Installer'sManual
SolarWaterHeatingSystems

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Unit 1: Introduction to Solar Energy

1.1 Solar energy

Solar energy is the sun's radiation that reaches the earth. It is the most readily available source of energy. The sun is the earth's power station and the source of all energy on our planet. We use the solar energy every day in many different ways. When we hang washed clothes outside to dry in the sun, we are using the solar heat to do work, drying our clothes. Plants use the solar light to make food. Similarly, solar panels absorb the energy of the sun to provide heat for cooking and for heating water.

1.2 The need to use solar energy

As the population in India is growing and the pace of development is increasing, energy is becoming more expensive and our cities and towns face a major power crisis. The reality is that resources like coal, oil and natural gas will not be around forever. We all realise today, that we need alternatives sources of energy that are renewable. Renewable energy is derived from natural resources such as sunlight, wind, tides and geothermal heat. Solar energy or energy powered by the sun is one of the most promising future renewable energy sources.

1.3 Basic Principle

Solar energy consists of light and heat emitted by the sun, in the form of electromagnetic radiation. Technology today helps to capture this radiation and turn it into usable forms of solar energy -

such as heating or electricity.

Thus energy from the sun can be categorized in two ways:
(1) In the form of heat (or thermal energy), and

(2) In the form of light energy.

Solar energy can be converted to thermal (or heat) energy and used to:

- Heat water – for use in homes, buildings, or swimming pools.
- Heat vessels – for cooking food
- Heat spaces – inside greenhouses, homes, and other buildings.

Solar thermal technologies are devices that use the solar heat energy to heat substances (such as water or air) for applications such as solar cooker, water heaters and pool heating. There are a variety of products available in the market that use solar thermal energy. Often the products used for this application are called solar thermal collectors.

Solar energy can be converted to electricity in two ways:

- Photovoltaic (PV devices) or "solar cells" – change sunlight directly into electricity.
- Solar Power Plants - indirectly generate electricity when the heat from solar thermal collectors is used to heat a fluid which produces steam that is used to run turbines to generate power.

1.4 Factors to consider for using solar energy

A few factors which need to be looked at when determining the viability of solar energy in any given location are the following:

- Geographic location
- Time of day

- Season
- Local landscape
- Weather conditions

Geographic location

Geographic location plays a vital role in harnessing solar energy. India is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun. In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The country has the capacity to receive 4500 trillion kWh of pure solar energy each year. This allows solar energy in India to be a viable option.

The highest annual global radiation is received in Rajasthan and northern Gujarat. In Rajasthan, large areas of land are barren and sparsely populated, making these areas suitable as locations for large central power stations based on solar energy.

Time of Day

Solar energy is at its peak at mid moon. A solar energy system works in the morning and in the late afternoon. It however reaches its maximum efficiency around noon time.

Season

A solar energy system is more efficient during summers than in winters when the days are shorter.

Local landscape

A solar energy system has to be installed in an open area unaffected by shade. If even a small section of the system is shadowed, the efficiency reduces. This is the reason why solar energy systems are

placed mostly on roofs. Even in this case, care needs to be taken to ensure that no tall trees or taller neighbouring buildings cast a shadow on the system.

Weather conditions

Weather conditions have a large impact on the energy output of the solar energy system. Cloud cover, rain, snow, fog and smog all reduce the amount of sunlight that reaches the system. The system will work but its efficiency will be greatly reduced.

1.5 Measuring Solar Energy

Radiation data (the amount of solar energy available at a given location) for solar electric (photovoltaic) systems is often represented as kilowatt-hours per square meter (kWh/m2). Direct estimates of solar energy may be expressed as watts per square meter (W/m2).

1.6 Applications of solar energy

There are a variety of technologies that have been developed to take advantage of solar energy. The technologies are classified as passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. **Passive solar** technology uses sunlight for energy without active mechanical systems. Such technologies convert sunlight into usable heat (water, air, thermal mass), cause air-movement for ventilating, or store heat for future use, without the assistance of other energy sources. While costs associated with operating these products may be limited or nil, maintenance costs are very low.

Unit 2: Solar Thermal Energy

2.1 Solar collectors

Solar thermal energy is the technology used for harnessing solar energy for thermal energy (heat). A *solar thermal collector* captures the radiant energy from the Sun and converts it into heat. The most basic type of collector is the solar cooker. And the most common type of solar collector is the roof-mounted domestic hot water system. Solar collectors are a cheap and effective means of converting sunlight into thermal heat.

2.2 Working principle of a solar collector

A solar collector works on the principle of converting solar energy into heat by taking advantage of a process known as the *greenhouse effect*.

The basic idea is that the *solar energy* passes through a layer of glazed glass where it is absorbed by the underlying material. The solar energy excites the molecules in the underlying material resulting in heat. The glazing of the glass prevents the heat from escaping, thereby effectively capturing the heat.

Once that heat is captured we can put it to good use! But in order to use it, you first need to understand some of the basic principles of heat.

2.3 What is heat?

Heat is simply a form of energy associated with the motion of molecules.

When the *electromagnetic waves* coming from the Sun hit an object, they excite the molecules of that object causing them to move. This molecular movement is *heat*.

Heat is always moving from higher to lower temperatures until the temperatures are equal. This is known as **heat transfer**. If you place two objects next to each other, the warmer object will cool down as its heat is transferred to the cooler object. The cooler object in turn will warm up.

This *heat transfer* is driven by the difference in temperatures of the objects. The *heat transfer rate* is proportional to the difference in temperature. The larger the difference in temperature between the objects, the faster the heat moves.

Understanding Heat Movement

To really understand *solar thermal energy*, you need to understand about heat movement. This is especially important for passive solar energy applications.

There are three basic physical ways that heat moves:

- Conduction
- Convection
- Radiation

Conduction is the transfer of heat through a solid material, or from one material to another where their surfaces are touching. Heat is conducted more easily through a solid material than through layers of material, even when the layers are held together tightly. This is important as the conduction of heat through building materials is a major source of heat loss.

Convection is the transfer of heat by a moving fluid, usually air or water. Natural convection is caused by the heating and cooling of the air in a room as it contacts objects. As air is warmed, it expands resulting in it having a lower density than the cooler air around it. Since its density is lower than the cool air, it will rise. As the air cools, its density increases and it will sink, starting the process all over again. This movement of air is known as convection current.

Radiation is the transfer of energy via electromagnetic waves. The transfer of energy from the sun across nearly empty space is accomplished primarily by radiation. Radiation occurs without the involvement of a physical substance as the medium. The sun emits many forms of electromagnetic radiation in varying quantities.

Darker-colored objects **absorb** more visible radiation, whereas lighter-colored objects **reflect** more visible radiation.

The figure given below summarises the different mechanisms of energy transfer.

