Module and Array design

Module Design

A module is a group of collectors that can be grouped into parallel flow and combined series-parallel flow. Parallel flow is more frequently used because it is inherently balanced, has a low pressure drop, and can be drained easily. Figure 8.1 illustrates the two most popular collector header designs: external and internal manifolds.

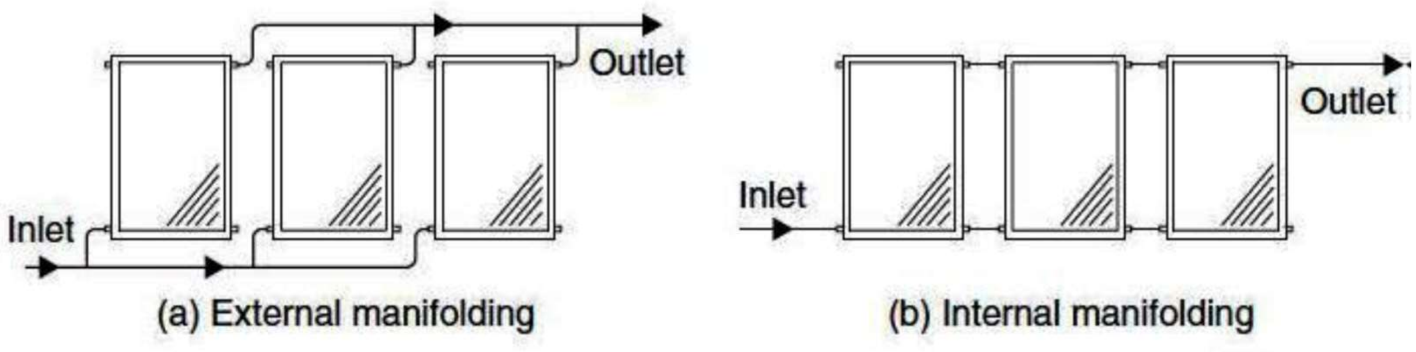


Figure 8.1 Collector manifolding arrangements for parallel flow modules

External manifold collectors are generally more suitable for small systems. **Internal manifolding** is preferred for large systems because it offers a number of advantages. These are cost savings because the system avoids the use of extra pipes (and fittings), which need to be insulated and properly supported, and the elimination of heat losses associated with external manifolding, which increases the thermal performance of the system.

Module Design

When arrays must be greater than one panel high, a combination of series and parallel flow may be used, as shown in **Figure 8.2**. This is a more suitable design in cases where collectors are installed on an inclined roof.

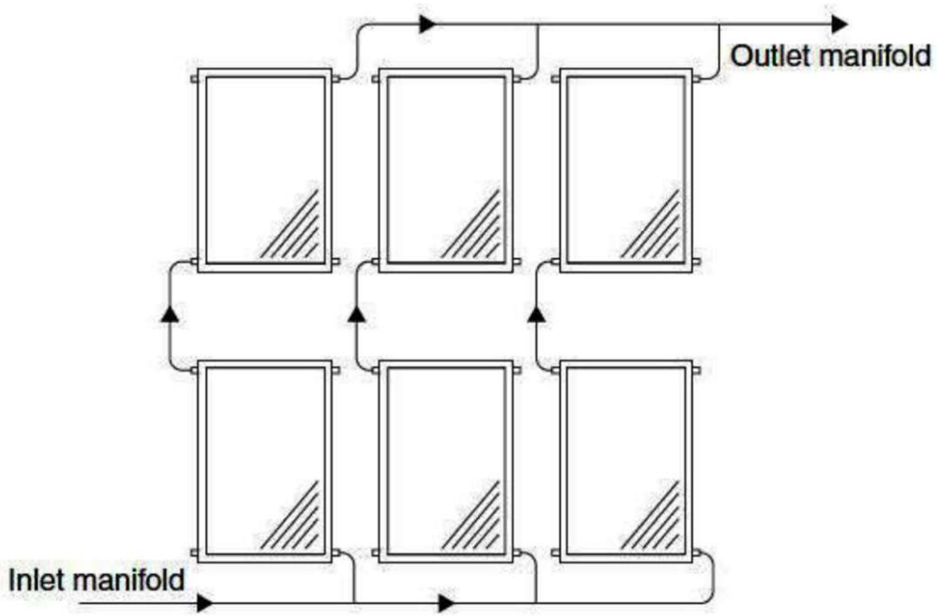


Figure 8.1 Collector manifolding arrangement for combined series-parallel flow modules

Array Design

Basically, two types of systems can be used: **direct return and reverse return**. In **direct return**, shown in **Figure 8.3**, balancing valves are needed to ensure uniform flow through the modules

