



User's handbook on
SOLAR WATER HEATERS.



International Copper Promotion Council (India)

Preface



Government of India
Ministry of New and Renewable Energy
UNDP/GEF GLOBAL SOLAR WATER HEATING PROJECT

No. _____

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PREFACE

The gross potential for solar water heating systems in India has been estimated at 140 million sq. m. of collector area. Of this, 40 million sq. m. has been estimated as the realizable techno-economic potential. A total of 3.52 million sq. m. of collector area has so far been installed in the country for solar water heating. The achievement so far has been modest compared to the overall potential. However, a reasonable infrastructure has emerged and experience is available for manufacture and installation of solar water heating systems. A target of 5 million sq. m. has been set for the 11th Plan (2007-12) and a goal of 20 million sq. m. for 2022 under the Jawaharlal Nehru National Solar Mission.

The Ministry is implementing a UNDP/UNEP/GEF project on "Global Solar Water Heating Market Transformation and Strengthening Initiative" under UNDP's India Country Program. The objectives of the project are to accelerate and sustain the solar water heating market growth in India and to use the experiences and lessons learned in promoting a similar growth in other countries participating in the Global project; to establish a supportive policy and regulatory environment; to build up the market demand; and, to strengthen the supply chain. The project will contribute to the 11th Plan target of five million sq. m. through installation of two million sq. m. of solar water heating systems. Harnessing five million sq. m. of collector area will lead to 25 million tonnes of GHG emission reduction.

One of the important outcomes of the project is to enhance awareness and provide information to different end-users of solar water heating systems about the technology, equipment, installation practices and cost economics. The Users' Handbook for Solar Water Heaters has accordingly been prepared under the UNDP/GEF project to provide guidance to end-users on general technical specifications, choice of technology, sizing, cost and economic factors, installation and operation and maintenance of solar water heating systems. The Handbook has been prepared by the International Copper Promotion Council (India) and the contents have been structured in a user-friendly format.

It is hoped that the Handbook will assist potential users in making informed decisions about installation of solar water heaters to meet their hot water requirements.


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Foreword

The use of hot water for bathing and other purposes has become an integral part of modern lifestyles. With the abundant availability of sunlight in our country, even in colder regions, solar water heating is a natural solution. It has been established that the investment in solar water heaters pays itself back through saved electricity costs in 4 to 5 years and thereafter the hot water becomes available for free over the lifetime of the equipment of more than 15 years. Government subsidized loans are available to finance the equipment costs.

In spite of these facts, the penetration of solar water heaters remains far below potential. One of the barriers that has been identified, is the lack of organized information with users about the different technologies available, the selection and sizing of equipment, evaluation of costs and questions concerning installation, maintenance and trouble-shooting.

It is to address this need that the International Copper Promotion Council (ICPCI) is publishing this handbook, as a partner of the Ministry of New & Renewable Energy, Government of India and the Global Environment Fund in the Global Solar Water Heater Market Transformation and Strengthening Initiative project.

We hope that users will find this handbook of value.



Ajit Advani
Dy. Regional Director-Asia, ICA and CEO, ICPCI



Introduction

Solar thermal technologies hold significant promise for India with high solar insolation of 4.6.5 kWh/ sq.m /day for an average of 280 sunny days. Solar water heating system is a commercially viable and technologically mature product which has existed in the country for many years. Yet, against a technical potential of 45 million sq. km. of collector area only a little over 2.5 million sq. km of collector area has been installed. This works out to a little more than 2 sq.m./1000 people as against countries like Israel and Cyprus, which have over 500 sq.m./1000 people.

In order to transform the solar water heating market in India, the Ministry of New and Renewable Energy (MNRE) has joined hands with UNDP/UNEP/GEF Global Solar Water Heating Market Transformation Strengthening Initiative. Under this project, India aims to achieve 10 million sq meter additional collector area by 2012. In absence of any intervention, the market was projected to add 3 million sq meters during this period. International Copper Promotion Council (India) is also a partner to this project in India.

The climate of India varies from extremes to moderate due to its large geographic size and varied topography. The climatic conditions in the northern hills are quite different than that of southern parts of India and in plains also, extreme climatic conditions are common. Use of hot water is common for residential applications in cooler regions of the country. In urban and semi urban areas also, the hot water use is becoming a part of the life style. In all these areas water is normally heated up with electricity which is expensive and is not available for 24 X 7. Therefore, solar water heating system can be a suitable alternative to meet the growing hot water demand requirement in the country without exerting further demand pressure on electricity generation capacity in the country. However, in quite a number of cases solar water heaters had failed to earn appreciation of the users due to suboptimal design, inferior product quality, mismatch of technology with environment and water quality and bad installation practices.

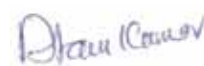
Purpose of this hand book is to provide guidance to customers to look at various aspects while selecting a solar water heater for their hot water requirements and take an informed decision while purchasing a solar water heating system. The book contains the following chapters to help the customers with:

- 1) **The general technical specifications a user should look at while selecting a solar water heating system.**
- 2) **Choice of technology for a particular application keeping in mind the environmental conditions and hot water applications.**
- 3) **Determine size of the water heating system for different residential and commercial applications. This chapter also provides a simple mathematical model to decide the approximate size of the solar heating system in residential application.**
- 4) **Need to look at the various economic factors while evaluating the cost of solar water heating systems.**
- 5) **Different aspects the users need to look at while having the solar water heating systems installed**
- 6) **Regular and periodic maintenance and the trouble shooting methods**
- 7) **Frequently asked questions (FAQ)**

The chapter also has annexure A and annexure B which give the details of:

- 8) **Principles of solar water heating systems**
- 9) **Successful illustrations of solar water heating systems in residential, commercial and industrial applications in India.**

Rational of this book is to provide adequate information to the solar water heater users to help in selecting the right technology and product for their applications. We hope the book will be useful to the solar water heater users in procuring the systems and also in getting optimum results from these systems.



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Acknowledgement

This hand book on solar water heater is an effort to provide guidance to the users to select the right technology and product for hot water application.

Many organizations and individuals have contributed significantly with their ideas and suggestions to shape up this hand book. The objective of this hand book would not have been completed without active supports of:

The Ministry of New & Renewable Energy (MNRE)

- Shri Deepak Gupta-Honourable Secretary
- Dr. Bibek Bandopadhyay-Advisor
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- Shri S K Singh-Director Solar Energy Center
- Dr. A K Singhal-Director
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Chapter 1

General technical specification of solar water heaters

Introduction

India is blessed with abundant solar energy. Solar water heater system is a technically proven successful application for use of this energy. However the market for the solar water heater is not yet developed fully. This informative hand book on solar water heater is prepared, for the Ministry of New and Renewable Energy (MNRE), to address the concerns of solar water heater system users for different solar water heating applications.

Objective

The objective of the hand book is to help users make the right and informed decision while purchasing solar water heater.

This hand book also intends to develop a better understanding of the solar water heating systems and to provide basic guidance for periodic maintenance and trouble shooting mechanisms for a reliable and durable service from the solar water heater.

Guidelines on technical specifications

Scope: These guidelines on specifications are created for end users of solar water heater for small residential (up to capacity of 300 litres/day) and large residential, commercial & industrial applications

Site and service conditions: India is a tropical country. The climatic conditions and water quality vary from place to place. The solar water heating systems have to meet the requirement of ambient temperature variations from -5° C to 40° C; altitude ranging from 0 meters to 10000 meters above mean sea level, relative humidity ranging from 30% to almost 100%, wind velocity ranging from 2 meter/sec to 7 meter/sec with possibility of hail storm in many places.

Reference standards: The Ministry of New and Renewable Energy (MNRE) has helped in formulation of Indian Standards for Solar Flat Plate collectors by BIS. These standards are recognized and accepted nationally.

Test, Inspection and Test report: There are mainly two test reports namely type test report and routine test report.

The type test certificate has data pertaining to design, raw material, workmanship and quality control during manufacturing process. It certifies that all the critical parameters pertaining to overall system efficiency are well within the range set by the standard.

The routine test certificate provides all data that need to be verified before the system is dispatched from the manufacturer's factory to the site of installation. In case of larger installation, the users may also visit the manufacturer's factory to inspect the

quality standard followed during manufacturing and witness the routine tests performed by the manufacturer before dispatch of systems.

Drawings and instructions: All drawings must be furnished to illustrate significant components of the solar water heater system with installation instructions along with necessary drawings, plumbing instructions with necessary drawings, safety instructions with drawing at the time of installation, and routine maintenance instructions.

Depending on specific site conditions, it is necessary to provide a set of special instructions to the user in an explicit and easy to assimilate format, for reliable and smooth operation of the solar water heater system.

Ratings and features: The capacity of the system and all major characteristics of the system must be specified on the name plate. The system must also carry a detailed specification of important parameters in the user manual for the customer reference. Table of suggested details is given below.

Table 1

SI No	Parameters	FPC based systems	ETC based systems
Collector name plate details			
01	Name & Address	Manufacturer's name & address	Manufacturer's name & address
02	Product type and code	FPC – (Product Code)	ETC – (Product Code)
03	Collector area	2 Square meter	No of tubes 15 or more
04	Absorber materials	Riser and fins with selective coating	Glass with selective coating
05	Collector box	Aluminum/ GI/ MS with corrosion protection	
Storage tank name plate details			
01	Name & Address	Manufacturer's name & address	Manufacturer's name & address
02	Product type and code	Vertical / Horizontal – (Product Code)	Horizontal – (Product Code)
03	Capacity	In liters	In liters
04	Construction	Insulated tank with cladding	Insulated tank with cladding
05	Material	Stainless Steel grade 304 or better	Stainless Steel grade 304 or better
06	Water flow mechanism	Forced / Thermo siphon	Forced / Thermo siphon
07	Insulation	Density XX mm / m ³ , Thickness mm	Density XX mm / m ³ , Thickness mm
08	Heat exchanger	Yes / No	Yes / No
09	Electrical back up	XX KW booster heater	XX KW booster heater
The following table gives the important technical specifications for the user to specify at the time of obtaining quotations and before taking the purchase decisions			
SI No	Parameters	FPC based systems	ETC based systems
Collector specifications			
01	Absorber material (Fins)	As per BIS standard IS – 12933, 2003	
02	Absorber coating		
03	Riser		
04	Header		
05	Bonding between riser & header		
06	Bonding between fins & tubes		
07	Back insulations		
08	Side insulations		
09	Collector box		
10	Collector bottom sheet		
11	Collector stand		
12	Glazing		
13	Retainer angle of glass		
14	Beading of glass		
15	Absorber Area		
16	Collector tilt		
17	Heat Transfer medium		
18	Collector Area		
19	Number of fins		
20	Dimensions		

General Requirements

It is necessary to have solar water heating system with the right technology, features and capacity to ensure a long term reliable and smooth operation of the system. Installation of the solar water heater in the right manner, suitable for the specific site conditions is very important for optimal performance of the system.