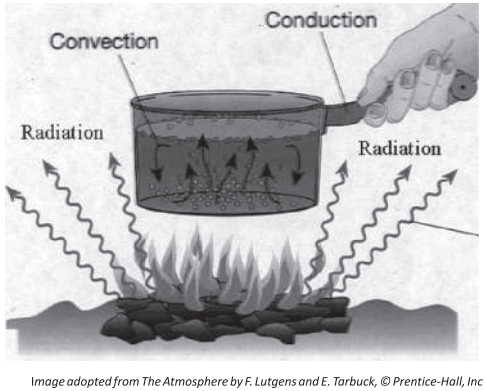


Image adopted from The Atmosphere by F. Lutgens and E. Tarbuck, © Prentice-Hall, Inc

2.4 Solar thermal energy applications

2.4.1 Water heating

The most common use for solar thermal technology is for domestic water heating. Hundreds of thousands of domestic hot water systems are in use throughout the world.

2.4.2 Solar cooking

Solar cookers fall into two main categories -solar box and direct solar concentrators. The basic design for a solar box is that of a box with a glass cover. The box is lined with insulation and a reflective surface is applied to concentrate the heat onto the pots. The other approach is to reflect the sunâ€˜s rays onto a pot, often with a parabolic dish. The pots can be painted black to help with heat absorption.

The main advantage to solar cookers is that wood does not need to be purchased or collected, which is often a very time consuming activity for women.

Many variations of solar cooker have been developed from the very basic reflective ca rd boa rd sheet box to the very sophisticated large-scale institutional and commercial solar cookers now being used in India.

2.4.3 Solar drying

Controlled drying is required for various crops and products, such as grain, coffee, tobacco, fruits vegetables and fish. Solar thermal technology can be used for this purpose. The main principle of operation is to raise the heat of the product, which is usually held within a compartment or box, while at the same time passing airthrough the compartment to remove moisture.

The flow of air is often promoted using the 'stack' effect which takes advantage ofthe fact that hot air rises and can therefore be drawn upwards through achimney, while drawing in cooler air from below. Alternatively a fancan be used.

Solar crop drying technologies can help reduce environmental degradation caused by the use of fuel wood or fossil fuels for crop drying and can also help to reduce the costs associated with these fuels and hence the cost ofthe product.

2.4.4 Desalination / Distillation

Basic solar stills can be used to purify water in remote regions wherecontaminated water is present. They can be used to remove impurities such as fluoride and salts to produce drinking water.

The basic still is made of a glass or transparent plastic cover and a shallow tray ofwater which has a black backing to trap energy. When the sun heats the water up within the still water evaporates which then condenses on the underside of the covering glass. The glass is at an angle so the water drains off and is captured in a trough separate to the contaminated water.

Solar distillation can be combined with other useful functions so that a solar still may also be used for rainwater harvesting if modified slightly.

2.4.5 Solar Pasteurization

In pasteurization, water is heated to 65°C for about six minutes,killing all the germs, viruses, and parasites that cause disease in humans, including cholera and hepatitis A and B. This is similar to what is done with milk and other beverages. It is not necessary to boil the water as many people believe. Pasteurization is not the only way to decontaminate drinking water, but it is particularly easy to scale down so that the initial cost is low.

2.4.6 Solar thermal energy in architecture

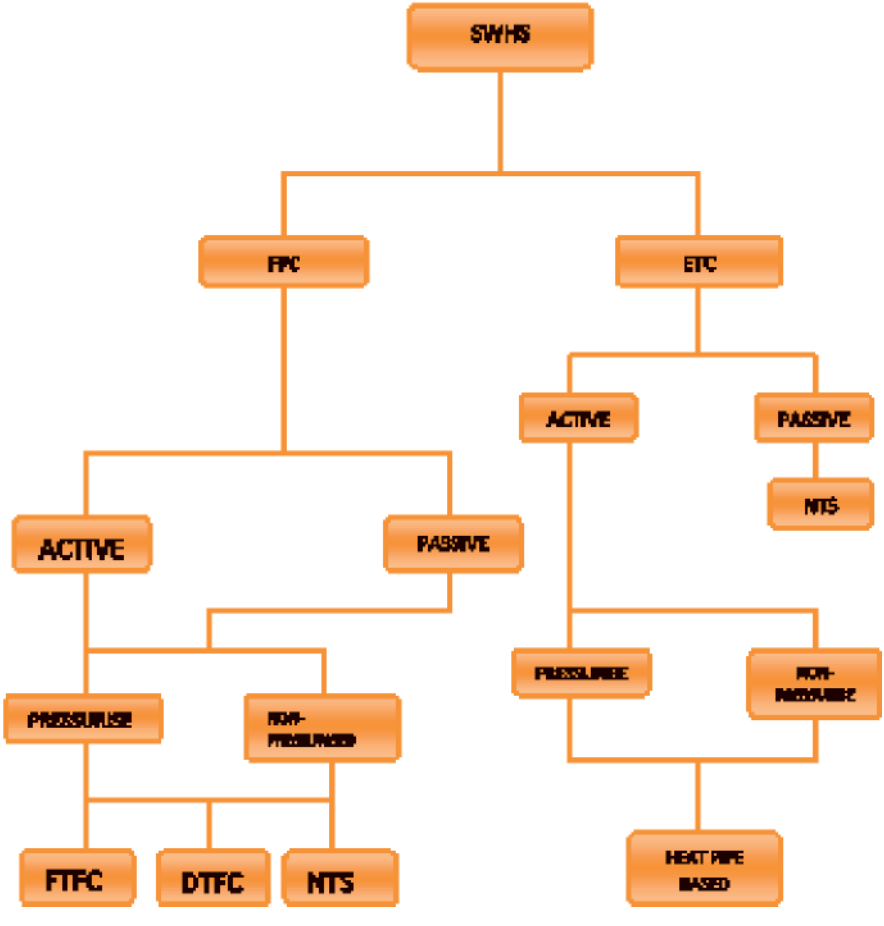
Providing comfortable buildings, while reducing the use of conventional fuels and electricity, can be obtained through solar passive architecture. Solar Passive Architecture involves blending architectural principles and solar energy to design interiors which remain warm in winter and cool in summer, thus providing year-round comfortable indoor environment. Solar designs can save upto 90% ofthe energy required to cool or heat a building. The benefit of solar energy is utilized through designing energy efficient buildings. Here specific attention is directed to the site and location of the dwelling, the prevailing climate, design and construction, solar orientation, placement of glazing-and-shading elements, and incorporation of thermal mass.

Unit 3: Solar Water Heaters (SWH)

Unit 3 Solar Water Heaters (SWH)

3.01 Solar Water Heating Systems

CLASSIFICATION OF SWH:



A solar water heating system is a device that uses solar energy to heat water for domestic, comercial, and industrial needs. Heating of water is the most common appication of solar energy in the world. A typical solar water heating system can save upto 1500 units of electricity every year, for every 100 litres per day of solar water heating capacity.