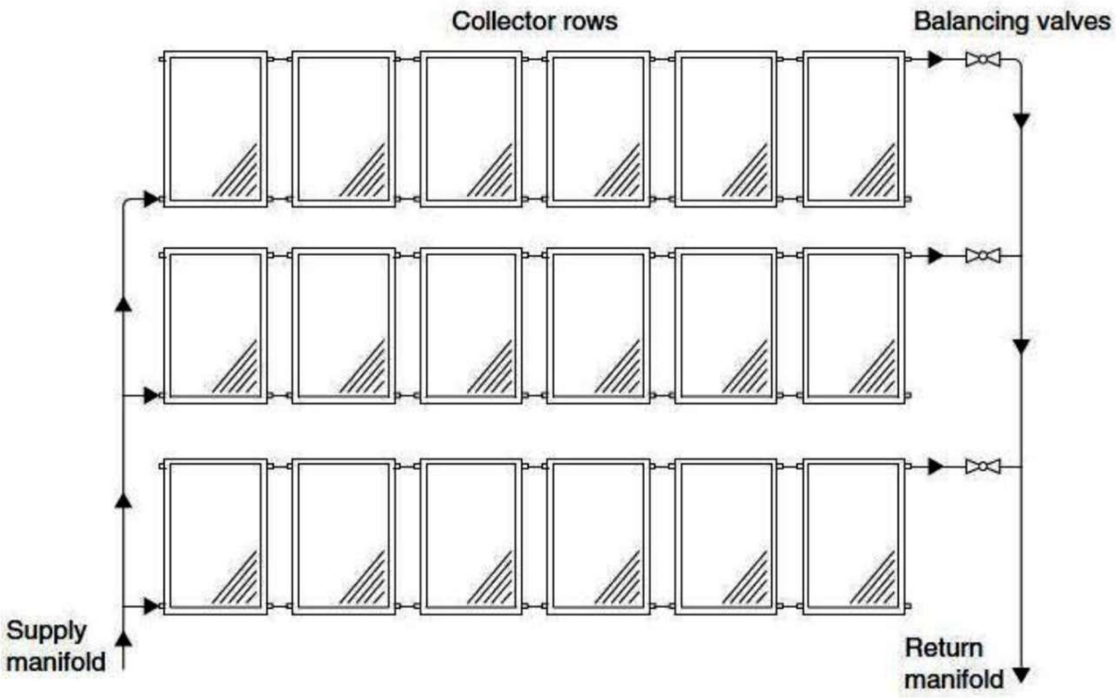
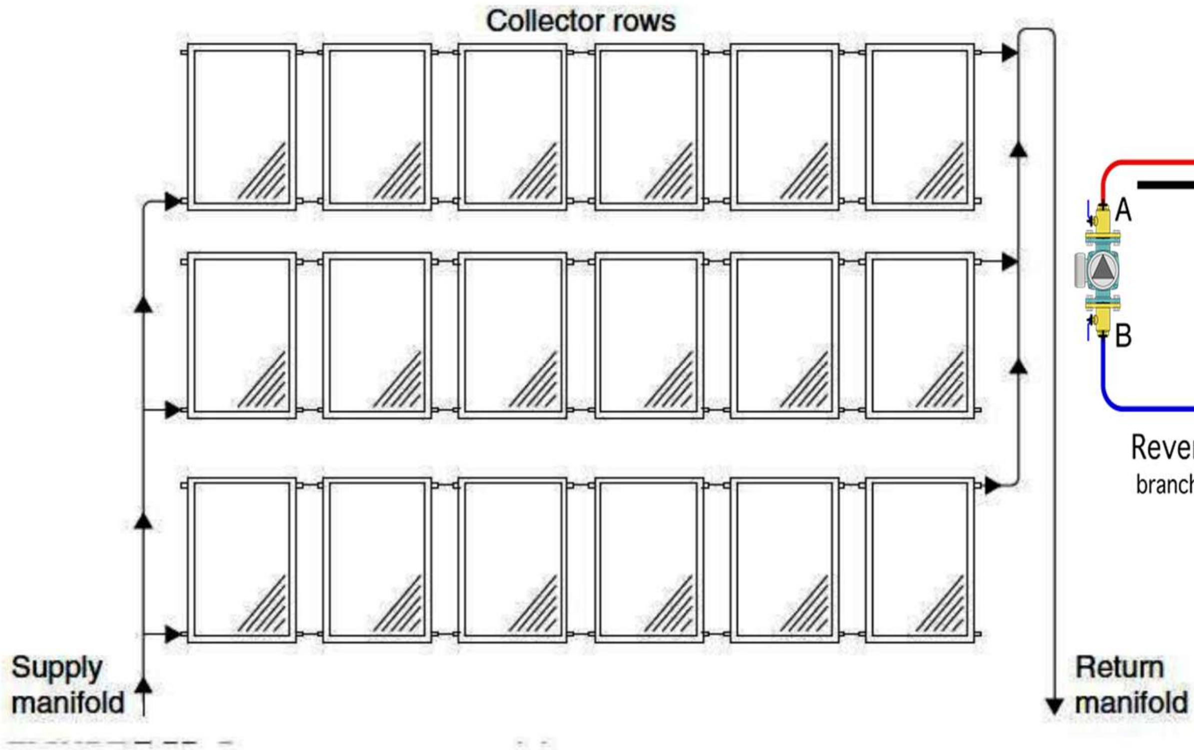
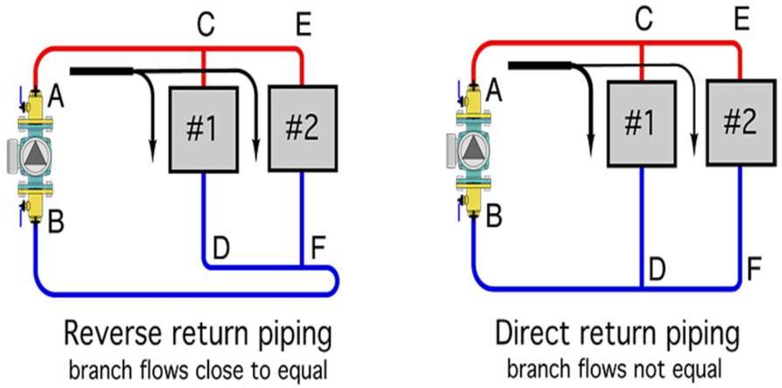


Figure 8.3 Direct-return array piping.