In case of a large system located at the rooftop of buildings, provision of lightning arrester must be made in case it is not already provided.

The name plates should be easily visible to the installers. Safety instruction must be provided along with the system to ensure installation safety at site.

Additional system requirements

Following additional system-technology features may help in selection of the solar water heating system with appropriate technology, suitable for the size and site conditions.

Thermo siphon system: For small application, up to 3000 liters capacity, users may prefer thermo siphon system for its simplicity and ease of operation. In such cases, the source of the cold water must be placed at least 7 feet above the terrace level for size up to 500 liters, (for larger tank sizes, the height requirement may go up to 10 feet or higher), where solar water heater system will be installed.

Forced circulation system: For systems of size larger than 3000 liters per day, customer may choose forced circulation system. These systems may also be used for smaller than 3000 litres/day capacity also where thermo-siphon system can not be used due to limitation of height of the cold water tank.

Solar water heater with heat exchanger: In places where water quality is not suitable for direct use in the solar collector, or in cold regions where water in the collector may freeze in the night, solar water heater system with indirect heating is required. Users located in low temperature zones (minimum night temperature of 2° C and below) have to use solar water heater with indirect heating with antifreeze. If the water pressure coming from the cold water source is very high (above 3 bar) it will be necessary to use heat exchangers.

For thermo siphon system, heat exchangers shall be always in the hot water storage tank. Whereas for forced flow systems, heat exchanger may be inside the hot water storage tank or located outside the tank depending on the design.

Flat plate collector: Flat plate collector collects solar radiation and converts solar energy into heat energy for heating water. Flat plate collector should be reliable, durable with a useful life of 15 years or more. Main characteristics of this collector should be :

- Resistance to environmental conditions (marine environment, rain, dust, hail etc.)
- Resistance to large variations in temperature
- Resistance to leakage from any part of the system
- Stable and durable
- Easy to install
- Efficient in energy conversion

These characteristics are required to be fulfilled by the collector in the existing BIS standard IS-12933-2003. Main components of the Flat plate collector shall be important to meet above characteristics.

- 1 Casing
- 2 Seal
- 3 Transparent Cover
- 4 Thermal Insulant
- 5 Absorber Plate
- 6 Tube

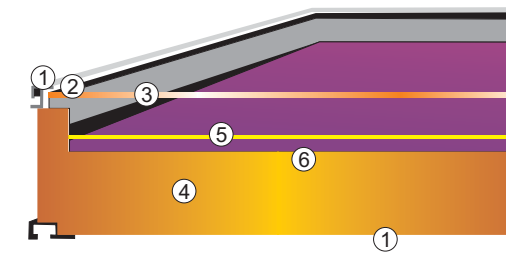


Fig 1: Flat plate solar collector cutaway view

Casing

Casing contains all the components of the collector and protects them from environmental impact. Casing shall also make the collector sturdy and stable. Material used for casing must be resistant to corrosion.

Seal

Seal is made out of elastic material to prevent leakage and ingress of rain water into the collector. Sealing material must withstand high temperature variation and ultra violet (UV) radiation. (to ensure a long life of 15 years, or more.)

Transparent cover

Transparent cover should be made of toughened glass with high transmission co-efficient (close to 1). This also protects the components inside the collector from environmental impact.

Thermal insulation

Thermal insulation reduces undesirable heat loss from the back and sides of the collector area. The insulation must also be able to withstand the maximum temperature of the absorber plate.

Absorber plate

Absorber plate absorbs the solar energy and converts it to heat energy in the fluid. The absorber is made out of high conductivity material like copper with selective coating on it for maximum absorption of solar radiation and minimum emission of infrared radiation.

Tube

The fluid that flows through the collector shall collect the heat for useful application. The transfer of heat shall take place mainly through conduction and convection process. Therefore, the tubes should be made out of high conductivity material like copper.

Evacuated tube collector: Evacuated tube collector use solar energy to heat the fluid inside the tube through absorption of radiation, but reduce the loss of heat to atmosphere due to vacuum inside the tube. Evacuated tube has different sub categories based on material used and application requirement. Life of the evacuated tube shall vary from 5 years to 15 years. Main characteristics of the evacuated tube collector should be :

- Capability to endure environmental conditions (rain, dust, etc. and in some cases marine environment)
- Capable of enduring large variations in temperature
- Resistance to leakage from any part of the system
- Stable and durable
- Easy to install
- Efficient in energy conversion

These characteristics are required to be fulfilled by the collector in the existing MNRE standard. Main components of the evacuated tube collector should meet above characteristics.

Glass tube

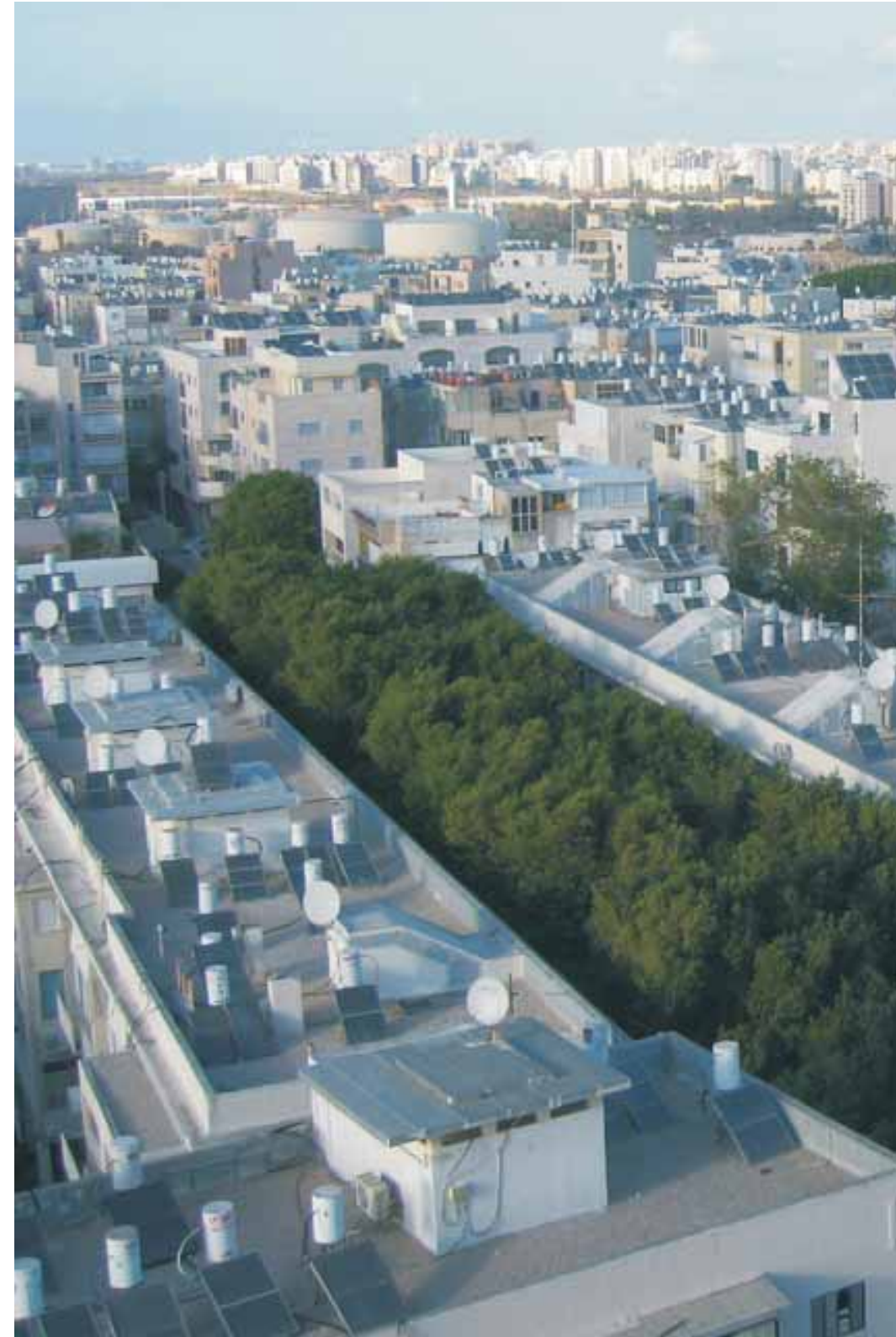
The glass tube shall be formed by fusing two co-axial glass tubes at both the ends. Air between the two glass tubes is evacuated to create vacuum which works as insulation. Outer surface of inner tube in the evacuated tube collector forms the collector area

Absorber coating

Absorber coating shall be applied on the outer walls of inner tube selectively to absorb the solar radiation to collect energy and to convert light energy into heat energy. The selective absorption coating has absorption co-efficient of 0.94 or more and emissivity of 0.12 or less. The coating should remain intact for the life of the system.

Gasket

Gasket between the tank and ETC or Manifold and ETC is very crucial for the trouble free performance of the water heating system with ETC. The gasket should be capable of sustaining the temperature and pressure encountered. This should fit tightly above the tube to avoid any leakage. Life of the gasket should be equal to the life of the entire system.



Chapter 2

Selection of right technology

Introduction

Solar water heaters are available in two different technologies known as Flat Plate Collector technology (FPC) and Evacuated Tube Collector technology (ETC). Both FPC and ETC products are available in India. ETC systems with heat pipes are also available but these are not being used commonly. The customer may choose the right technology for his specific hot water requirement and as per site limitation. Problems have been observed at times, at site due to selection of unsuitable technology.

Objective

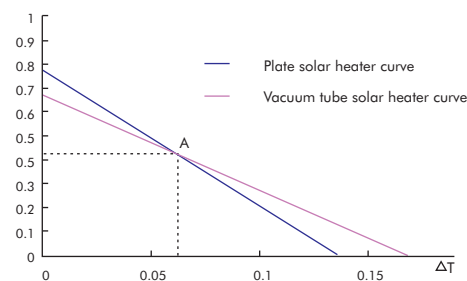
The objective of this chapter is to create familiarity with the technology of solar systems to enable the user to make an informed choice of a Solar Water heating system as per location, environment and requirement of hot water.

