BMM4753 RENEWABLE ENERGY RESOURCES

Chapter 3. Solar Thermal Collectors

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Energy Sustainability Focus Group

Chapter 3. Solar Thermal Collectors

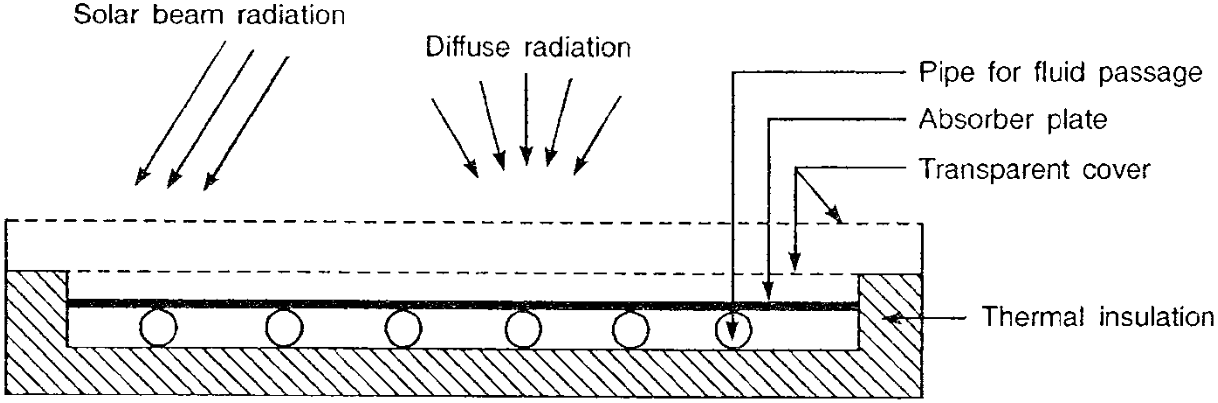
Summary

3.1 Introduction

A solar thermal energy collector is an equipment in which solar energy is collected by absorbing radiation in an absorber and then transferring to a fluid. In general, there are two types of collectors:

- **Flat-plate/evacuated tube solar collector:** It has no optical concentrator. The collector area and the absorber area are numerically the same, the efficiency is low, and temperatures of the working fluid can be raised only up to 100°C.
- **Concentrating-type solar collector:** The area receiving the solar radiation is several times greater than the absorber area and the efficiency is high. Mirrors and lenses are used to concentrate sun rays on the absorber, and the fluid temperature can be raised up to 500°C. For better performance, the collector is mounted on a tracking equipment to always face the sun with its changing position.

3.2 Construction – Flat Plate Collector



Consists of five major parts:

a) **Metallic flat absorber plate** of high thermal conductivity made of copper, steel, or aluminum, and having black surface, thickness 0.5-1 mm.

b) **Tubes or channels** soldered to the absorber plate. Water flowing through these tubes takes away the heat from the absorber plate. The diameter of tubes (1.25 cm) while that of the header pipe (2.5 cm) which leads water in and out of the collector and distributes it to absorber tubes.

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3.2 Construction – Flat Plate Collector

c) **Transparent toughened glass sheet** of 5 mm thickness cover plate to reduce convection losses through a stagnant air layer between the absorber plate and the glass. Radiation losses are also reduced as the spectral transmissivity of glass is such that it is transparent to short wave radiation and nearly opaque to long wave thermal radiation emitted by interior collector walls and absorbing plate.

d) **Fiber glass insulation** of thickness 2.5-8 cm at the bottom and on the side to minimize heat loss.

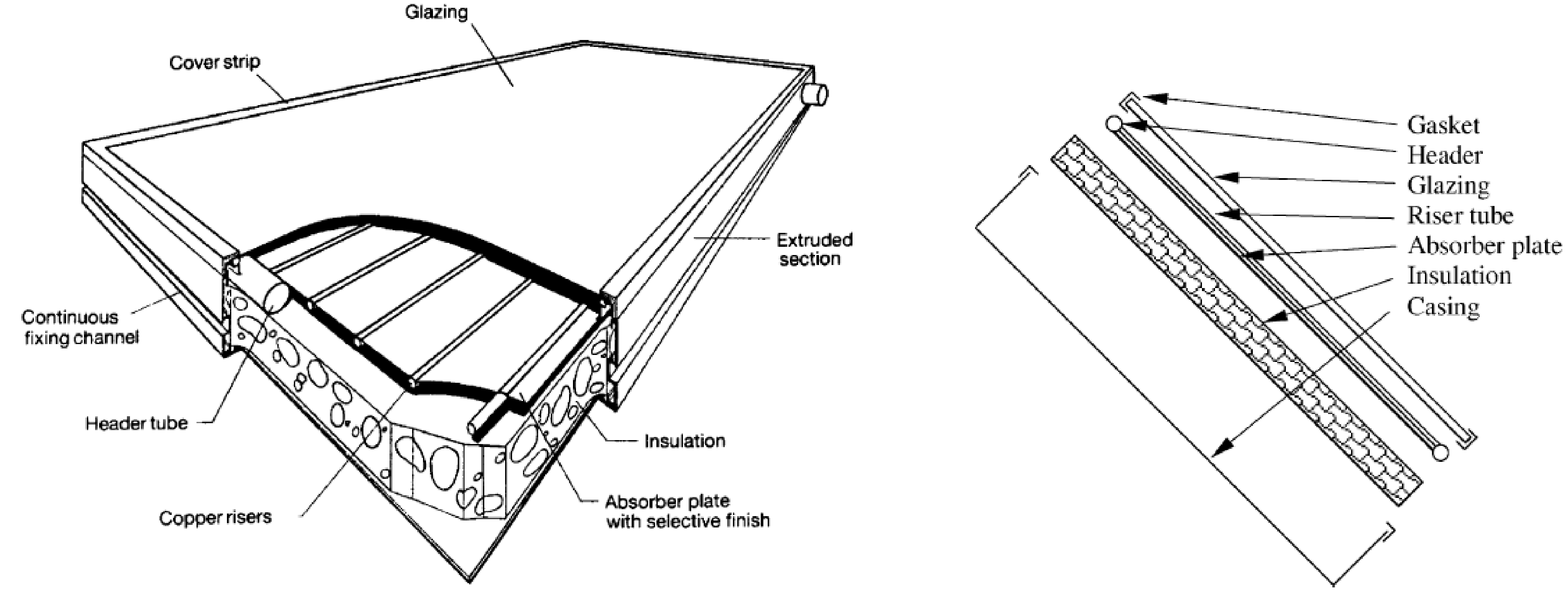
e) **Container** encloses the whole assembly in a box made of metallic sheet or fiber glass.

3.2 Construction – Flat Plate Collector

- Since the heat transfer fluid is liquid, it is also known as liquid flat-plate collector.
- Commercially available collectors have a face area of 2 m^2.
- The whole assembly is fixed on a supporting structure that is installed in a tilted position at a suitable angle facing south in northern hemisphere.
- For the whole year, the optimum tilt angle of collectors is equal to the latitude of its location.
- During winter, the tilt angle is kept 10-15° more than the latitude of the location while in summer it should be 10-15° less than the latitude.

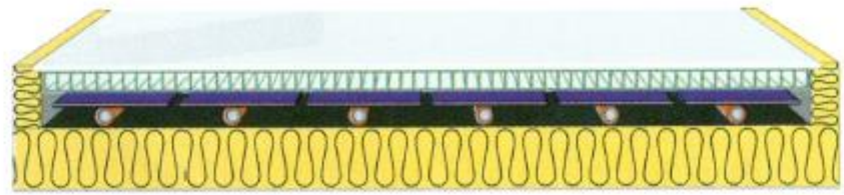
3.2 Construction – Flat Plate Collector

Use both beam and diffuse solar radiation, do not require tracking of the sun, and are low-maintenance, inexpensive and mechanically simple.

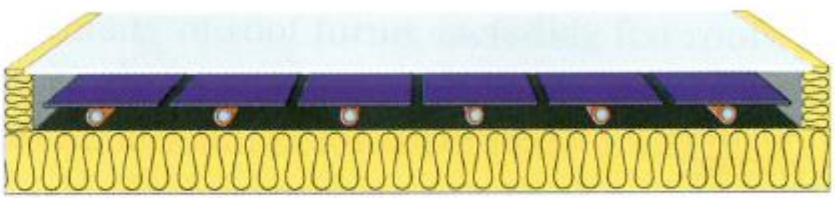


3.2 Construction – Flat Plate Collector

unglazed collector, absorber

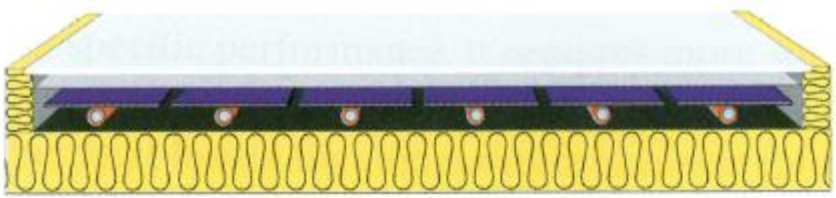


collector with transparent heat insulation

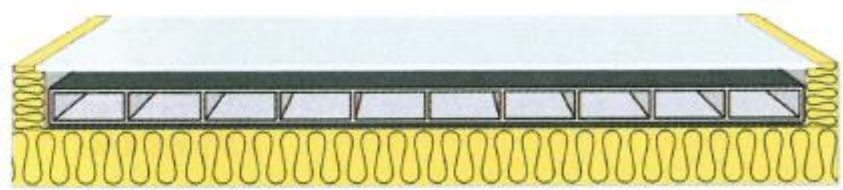


standard flat collector

vaccum flat-plate collector (with pillars)