Array Design

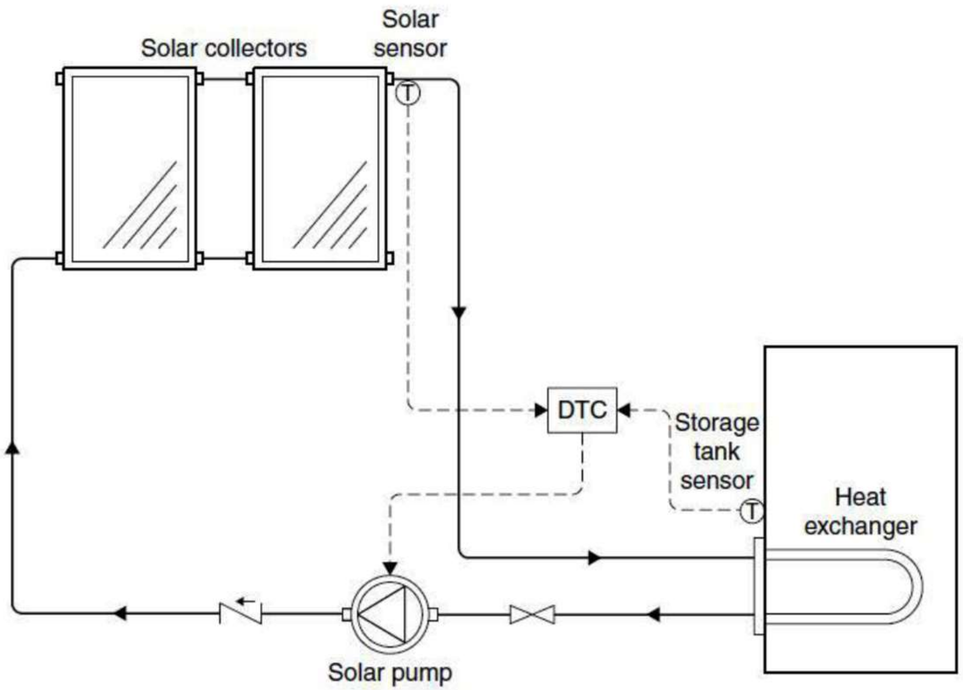
Whenever possible, modules must be connected in a reverse-return mode, as shown in **Figure 8.4**. The **reverse return** ensures that the array is self balanced, as all collectors operate with the same pressure drop