Type of collectors:

1. Flat Plate Collector
2. Evacuated Tube Collector

1) Flat plate collector

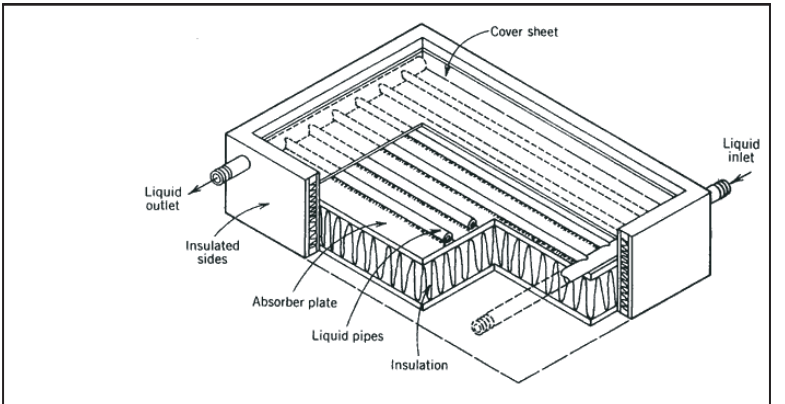


Fig. 3.1

Frame: collector's insulating case that is enclosing the glass.

Glass: Transluscent covering (glass, fibre glass, polycarbonate) that allows solar radiation to pass through; the heat produced is trapped in the collector.

Absorbing plate: selectively coated metallic sheet that harnresses heat from solar radiation and transfers it to the coolant fluid.

I**nsulation:**Material placed on three sides of the absorbing plate inside the frame to reduce heat loss.

Flow Tube: Tube containing a coolant(water/air) that is used to recover and carry heat from the absorbing plate.

3.2 Basic working Principle:

The basic principle of a solar hot water heater is that the water passes through a solar collector that heats the water. the solar collectors are exposed to sunlight and this energy is used to heat the water. the water then passes to an insulated storage tank that conserves the heated water for later usage.

There are two variations based on this principle:

Active and pasive systems.

The active system uses a pump to move the water from the collectors to the storage tank.

The passive system has no power source to move the water but moves it through gravity.

Advantages of this system are:

- Cost effective
- Self operating - no attendance required
- No need to have power for operation / No sophisticated instruments
- No moving parts hence no wear & tear / maintenance

Limitations / Disadvantages:

- Limitation of the size / capacity of system. Beyond 3000LPD, the flow becomes sluggish and efficiency is reduced
- Rigid rules for the system construction. e.g. Overhead cold-water tank having minimum head, hot water tank to be above the panels only etc
- Cold water is mixed in the hot water every time the hot water is drawn. This results in less output than the designed capacity.

Flat plate colectors based Solar Water Heaters:

here, the solar radiation is absored by flat plate collecors which consist of an insulated outer metallic box covered on the top with glass sheet.

Inside, there are selectively coated metallic absorber sheet with riser tubes to carry water. The absorber absorbs the solar radiation and trand=sfers the heat to the flowing water.

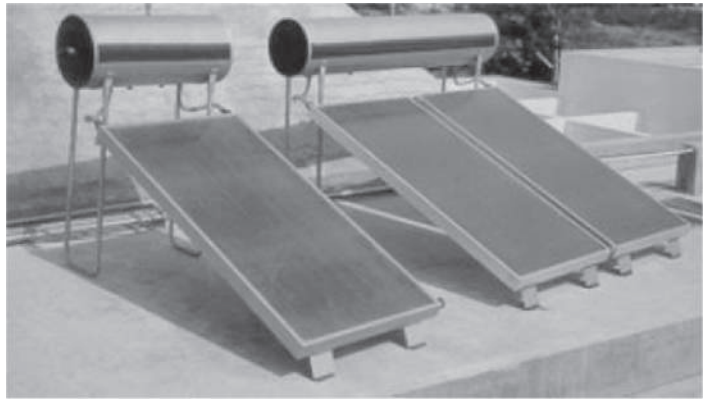


Figure: *Flat Plate Collector based Solar Water Heaters*

Design

A solar water heating system consists of (1) flat plate solar collector, (2) insulated storage tank kept at a height behind the collector, (3) insulated hot water carrying pipes and (4) cold water carrying pipes. The system is generally installed on the roof or on open ground, with the collector facing the sun and connected to a continuous water supply.

The flat plate collector comprises of: (1) front glass glazing (2) blackened metallic (copper) absorber sheet with built-in channels or riser tubes welded to it to carry water. The entire assembly is placed in a flat metallic box. In certain models, evacuated glass tubes are used instead of copper; a separate cover sheet and insulating box

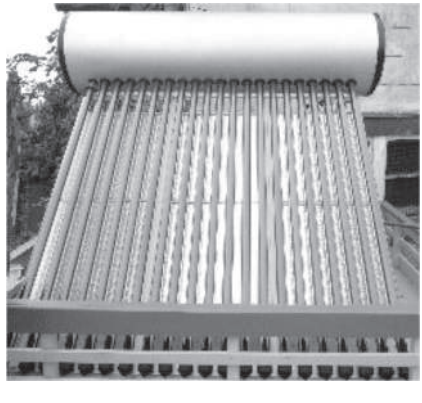
are not required in this case.

Water flows through the tubes, absorbs solar heat, and is stored in a tank. The hot water so stored can be used for various applications at homes, such as bathing, cleaning, and washing. It can also be used for a variety of industrial applications. The water stored in the tank remains hot overnight as the storage tank is insulated and heat losses are small. Flat-plate solar collectors are manufactured in India; however, the tubes for evacuated tube collectors are imported. So far, about 40 Lakh square metres of collector area has been installed in the country.

3.4.2 Evacuated Tube Collector (ETC) based Solar water heater

Here the collector is made of double layer borosilicate glass tubes evacuated for providing insulation. The outer wall of the inner tube is coated with selective absorbing material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube.

The capital cost is less as compared to Flat Plate Collector based system. The ETC tubes are better suited for use in hard water conditions- as they are less prone to the effects of scaling.



Solar water heating system are classified in 2 types based on the circulation of water.

a) Thermosyphon system.

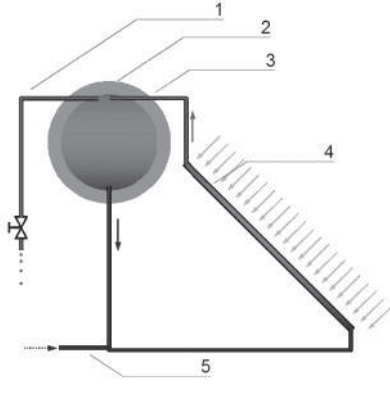
b) Forced flow or forced circulation system.

3.4.3 **Domestic solar water heating system**

) NATURAL THERMO SIPHON (NTS):

This is the simplest way of operating a SWHS and hence is popular. Hot water becomes lighter and has a tendency to rise. The cold and hence heavier water at the bottom of the solar flat plate collector pushes the hot water up; it gets collected in the hot water storage tank. The cold water due to gravity fills up the vaccum created by the hot water pushed up. This cycle continues till adequate heat from the sun is available during the day.