Selection of the right technology

Performance of ETC and FPC based solar water heater systems varies with location, seasons and many other external factors. A report received from the Beijing Solar Energy Institute confirms the statement.

Ambient air temperature: Ambient (outdoor atmospheric) air temperatures during night and day play an important role in selection of the right technology. In cold climatic conditions where ambient temperature reaches the freezing temperature of water, performance of heat pipe based ETC based system is better as compared to FPC based system. Similarly, direct heating of water is not advisable in such conditions. It is recommended that the customer should opt for heat pipe based ETC system or FPC based system with heat exchanger, if the ambient temperature can go below 2° C. The following explanation illustrates the above mentioned fact.

Graph 1



In the figure, the Y axis represents efficiency of the solar collector and X axis represents ratio of temperature difference to the solar radiation. Therefore, $\Delta T = (T_i - T_a) / G$

Where T_i = Inlet temperature of the fluid inside the solar collector, in ° C
 T_a = Temperature of outdoor air, in ° C
 G = Solar radiation on the collector plane, in W/m²

It is seen from the graph that at point A, the performance of FPC and ETC is same. As ΔT increases from reference point A, ETC performs better than FPC whereas with the decrease of ΔT from reference point A, FPC performs better than ETC.

Table 2

Temperature difference °C	0	10	15	20	25	30	35	40	45	50	55	60	70	80
Plate solar heater efficiency	0.74	0.68	0.66	0.63	0.60	0.57	0.55	0.52	0.49	0.46	0.43	0.41	0.35	0.30
ETC solar heater efficiency	0.59	0.56	0.55	0.54	0.53	0.51	0.50	0.49	0.48	0.46	0.45	0.44	0.41	0.39

The efficiency curve test

The efficiency curve is derived from the table 2 above. When solar radiation is 800w/m² and temperature difference is 50°C, performance of both the collectors is same. As the temperature difference decreases, FPC performance is better and when the temperature difference increases, ETC performance is better. Going by the result of the study conducted by the Beijing Solar Energy Institute, it is clear that FPC shall perform better in hot climatic conditions whereas ETC shall perform better in cold climatic conditions.

In a tropical country like India where seasonal variations are quite wide, solar water heater should be selected considering the winter climatic conditions. Table 3 below gives the temperature of some selected places across the country in the month of December.

Desired temperature of hot water: Required temperature of hot water shall vary depending on application and accordingly suitable technology must be selected. Following table provides general guideline for selection of a suitable technology for various temperature applications.

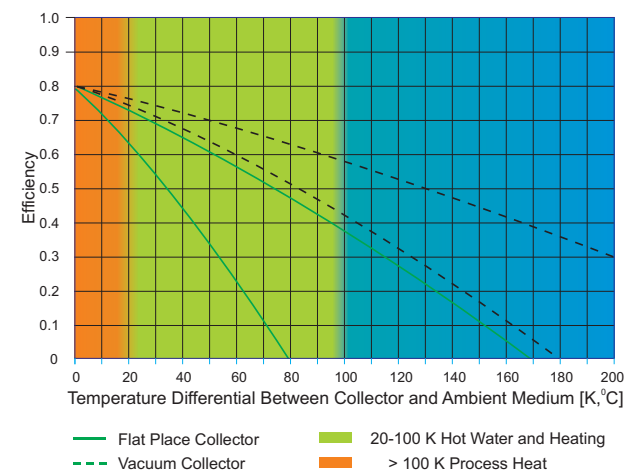
Table 3

Application	Technology
Low temperature application from 40° C up to 80° C	FPC / ETC
Medium temperature application from 80° C to 120° C	Heat pipe ETC
High temperature application from 120° C to 250° C	Solar concentrator
Low temperature commercial application (swimming pool)	FPC / ETC

Following graph shows the performance of FPC and ETC with different solar radiation intensity for different applications. However, customer's concern is the performance,

durability and reliability of the entire system and not merely the performance of the collector. Therefore customer must pay attention to the following points as well while selecting the technology.

Graph 2



Water quality: Water quality plays an important role in selection of the technology as well as heat exchange mechanism. Selection of technology and material based on water quality is outlined below.

Temporary hard water

When temporary hard water is heated, dissolved material in water separates. This material accumulates in different parts of the collector system. This is called scale formation. Formation of scale is faster in FPC based system than in ETC based system. However, scale formation takes place in ETC based system as well. In such kind of water, indirect heating through heat exchanger is recommended. In case of indirect heating scale formation takes place at the heat exchanger surface, which can be easily cleaned at periodic intervals.

However, newer technologies are coming in where inner surface of the collector tubes are treated with special chemical to reduce scale formation. Customer must ask specific information about this technology along with manufacturer's specific guarantee before going in for direct heating of temporary hard water.

Permanent hard water

Permanent hard water does not create problem in the performance of FPC or ETC based system. However, if the system remains filled with water during summer and is overheated continuously, concentration of the dissolved solids goes up causing formation of scale over a period of time.

Saline Water

Saline water corrodes mild steel, galvanized piping as well as stainless steel. Copper is not affected to a great extent. Therefore, in saline atmosphere both FPC and ETC can be used. However, stainless steel storage tank must be avoided. Instead mild steel storage tank can be used with proper treatment and paint protection. Regular maintenance is necessary in saline water conditions.

Acidic Water

Acidic water is corrosive to mild steel, galvanized iron, copper and other metals. It is also corrosive to stainless steel if the water contains sulfides, chlorides and fluorides. ETC based systems should be used in such water conditions. However, such water quality is rare.

Alkaline Water

This is the most common water and moderate alkalinity is tolerated by mild steel, copper, stainless steel and galvanized iron. However galvanized iron starts losing zinc which deposits on copper surfaces in the same system. Both FPC and ETC can be used in such water conditions. Insulated PVC pipes may be used instead of GI pipes to avoid zinc depletion.

Water with high turbidity

Turbidity in water is because of high amount of suspended solids. These solids will settle down slowly when the water stays for a long time in any container. These suspended solids are often charged particles. The charge gets neutralized slowly in contact with metals and slow settling takes place. Turbid water should be avoided in solar water heating systems as it affects both FPC as well as ETC systems. If turbidity in water can not be avoided, periodic maintenance must be carried out for reliable and smooth operation of the system.

Treated water (for removing hardness)

Water treatment is usually done before feeding into the boiler in order to remove hardness. However, hardness removal process makes water saline and scale formation takes place. This water is not suitable for either FPC or ETC and should be avoided. This water is not suitable for stainless steel tank also.

Other environmental factors: In areas where hail is common, ETC should not be used as glass tubes are likely to break due to hail storm. Similarly in areas where animals like monkeys or cats frequent the solar water heater installation area, glass tubes of ETC may break leading to system shutdown. Therefore it is advisable not to use ETC based systems in these areas.



Chapter 3

Sizing of solar water heater system

Introduction

It is extremely important to select the correct size of the solar water heater system. The solar water heater sizing needs to be done based on the hot water requirements and the hot water use habits of the people in a family. The basic idea of having a solar water heater is to reduce electricity consumption for water heating. An under-sized system is insufficient to meet the hot water requirement, an over sized system will result in overheating of the water. As back-up system is required for cloudy days, it may be possible to manage with marginal back up use in extreme weather to optimize the size of the system for use in the rest of the year

Objective

Basic objective of this chapter is to provide a simple general guideline to select the right size of the solar water heater. Selection of solar water heater system in large residential, commercial and industrial applications is complex in nature and therefore elaborate calculations may be necessary to size the solar water heater system. However following guidelines can be used fairly accurately for small residential applications and to get a general idea about the size of the solar water heater systems for large residential and commercial installations.

Sizing of solar water heater system

The requirement of hot water varies from person to person. However, it is estimated that the average hot water requirement per person per day in an average household in India is around 40 liters. Following two tables show the hot water requirement for different applications in Indian households, and small commercial establishments respectively.

Table 4: Water consumption pattern for residential applications at 40 degree centigrade

Water consumption pattern in high end bungalows in cities		Liters
Bathing per person per day		80
Wash basin per person per day		20
Kitchen wash per person per day		15
Clothes wash per person per day		10
Heat loss and hot water wastage factor		30%
Water consumption pattern in high end residential flats in cities		
Bathing per person per day		60
Wash basin per person per day		10
Kitchen wash per person per day		15
Clothes wash per person per day		10
Heat loss and hot water wastage factor		25%
Water consumption pattern in average residential flats in cities		
Bathing per person per day		40
Wash basin per person per day		10
Kitchen wash per person per day		15
Clothes wash per person per day		00
Heat loss and hot water wastage factor		20%
Water consumption pattern in semi urban households		
Bathing per person per day		40
Wash basin per person per day		10
Kitchen wash per person per day		00
Clothes wash per person per day		00
Heat loss and hot water wastage factor		20%
Water consumption pattern in rural households		
Bathing per person per day		40
Wash basin per person per day		00
Kitchen wash per person per day		00
Clothes wash per person per day		00
Heat loss and hot water wastage factor		15%

Table 5: Water consumption pattern in small commercial establishments, at 40 degree centigrade.