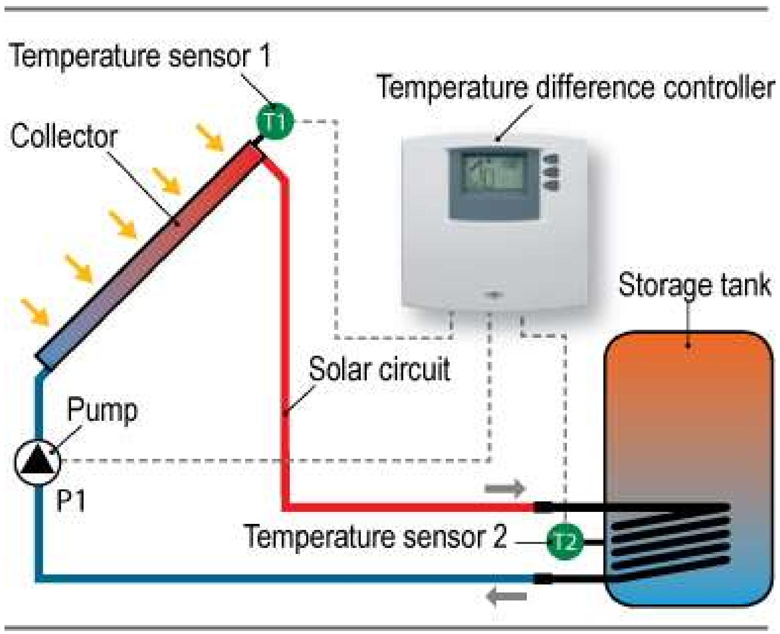




Differential temperature controller

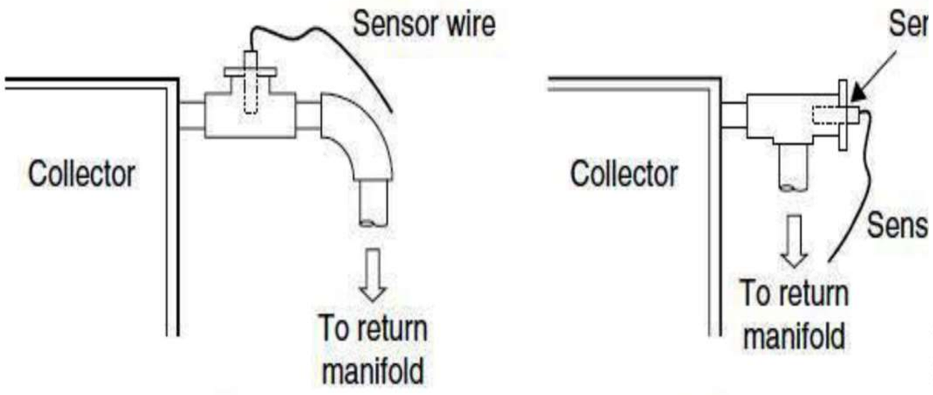
The basis of solar energy system control is the **differential temperature controller (DTC)**. This is simply a fixed temperature difference (ΔT) thermostat with hysteresis. The differential temperature controller is a comparing controller with at least two temperature sensors that control one or more devices. Typically, one of the sensors is located at the top side of the solar collector array and the second at the storage tank, as shown in Figure 8.5



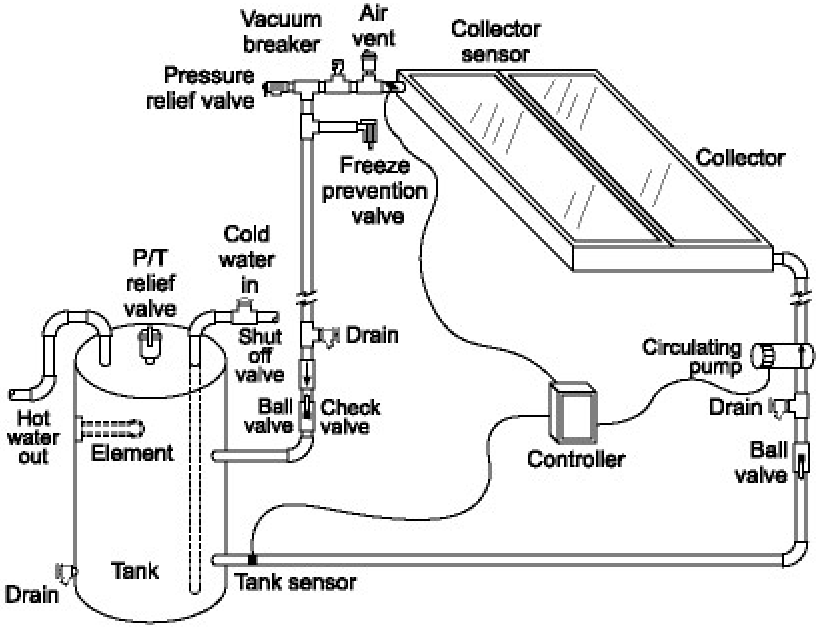


Placement of Sensors

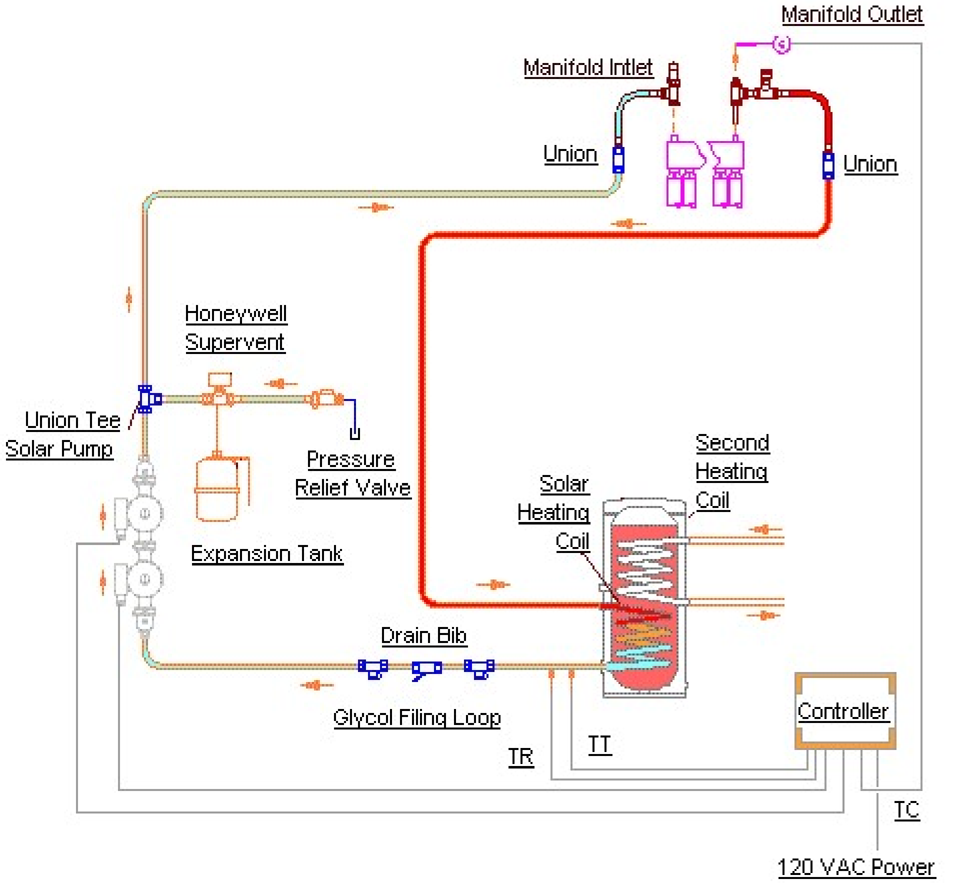
Usually a T piece is used and the sensor is placed in a deep well with a few drops of oil, which ensures good contact, as shown in Figure 8.6a, or on the side of the T piece, as shown in Figure 8.6b.