Most domestic solar water heaters are provided with electrical back-up. Electrical heating elements are usually placed in the storage tank and can be switched on during cloudy days. In some cases, the solar-heated water is led into an existing electric geyser; the geyser needs to be switched on only in cloudy conditions. Most domestic systems are in the capacity range of 100– 500 litres of hot water per day.



Advantages of this system are:

- Cost effective
- Self operating - no attendance required
- No need to have power for operation / No sophisticated instruments
- No moving parts hence no wear & tear / maintenance

Limitations / Disadvantages:

- Limitation of the size / capacity of system. Beyond 3000LPD, the flow becomes sluggish and efficiency is reduced
- Rigid rules for the system construction. e.g. Overhead cold-water tank having minimum head, hot water tank to be above the panels only etc
- Cold water is mixed in the hot water every time the hot water is drawn. This results in less output than the designed capacity.

3.4.5 Forced circulation system:

In the forced flow system, a pump is used for circulating water between the collectors and the insulated hot water storage tank. The forced flow systems are more efficient as compared to thermosyphon systems due to higher flow rate. Generally, the pumps are operated by differential temperature control (DTC) system, which senses the pre-setting temperature difference between inlet and outlet of the collectors.

B) Fixed Temperature Forced Circulation (FTFC) System:

In this, the hot water from the panels / collectors is pumped to the storage tank, on reaching the preset temperature only. The pump operation is automatic. When the hot water is pumped, the cold water pumped in fills the vaccum. The pump automatically stops on sensing the temperature at the outlet sensor point being lower than the preset value. This way the system operates during the day.

Advantages of this system are:

- No limit on the size of the system
- Flexibility in system installation
- Guaranteed temperature output
- Better efficiency
- Reduced cost of superstructure / separate overhead tank

Limitations / Disadvantages:

- Needs continuous electricity for system operation
- The electronic controls may require periodical maintenance

Differential Temperature Forced Circulation (DTFC) System:

This system works on the principle of Differential Temperature. Whenever the difference between the temperature at the collector

array outlet and the tank bottom is higher than the preset value, the pump circulates the water imparting the heat from the collectors ton the water in the tank. This way the total system capacity is heated through out the day. The pump stops automatically once the temperature difference is within the preset value.

Advantages of this system are:

- No limit on the size of the system
- Flexibility in system installation
- Guaranteed system output
- Better efficiency

Limitations / Disadvantages:

- **Needs continuous electricity for system operation, which can be connected through generator back up / inverter**
- **The electronic controls may require periodical maintenance**

3.4.6 Site selection

Site conditions are important. Collectors should face directly south as we are in the northern hemisphere. Turning a collector southeast or southwest can affect its performance by about 20% or more. If hot water is needed by noon, face the collector to the southeast; if hot water is more important in late afternoon, face the collector to the southwest.

The site should be free from shade. Collectors should be placed so

that they can be tilted from the horizon to an angle equal to the latitude of the location. For better output in winter the angle of inclination should be latitude + 15 degree. If the latitude is unknown, the collector can be placed at a 45[degrees] angle, except in areas near the equator). The latitude for your area can be obtained from an atlas or globe.

3.4.7 The systems can also be classified as direct heating and indirect heating type

3.4.8 Procedure for Operation and Maintenance

Before starting the system, do the following:

1. Check water in the cold water supply line and also storage tank. In case there is no water, fill the tank with water. The system should never be operated if water is not available. Without water the pump will be damaged. A thermosiphonic system will not deliver hot water at the point of use if there is no continuous supply of cold water.
2. Check the collector glazing. It should not be dirty. In case dirt is deposited on the glazing it should be cleaned.
3. Open all the control valves as suggested by the supplier
4. Check electrical supply.
5. Check the water pump. It should not be jammed.
6. Check whether the Non Return Valve (NRV) on the cold water

inlet side is working.

7. Ensure the lever of mixer in the bathroom is on either left or right side AND NOT IN THE MIDDLE to avoid mixing of hot / cold water.

Operation of the Solar Water Heater

1.After ascertaining that the requirements indicated above are fulfilled, start the circulating pump. The water will start circulating in the collector system and after getting heated will be collected in the storage tank. The temperature of water in the storage tank will rise which can be seen in the temperature indicators provided in the system. There is a possibility of air locking in collector riser tubes and headers which can be released by increasing the flow of water by opening control valves. As soon as the control valves are opened beyond the limits suggested, water will start coming out from the air vents. Keep the valves in this position for some time and then bring them to their original position or as soon as water stops coming out of the air vents.

2.In a thermosiphonic system hot water will start collecting in the storage tank as soon as sunlight falls on the collector and water is available in the system.

Maintenance of the SWH

i. Remember to keep the collector at a 45[degrees] angle if the latitude of your area is unknown.

ii. The hot water will rise to the top of the tank. When all of the

water is to be used, it can be drained from the faucet; when only a small amount of water is needed, the hottest water can be taken from the top of the tank.

iii. Whenever water is being heated, the water level should be kept above the tank's upper hose connector to allow the water to circulate or the thermosyphon system will not work.

iv. Lubricate the motor periodically to avoid any damage due to high friction.

v. Protect the pump from exposure to dirt and rain.

vi. The water heater works best when the connecting hoses are as short as possible.

vii. Rubber hoses may have to be replaced every two or three years. If metal other than galvanized sheet metal is used, such as untreated sheet metal, the lifespan of the system will be shortened considerably due to rust. Once the collector starts to rust, it must be replaced.

viii. Untreated sheet metal can be painted with several coats of rustproof paint if it can be obtained. However, you should check the painted area in six months to make sure it is not peeling off. It is also helpful to wrap the tank in insulation materials.

ix. Clean the glass once a month for best results. And if you live in a hard water area, descaling process once every year is recommended. Scaling is the build up of mineral deposits in the pipes. Deposition of hard scales in the absorber tubes of flat plate collectors is a serious problem. It not only reduces

the efficiency of operation, but may eventually prevent heat absorption totally. By flushing the system out periodically scaling can be prevented (only if water is hard). Titanium micro technology coating prevents formation of rust and scales in the piping.

x. To begin using the solar water heater, make certain the tank is 46cm above the top of the collector, to give proper circulation of water. Fill the tank with clean water. Check for leaks.

xi. Use cross-linked polyethylene composite pipes, as it is a non-stick material and also has very low thermal conductivity minimising heat loss.

4.0 SYSTEM INSTALLATION:

Considerations:

1. Site Survey Notes: The installer has to visit the site in order to study the site conditions. He has to prepare a brief note enabling him to design the system layout accordingly.

The important points to be noted during the site visit are as follows -
a. Marking the South Direction.

b. Estimating the piping quantities required based on the shortest piping route.

c. Marking the shadow pattern and finding the shadow free region.
d. Studying various options for system installation and choosing the best.

2. Marking Lines: The installer has to do the marking of the systemlayout with precise dimensions, so as to aid him in the actual installation process. This ensures that the collectors are oriented properly, as well as reduces the plumbing required (in the sense that unnecessary piping is avoided). The system installer must mark the collectors and tank diamensions on the terrace and ensure the same is in straight line/level and orientation. The angle of inclination will depend on the site and application.