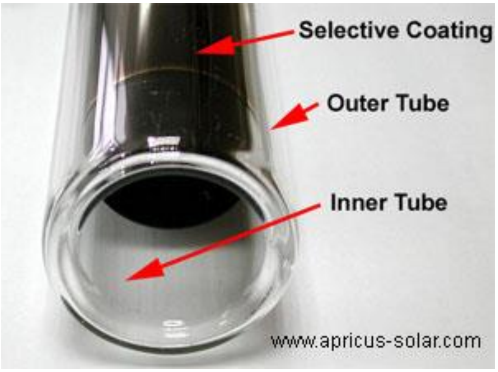
collector with limited convection

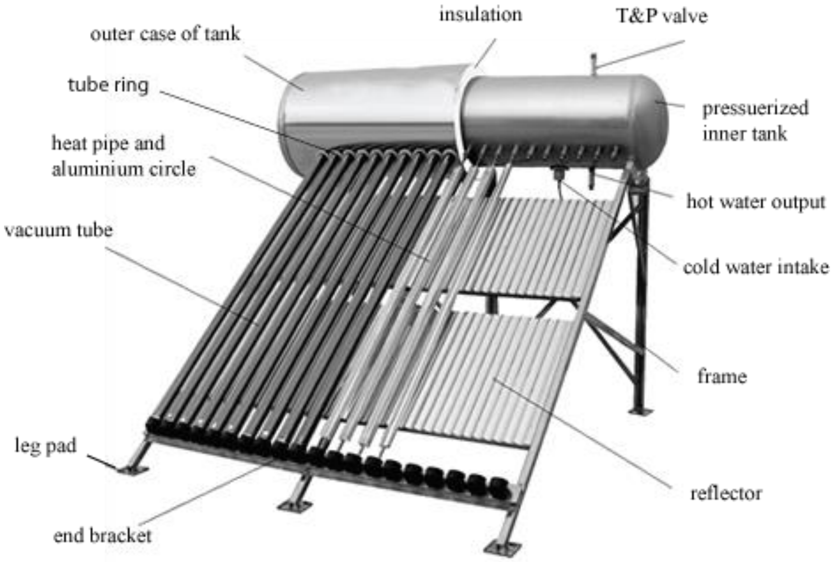


air collector

3.2 Construction – Evacuated Tube Solar Collector

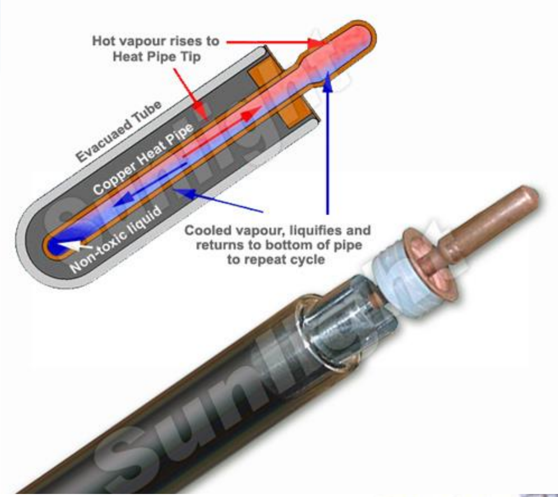
- A collector consists of a row of parallel glass tubes.
- A vacuum inside every single tube extremely reduces conduction losses and eliminates convection losses.



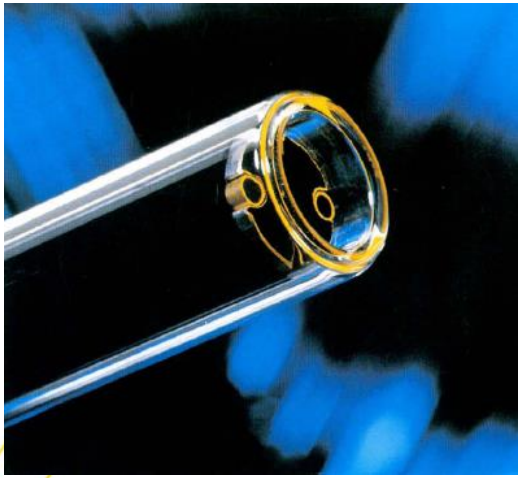


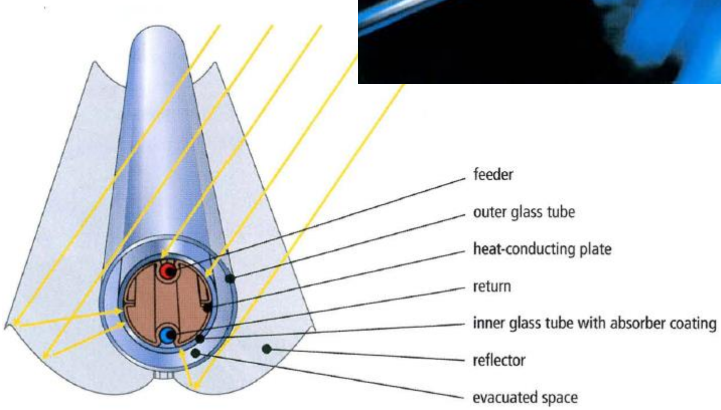
3.2 Construction – Evacuated Tube Solar Collector

Heat pipe



Sydney tube





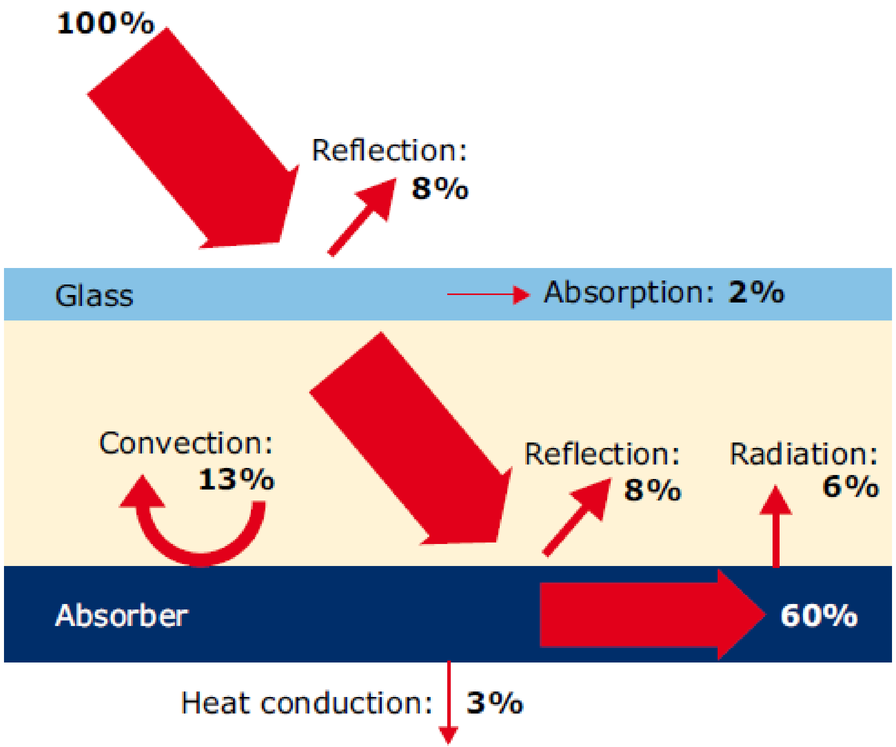
3.3 Limitations of Flat-Plate Collector

Motion	Collector type	Absorber type	Concentration ratio	Indicative temperature range (°C)	
Stationary	Flat plate collector (FPC)	Flat	1	30–80	Low temperature
	Evacuated tube collector (ETC)	Flat	1	50–200	
	Compound parabolic collector (CPC)	Tubular	1–5	60–240	
Single-axis tracking			5–15	60–300	Medium temperature
	Linear Fresnel reflector (LFR)	Tubular	10–40	60–250	
	Parabolic trough collector (PTC)	Tubular	15–45	60–300	
	Cylindrical trough collector (CTC)	Tubular	10–50	60–300	
Two-axes tracking	Parabolic dish reflector (PDR)	Point	100–1000	100–500	High temperature
	Heliostat field collector (HFC)	Point	100–1500	150–2000	

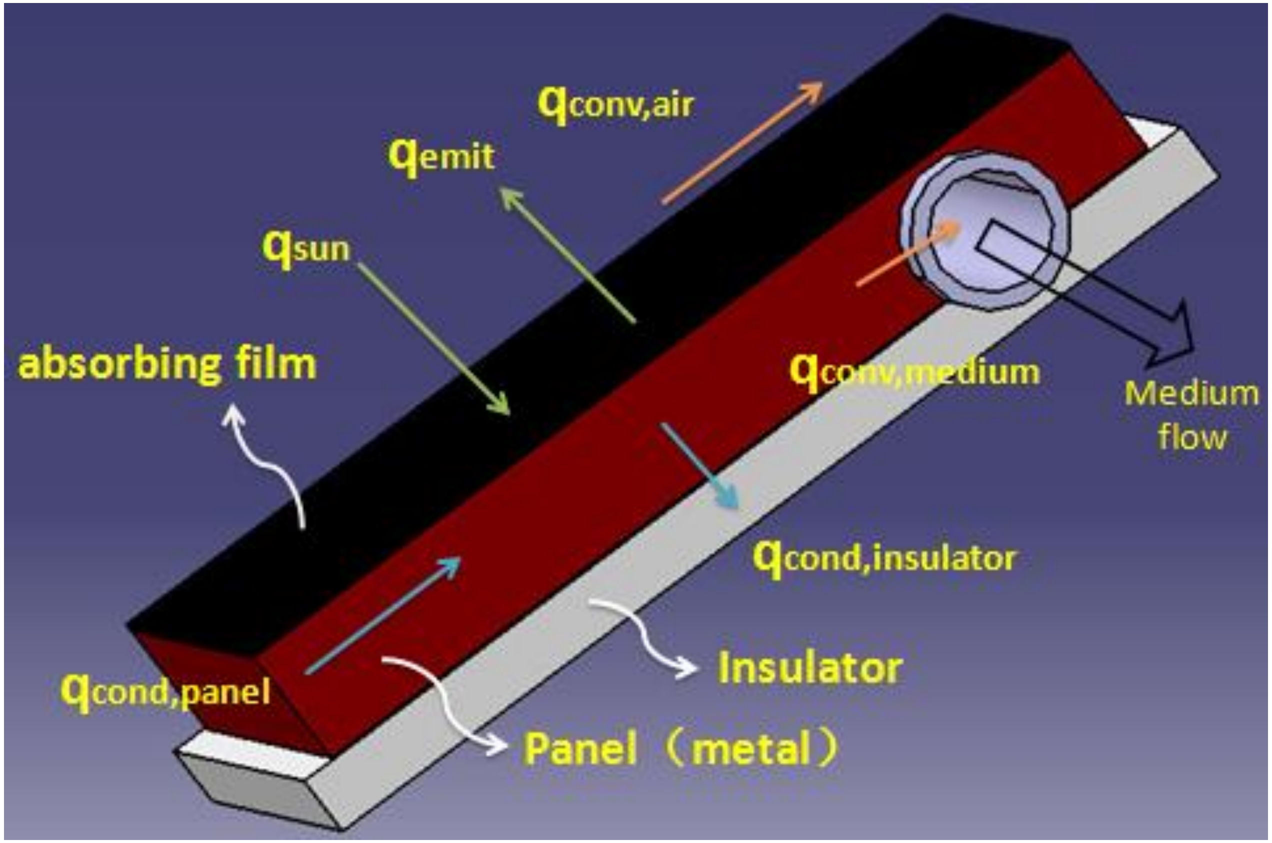
Note: Concentration ratio is defined as the aperture area divided by the receiver/absorber area of the collector.