(a) Deep well (b) Side of T piece

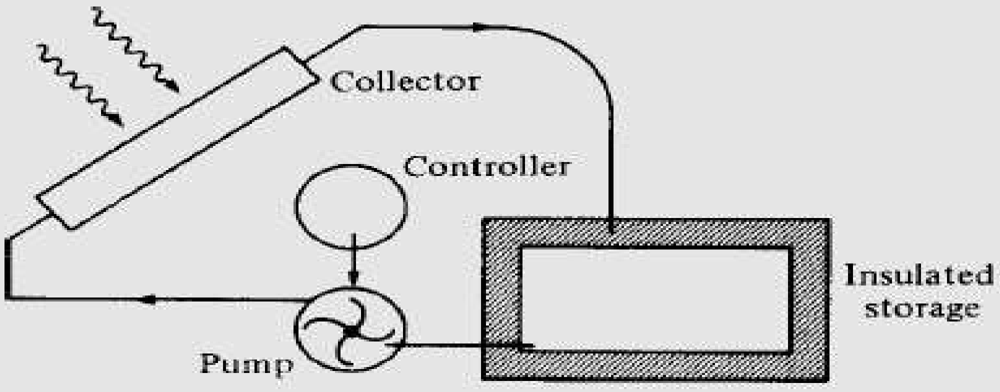


Residential Solar Hot Water and Space Heating System



Assignment

A flat plate collector measuring 2 m × 0.8 m has a loss resistance $r_L = 0.13\ m^2\ K\ W^{-1}$ and a plate transfer efficiency $\eta_{pf} = 0.85$. The glass cover has transmittance $\tau = 0.9$ and the absorptance of the plate is $\alpha = 0.9$. Water enters at a temperature $T_1 = 40\ °C$. The ambient temperature is $T_a = 20\ °C$ and the irradiance in the plane of the collector is $G = 750\ W\ m^{-2}$.



a Calculate the flow rate needed to produce a temperature rise of 4 °C.

b Suppose the pump continues to pump at night, when $G = 0$. What will be the temperature *fall* in each passage through the collector? (Assume that $T_1 = 40\ °C$, $T_a = 20\ °C$ still.)

Practical considerations

Installation of large collector arrays presents specific piping problems.

1. Pipes, Supports, and Insulation

The material of a solar energy system piping may be copper, galvanized steel, stainless steel, or plastic. All pipes are suitable for normal solar system operation except plastic piping, which is used only for low temperature systems, such as swimming pool heating.

2- Pumps

For solar energy systems, centrifugal pumps and circulators are used. Circulators are suitable for small domestic-size systems. Construction materials for solar system pumps depend on the particular application and fluid used in the circuit.

3 Valves

Using too many valves, however, should be avoided to reduce cost and pressure drop. The various types of valves required in these systems are isolation valves, balancing valves, relief valves, check valves, pressure reducing valves, air vents, and drain valves. These are described briefly here.

3.1 Isolation valves. Isolation or shutoff valves are usually gate of quarterturn ball valves.

Practical considerations

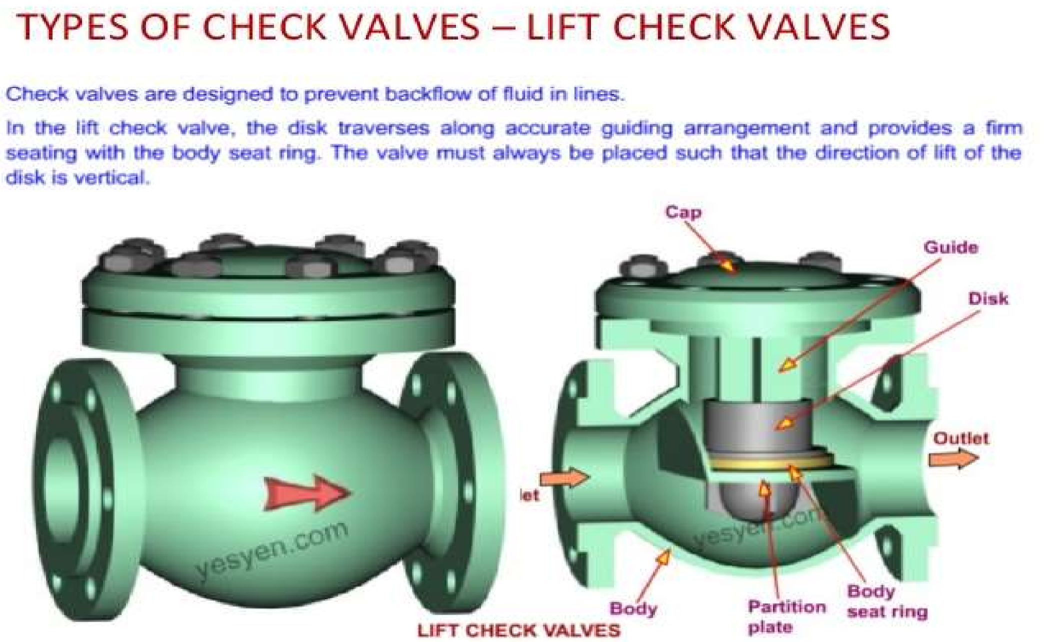
3.2- Balancing valves. Balancing or flow-regulating valves are used in multi row installations to balance the flow in the various rows and ensure that all rows received the required quantity of flow.