3. Bill of Material: The installer has to prepare a BoM (Bill of Material) so as to avoid delays in installation. The BoM helps the installer in carrying the exact required amount of material to the site, thus avoiding wastage of material, handling and ensuring a quick and smooth installation.

4. Tools required: The installer must prepare a list of the tools required at each specific site along with the BoM. This helps in avoiding interruptions in the installation process due to lack of proper tools and results in professional quality work apart from safety.

5. Step-by-step installation procedure: The step-by-step installation procedure is described below (Pl. refer Photograph plates)
a. Lifting/hauling of the system and accessories on the roof.

b. Marking the system layout with chalk on the terrace.

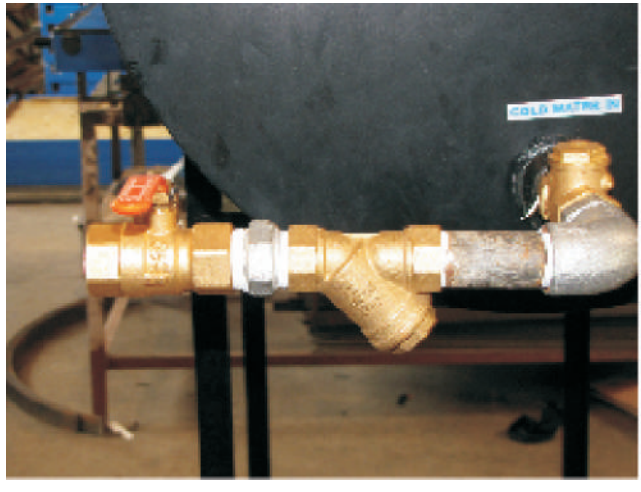
c. Unpacking and cleaning of the system.

d. Assembly of the tank stand and installation of the hot water tank with vent/ Air Release Valve.

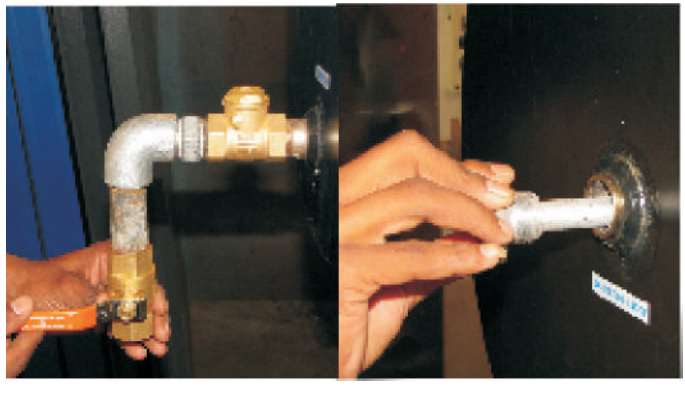
d. Assembly of the tank stand and installation of the hot water tank with vent/ Air Release Valve.

e. Assembly of the collector with stand and installation.

f. Connection between collectors and tank (hose/system piping)



g. Connection of cold water inlet including strainer, Non Return Valve and Ball Valve to the tank and hot water user piping from the tank.



l. Complete the clipping/clamping of piping after insulation and cladding and connect to user points through Non Return Valves.

h. Install the overhead cold water tank and make connections for cold water inlet, overflow and outlet to the hot water tank inlet. Provide air vent, Ball cock/ level sensor probes as applicable. (Only when required to be added)

i. Install and connect the electrical back up heater coil/s.

j. Ensure that all joints are properly tightened and check for leakages by allowing the cold water to the system.

k. Anchor the collectors and tank stand by anchor fasteners or by providing concrete pedestals of adequate size.

m. Check the complete system for performance and leakages including the piping and availability of hot water at the user points.

n. Demonstrate the system working to the user and explain the system working and upkeep requirements.

6. **Right/Wrong procedure:**

Activity	**Right way**	**Wrong way**
System orientation	Facing true south	Off south or parallel to the building parapet
System- Angle of inclination(AOI)	Decide as per the latitude of the location/city, hot water application and specific site requirements.	Wrong angle. E.g. for bathing system as maximum hot water is required during winter, the AOI should be latitude plus 15 Degree. For all round the year fixed performance, the AOI should be same as latitude and for more output in summer, the AOI should be latitude minus 15 degree.
System location	Check for the shadow pattern during winter	Normally the installers check for the period

System Location (cont.)	and also care for the morning and afternoon movement of Sun	when the system is being installed. This results in poor system performance during the different seasons.
Cold water Inlet piping	Install a strainer on the inlet piping to filter the sediments and avoid clogging of the collector header affecting the water circulation and hence the system performance. Connect the cold water inlet to the hot water tank with a S bend to avoid air lock whenever the	Strainer not provided . This will result in some cost saving but may affect system performance. Cold water pipe is directly connected to the tank inlet without the S bend. This though saves the piping cost, results in air locks. Non Return Valve not provided. This will

Cold Inlet (cont.)	overhead cold water tank goes empty. Provide a Non Return Valve according to the direction shown on it. **T**he cold water piping (from hot water tank bottom to collectors- part of the system piping) in case of a NTS system requiring system piping should be properly sized to ensure equal flow and pressure to all the collector rows. Cold water inlet should be connected to the lower point of the hot water storage	result in loss of hot water due to mixing. The cold water piping is connected through a single pipe having number of branches of the same size. Cold water inlet is connected at top.

Cold Inlet (cont.)	tank. (Exception is Fixed Temperature Forced Flow system where there will be no cold water connection to the hot water storage tank.) The cold water inlet connection to the tank nipple should be using an equal TEE with a plug on the lower side to be used as drain.	
Hot Water piping	Connect the hot water outlet at the top of the hot water tank. Ensure slope towards the user points and the hot water piping should not climb up at	Connected to lower tank nipple. (except in case of Fixed Temperature Forced Flow or Non Mixing system) Pipeline is laid on the

Hot Water (cont.)	any place. Install Non Return Valve on the cold and hot water inlet to each bathroom having mixers. Ensure minimum bends and fittings to minimize pressure drop. Proper insulation should be provided. Drain or recirculation loop to be provided to save wastage of water before the hot water is available at the tap. Prefer composite pipes having smooth	terrace and then rises up to pass through the parapet enroot to the user points. NRVs are not installed or are installed only on the hot water inlet. GI piping is used involving 90 Degree bends/elbows. Insulation is not provided or is of inferior quality. Not provided resulting in wastage of water and customer dissatisfaction. GI pipes having rough inner surface used

Hot Water (cont.)	inner surface and also low conductivity. This also will allow piping without sharp bends. The hot water piping should be telescopic to ensure equal pressure to users on different floors OR pressure reduction valves should be used. In case of pressurized water supply, the pipe type/size should take into consideration the frictional losses.	causing of scale deposition and build up. Non telescopic piping results in pressure difference leading to user complaints. The frictional losses are not taken into consideration leading to pressure and temperature loss.
System piping	Total system piping (Cold/Hot side) should be insulated. Hot water pipe	Cold water side is not insulated. Right angle bends are provided to save