3.4 Thermal Losses in Solar Flat Plate Collector

Main losses during angular operation



3.4 Thermal Losses in Solar Flat Plate Collector



3.4 Thermal Losses in Solar Flat Plate Collector

The performance of solar collector can be improved by enhancing the useful energy gain from incident solar radiation with minimum losses. Thermal losses have three components:-

- **Conductive** loss is reduced by providing insulation on the rear and sides of the absorber plate.
- **Convective** loss is minimized by keeping an air gap of about 2 cm between the cover and the plate.
- **Radiative** losses from the absorber plate are lowered by applying a spectrally selective absorber coating.

During normal steady-state operation, useful heat delivered by a solar collector is equal to the heat gained by the liquid flowing through the tubes welded on to the underside of the absorber plate minus the losses.

3.4 Thermal Losses in Solar Flat Plate Collector

The energy balance of the absorber can thus be represented by a mathematical equation,

$$Q_u = A_p S - Q_L$$

where

Q_u = useful heat delivered by the collector (W)

S = solar heat energy absorbed by the absorber plate (W/m^2)

A_P = area of the absorber plate (m^2)

Q_l = rate of heat loss by convection and re-radiation from the top, by conduction and convection from the bottom and sides (W)

Solar flux on inclined surface is given by

$$I_T = I_b R_b + I_d R_d + (I_b + I_d) R_r$$

3.4 Thermal Losses in Solar Flat Plate Collector

Solar flux absorbed by inclined surface is given by multiplying $\tau\alpha$

$$S = I_T\tau\alpha = I_b R_b (\tau\alpha)_b + [I_d R_d + (I_b + I_d) R_r]\,(\tau\alpha)d$$

Instantaneous collector efficiency

$$\eta_i = \frac{Q_u}{A_p I_T}$$

3.4 Thermal Losses in Solar Flat Plate Collector

Heat loss from collector using the total loss coefficient is given by,

$$Q_l = U_T A_P (T_P - T_a) \text{ , kW}$$

where, U_T = total loss coefficient, kW/m^2.°C

T_P = average temperature of the absorber plate, °C

T_a = ambient temperature of surrounding air, °C

A_P = area of the absorber plate, m^2

The collector loses heat from the top, the bottom and the sides,

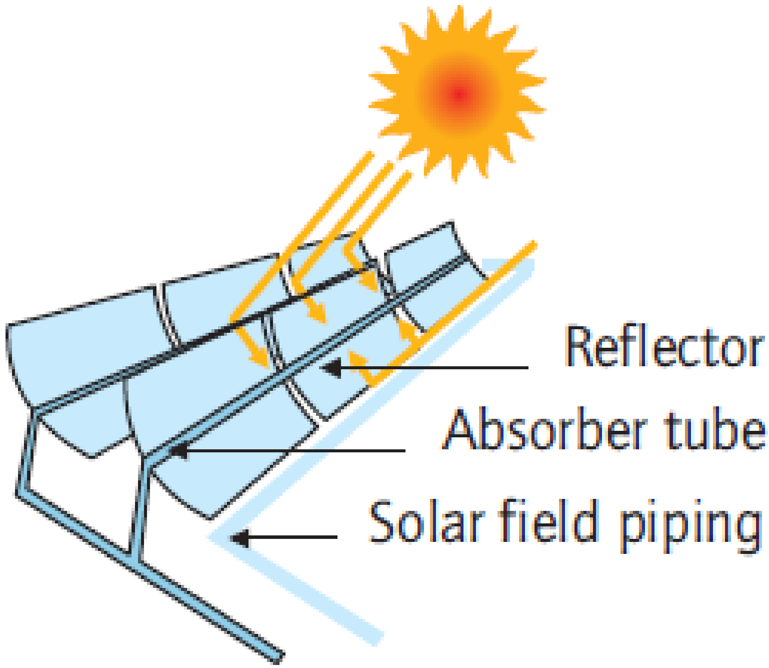
$$Q_l = Q_t + Q_b + Q_s \text{ , kW}$$

where, Q_t = rate of heat loss from the top, kW

Q_b = rate of heat loss from the bottom, kW

Q_s = rate of heat loss from the sides, kW

3.5 Types of Solar Concentrators – Parabolic Trough



- Consist of parallel rows of mirrors (reflectors) curved in one dimension to focus the sun's rays.
- All parabolic trough plants currently in commercial operation rely on synthetic oil as the fluid that transfers heat from collector pipes to heat exchangers.

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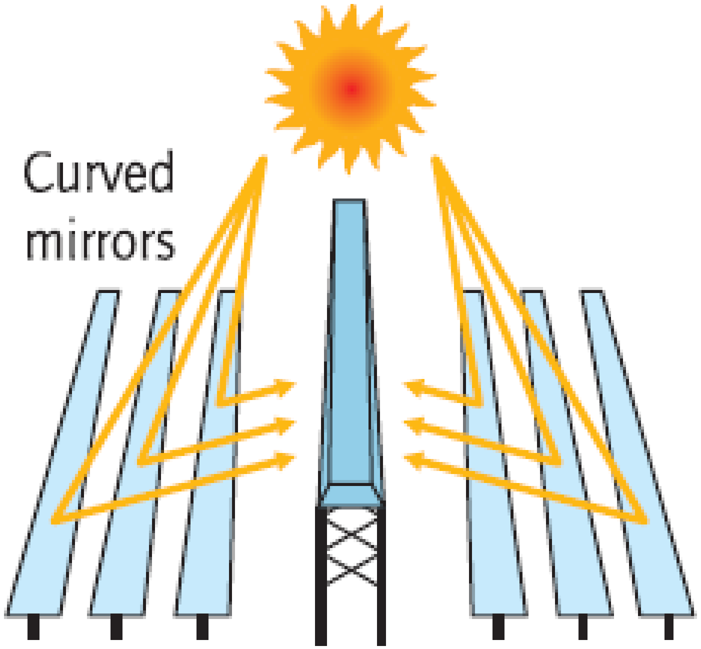
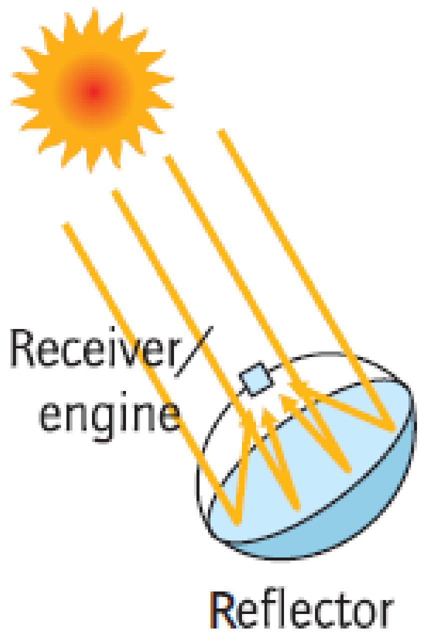
3.5 Types of Solar Concentrators – Linear Fresnel Reflector



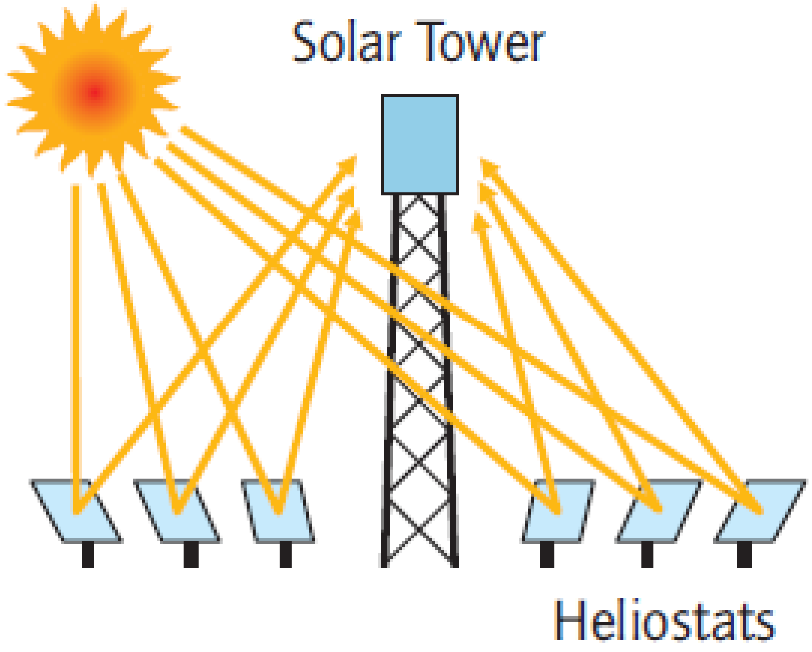
- Approximate the parabolic trough systems but by using long rows of flat or slightly curved mirrors to reflect the sun's rays onto a downward-facing linear, fixed receiver.
- Simple design of flexibly bent mirrors and fixed receivers requires lower investment costs and facilitates direct steam generation.