BALANCING VALVE WITH FLOW METER, FOR SOLAR THERMAL SYSTEMS

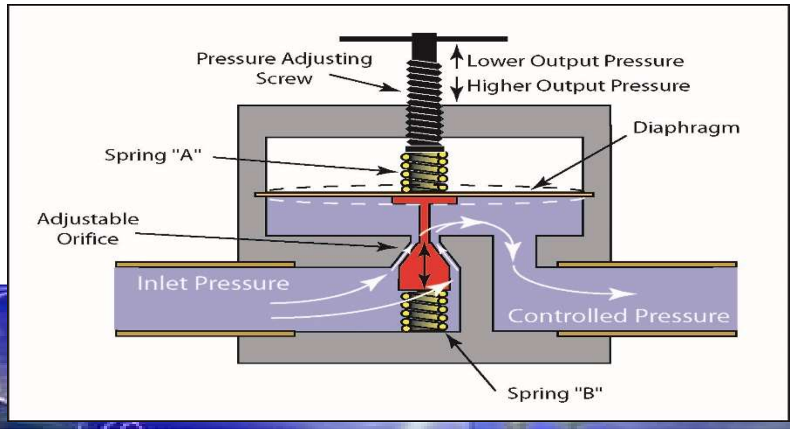
3.3- Relief valves. Pressure safety or relief valves are designed to allow esca of water or heat transfer fluid from the system when the maximum working pressure of the system is reached.

Pressure Relief Valve

3.4- Check valves. Check valves are designed to allow flow to pass in only one direction. In doing so, flow reversal is avoided



3.5- Pressure-reducing valves. Pressure-reducing valves are used to reduce the pressure of make-up city water to protect the system from overpressure.



Practical considerations

3.6- Automatic air vents. Automatic air vents are special valves used to allow air to escape from the system during fill-up

3.7- Drain valves. Drain valves are used in drain-down systems. These are electromechanical devices, also called solenoid valves, that keep the valve closed as long as power is connected to the valve (normally open valves).

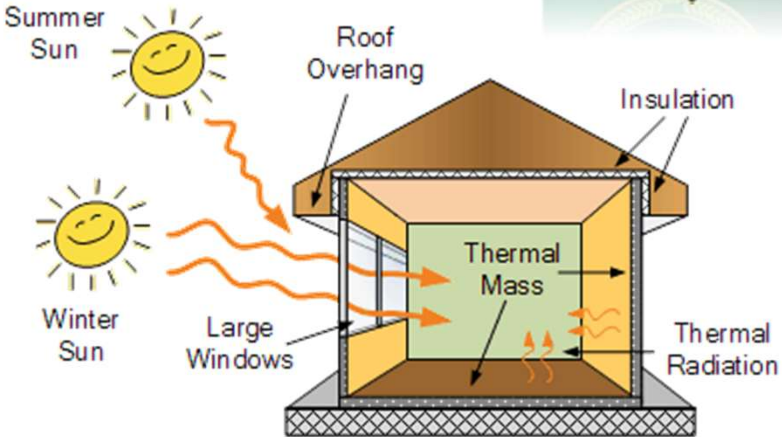
4- Instrumentation

Instrumentation used in solar energy systems varies from very simple temperature and pressure indicators, energy meters, and visual monitors to data collection and storage systems.

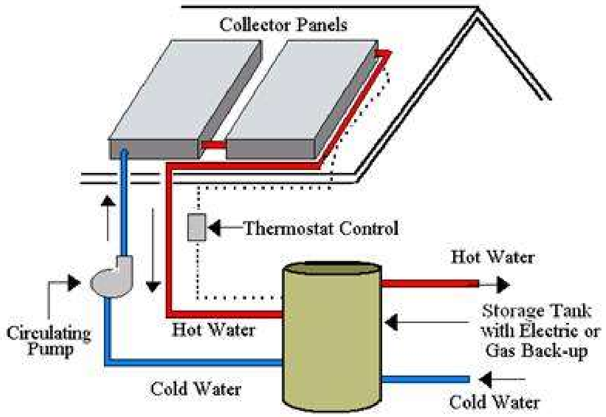
Solar Space Heating and Cooling

The two principal categories of building solar heating and cooling systems are:

1- **Passive system** is applied to buildings that include, as integral parts of the building, elements that admit, absorb, store, and release solar energy and thus reduce the needs for auxiliary energy for comfort heating.