System Piping (cont.)	connecting collectors to the tank should be gradually sloping. Air release valves/keys should be provided. Expansion loop should be provided for large systems.	piping. Not provided affecting the system circulation due to air locking. Not provided resulting in steam buildup.
Forced Flow systems	Select the pump capacity based on the system size and head to get the required flow rate by referring to the pump selection chart. Control panel and pump should be properly protected	Pump is selected based on judgement rather than calculations. Proper weather protection is not provided. Undersized/incorrect type wires are used leading to possibility of

Forced Flow (cont.)	from weather. Wiring connections should be using correct size/type of wire and all joints should be secure and protected. System piping should be on correct series/parallel basis of collector array. Standby/back up power should be provided/connected. The hot water storage tank should be close to the collectors.	damage/short circuit. Collector grouping not proper leading to low efficiency and also steam build up. System is not connected to back up power leading to non working due to power cut/load shading. Large distance resulting in heat loss during system operation.
Heating back- up system	The type of back up should be selected	Easy approach leading to electrical back up

Heating Backup (cont.)	based upon the site, availability of resource and the cost. Back up heater capacity should be calculated depending on the application of hot water and the nature of user activity.	on large systems having cheaper and greener fuels availability at site. Back up heater normally undersized provided leading to customer dissatisfaction. Also due to lack of controls the back- up works making the solar energy redundant.
Re-circulation system	Provide proper recirculation system either timer or temperature sensor based wherever required.	Absence of re-circulation system in case of large length of user piping leads to water wastage and dissatisfaction.

7. Do's and Don'ts :

Activity description	Dos	DON'Ts
Lifting of system on the roof	Wrap the rope around the collector tightly to lift.	Lift the collector by wrapping the rope around the copper headers.
	Lift the tank using belt slings securely holding the tank.	Lift the tank using rope fastened to the tank barrel pieces/nipples.
	Use expert rigging gangs in case of large tanks/ high rise building systems.	Attempt to lift on high rise buildings without proper resources.
Anchoring the system	Anchor the stands using correct size/type anchor fasteners.	Use plumbing nails to anchor the system.
	Provide concrete	Leave the system

	pedestals to anchor.	without anchoring.
Connecting the collectors	Cover the collector to avoid getting burns while working on header/flange connection. Use hand gloves /apron.	Work without hand gloves.
	Ensure full tightening of flange connecting bolts with proper gaskets.	Work on connections when the Sun is shining without proper care.

8. Plumbing tips:

a)Use shortest route for user piping.

b)Use telescopic piping for multi-storyed building.

c) Use right type of plumbing materials and jointing.

d)Insulate and clad the hot water piping- Energy loss to be reduced.

e)Secure the piping with proper clamps/supports.

9. **Lifting/rigging on high rise buildings:** a) Study the site conditions carefully to prepare rigging plan.

   b)Utilise the services of expert rigging gang with lifting equipments.

   c)Ensure the area directly under the lift is free of any humans/animals.

   d) Ensure that the lifting equipments are safe and in good working condition.

   e) Avoid anchoring/supporting the equipments with any temporary/weak structure.

10. **Anchoring of the system:** a)The system collectors, collector mounting structure and hot water tank stand should be properly anchored. The anchoring can be by way of concrete pedestals putting adequate weight or by using anchor fasteners or by fastening/anchoring to the permanent structure like wall/column etc. In case of waterproofed terrace, chemical based anchor fasteners should be used to avoid leakage.

11. **Tank materials:** The hot water tanks are mainly manufactured from MS or SS (Mild Steel or Stainless Steel). The merits and demerits of each material are mentioned below:

a) Mild Steel –

MERITS:

Low skills/cost of welding.

Withstands suspended heavy metals in the water better.

Can be repaired on site with local labor/equipments.

DEMERITS:

Needs protective coating to avoid rusting/corrosion.

Higher sheet thickness required adding weight.

Unsuitable for water with low pH.

b) Stainless Steel:

MERITS:

Lower thickness as compared to MS- Less weight.

Hygienic and non-corroding.

Does not need maintenance.

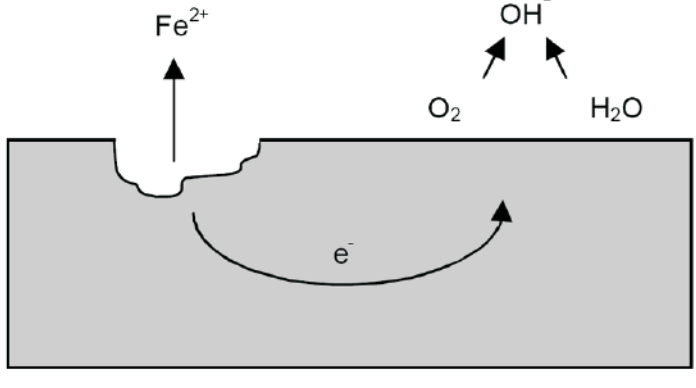
DEMERITS:

Weak aainst suspended heavy metals.

Galvanic corrosion needs to be avoided/controlled.

12. Galvanic corrosion: Galvanic corrosion occurs when two dissimilar metals come into contact with each other in the presence of an electrolyte. In case of solar systems, the dissimilar metals used in the construction of the flat plate collector come into contact with rain water, thereby giving rise to Galvanic corrosion. The corrosion takes place near the rivets and screws, which leads to creation of air gaps, resulting in minor heat losses from the collector. This affects the system performance over the years. Also, sometimes water may enter into the collector, leading to damage to the insulation material. In such a case, the collector has to be opened and the insulating material changed, and then sealed with fresh materials.

13. **Sacrificial Anode:** To avoid galvanic corrosion, a sacrificial anode is used in solar hot water tanks. A sacrificial anode is a metal rod (more anodic than the material to be protected). Generally an Aluminium/Magnesium rod is used. The sacrificial anode gets corroded over time and needs to be replaced periodically.
14. **Protective coatings:** In places where the water is hard in nature, systems having MS tanks with 'epoxy'/glass enamel coating done on the inside are used. The coating is a layer of non-stick material on the tank surface, which prevents the scales from sticking to the tank surface. It also helps in avoiding pitting corrosion.
15. **Pitting corrosion:** Pitting is another form of corrosion which is very dangerous in nature. It occurs generally in a surface with defects. The best way to prevent it is to give a coat of protective layer on the parent material.Osmosis softeners, magnetic and electronic water conditioners.