3.5 Types of Solar Concentrators – Parabolic Dish Reflector



- Concentrate the sun's rays at a focal point propped above the centre of the dish. The entire apparatus tracks the sun, with the dish and receiver moving in tandem.
- Most dishes have an independent engine/generator (such as a Stirling machine or a micro-turbine) at the focal point.

3.5 Types of Solar Concentrators – Heliostat Field Collector



- A heliostat is a device that includes a plane mirror which turns so as to keep reflecting sunlight toward a predetermined target.
- Heliostat field use hundreds or thousands of small reflectors to concentrate the sun's rays on a central receiver placed atop a fixed tower.

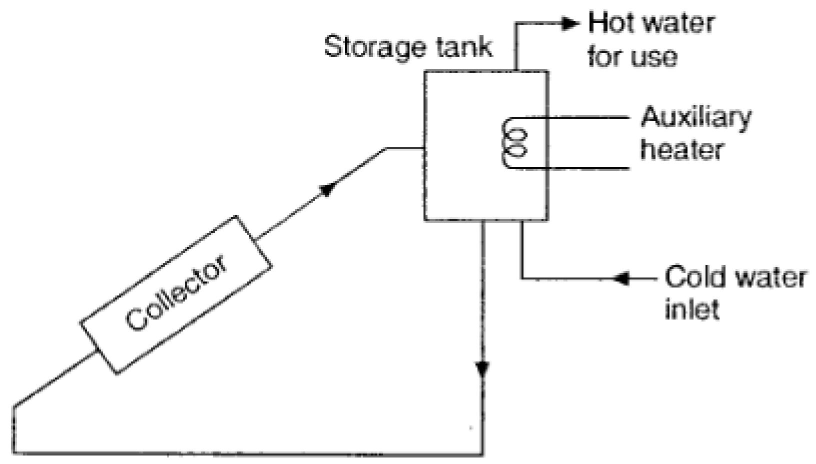
3.6 Applications

The most promising among them is the solar water heating system for domestic and commercial use. Solar industrial water heating systems are used in textile, food processing, dairy, chemical and other industries.

The use of concentrating-type solar collector produces high quality thermal energy, used in thermodynamic cycles to obtain work in solar thermal plants. Solar air-heaters, solar dryers, solar kilns, and space heating with solar passive architecture save fossil fuel energy. Solar cooling and refrigeration is quite attractive as cooling demand is more when the sunlight is strongest. Economic evaluation suggests that solar thermal devices are financially viable as the payback period is within their lifetime

3.6 Applications – Solar Water Heating

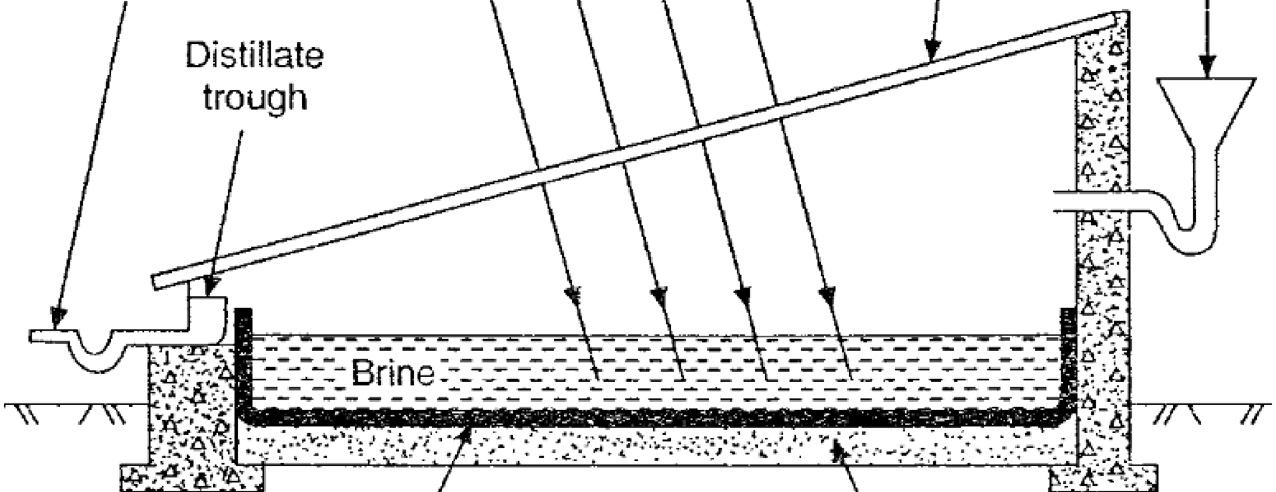
It is one of the most common applications of solar energy. The system consists of a flat-plate solar collector, normally single glazed, and a storage tank kept at a height. It is installed on a roof with the collector facing the sun and connected to a continuous water supply.



Natural circulation solar water heater.

Water flows through the tubes, absorbs solar heat and is stored in a tank. Water circulation is entirely based on the density difference between the solar-heated water in the collector and the cold water in the storage tank. Hot water for use is taken out from the top of the tank. An auxiliary heating system is provided for use on cloudy and rainy days.

3.6 Applications – Solar Distillation



Cross section of a solar still.

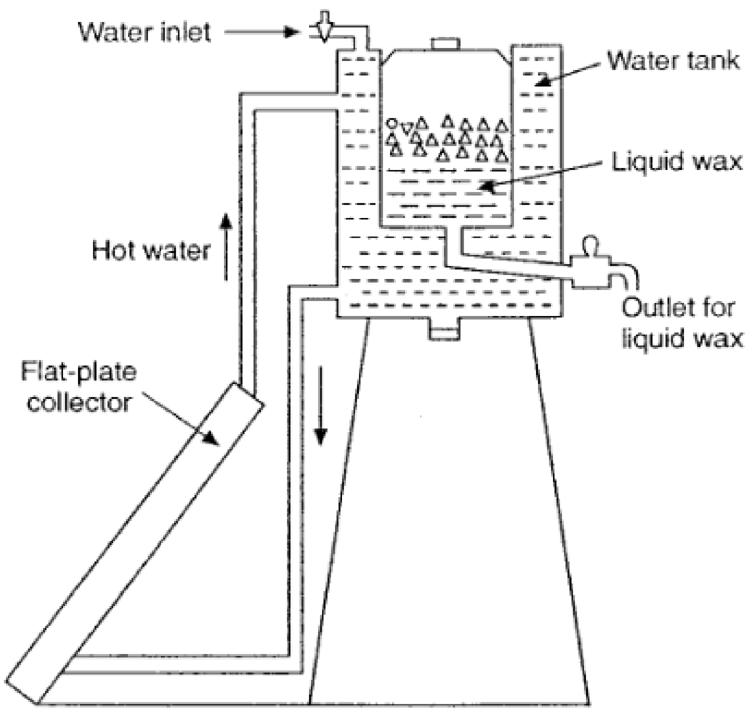
3.6 Applications – Solar Distillation

Safe drinking water is scarce in arid, semi-arid and coastal areas, though an essential requirement for supporting life. At such places, saline water is available underground or in the ocean. This water can be distilled utilizing abundant solar insolation available in that area. A device which produces potable water by utilizing solar heat energy, is called 'solar water still'.

A 'solar still' consists of a basin with black bottom having trays for saline water with shallow depth. A transparent air-tight glass or a plastic slanting cover encloses completely the space above the basin. Incident solar radiation passes through the transparent cover and is absorbed by the black surface of the still. Brackish water is then heated and water vapors condense over the cool interior surface of the transparent cover. The condensate flows down the glass and gets collected in troughs installed as outer frame of the solar still. Distilled water then is transferred into a storage tank.

3.6 Applications – Liquid Bath Solar Wax Melter

Candle and Match industries utilize wax, which needs melting for further processing. Use of solar heat energy is a viable option and cuts down the use of oil and fire wood. It consists of a flat-plate collector connected to a water storage tank built around a wax chamber, as shown. Hot water from the flat-plate collector circulates in the storage tank that transfers heat to the solid wax. When the temperature reaches the melting point, phase change occurs and the liquid wax is collected.



Liquid bath solar wax melter.

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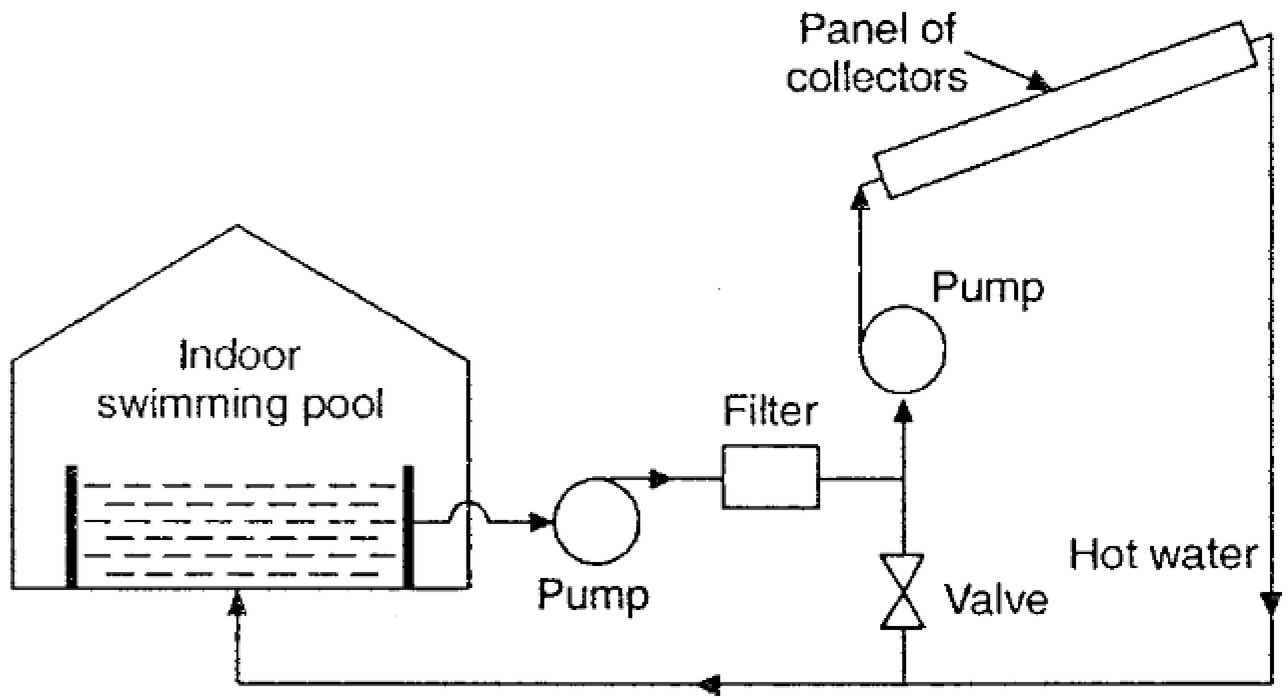
3.6 Applications – Solar Heating of Swimming