Water consumption in beauty saloon		Liters
Shaving per person		0.5
Hair rinsing per person		05
Water consumption in small clinic / dispensary		
Hot water per patient		05
Water consumption in small hospitals (30 beds or less)		
Hot water per patient		60
Water consumption in restaurants / Canteens		
Hot water per guest		05
Water consumption in small office		
Hot water requirement per employee		02
Water consumption in Hostels		
Hot water requirement per student		40
Water consumption in large hospitals (more than 30 beds)		
Hot water requirement per bed		300
Water consumption in large hotels		
Hot water requirement per room		300 - 600

Based on the above table, we can calculate the approximate size required for solar water heating system. Following illustration can help the user to calculate the approximate hot water requirement and corresponding size of the solar water system to ensure the required amount of hot water use only for residences and for small commercial establishments for bathing and hand washing applications

The illustration is for an average residential flat in city area with 4 people staying in the flat. (Typical size of a nuclear family)

Table 6:

SL No.	Description	Water/person/day	No of persons	Total water requirement
01	Bathing	40	4	160
02	Wash basin	10	4	40
03	Kitchen wash	15	4	60
04	Clothes wash	0	4	0
05	Total requirement			260

Therefore total hot water requirement at 40°C for a family of 4 in an average residential flat in a typical city is 260 liters. There is heat loss in the pipes and mixing of cold water with the hot water in the hot water tank. Considering a heat loss factor of 20% for average residential flat in city area, hot water requirement will be:

Table 7:

SL No.	Description	% loss of total requirement	Total water requirement
06	Heat loss and hot water wastage factor	20	52
07	Total hot water requirement at 40°C.		312

Hot water is required mainly in the winter season and therefore the system should be designed to meet the hot water requirement during winter. Table 7 gives the hot water output of a typical 100 liter system at 60°C and the output varies from place to place depending upon environmental conditions.

a) For example, if a user stays at Leh, he will get 89 liters of hot water at 60°C from a 100 liter system, when the cold water temperature at 6°C. The ratio of cold water to hot water mix is given by the following formula:

$$\text{Quantity of cold water} = \frac{\text{Hot water temperature} - \text{Use water temperature}}{\text{Mean water temperature} - \text{Cold water temperature}}$$

$$= \frac{60 - 40}{40 - 6} = \frac{20}{34} = \frac{1}{1.7}$$

From the above, we can conclude that 116 liters of cold water at 6° C needs to be mixed with 196 liters of hot water at 60° C to get 312 liters of water at 40° C. Now from the table 7, we can see that a 100 liter system at Leh can deliver 89 liters of hot water per day. Therefore, to get 196 liters of hot water, collector area needs to be 4.2 sq meters [2 X (196/89) = 4.2]. Considering annual climatic condition of Leh, 200 liters of storage tank capacity is more than sufficient. Therefore, the size of the solar water heating system must be as follows.

Hot water requirement per day at 40°C	312 liters
Size of the storage tank	200 liters
Size of the collector area	4sq meters

b) If we need to calculate the size of the solar water system for Delhi, we shall get

$$\frac{\text{Quantity of cold water}}{\text{Quantity of hot water}} = \frac{\text{Hot water temperature} - \text{Use water temperature}}{\text{Use water temperature} - \text{Cold water temperature}}$$

$$\frac{\text{Quantity of cold water}}{\text{Quantity of hot water}} = \frac{60 - 40}{40 - 10} = \frac{20}{30} = \frac{2}{3}$$

Therefore, 125 liters of cold water at 10° C needs to be mixed with 187 liters of hot water at 60° C to get 312 liters of water at 40° C. Now from the table 7, we can see that a 100 liter system at Delhi can deliver 102 liters of hot water per day. Therefore, to get 187 liters of hot water, collector area needs to be at 3 sq meter [2 X 187/102 = .3.6] However, if 3.6sq meter is not a standard size of collector available in the market, customer needs to go for the next higher size. Hence the size of the solar water heating system may be as follows.

Hot water requirement per day at 40°C	312 liters
Size of the storage tank	200 liters
Size of the collector area	4 sq meters

c) If we need to calculate the size of the solar water system for Kolkatta, we shall get

$$\frac{\text{Quantity of cold water}}{\text{Quantity of hot water}} = \frac{\text{Hot water temperature} - \text{Use water temperature}}{\text{Use water temperature} - \text{Cold water temperature}}$$

$$\frac{\text{Quantity of cold water}}{\text{Quantity of hot water}} = \frac{60 - 40}{40 - 19} = \frac{20}{21} = \frac{1}{1}$$

Therefore, 156 liters of cold water at 19° C needs to be mixed with 156 liters of hot water at 60° C to get 312 liters of water at 40° C. From the table 7, we can see that a 100 liter system at Kolkatta can deliver 127 liters of hot water per day. Therefore, to get 156 liters of hot water, collector area needs to be only 2 sq meter [2 X (156/127) = 2.4]. However, to store hot water close to 156 liters, 200 liters of storage tank capacity should be used. However, if hot water is used regularly, a 150 liter storage tank is also more than sufficient. It is always advisable to have the storage tank of a little higher capacity to avoid overheating during summer season. Therefore, size of the solar water heating system may be as follows.

Hot water requirement per day at 40°C	312 liters
Size of the storage tank	150 - 200 liters
Size of the collector area	2 to 3sq meters

d) If we need to calculate the size of the solar water system for Mumbai, we shall get

$$\frac{\text{Quantity of cold water}}{\text{Quantity of hot water}} = \frac{\text{Hot water temperature} - \text{Use water temperature}}{\text{Use water temperature} - \text{Cold water temperature}}$$

$$\frac{\text{Quantity of cold water}}{\text{Quantity of hot water}} = \frac{60 - 40}{40 - 23} = \frac{20}{17}$$

Therefore, 163 liters of cold water at 23° C needs to be mixed with 149 liters of hot water at 60° C to get 312 liters of water at 40° C. From the table 7, we can see that a 100 liter system at Mumbai can deliver 171 liters of hot water per day. Therefore, to get 139 liters of hot water, collector area needs to be only 1.7 sq meter [2 X (149/171) = 1.8] If the minimum size of the collector available in the market is 2 sq meter, customer will have to select 2 sq meter as the required size. However, to store a hot water close to 171 liters, 400 liters of storage tank capacity should be used. However, if hot water is used regularly, a 300 liter storage tank is more than sufficient. It is always advisable to have the storage tank of little higher capacity to avoid overheating during summer season. Therefore, size of the solar water heating system may be as follows.

Hot water requirement per day at 40°C	312 liters
Size of the storage tank	300 - 400 liters
Size of the collector area	1.8 - 2 sq meters

Place	Latitude Inclination Degree	Collector Temperature Degree	Day Ambient Temperature Degree C	Cold Water Radiation Degree C	Solar Inclination KWh/day	At Temperature KWh/day	Hot Water Output Degree C	Approx Litres/day
Northeast Plain								
Siliguri	24.83	40	20	14	4.176	6.26	60	111
Dibrugarh	27.48	42	20	14	3.74	5.71	60	101
Gahauti	26.1	41	22	18	4.018	6.29	60	126
Agarthala	23.88	39	23	18	4.094	5.92	60	120
West Plains								
Bikaner	28	43	19	13	4.208	7.21	60	124
Jaiselmer	26.9	42	18	12	4.361	7.41	60	124
Jaipur	26.82	42	18	12	4.461	7.58	60	127
Jodhpur	26.3	41	21	14	4.508	7.57	60	136
Kota	25.18	40	20	13	4.67	7.72	60	134
Udaipur	24.38	39	21	14	4.71	7.54	60	135
Ahmedabad	23.07	38	24	17	4.822	7.64	60	151
Baroda	22.3	37	27	20	4.886	8.03	60	176
Surat	21.2	36	27	22	4.859	7.13	60	166
Rajkot	23.42	38	26	22	4.764	7.22	60	167
Nagpur	21.15	36	23	16	4.814	7.22	60	138
Mumbai	19.12	34	27	23	4.948	7.13	60	171
Pune	18.53	33	22	15	5.03	7.11	60	132
Solapur	17.67	32	25	18	5.159	7.16	60	147
Goa	15.48	30	26	21	5.37	7.22	60	162
Centre Plains								
Gwalior	26.23	41	20	13	4.303	7.11	60	123
Bhopal	23.27	38	24	17	4.652	7.28	60	144
Indore	22.72	38	23	16	4.772	7.28	60	139
Jabalpur	23.15	38	22	15	4.516	7.00	60	130
Satna	24.37	39	20	13	4.54	7.36	60	128
Raipur	21.27	36	20	13	4.54	7.36	60	128
South Hills								
Kodaikanal	10.23	25	15	9	5.19	6.22	60	93
Ootacmund	11.4	26	12	6	5.264	6.46	60	88
South Plains								
Hyderabad	17.45	22	24	17	5.133	7.03	60	139
Bangluru	12.95	28	22	16	4.949	6.20	60	118
Coimbtore	11	26	26	20	5.141	6.30	60	138
Chennai	13	28	26	22	4.707	5.83	60	136
Kanayakumari	8.08	23	26	22	5.082	6.01	60	140
Tiruchapalli	10.77	26	26	21	4.949	6.08	60	138
Trivandrum	8.48	23	26	22	5.498	6.58	60	153
Visakhapatnam	17.72	32	24	20	4.992	6.92	60	149
Manglore	12.92	28	28	22	5.302	6.79	60	160
Portblair	11.67	26	28	24	4.641	5.63	60	143





Chapter 4

Cost evaluation of solar water heater system

Introduction

There is a general tendency of customers to look at the initial cost while taking purchase decisions. However, the products initially cheaper may cost more over life time when compared with other similar products. Therefore, the concept of life cycle cost evaluation of solar water heater is important for the customers while taking purchase decisions.

Objective

The objective of this chapter is to introduce the principles of life cycle cost evaluation while taking purchase decisions of solar water heater. The initial cost of solar water heater system is recovered through savings of energy bills over a period of time.

Life cycle cost principles

There are many factors to be considered while evaluating life cycle cost of solar water heating system. These factors are interest rate, inflation rate, unit cost of electricity, operation & maintenance cost and solar water heater service life. All these factors are affected by fluctuations in the economy, government policies, electricity tariff, etc.

Interest Rate: Interest rate is an important part of the loan. Terms and conditions of loan such as interest subsidy offered by MNRE, loan terms, pre payment penalty, time taken for approval etc. need to be checked by the customers before finalizing loans with a particular bank.

Inflation Rate: This factor shows the effect of inflation rate on the real value of money. Substantial increase in the price of the solar water heater system is due to the increase in inflation rate which means decrease in the value of money. With the rise in inflation rate, price of goods will increase.

Electricity/ Fuel rate: One of the main reasons to go for solar water heating system is to cut down on electricity consumption. Unit cost of electricity varies from place to place and electricity tariff in a state is determined by the state electricity regulatory commission, which is revised from time to time. It is very important to understand how much savings are generated by reduction in electricity consumption from the solar water heating system over its service life.

Operation & maintenance cost: Operation and maintenance cost needs to be calculated from the accumulated expenses under the following heads:

- Solar water heater system cost (collector, storage tank with necessary plumbing)
- interconnection and installation)
- Freight & insurance cost
- Loading and unloading cost at the site of installation
- Excise, customs, octroi and sales tax levied on the products.
- Administrative and general cost
- Regular and periodic maintenance cost
- Depreciation cost

This figure needs to be calculated based on information from many manufacturers, different category of users and solar water heater experts. More realistic the expenses, more accurate the O&M cost. It is recommended that the customer must ask the O&M cost per liter of hot water per year from the manufacturer to arrive at the O&M cost of the entire system for a year.