2- **Active systems** are the ones that employ solar collectors, storage tank, pumps, heat exchangers, and controls to heat and cool the building



Active Solar Water Heating System

Solar Space Heating and Cooling

1- Thermal load estimation : three basic terms that are important in thermal load estimation are explained.

Heat gain

Heat gain is the rate at which energy is transferred to or generated within a space and consists of sensible and latent gain. Heat gains usually occur in the following forms:

1. Solar radiation passing through glazing and other openings.
2. Heat conduction with convection and radiation from the inner surfaces into the space.
3. Sensible heat convection and radiation from internal objects.
4. Ventilation and infiltration.
5. Latent heat gains generated within the space.

Thermal load

The thermal load is the rate at which energy must be added or removed from a space to maintain the temperature and humidity at the design values.

Heat extraction rate

The heat extraction rate is the rate at which energy is removed from the space by cooling and dehumidifying equipment.

Methods of thermal load estimation

1- The heat balance method
2- The transfer function method
3- Heat extraction rate and room temperature
4- Degree day method
5- Building heat transfer

2- Space heating and service hot water

Depending on the conditions that exist in a system at a particular time, the solar systems usually have five basic modes of operation:

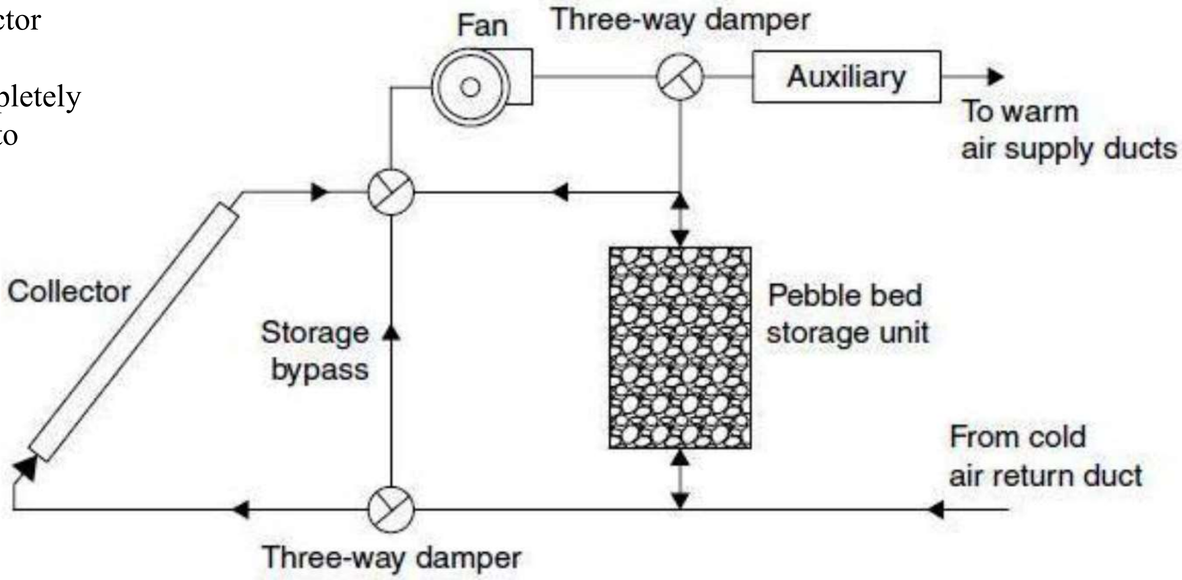
1. When solar energy is available and heat is not required in the building, solar energy is added to storage.
2. When solar energy is available and heat is required in the building, solar energy is used to supply the building load demand.
3. When solar energy is not available, heat is required in the building, and the storage unit has stored energy, the stored energy is used to supply the building load demand.
4. When solar energy is not available, heat is required in the building, and the storage unit has been depleted, auxiliary energy is used to supply the building load demand.
5. When the storage unit is fully heated, there are no loads to meet, and the collector is absorbing heat, solar energy is discarded (الطاقة الشمسية تهمل).