Schematic diagram of an indoor solar-heated swimming pool

3.6 Applications – Solar Heating of Swimming

Solar energy can be used for maintaining swimming pool temperature during winter. It is necessary in extreme cold climate conditions to maintain water temperature between 20°C and 25°C. A swimming pool loses heat by conduction, convection, radiation and evaporation. An indoor swimming pool has the advantage of being maintained at the required temperature and being protected from dust, climate and birds. The area of the solar collectors required depends upon the capacity of the pool and the climatic conditions. Basically, the system has three sections: (i) solar collectors, (ii) water circulation pipes and pumps, and (iii) control system. The cost of the system depends on the availability of solar radiation, the type of collectors and atmospheric conditions.

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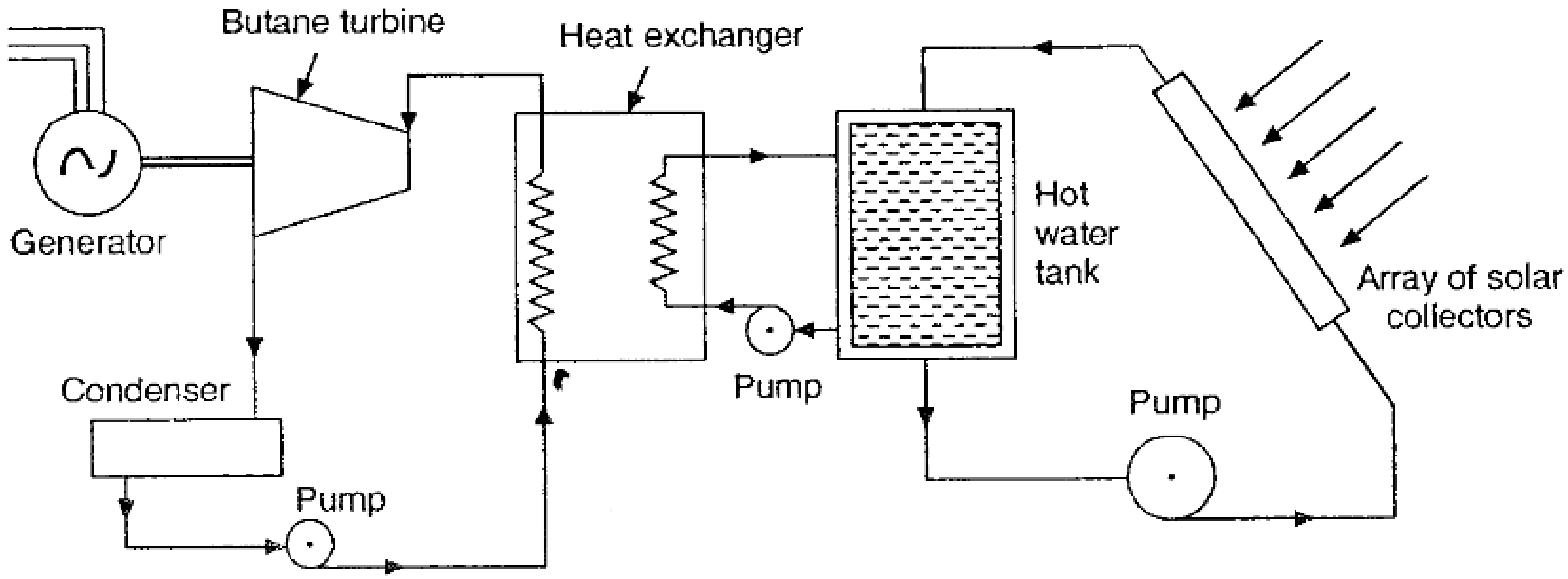
3.6 Applications – Solar Thermal Power Plants



Low temperature solar power plant.

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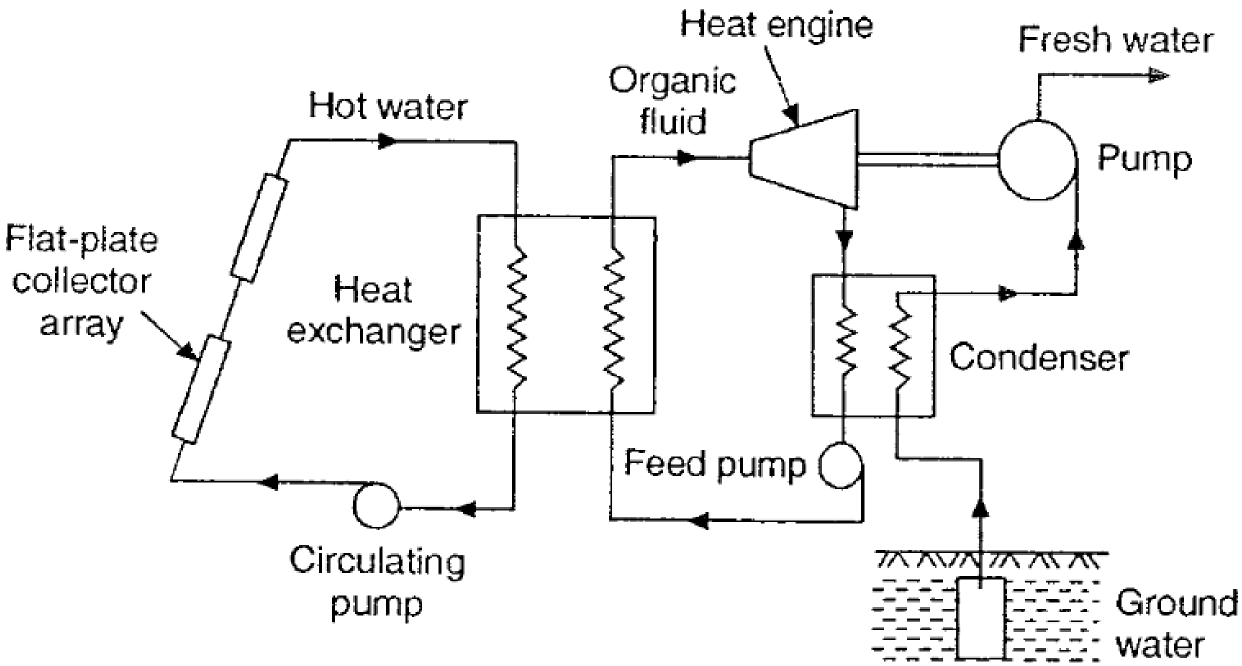
3.6 Applications – Solar Thermal Power Plants

Solar thermal power generation involves the collection of solar heat which is utilized to increase the temperature of a fluid in a turbine operating on a cycle such as Rankine or Brayton. In the other method, hot fluid is allowed to pass through a heat exchanger to evaporate a working fluid that operates a turbine coupled with a generator.

Solar thermal power plants can be classified as low, medium and high temperature cycles. Low temperature cycles operate at about 100°C, medium temperature cycles up to 400°C, while high temperature cycles work above 5OO°C

3.6 Applications – Solar Pumping Systems



Schematic of a solar pump.

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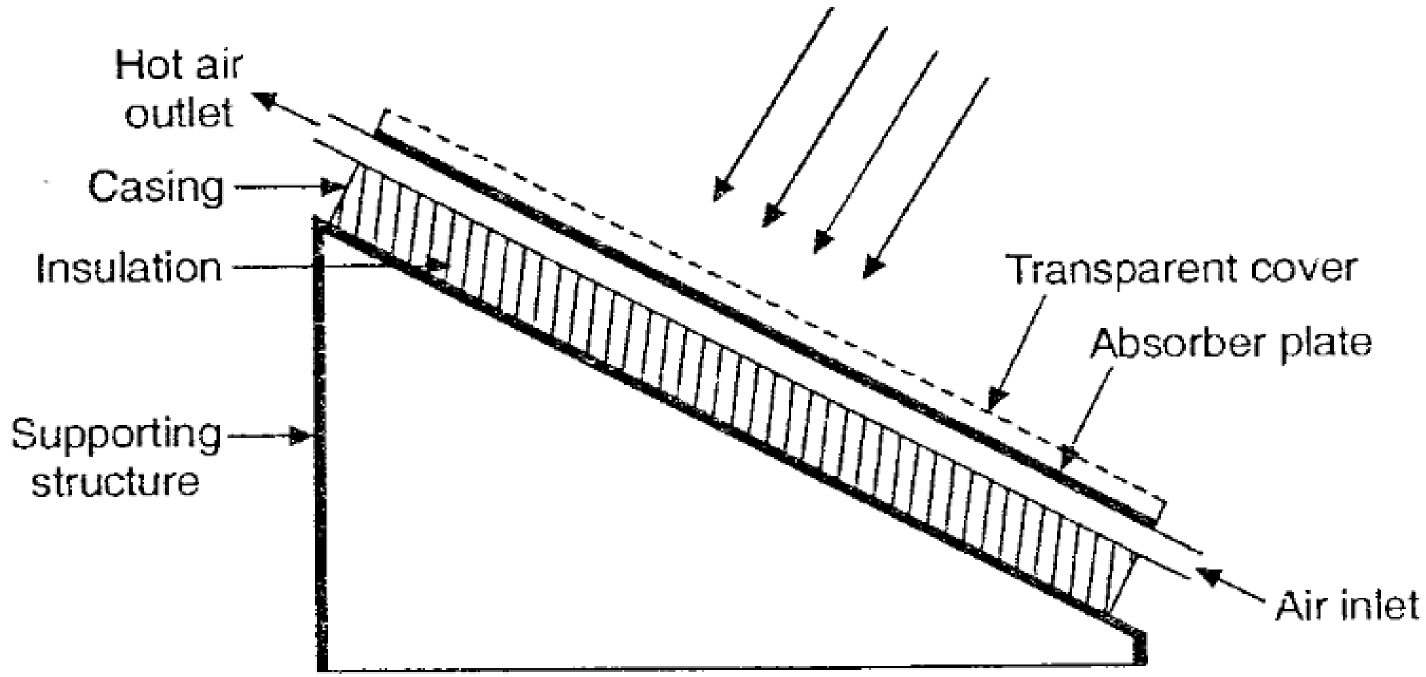
3.6 Applications – Solar Pumping Systems