Solar water heater service life: The service life of a solar water heater system varies widely depending upon technology, manufacturing quality, water quality and maintenance of the system. Flat plate collectors may be in service even after 20 years of operation whereas glass based evacuated tube collector may go out of service even before 5 years of service. After discussions with reputable solar water heater manufacturers, it is confirmed that the recommended service life of flat plate tube collector is 15 years while that of all glass evacuated tube collector is 5 years.

Table 9

Financial Analysis for Solar Heating System at Chelsea Mills Manesar

Solar Flat Plate Collector	410 Nos.
Size of Tank	10000 Ltrs.
Size of System	50000 Ltrs.
Energy Saved	271 Liters of Diesel per day
Cost of Project	46.50 Lacs.
Year of Installation	2006
Depreciation Benefit	80% for 1st year Diesel savings 271.00 Liters / Day Annual
Diesel savings (325 days of operation)	88075 Liters / year
Annual Energy Saving	Rs. 1585350 @ Rs. 18/Liter Diesel in 2006 Rs. 1761500 @
Rs. 20/Liter Diesel in 2007	Rs. 2201875 @ Rs. 25/Liter Diesel in 2008 Rs. 2201875 @
Rs. 25/Liter Diesel in 2009 Pay Back Period	2.37 years

Table 10

Net return on investment / year	Rs.3048619
Net % Return in investment / Year	66%

Detail cash flow analysis

Project Cost	Rs.4650000
Interest on capital employed	12%
Operation & Maintenance cost	2% of project cost escalating at 10% per year
Fuel cost	10% escalation per annum after 2009

Quarterly Cash Flows

Year	2006	2007	2008	2009	2010
Savings	1585350	1761500	2201875	2201875	2422063
Interest Payment	558000	76985	90487	0	0
Maintenance	93000	102300	112530	123783	136161
Depreciation Benefit	1149480	229896	45979	0	0
Net Cash Flow	2083830	1812111	2044837	2078092	2285901
Cumulative net inflow	2083830	3895941	5940778	8018870	10304771

Year	2011	2012	2013	2014	2015
Savings	2664269	2930696	3223765	3546142	3900756
Interest Payment	0	0	0	0	0
Maintenance	149777	164755	181231	199354	219289
Depreciation Benefit	0	0	0	0	0
Net Cash Flow	2514491	2765940	3042534	3346788	3681467
Cumulative net inflow	12819263	15585203	18627737	21974525	25655992

Year	2016	2017	2018	2019	2020
Savings	4290831	4719915	5191906	5711097	6282206
Interest Payment	0	0	0	0	0
Maintenance	241218	265340	291874	321061	353167
Depreciation Benefit	0	0	0	0	0
Net Cash Flow	4049613	4454575	4900032	5390035	5929039
Cumulative net inflow	29705606	34160180	39060213	44450248	50379287



Chapter 5

Installation of solar water heater system

Introduction

Performance of solar water heater will depend largely on the proper installation of the system. Following the proper installation guide is also important for the safety of the installers during installation and safety of the people post installation.

Objective

The objective of this chapter is to give a general idea of solar water heater classification based on installation practices and to lay the basic guidelines during installation of solar water heater systems. Depending upon the kind of systems, fluid circulation principles, structure of the installation plane etc. installation practices are different.

Solar water heater classification based on installation practices

Prefabricated solar systems: Prefabricated systems are sold as a single product under a single brand name. These kinds of systems are sold as a package and are ready for installation at sites. These are normally direct systems. If any of the components of the prefabricated systems is altered, the system no longer remains a prefabricated system. In India, we do not have any standard for prefabricated systems, however efforts are on to develop one in line with EN- 12976 1: 2000 and EN -12976 2: 2000.

Custom built solar systems: Custom built system is normally built with a set of components to meet the specific demand of the customer. Here each individual component is tested separately as per the standard and then test results are combined together to review the complete system. India has a BIS standard for the collector under IS12933:2003. However, BIS does not have standard for other components of the system. Efforts are on to develop standards for each component of the custom built system in line with ENV 129771:2000.

Thermo siphon system: This is the most widely used system configuration. In thermo siphon system, cold water will flow into the system due to pressure difference and therefore the source of the cold water must be placed at least 7 feet or more, higher above the terrace level where solar water heater system will be installed.

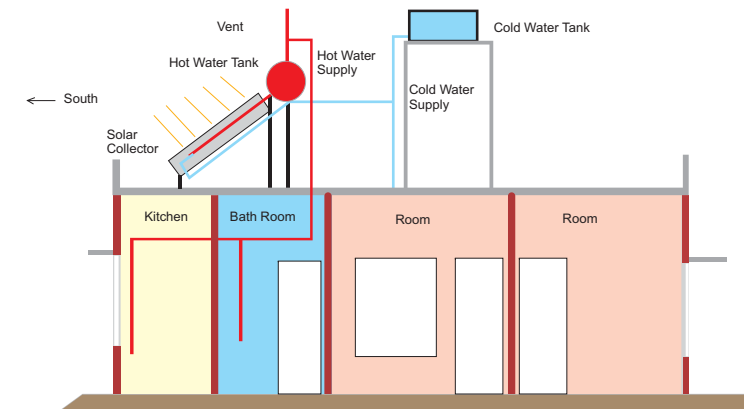


Fig2: Thermo siphon system with over head tank

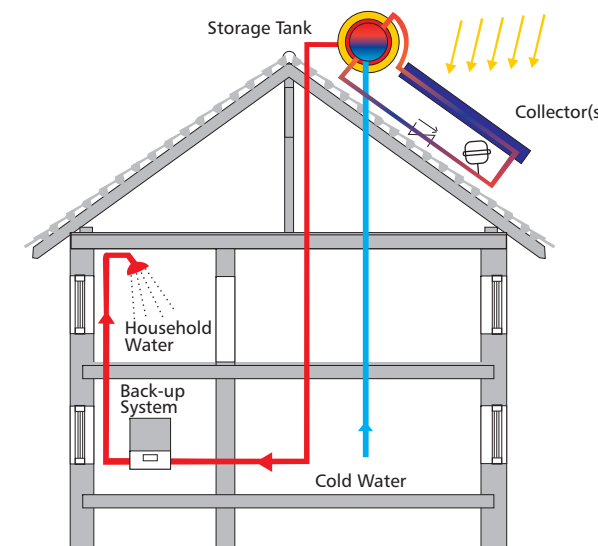


Fig3: Thermo siphon system with pressurized water supply

Forced circulation system: In forced circulation, source of cold water supply can be at any level as water shall be pumped into the system. It is recommended to use forced circulation system where source of cold water is not placed at sufficient height. In case of large systems also, it is recommended to have forced circulation system to attain sufficient water pressure and to maintain uniform water temperature.

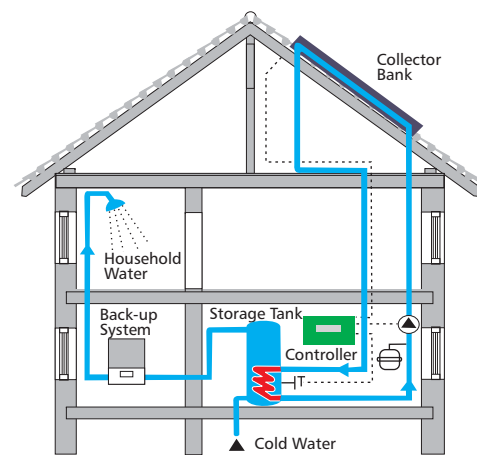


Fig4: Forced circulation with heat exchanger

Solar water heater with heat exchanger: Water quality and ambient temperature varies from place to place. If the water is hard, it will deposit minerals inside the water tubes of the solar collector. As a result, the collector tubes may get blocked and performance of the system reduced drastically.

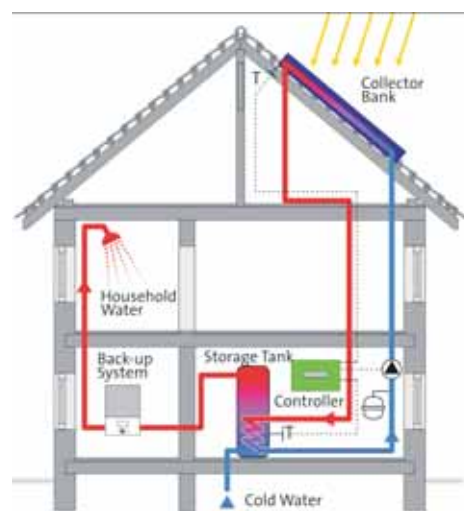


Fig5: Forced circulation with heat exchanger

Compact type (direct insertion type in case of ETC): Most of the solar water heaters installed in the country are the compact type. Here either the solar collectors are directly inserted into the hot water storage tank (ETC based system) or the collector and the storage tank are placed together with a small and flexible interconnection pipe. (FPC based system)



Fig6: Compact type FPC based system



Fig7: Compact type ETC based system

Body-separation type system: Body-separation type solar water heaters are forced circulation type system and normally come with a heat exchanger. Here solar collectors are separated from water tanks and collectors may be installed either on roof or on façade as per convenience of installation and operation.

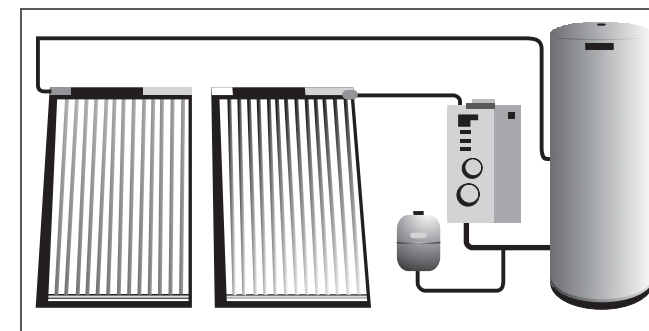


Fig8: Body separation type system

Planning of installation

The installation of solar thermal heating has a series of processes.