Solar Space Heating and Cooling

3- Air systems

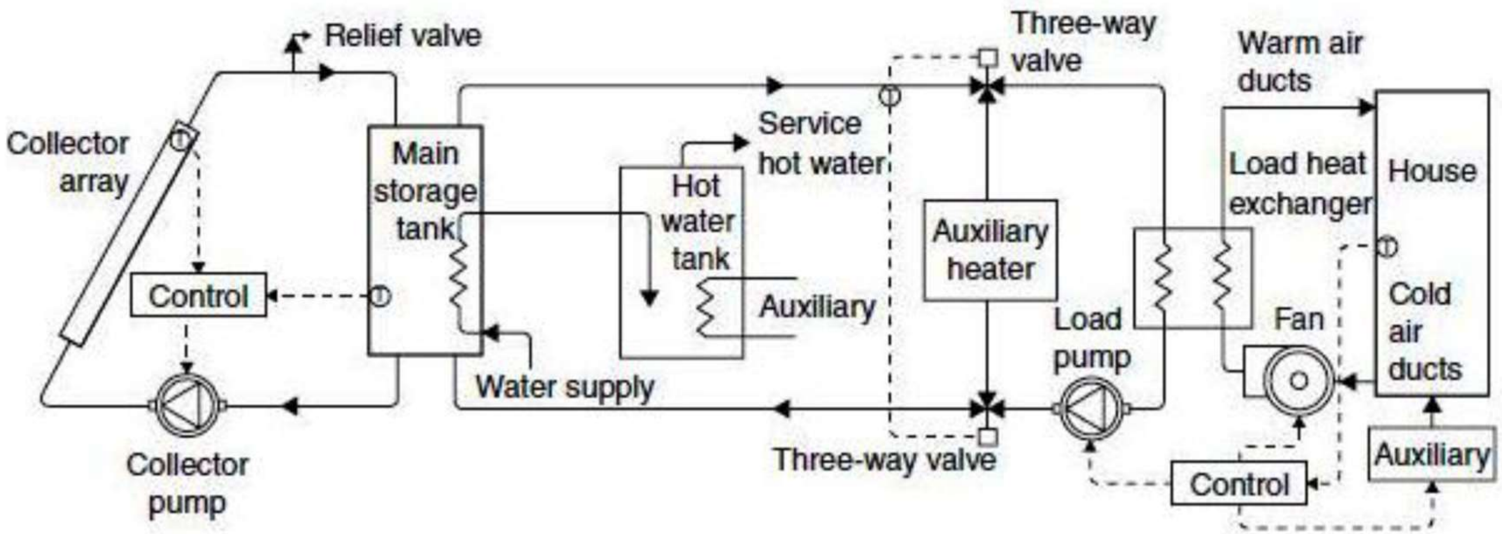
A schematic of a basic solar air heating system with a pebble bed storage unit and auxiliary heating source is shown in **Figure 4.1**.

It is also possible to bypass the collector and storage unit when there is no sunshine and the storage tank is completely depleted and use the auxiliary alone to provide the required heat



Solar Space Heating and Cooling

4- Water systems Many varieties of systems can be used for both solar space heating and domestic hot water production



A schematic diagram of a solar heating and hot water system is shown in **Figure 4.2**. Control of the solar heating system is based on two thermostats: the collector storage temperature differential and the room temperature. The collector operates with a differential thermostat.

Solar Space Heating and Cooling

5- Location of auxiliary heater

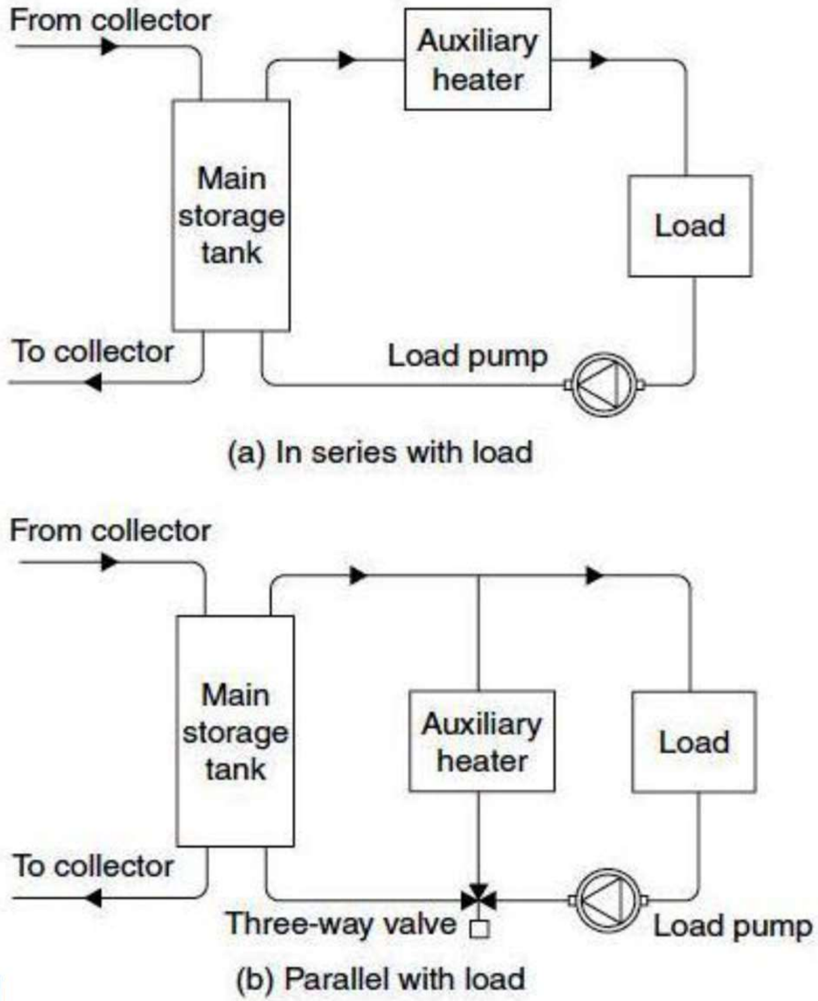


Figure 4.3 Auxiliary energy supply in water-based systems.