Water pumps can be driven directly by solar heated water or fluid which operates either a heat engine or a turbine. For low heads, the pump driven by vapor of a low-boiling point liquid heated by a flat-plate collector is used as shown. Solar flat-plate collector arrays are installed to heat water or an organic fluid. Hot fluid then flows to a mixing tank/storage tank and then to a heat exchanger to convert the working fluid of the heat engine from liquid to vapor. It may be noted that R-115 is an acceptable working fluid as it gives high cycle efficiency besides its low cost. Hot transport fluid or water is fed again into the collector circuit by a circulating pump. With heat engine cycle, discharged vapor from the turbine flows into the condenser where the vapor gets condensed. Working liquid is fed into the heat exchanger by a feed pump to complete the cycle. Pumped water is used as a coolant in the turbine condenser. A higher temperature in heat exchanger or boiler, provides a high engine efficiency. An optimum range of operating temperature is used for a solar pumping system to attain maximum efficiency.

3.6 Applications – Solar Air Heaters

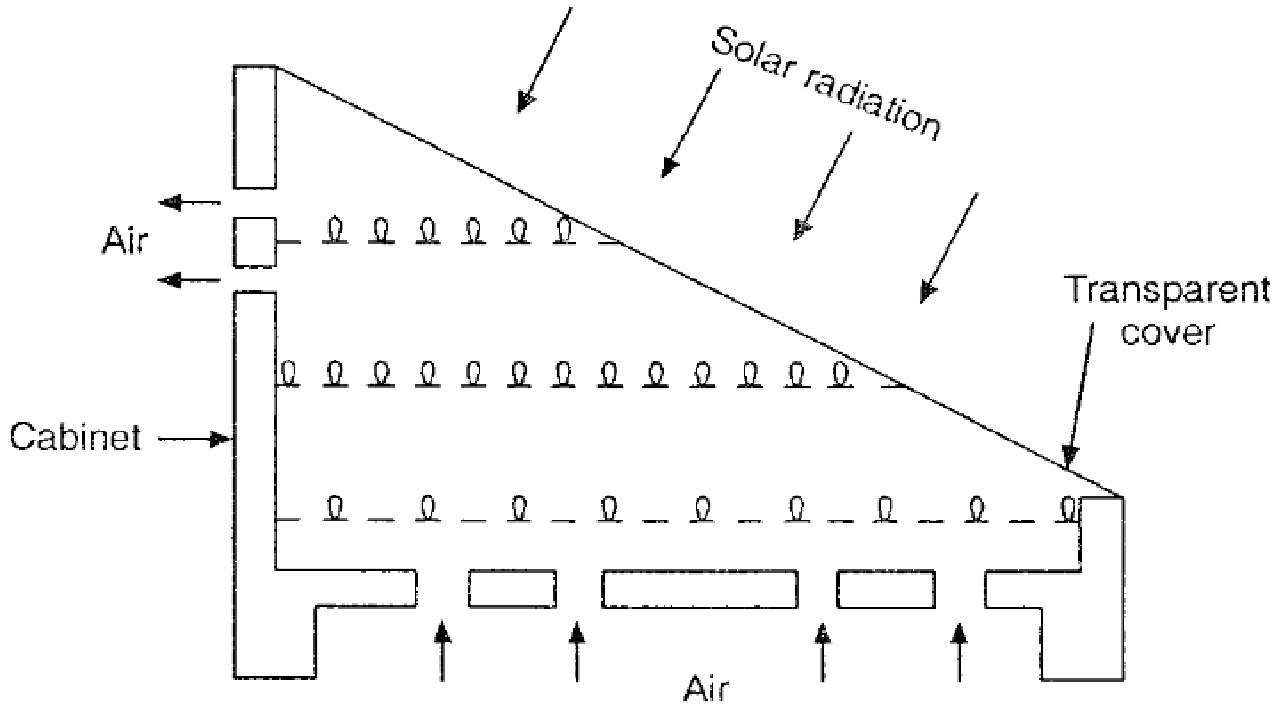


Solar air heater.

3.6 Applications – Solar Air Heaters

A solar air heater constitutes a flat-plate collector with an absorber plate, transparent cover at the top, a passage through which the air flows and insulation at the bottom and sides as shown. Air passage is only a parallel plate duct. Air to be heated flows between the cover and the absorber plate which is fabricated from a metal sheet of 1 mm thickness. Cover is either made of glass or plastic of 4 to 5 mm thickness, glass wool of thickness 5 to 8 cm is used for bottom and side insulation. Full assembly is encased in a sheet metal box and kept inclined at a suitable angle. The face area of a solar heater is about 2 m^2, matching the heat requirement. The value of heat transfer coefficient between the absorber plate and the air is low and the operating efficiency of a simple air heater is also low.

3.6 Applications – Solar Crop Dryers

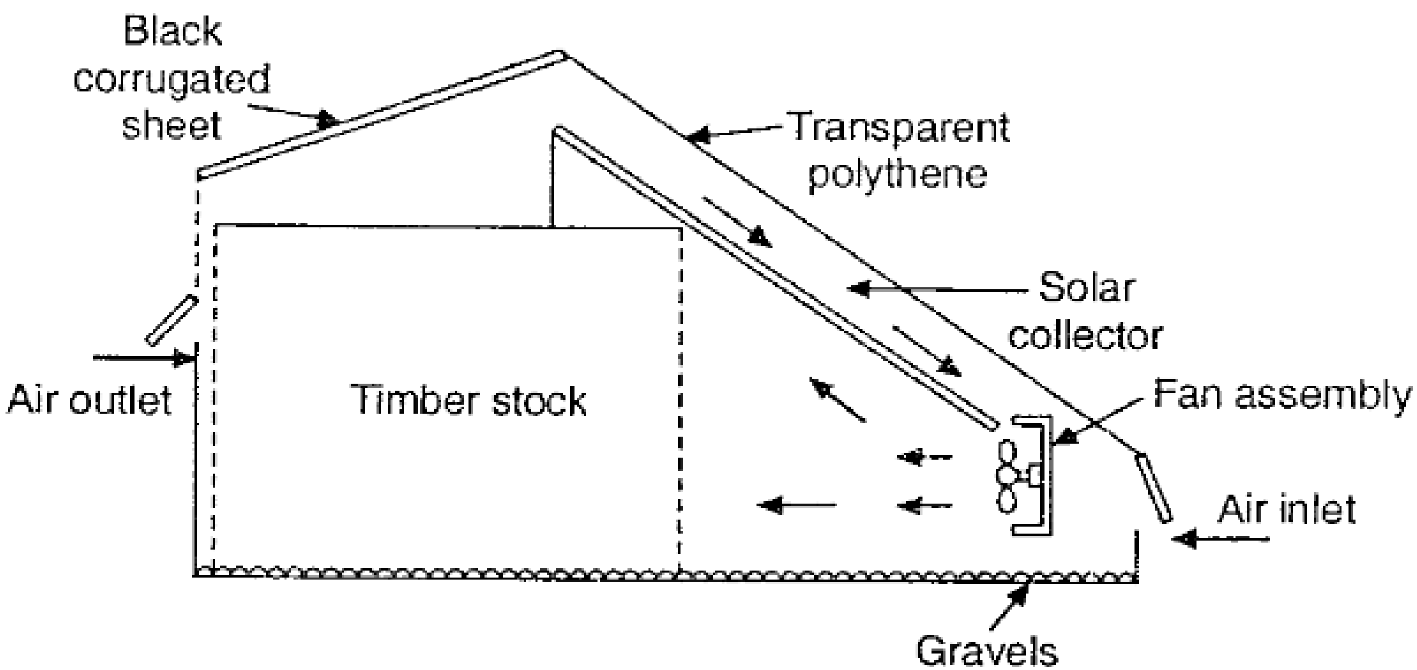


Cross section of a cabinet dryer.

3.6 Applications – Solar Crop Dryers

Solar energy is effectively utilized for controlled drying of agriculture produce to avoid food losses between harvesting and consumption. High moisture crops are prone to fungus infection, attack by insects and pests. Solar dryers remove moisture with no ingress of dust, and the product can be preserved for a longer period of time. A cabinet type solar dryer consists of an enclosure with a transparent cover as shown. Openings are provided at the bottom and top of the enclosure for natural circulation. The material to be dried, is spread on perforated trays. Solar radiation enters the enclosure, is absorbed by the material and internal surfaces of the enclosure. Consequently, moisture from the product evaporates, the air inside is heated and natural air circulation starts. The temperature inside the cabinet ranges from 50°C to 75°C and the drying time for products like dates, grapes, apricots, cashew nuts and chilli varies from 2 to 4 days. For large-scale drying, i.e. seasoning of timber, corn drying, tea processing, tobacco curing, fish and fruit drying, solar kilns are in use.

3.6 Applications – Solar Kilns



Side view of timber solar kiln.

3.6 Applications – Solar Kilns

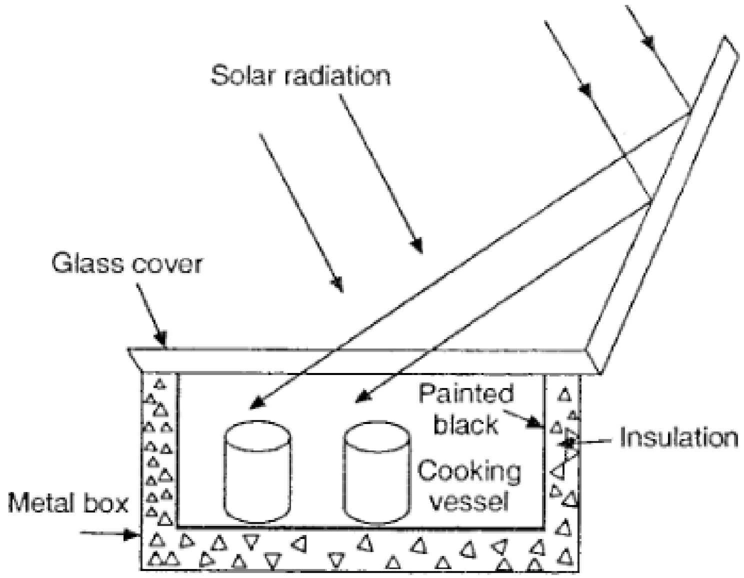
In a solar kiln, heating and drying of products on a large scale, like tea, corn, fruits, timber, etc. is done by solar energy. It operates on the principle that a transparent glass sheet or polythene sheathing allows solar radiation to pass through into the kiln and blocks long wavelength radiation emitted by products like timber back into the atmosphere. The important factors affecting the drying process are:

- Relative humidity and temperature of the air
- Air flow rate
- Initial moisture content of the product
- Final desired moisture content of the product.

A solar kiln used for seasoning of timber consists of three major parts: (i) a wood seasoning chamber, (ii) a flat-plate collector, and (iii) a chimney seasoning chamber which is placed on a raised masonry platform. The chimney creates a natural draught in the seasoning chamber. causing hot air circulation around stacked wood as shown.

3.6 Applications – Box Solar Cooker

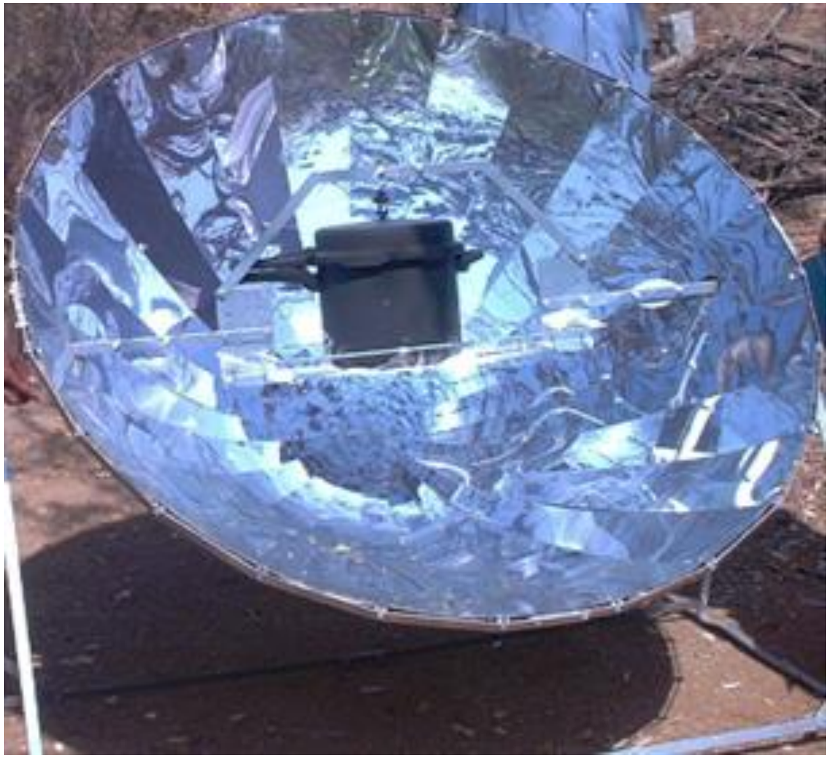
Several varieties of solar cookers are available to suit different requirements. It consists of an outer box made of either fiber glass or aluminum sheet, a blackened aluminum tray, a double glass lid, a reflector, insulation and cooking pots as shown. blackened aluminum tray is fixed inside the box, and sides are covered with an insulating material to prevent heat loss. A reflecting mirror provided on the box cover increases the solar energy input. Metallic cooking pots are painted black on the outer side. Food to be cooked is placed in cooking pots and the cooker is kept facing the sun to cook the food.



Box solar cooker.

3.6 Applications – Dish Solar Cooker

A dish solar cooker uses a parabolic dish to concentrate the incident solar radiation. A typical dish solar cooker has an aperture of diameter 1.4 m with focal length of 0.8 m. The reflecting material is an anodized aluminum sheet having reflectivity of over 80%. The cooker needs to track the sun to deliver power of about 0.6 kW. The temperature at the bottom of the vessel may reach up to 400°C which is sufficient for roasting, frying and boiling. It can meet the requirement of cooking for 15 people.



3.6 Applications – Dish Solar Cooker

Solar Steam Cooking System for 15’000 people (World’s largest) in India food welfare program

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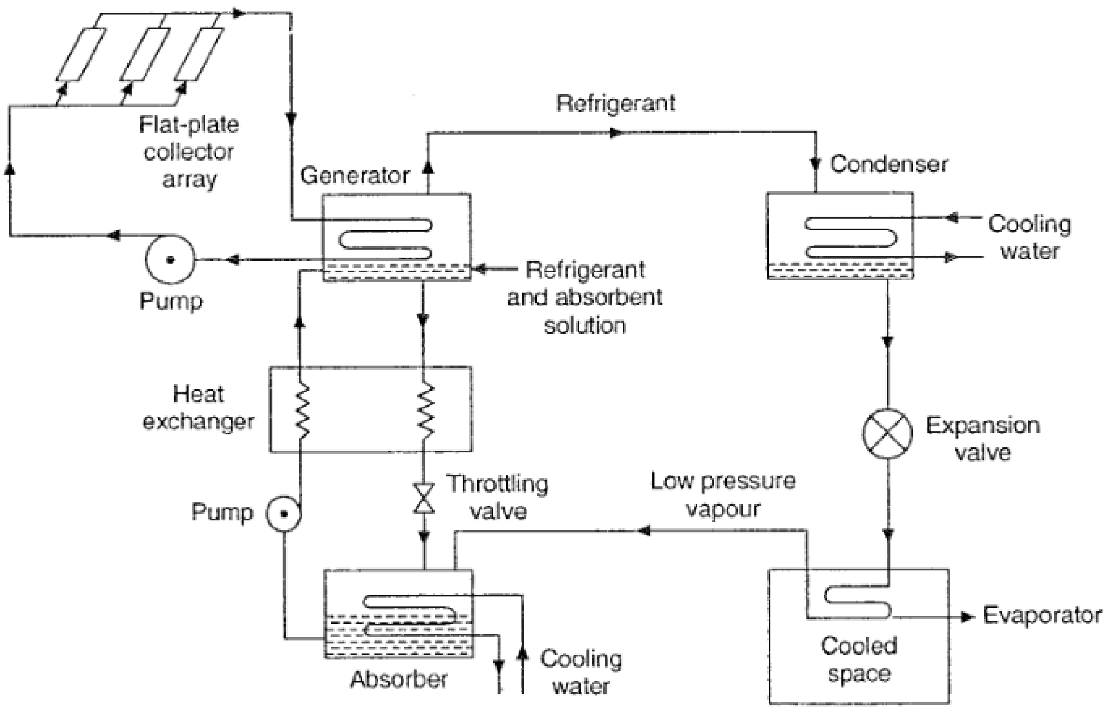
Solar Steam Cooking System for 15’000 people (World’s largest) in India food welfare program

3.6 Applications – Solar Absorption Cooling System

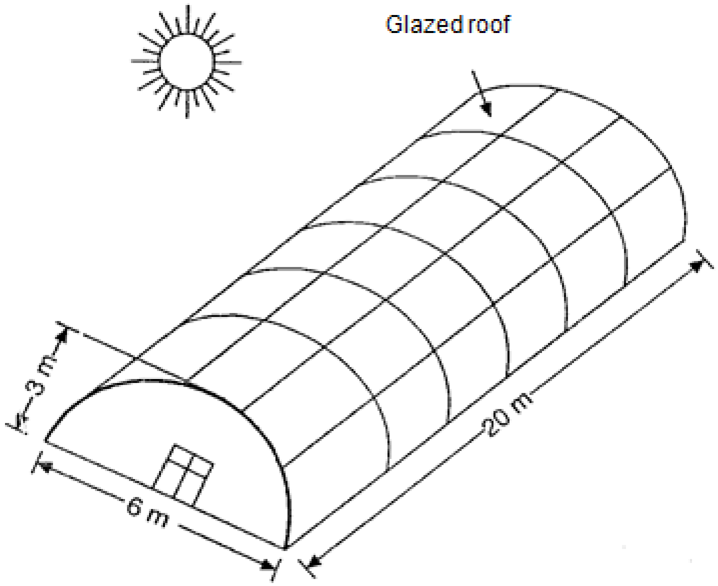


Solar absorption cooling system.