Design:

Design means selection of right technology, proper sizing of the solar water heating system and selection of the locations for collectors & storage tank installation in the building. The design drawing must be prepared before installation (Refer chapter 2 and chapter 3)

Recommended clearance between collector banks:

In an assembly of collector banks, installation should be done in such a way that the shadow on one collector bank does not fall on the other, to get maximum output. Following graph shows the distance between two collector banks based on the angle of tilt.

Fig: Distance between banks vs. angle of tilt.

Assembly of collectors:

Assembly of collectors should be installed in such a way that it is easy to do regular and periodic maintenance.



Fig9: Assembly of collector Easy to maintain.

Support structure:

Support structure should be stable, resistive to corrosion and angle of tilt must be proper. Support structure must be anchored to the roof or ground firmly by cement concrete blocks or anchor bolts. The anchoring must be sufficient to ensure that strong winds are not able to topple the structure and solar collectors.

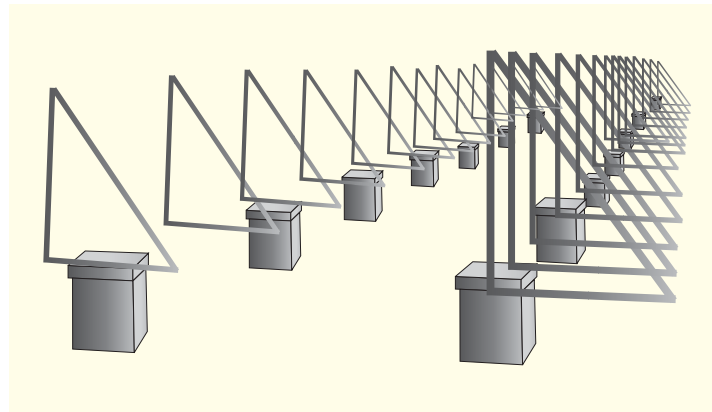


Fig10: Fabrication of support structure

Storage tank:

Proper attention should be there while installing the hot water storage tank on the rooftop. (Design of the roof to take the load of the tank with water. How to transfer the load of the tank to the building columns and beams) Attention to small things such as whether the storage tank can pass through the terrace door or whether there is sufficient place for a crane to operate for lifting the storage tank up to the terrace, are important. Following points should be taken care of while installing the storage tank.

- Proper insulation of the storage tank
- Proper installation of the sacrificial anode.
- Avoid uses of different materials to prevent galvanic corrosion.



Fig11: Installation of storage tank

Connection of hot water storage tanks is also important to receive maximum output. Figure below shows the right and wrong method of interconnections of the storage tanks.

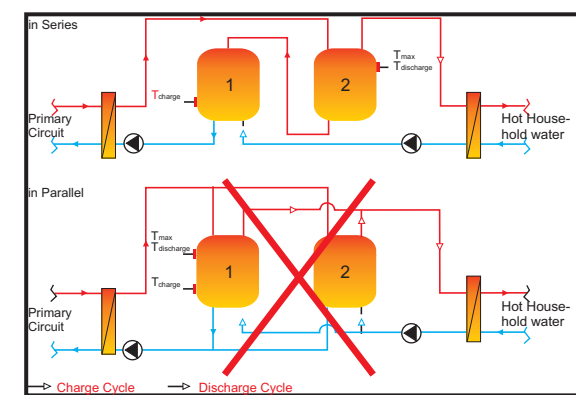


Fig12: Interconnection of storage tanks

Plumbing:

Compact type ETC system does not require any piping between the collector and the hot water storage tank whereas FPC based direct system requires a flexible connection between the collector and the storage tank.

Body separation type system (ETC and FPC both) require internal piping between the collector and the hot water storage tank. Since body separation type systems normally come with heat exchanger, piping needs to be insulated adequately to limit heat loss.

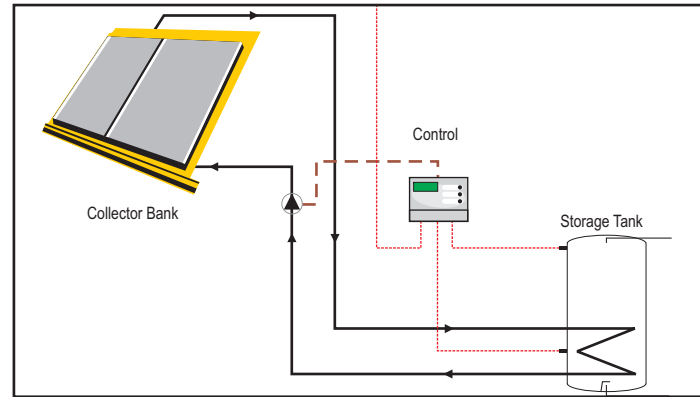


Fig13: Body separation type collector

Cold water plumbing:

1. PVC or GI pipe may be used up to the cold water inlet of the system. Proper care should be taken so that there is no leakage at the joints. If GI pipe is used, the pipe should be painted externally to avoid galvanic corrosion.
2. The connection of cold water supply to collectors should be either horizontal or continuously moving downwards to the collector.
3. For thermo siphon system, height of the bottom of the cold water source (typically a storage tank) should be at least 7 feet or more, above the terrace level where solar water heating system shall be installed.
4. Separate piping should be done from the cold water source (storage tank) to the hot water storage tank.
5. In the cold water line, a separate gate valve and a union have to be provided at a point near and below the solar hot water storage tank.
6. Cold water air vent pipe is to be provided at the point from where the cold water pipe from the cold water source drops down.
7. The top height of the air vent pipe provided at the drop down point should be at least 2 feet higher than the cold water source overflow outlet.
8. If a separate cold water tank is provided for the solar water heater, the capacity of the cold water tank should be at least double the size of the solar water heating system.
9. Cold water tank should be kept clean and covered.
10. It is recommended to use a non return valve at the inlet of the cold water into the hot water storage tank.

Hot water plumbing:

1. Hot water connection can be done with insulated GI or copper pipes. Special attention should be given to ensure that the plumbing does not get damaged due to thermal expansion and contraction.

2. Zigzag piping is likely to create air bubbles inside pipes, blocking the flow of water, resulting in system overheating and steam generation.
3. The hot water pipe should be comparatively of smaller diameter and of shorter lengths. Smaller diameter and shorter lengths will reduce heat loss.
4. Hot water air vent pipe should be at least 2 feet higher than the cold water air vent.
5. In the hot water delivery line, only one union has to be provided in the nearest point of the solar system.
6. If the hot water line is taken via geyser, it should be connected to the outlet point of the geyser.

Table: 11

The Table below shows the Pipeline Capacity and the Cold water expected to be removed in the morning from one meter of hot water pipe before hot water flow starts

Nominal Pipe Dia GI Medium Class	Capacity/meter Litre/meter	Weight /meter Kg	Specific Heat	Equivalent water From 20 to 60 Deg Heating of pipe	Total hot Water Loss Every Morning Per meter pipe
15	0.201	1.22	0.11	0.134	0.34
20	0.367	1.58	0.11	0.174	0.54
25	0.581	2.46	0.11	0.271	0.85
32	1.012	3.15	0.11	0.347	1.36
40	1.371	3.61	0.11	0.397	1.77
50	2.206	5.1	0.11	0.561	2.77

Insulation:

All hot water piping needs to be insulated. The insulation is done with flexible foam materials like nitro-flex tubing or with glass-wool pads or with polyurethane pipe sections. The insulation is to be protected from rain water and solar radiation damage by covering with aluminum, GI sheet or fibre-glass cladding.

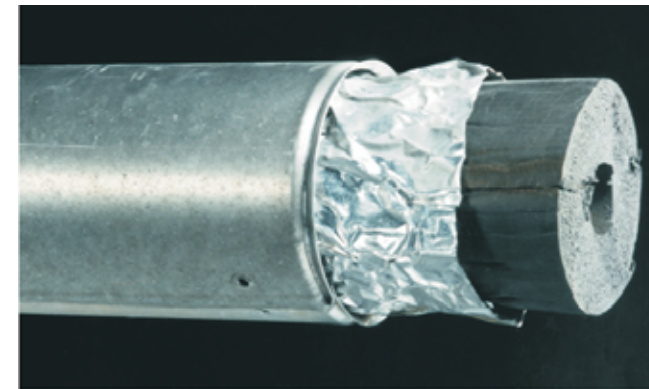


Fig14:

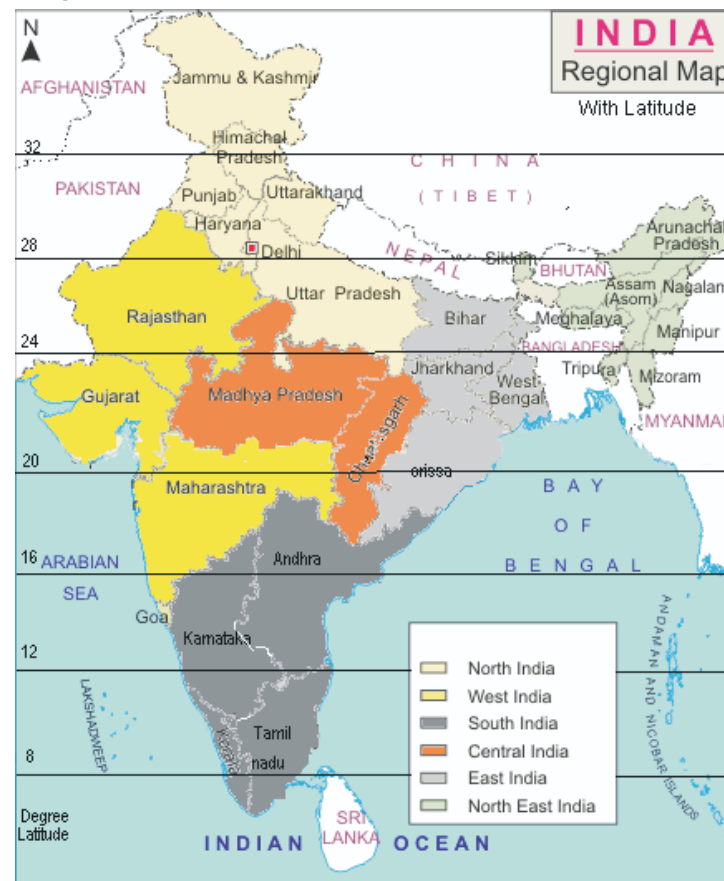
Special attention must be paid to insulation if the hot water piping is inside brick walls. The loss of heat to wall from pipe in the wall is many times more than the loss of heat from exposed pipe to air. Cold water piping and hot water piping must be kept separate.