16. **Protection for superstructures:** The superstructure which is made for mounting of collectors on buildings needs to be protected from corrosion. The structure is exposed to the element and needs to be protected, as its failure will lead to destruction of the system. The most important thing to be kept in mind while doing the structure is the material itself. The material should be 'hot-dip galvanised' and then properly painted using rubber paint. The structure needs to be inspected from time to time, and in regions with corrosive environments, periodic maintenance of the structure needs to be done.
17. **Water Softeners:** In regions with hard water, it is always advisable to use water softeners in the system. Water softeners are used to reduce the hardness of the water, thereby reducing the problem of scaling and subsequent corrosion and fouling. The various options available for water softening include resin based softeners, Reverse Osmosis softeners, magnetic and electronic water conditioners.
18. **Water chemistry:** The water needs to be tested using a simple kit before deciding the system type. The salts like Calcium and Magnesium cause scaling when the water is heated. Keeping the system output temperature low can be one of the solutions to avoid the softener and scaling up to a limit. Alternatively heat exchanger based system can be a solution. The other contents of water can help in deciding the hot water tank material.
19. **Soft/Hard water systems:** The type of system should be

chosen depending upon the water quality. Evacuated Tubes are more suitable for hard water. However, the tank material needs to be chosen carefully. Heat Exchanger based system either with Evacuated Tube collector or Flat Plate Collector can be a good option.

20. **Insulation materials:** The hot water storage tank, system piping as well as the user piping should be provided with appropriate type of insulation to avoid/minimize the heat loss. This will improve the system efficiency and customer satisfaction level. For the tanks of capacity below 1000 liters, CFC free Poly Urethene Foam insulation done in the manufacturing shop offers benefits like, better aesthetics, ease in handling, better insulation effect and long life service etc. For larger tanks Rock wool or Glass wool insulations are used. The rock wool is corrosive in nature. Care must be taken to ensure that moisture does not reach the bottom layer of rock wool. The wool pads must be secured with GI wire. chicken mesh to avoid settling. Aluminium cladding with properly matched joints should be provided to avoid contact with moisture. EPDM/Neoprene rubber sheet can also be used for tank insulation but is costlier.

For the piping EPDM/Neoprene rubber sleeves, PUF sections, rock wool/glass wool etc. can be used with proper cladding.

TROUBLE SHOOTING FOR SOLAR WATER HEATING SYSTEM

Sr. No.	Observation/Complaint	Probable Cause	Corrective Action
01	No hot water in the bathroom but Natural Thermo-Siphon system heated	**A**irlock in hot water tank.	**C**lean Air Release Valve, Remove Air by opening the pipe connections
		Mixing in bathroom mixer	**C**heck the reverse flow of water at system outlet, check mixer levers-set right
		Strainer chocked	**C**heck and clean the strainer
		Error in valve setting in case of connection thru boiler	**C**heck the valve setting and correct.
		Collector cover glass dirty	**C**lean cover glass

02	Hot water available only during sunny hours	**N**on Return Valve on the cold water inlet side failed	**R**epair/replace the NRV.
		Mixing in bathroom mixer	**E**nsure mixer lever on either side, ensure NRVs on cold and hot inlet for each mixer point.
		Excess usage exhausting the system capacity	**E**xplain system capacity and educate about usage, advise use of back up as required.
03	Hot water availability less than the system capacity	**B**lockage in thermo-siphon loop.	**C**heck and clean the collector header and system piping.
		Scaling affecting flow and heating.	**D**escale the collectors and piping.
		Improper venting.	**R**epair/replace the insulation and cladding.
		Poor insulation resulting in heat loss.	**A**dvise usage control / back up use.

		Evening usage.	
04	Hot water flow with low pressure- Pressure drop.	**S**trainer on the cold side choked. **B**lockage in thermosiphon loop. **A**ir lock in the system. **I**mproper venting. **S**caling in user piping. **B**lockage of mixer port.	**C**lean the strainer. **C**lean the collector absorber and system piping. **R**emove air lock. **C**orrect vent. **D**e-scaling of user piping. **C**lean the mixer of sediments.
05	Vapour inside collector –low output	**L**eakage in absorber assembly. **L**eakage from grommets/collector frame/retainer angle. **I**nsulation containing moisture.	**R**epair absorber. **E**nsure the collector joints are leak proof. Apply sealant.
06	Collector glass breaks without any impact	**C**ollector frame not placed in level and securely supported.	**C**orrect the leveling. Secure after alignment.
07	No hot water available in case of boiler through connection	**I**f solar output connected to boiler	**R**emove cold water to ensure

		inlet, stored water must have cooled down. If connected to boiler outlet, the positioning of valves to bypass the boiler is wrong.	hot water from system. Correct the valve settings.
08	System heats water but no reduction in electricity bill	Excess usage. Defective thermostat.	Establish the fact. Replace thermostat.
09	Electricity bill high but back up heating not working	Scaling on electrical heater coil. Mixing losses.	Clean the coil to clear scaling. Check and set the mixer lever.
10	Hot water tank leaking	Air release valve choked. Cold water pressure more than the designed pressure.	Clean Air Release Valve/repair. Repair tank and use Pressure Reducing Valve.
11	System heats but no hot water in the morning	Failure of NRV on the cold line. Mixing on user side.	Repair/replace Take corrective action on NRV/ mixer lever.
12	ETC system leaking	Cold water pressure above limit. Air lock.	Put PRV. Remove Air lock. Correct alignment

		System/manifold not properly leveled.	and secure.
13	Forced Circulation system not working	**P**roblem with controller/control panel wiring. **P**roblem with pump. **S**caling of sensors. **L**oose contacts in wiring.	Check controller, other components one by one and take corrective action. **C**heck and repair/replace. **C**lean/replace. **T**ighten all connections after cleaning flux.
14	Forced Circulation system pump runs continuously	**S**caling on sensors. **P**roblem with setting/working of controller.	**C**lean / replace. **R**eset the controller.
15	Pump breaks down frequently	**D**ust blocking the pump. **S**caling on sensor. **V**oltage fluctuation.	**C**lean/service. **C**lean/replace. **P**rovide voltage stabilizer.
16	Indirect heating system not working	**N**o fluid in the heat exchanger. **S**caling on the heat exchanger surface.	**R**eplenish thermic fluid. Descale the heat exchanger.
17	System tank leaking after booster pump installation	**H**ot water tank not designed for the	**R**educe the inlet pressure/ replace

		pressure. **I**nadequately sized air vent in case the pump is fitted on the outlet side.	with pressurized tank. **C**orrect the size of vent.

5.0 FREQUENTLY ASKED QUESTIONS(FAQ):

How do we decide the collector area in Sq. Mtr. For a particular system capacity?

The collector area will depend up on factors like:
the solar insolation(incident solar radiation) at site, system location, temperature rise expected,system working principle i.e. Natural Thermo-Siphon or Forced Circulation etc. apart from the collector efficiency and the system orientation etc. The collector area needs to be calculated using standard formulae.

What is meant by ISI Mark Flat Plate Collector? Why is it required?

The ISI mark collector means collector confirming to material and manufacturing standards as per BIS 12933-2003 and meets the minimum efficiency norms. This means a standard product that can deliver the expected output and safety. It is required to assure the buyer/installer that the product will give the expected performance.

How to decide the system piping layout and pipe sizes?

The system piping layout should be such that:
there are no sharp turns/bends
the pipe size should allow free flow without any pressure drop affecting the circulation. Also
the cold and hot water pipe sizes should be designed to allow equal flow to all collectors/rows.
Adequate air release arrangement should be provided.