3.6 Applications – Solar Absorption Cooling System

A simple solar-operated absorption cooling system is shown. Water is heated in a flat-plate collector array and is passed through a heat exchanger called the generator. Suitable chemical solutions for absorption cooling are: (i) NH_3H_20 where NH_3 is used as the working fluid, and (ii) LiBr-H_20 solution, where H_20 operates as the working fluid. The whole system consists of four units: generator, condenser, evaporator, and absorber. The generator contains a solution mixture of absorbent and refrigerant, and this mixture gets heated with solar energy. Refrigerant vapor is boiled off at a high pressure and flows into condenser, where it gets condensed rejecting heat and becomes liquid at high pressure. Refrigerant then passes through the expansion valve and evaporates in the evaporator. The refrigerant vapor is then absorbed into a solution mixture taken from the generator in which the refrigerant concentration is quite low. The rich solution thus prepared is pumped back to the generator at a high pressure to complete the cycle. A heat exchanger is provided to transfer heat between solutions flowing between the absorber and the generator.

3.6 Applications – Solar Greenhouse



Schematic diagram of a pipe-framed greenhouse.

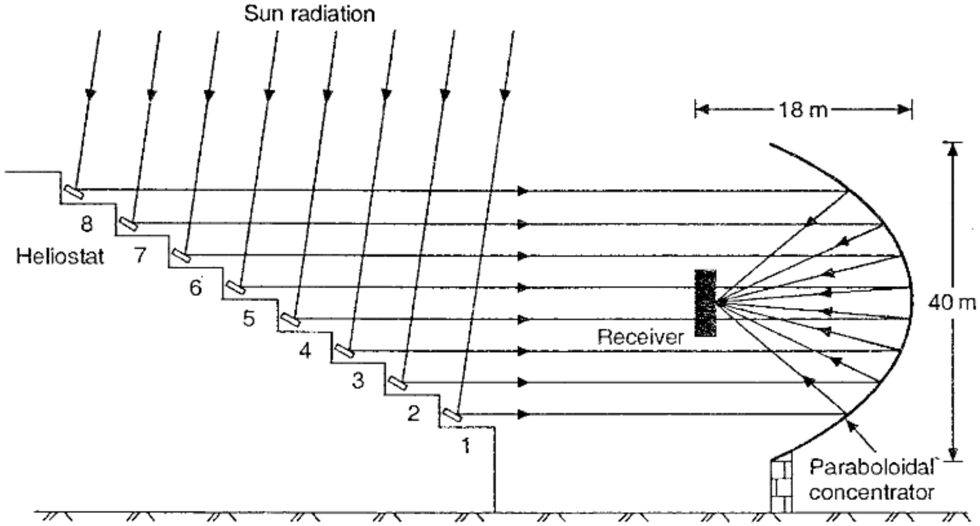
Solar greenhouses are structures covered with glass or plastic sheets, suitable to grow vegetable and flowers under adverse climatic conditions. The basic requirements for a plant growth are: (i) light intensity, (ii) temperature, (iii) humidity, and (iv) amount of CO_2 in plant environment. Plants manufacture their food by a photosynthesis process which maintains a balance with respiration.

In the respiration process, which is the reverse of photosynthesis, energy is liberated and used by the plant for nutrient uptake, division of cells and protein formation. Plants grow if photosynthesis is more than respiration and stop growing if both activities are equal. Plants will slowly perish if photosynthesis is less than respiration.

3.6 Applications – Solar Furnace

A solar furnace is an optical equipment which concentrates solar radiation on a small area for creating a high temperature. Two ways to make a concentrated radiation in a small area from a large area receiving solar radiation:-

- refraction from a big single lens or multiple lenses
- paraboloid reflector either single or heliostat type.



1000 kW solar furnace with heliostats.

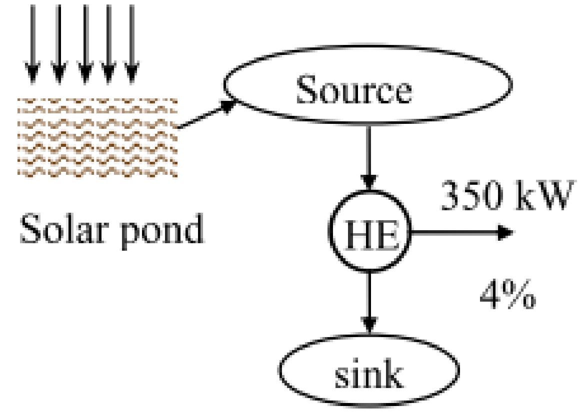
The first 1000 kW solar furnace France 1973 has 63 heliostats at 8 stages and reflected sun rays to the concentrator parallel to its optical axis.

3.6 Applications – Solar Pond

Solar energy stored in large bodies of water, called solar ponds, is being used to generate electricity. If such a solar power plant has an efficiency of 4 percent and a net power output of 350 kW, determine the average value of the required solar energy collection rate, in kJ/h.

The rate of solar energy collection or the rate of heat supply to the power plant is determined from the thermal efficiency relation to be

$$\dot{Q}_H = \frac{\dot{W}_{net,out}}{\eta_{th}} = \frac{350\text{ kW}}{0.04}\left(\frac{3600\text{ s}}{1\text{ h}}\right) = \mathbf{3.15 \times 10^7\ kJ/h}$$



3.7 Recent Development in Solar Thermal Application

The world's largest solar thermal plant recently opened in Riyadh, Saudi Arabia. The new plant is almost double the size of what was previously the largest solar thermal facility (located in Denmark), and it will generate enough power to heat water for a university of 40,000 students. GREENTecONE, an Austrian solar design company, supplied the solar panels for the project.

3.7 Recent Development in Solar Thermal Application

Saudi Arabia, the world's leading oil producer, has completed its biggest solar power plant in 2014

- To generate one-third of the kingdom's electricity needs by 2032 to save 523,000 barrels of oil per day, currently for export
- Aim to have 41,000MW of solar capacity in next two decades
- Newly inaugurated 3.5MW photovoltaic plant, kingdom's biggest but it's small in terms of global solar projects,
- Plans to spend at least $109 billion over the next 20 years on a solar power network as it moves toward a post-oil future.
- Important milestone in the development of the solar industry in the Kingdom of Saudi Arabia
- China's Suntech Power Holdings provided the 12,694 ground-mounted photovoltaic panels for the project
- Avoid becoming net fuel importers within 20 years

NB: Oil prices at more than $100 a barrel
GCC = Gulf Cooperation Council states i.e. Saudi Arabia, United Arab Emirates, Kuwait, Qatar, Oman and Bahrain; solar energy advocates

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3.7 Recent Development in Solar Thermal Application

Abu Dhabi, world's largest single-unit solar power plant, a 100MW project known as Shams-1 nearing completion in oil-rich in the United Arab Emirates

- Electricity generation capacity of 100 megawatts
- world's next renewable energy center
- Built by solar power giant Masdar,
- Designed to provide 20,000 homes with electricity.
- Follow-on projects Shams 2 and 3 are expected to produce similar amounts of electricity.
- When completed, Shams 1 will be one of the largest concentrated solar power plants in the world and the largest of its kind in the Middle East
- The solar project, initiated in 2006, will become low-carbon Madinat Masdar, Arabic for Source City,

- It will also displace 175,000 tons CO^2/ year
- Plant covers 2.5 sq/km of desert, equivalent to 285 football pitches

3.7 Recent Development in Solar Thermal Application

Qatar's national food security program is helping develop the country's solar power

- Leading exporter of liquefied natural gas
- Emirate is working to run some 1,800MW of solar energy into its power grid by 2018 or 16%-18% percent of its electricity needs.
- The GCC, following pioneering Moroccan project, launched three years ago with plans for massive solar-energy farms across North Africa supplying power for the Middle East and Europe.
- Ambitious German-led project, with an envisaged Mediterranean super-grid, has recently run into problems after Siemens and Bosch, two of the main industrial supporters, backed out and the German government lost interest.

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Problem 3-1: Solar Water Heater

A family with 5 members plans to install a solar water heater which is mainly used for bath. The hot-water temperature required for bath is 50 ℃, while the annual average temperature of cold water is 23℃. Assuming that each person needs 60 liters of hot water for taking bath a day. How much heat should be provided by the solar water heater to satisfy the family's demand for bath?

(Note: water specific heat C_p is assumed to be 1 kcal/kg-°C, water density is 1 kg / *l*.)

$$Q = M \times C_p \times \Delta T$$

$$Q = \left(60 \frac{l}{person \times day} \times 5\, person\right) \times 1 \frac{kcal}{kg \times °C} \times (50°C - 23°C)$$

$$= \left(60 \frac{\cancel{kg}}{\cancel{person} \times day} \times 5\, \cancel{person}\right) \times 1 \frac{kcal}{\cancel{kg} \times °\cancel{C}} \times (50°\cancel{C} - 23°\cancel{C})$$

$$= 8100 \frac{kcal}{day}$$

Problem 3-2: Solar Water Heater

A solar water heater is equipped with an effective collect area of $1m^2$, and the daily cumulative insolation onto the collector is 4 kWh/m^2-day in February. If the average efficiency of the solar water heater is 0.5, how many kilo-calories (kcal) of heat can be collected by this solar water heater during a day? (Note: 1cal = 4.186J = 4.186 W × s).

$$Q_c = H \times A \times \eta$$

$$Q_c = 4\frac{kWh}{m^2 \cdot day} \times 1m^2 \times 0.5$$

$$= 2\frac{kWh}{day} = 2\frac{\frac{kJ}{s}\cdot 3600s}{day} = 7200\frac{kJ}{day} = 7200\frac{\frac{1}{4.186}kcal}{day}$$

$$= 1720\frac{kcal}{day}$$

Problem 3-3: Solar Water Heater

- The minimum heat demand is 8100 kcal/day, and there is a certain solar panel which can offer a heat supply of 1720 kcal/m^2 in a day. With the absence of auxiliary heating device, calculate the required installation area of the solar panel.
- If the effective area of this solar panel is 0.8 m^2 /piece, how many pieces of solar panel should be installed to collect this heat demand?

$$A = \frac{Q}{Q_c} \qquad A = \frac{8100\, {}^{kcal}\!/\!_{day}}{1720\, {}^{kcal}\!/\!_{m^2 \cdot day}} = \underline{4.764 m^2}$$

$$\frac{4.764 m^2}{0.8 m^2} \approx 5.955 \Rightarrow \underline{6\, pieces}$$

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