Orientation and angle of tilt:

Orientation of the collector and the angle of tilt are very important for optimum output of the solar system. Our country is located in northern hemisphere of the earth. The sun in winter rises in south east and sets in south west. The collector for all locations in India should be oriented in a direction facing south. At times compromises become essential due to non-availability of area where the solar collectors can be oriented and located in a shadow free area. The compromise must be limited to angle of 15 degrees towards west or east for minimal effect on output from the solar system.

The alignment of the axis of the earth in relation to the sun is such that the solar radiation reaches us from southern sky tilted at an angle from the overhead position. The angle of tilt at noon time corresponds to Latitude of the place on 22nd September. It becomes Latitude +23.5 degrees on 22nd of December. The angle of tilt starts to shift in the other direction and it corresponds to the latitude of the place again on 22nd March. The shift continues till the angle of tilt reaches latitude of the place - 23.5 degree on 22nd June around noon time.

Graph 4



Since we require more hot water in winter than in summer, orientation of the solar collector must be made to maximize noon time radiation on the collector in winter. Therefore the collector must be oriented facing south at an angle of $\text{Lat} + (10 \text{ to } 15)$ degree from the horizontal.

If we require the hot water equally in the winter and summer months, the angle of tilt of the collector may equal to the latitude of the place. If the requirement is higher in summer months the angle of tilt is to be less than the latitude angle of the place. The latitude angle for the places is determined by the distance of these places from the equator. It increases as the distance from the equator increases. (e.g. Latitude of Banglaru is 13 Degrees, Delhi is 29, and Srinagar is 34 degrees)

In some systems a number of solar collectors are required. It may not be possible to locate these in one line due to site restraint. In such cases it is necessary to keep adequate distance between the collectors to ensure that the shadow of one collector does not fall on the front surface of the other collector.

The hot water storage tank is normally located behind the collector and higher than the collector. When more than one system is installed in a place the shadow of one system should not fall on the collectors of the other system.

Specification:

Specification means listing down the key parameters of solar water heater based on design consideration, environmental conditions, water quality and return on investment. (Refer chapter 1 and chapter 4)

System dimensioning:

Once a particular manufacturer is shortlisted, next step would be to determine the dimensions of the system based on supplier's data. Here the dimension of the collector area, water storage tank etc will be required to plot on the installation drawing.

Assembly & installation:

It is important to work on the required support structure to install the system at site. This step will include fastening of collector and storage tank, commissioning of pipe work, pump system, control system and electrical back-up.

Once the assembly & installation is done, solar water heater system is to be tested & commissioned.

General considerations during installation planning

Shade: The collector must be installed in a shadow free area. Collector should not be placed in the direction where tree plantation is there. Trees may grow over a period of time and shadow may fall on the collector. In urban environment it may not be possible to achieve total freedom from shadows throughout the day. In such situations we must locate the maximum shadow free area on the building terrace to install the system. The aim should be to get a shadow free area at least for 3 to 4 hours on either side of the noon. This is a compromise and as a result there will be corresponding reduction in the output.

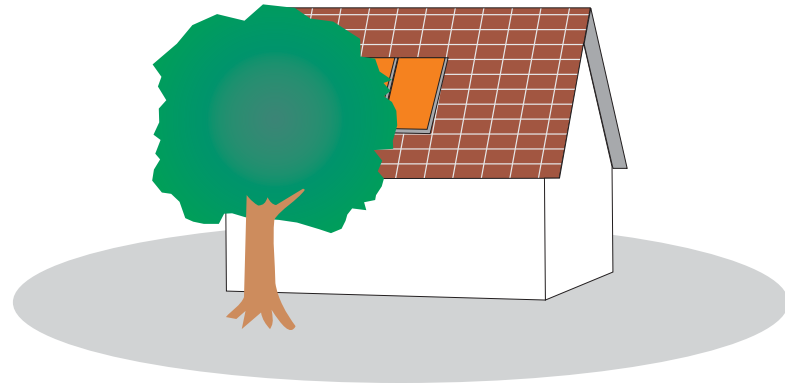


Fig15: Shadow of tree on the collector

In ETC based initial filling of water in the tank and tubes should be done in the morning when the tubes are cold. With sun exposure the tubes may become quite hot and if filled at that time, it may result in the breakage of the tubes due to sudden cooling.

Statutory rules: It is important to keep in mind the national, state and local municipal standards while installing a solar water heating system.

Safety: Safety is the most important consideration while installing the system. Below are the recommended safety tips during solar water heater installation.

- Wear proper safety dress and tie with safety rope during assembly.
- Take extra care while working on roofs. (specially taking care of loose tiles or electrical cables)
- Avoid working on inclined wet roof during rainy days.

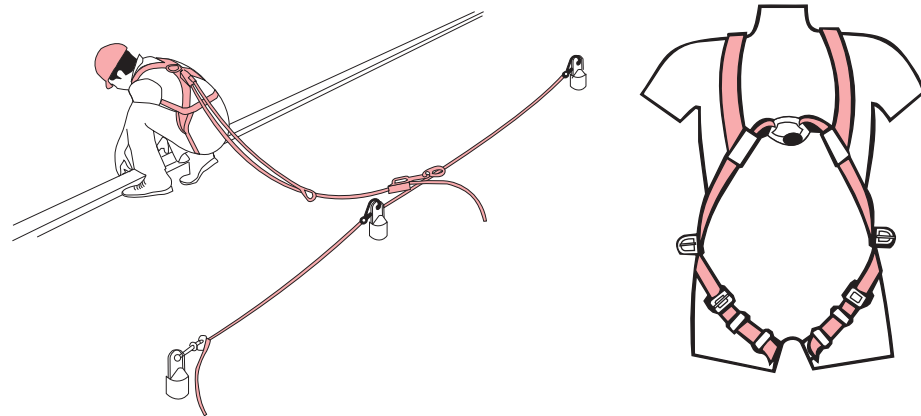


Fig16: Safety rules





Chapter 6

Maintenance and trouble shooting

Introduction

Regular and periodic maintenance is important for durable service life of any equipment. Solar water heater systems too need regular periodic maintenance for satisfactory service out of it.

Objective

Objective of this chapter is to explain the typical maintenance requirements of solar water heating systems. The chapter also covers the common problems the customers may face along with trouble shooting mechanisms.

Regular and Periodic Checks and Maintenance

1. Top glass cover is required to be cleaned periodically to allow the solar radiation to reach the absorber surface.
2. If the system is not be used in summer at all, it is required to drain off the water from the system completely in case of FPC Systems to avoid boiling of water in the storage tank.
3. Look for any sign of leakages in the system, in the collector and plumbing joints and have these rectified early. Leaving leakages, unattended in insulated piping, results in corrosion of the pipes.
4. Check for the back-up elements/ thermostats every year before winter period and have these replaced if gone bad.
5. For systems with heat exchangers installed with hard water check for water flow in the hot water pipes after each summer. At times scale deposits chocks the hot water outlet. In such cases, the hot water outlet along with the heat exchanger needs to be cleaned.
6. Check for physical conditions of supports. These may be required to paint periodically to avoid corrosion.
7. If water quality is bad and unsuitable for tank material, the tank may start leaking. Check for any leakages and report for changes/replacements.
8. Check for any construction in the neighborhood which is causing a shadow on the solar panel, the system may need to be shifted to shadow free location.
9. Check for any damage to insulation cladding, it may require replacement /repair if damaged for any reason.

Trouble Shooting

1. Pump is not operating during sunshine hours. This could be caused by
 - a. No electric power
 - b. Sensor malfunction
 - c. Controller malfunction
 - d. Pump failure.
2. Pump is operating with frequent on / off. This could be caused due to small gap between ON and OFF temperature settings OR pump circulation circuit is too large.
3. Tank pressure is too high. This could be due to high filling pressure OR vent / pressure release is not provided or not functioning properly.
4. Tank Pressure is too low. This could be caused by leakage or loss of cold water supply.
5. Pump does not stop in the evening. This could be caused by defective setting or defective sensors.
6. Storage tank cools down very fast at night. This could be caused due to recirculation pump not stopping at night or insulation of the tank got damaged.
7. Water does not heat sufficiently on clear days. This could be caused by dust on collectors, undersize system or damage to collector coating.



Chapter 7

Frequently asked questions (FAQ)

Does solar water heating system work on cloudy days?

Solar water heating is done by the energy received from the Sun. If the energy input is reduced or cut off by clouds the heating of water is reduced. All solar systems have back up heating devices for meeting these contingencies. In most of the solar water heating systems, the hot water heated on previous day, is used in the morning of the next day. It will be known by the evening if heating during the day has not taken place, and auxiliary heating can be switched on for heating in the night.

What is the life of the solar water heating system?

The solar water heaters are generally expected to last 15 Years, but solar water heating systems installed in 83-84 are still functional in most of the places. If water quality is not a problem we can expect solar water heating systems to last easily for 30-40 years. Some preventive maintenance for protection of exposed surfaces and pumps, valves, back- up systems and plumbing etc may be required, as for other systems in a building.

Does the output from solar water heating system decrease with age?

The output from the Solar Water heating system may marginally decrease over a period of time but the decrease is normally not very large.

What are the regular maintenance requirements?

The surface of the collector must be periodically cleaned to remove dust from the top surface to get optimum output from the system. Occasional observation of the solar water heating system to eliminate any plumbing leakages may help. The exposed metal surfaces may be examined for any damage to paint etc after monsoon period to avoid further damage. Some rubber or plastic components may not last beyond 10 years and may require replacement. Auxiliary heating elements also do not last through the life of the Solar Water Heating system and require replacement at times.

What are the guarantees on solar water heating systems?

All solar water heating system are guaranteed by manufacturers for one year. Some manufacturers provide guarantee of 5 years also. A large no of installers take annual maintenance contracts for larger systems for a fee, on mutually agreed terms.

Is it necessary to have a south facing shadow free area for installation of solar system?

Solar systems perform best in winter when installed facing south at optimum angle. The variation by 15 degrees to east or west does not affect the output significantly.



Annexure A

Introduction to Solar Heating

Heat transfer principles

The process by which the solar energy reaches us in spite of such a large distance between the sun and the earth is called 'radiation'. This phenomenon of exchange or transfer of energy happens between any two objects, facing each other even when they are away from each other even when there is no other material (solid, liquid or gas) between the two objects.