What are the different factors deciding the system performance?

The factors are:

- output temperature
- system location
- system layout
- collector efficiency
- tank and system piping insulation
- distance between the collectors and tank and usage pattern are the major factors deciding the system performance.

What should be covered under routine maintenance visit?

During routine maintenance visit one should:
Check and clean the strainer on the cold inlet line
Air Release Valve nozzle should be cleaned
All pipe and collector flange joints should be checked for leakages
Non Return Valve should be checked for proper working.
In case of a Forced Circulation system, check the control panel and pump and clean /service.
Wiring connections should be checked for loose contact.
The collector glass needs to be clean.
Check the user piping insulation and attend the smallest damage.

How frequently does the collector glass needs cleaning?

It depends on the system location, dust in the area, season etc. and can be decided out of experience.
How to decide the right type of system for a particular site?
Application, site location, space available, shadow pattern, system capacity are the factors which will guide for this decision.

What precautions need to be taken for installing ETC system?

The site should not have monkey menace. The system should be anchored properly. In case of monkey menace, a protective cage sholuld be provided or a flat plate collective system should be used.

What are the different options for de-scaling?

In the first place try to install a softener to avoid scaling. Alternatively design the system for low temperature rise to minimize scale. Descaling chemicals need to be used with close loop circulation system to clean the system.

What are the options to install a SWHS on a tin roof?

Check the supporting structure for the tin roof. The load should be transferred on the rafters/purlines and not on the tin. Care needs to be taken to ensure proper sealing to avoid leakage wherever holes are made to fix the system to the structure. In case the structure cannot support the complete system load, only collectors can be mounted on the roof with the support of the structure and tank can be placed on ground with a fixed temperature design.

What are the precautions necessary for installation of system for multi-storied buildings?

The following things need to be followed:

1)The steel structure for mounting of system collectors should be rigid enough and anchored properly.

2) The hot water tanks should be dish ended and properly vented.

3) Pipe line for hot water distribution should be to ensure equal pressure and flow.

4) Since the piping length in case of multi storied buildings is more, proper insulation is must.

5)Non Return Valves should be provided at the inlet of each bathroom.

6) Re-circulation loop / system should be provided with required capacity back up heating arrangement.

7)Load on the terrace should be within the designed load bearing capacity of the structure and got certified by the structural consultant.

8) Auto timer based control can be provided to control the usage hours for better satisfaction. 9)The hot water to each bathroom can either be provided through a separate tap or through the electric geyser/boiler.

When should we opt for a Forced Circulation system?

Forced Circulation should be chosen when the system capacity is more than 3000 lpd. The site conditions not allowing the typical tank and collector arrangement of Natural Thermo-siphon.

Why should the mixer lever be on either side and not in the center?

In case of a bathroom mixer without built in Non Return Valves, the central lever, if kept in the middle will allow mixing of cold and hot water. This will drain the hot water system and result in loss of system hot water. The lever should hence be kept on either side to prevent mixing.

In case of existing boiler, how to connect the solar hot water-?

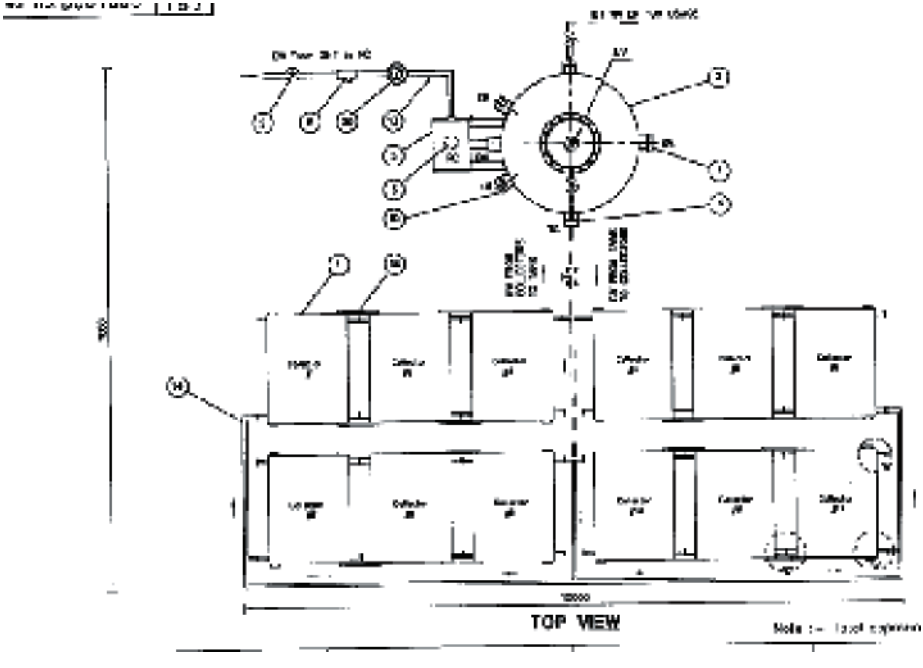
The solar hot water connection can either be given to the input of the geyser, so that the geyser can heat it when required. How ever, in this case every time after a gap the water in the geyser will become lukewarm consuming electricity or resulting in complaint of NOT GETTING HOT WATER. Alternatively the solar output can be connected through a bypass loop. So that during sunny period the hot water is directly used and during inclement weather the same can be heated using the geyser.

The re-circulation system should be connected to the hot water tank or an auxiliary tank with heater back up?

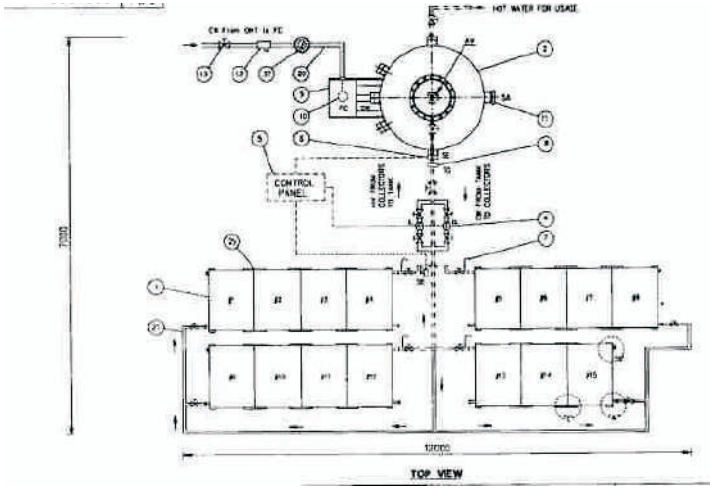
In case of the re-circulation system, the lukewarm water should be put back in a separate tank provided with back up heating. This tank should be inline connected to user piping after the hot water storage tank.

Specimen Installation Layouts:

1500lpd Solar Water Heating System(SWHS) Layout at $60^{O}C$



1500lpd SWHS layout 70^{O}C:



3000lpd SWHS layout: