A_c is the collector area.

$$Q_u = A_c\left[S - U_L\left(T_{plate} - T_{ambient}\right)\right]$$

Efficiency of flat-plate collectors

where S is the absorbed solar radiation, U_L is the total losses, T_{plate} is the temperature of the absorbing plate, and $T_{ambient}$ is the temperature of the air.

In a general case, when measurements of incident solar radiation (G_T) are available, the convenient approximation for the absorbed energy is given by:

$$S = (\tau\alpha)_{av} G_T$$

where $(\tau\alpha)_{av}$ is the product of transmittance of the collector cover and absorptance of the plate averaged over different types of radiation. In fact, $(\tau\alpha)_{av} \approx 0.96(\tau\alpha)_{beam}$ based on practical estimations.

Efficiency of flat-plate collectors

The maximum possible useful energy gain can be achieved when the collector is at the same temperature as the inlet fluid. In this case, the heat losses are minimized. However, in an actual operation setting, this is not always the case. To describe the effective (actual) useful energy gain via heat exchange, we should introduce the *heat removal factor* – $\boldsymbol{F_R}$

$$Q_u = A_c F_R \left[S - U_L \left(T_{plate} - T_{ambient}\right)\right]$$

$$Q_u = A_c F_R \left[(\tau\alpha)_{av} G_T - U_L \left(T_{plate} - T_{ambient}\right)\right]$$

$$\eta_i = \frac{Q_u}{A_c G_T}$$

Insulation and glazing

- ✓ Solar thermal collectors use a transport medium or heat transfer fluid to convert solar radiation into thermal energy.
- ✓ This is why insulation materials are so critical as they help to save and concentrate energy.
- ✓ Insulation materials prevent heat loss and stop the supporting material from overheating.
- ✓ By stopping thermal losses through the rear and the sides of the collector, insulation increases the efficiency of the collector, meaning the maximum amount of collected heat to be relocated to the circulating fluid.
- ✓ Insulation materials also enhance operational efficiency as they are easily accessible and serviceable, meaning they can be inspected and maintained easily.
- ✓ Insulation materials also mean components are safe to touch and the ambient air is cooler, resulting in a more comfortable work environment.

Insulation and glazing

❑ **Materials for insulation**

- ➢ Fibrous material (like Mineralwool, Glasswool, Asbestos fibers, Ceramic fibers, Woodwool etc.),
- ➢ Organic foams (like polyisocyanurate foam, polyurethane foam,
- ➢ phenolic foam, expanded polystyrene etc.),
- ➢ Cellular material (like foam concrete),
- ➢ Powders (like Saw dust, Rice husk etc.),
- ➢ Granular material (like Calcium Silicate, 85% Magnesia, etc.)

❑ The transparent cover is tempered soda-lime glass having reduced iron oxide content. The glass may also have a stippling pattern and one or two anti-reflective coatings to further enhance transparency.