When a solid object has a high temperature on one side and low temperature on the other side of it, the exchange of heat takes place from the high temperature side to low temperature side. Consider the case of a spoon placed in a cooking pot. The side of the spoon, inside the pot, is at a higher temperature, as compared to the handle portion. But if we keep the spoon, dipped in the pot for too long, the handle also becomes warmer. This phenomenon of exchange of heat through a solid material or between two solid materials in contact is called 'conduction'.

When a gas, like air or a liquid, flows over a hot surface, it gets heated or it gets cooled when flowing over a cooler surface. The exchange of heat has taken place between the liquid or gas, and that surface. This phenomenon of exchange of heat is called 'convection'.

Solar water heating principles

Let us examine the phenomenon of heating with solar energy. Sun radiates energy in the form of heat and light. A dark coloured surface of an object, when exposed to sun, absorbs most of the heat and the object gets heated up. As a result there is rise in temperature of the associated material by way of conduction. Since the dark coloured object has attained higher temperature than the surrounding air, it exchanges heat with the air by way of convection. Again, as the dark object is exposed to the atmosphere, it exchanges heat with the atmosphere by way of radiation.

If we can control the exchange of heat between the dark coloured object (absorber surface in the collector) and the material that is required to be heated up (water in the collector) by way of conduction or convection, it would be considered as a desirable heat exchange. The devices, used for solar heating, try to increase this desirable heat exchange and reduce the undesirable heat loss to air, atmosphere or other materials in contact. The device that is used for this controlled heat exchange and for converting the solar energy into useful heat is called 'solar collector'.

The solar radiation on earth comes from two sources. One, direct solar radiation that comes directly from the sun and other the diffused solar radiation that is scattered by the atmosphere or is reflected from the surrounding objects in a random form. Some of the devices of solar heating are able to use both the diffused as well as direct solar radiation while some are able to use only the direct solar radiation. Solar water heating systems use both.

Solar Water Heater Classification

As key components in building solar water heaters, solar collectors accept solar radiation, convert it to thermal energy and deliver it to water in the solar water heating system. Based on solar collector types, solar water heater systems are classified as flat plate solar heaters, all-glass vacuum tube heaters and heat pipe vacuum tube heaters.

Flat Plate solar water heaters

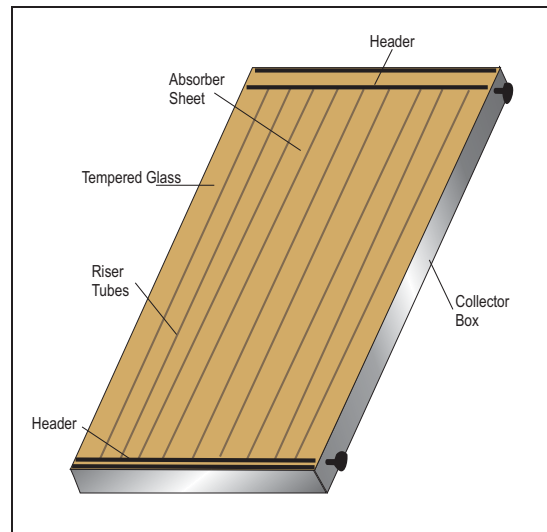


Fig17: Front view of a flat plate collector

As the name implies the solar flat plate collector has a surface exposed to the sun in the shape of a flat plate. A flat plate solar collector comprises of a transparent cover, absorber plate, a insulation layer and outer covering.

Heat collection theory:

After penetrating the transparent cover, sun's rays are projected on the absorber plate. The absorber plate goes on to absorb solar energy, converts it into heat energy, and passes the heat energy to the heat transfer medium inside the tubes. The temperature of the heat transfer medium (in this case water) rises.

The absorber plate is normally made of copper. In order to better absorb solar energy, the absorber plate is covered with a selective coating. The German TINOX coating can absorb 95% of solar energy and reflects back only 5% thermal energy.

Significance of different components of the flat plate collector:

The absorber plate is exposed to the sun and gets heated up by absorbing the solar radiation. Tempered glass is used to prevent absorber from direct contact with the atmospheric air and the loss of heat to the air by way of convection, while allowing solar radiation to reach the absorber surface. Collector box holds the glass in place. The collector box is insulated from all sides to prevent heat loss due to conduction. The bottom header is used for flow of cold water into the collector whereas the top header is used to take away the hot water. The top and the bottom headers are connected by a number of copper tubes. These tubes are called risers.

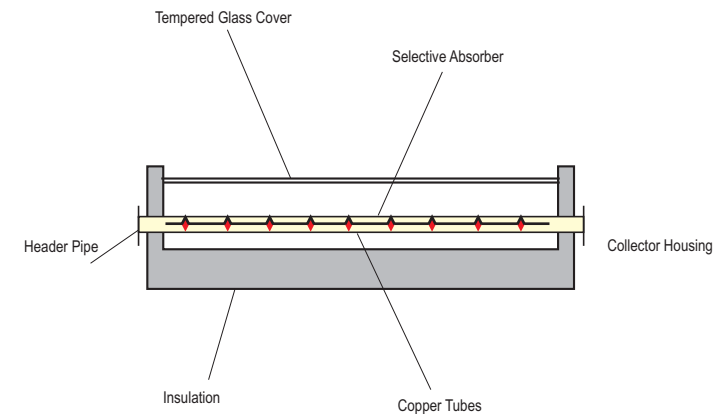


Fig18 Side view of a flat plate collector

Selection of materials for the solar collector is extremely important to achieve higher efficiency in a solar water heating system. Following points should be kept in mind while selecting materials for solar water heating systems.

1. Highest possible value for glass transmission coefficient. (close to one)
2. Absorber coating with highest absorption coefficient. (close to one)
3. Lowest emission coefficient of the absorber coating.
4. Conduction of heat from absorber plate to the tubes is governed by thickness and conductivity of material used and the contact between the absorber and the riser tubes. Therefore, it is desirable to have maximum possible contact between the riser tubes and absorber plate. High conductivity material should be used for this purpose.

The quality of the materials used and construction methods employed, which determine the life of the collector and its performance are-

1. Leakage resistance to avoid seepage of rain water
2. Corrosion resistance in different environmental conditions.
3. Resistance against ultraviolet radiation.
4. The resistance against cyclic heating and cooling effect.
5. Structural stability and resistance against wind.
6. Proper sealing properties of gaskets against cyclic heating and cooling effect.
7. Durable fasteners suitable for outdoor conditions.

8. Transparent and tempered glass to withstand natural calamities, monkeys or birds jumping onto it.
9. The design of the collector must be made considering expansion and contraction of materials due to temperature variation
10. Riser and the header should be resistant to corrosion and should not react with the chemical content of water. (quality of water/fluid used determine the compatibility of the tube materials for corrosion resistance)
11. Capability of the metal used in riser and header to withstand high temperature and pressure.
12. Capability of Insulation materials to withstand high temperature.

Sub classification of solar flat plate collectors

Based on number of covers:

Unglazed, single glazed or double glazed depending upon whether no cover, single transparent cover or two transparent covers with an air gap between the two covers have been used. The two cover system reduces the loss of heat to the ambient air compared to single transparent cover. However it also reduces the solar radiation reaching the absorber due to transmission loss through two covers. Therefore double glazed collectors are useful only in some special applications.

Based on type of absorber coating:

As black painted or selectively coated, depending on the use of black absorbing paint or selective coating on the absorber surface.

Based on material of the absorber:

Copper, Aluminium or Mild Steel are used as absorber materials. Unglazed collectors are made with plastic black materials also. However, each material will have different impact on the efficiency, reliability and durability of the solar water heater.

Evacuated tube Solar Collectors

There are mainly two types of evacuated tube solar collectors.

- All Glass vacuum tube collector
- Heat pipe type vacuum collector

All Glass vacuum tube collectors:

Looking like long thermos bottle liners, all-glass vacuum tubes comprise glass tubes (outer tubes), vacuum inter-space and inner glass tube (inner tube) .



Heat collection theory:

Solar energy radiation permeates outer glass tubes to heat water in the vacuum tubes. Since cold water has higher specific gravity and hot water has lower specific gravity, cold water flows downwards and hot water rises upwards in the inner tubes, this gradually raises water temperatures in the hot water tank.

The black part on the outer walls of inner tubes is selectively coated and serves as the medium for light to heat conversion in ETC. Sun's rays reach the absorber coating through the outer glass tubes. The coating absorbs the visible light and near infrared rays of sun's rays to convert light energy into heat energy. This raises the water temperature in the inner tubes. The selective absorption coating, made of Al-N/Al, is currently the most widely used coating. This coating is capable of absorbing 93% solar energy and reflects back 6%.

A vacuum inter-space between the outer tube and the inner tube reduces the heat loss, preserving heat, and thus promoting thermal collection efficiency.

The construction of all-glass vacuum tubes is fairly simple and production technology is well established.

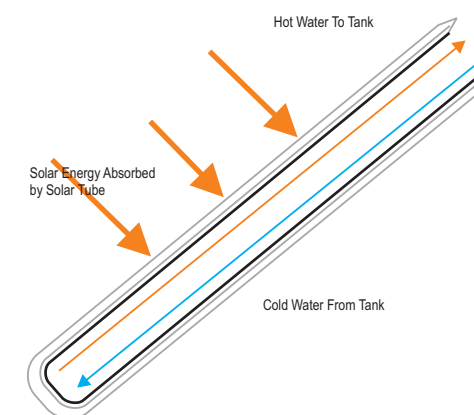


Fig20: Double Glass Evacuated Tube with inner tube coated and filled with water.

Heat pipe type evacuated tube collectors:

Heat pipe vacuum tube solar heaters consist of glass tubes, heat pipes and metal fins. These are classified into metallic heat absorbing vacuum tube solar heaters (big heat pipe), U tube solar heaters and others.

Metallic heat absorbing vacuum tube solar heaters (big heat pipes):

Also known as big heat pipes, with 100mm diameters. Such solar heaters are mainly used as high-grade pressurized water heaters.



Fig21: Heat Pipe

Metallic heat absorbing vacuum tubes have single layer glass (3mm extra thick high borosilicate glass) as outer walls, and vacuum inside. Absorber plates are made of copper-aluminum compound fins or pure copper fins. The surfaces of absorber fins are coated with selective absorbing coating. The inside of heat pipe has a working fluid under vacuum conditions.

Vacuum tubes rely on metal absorber plates inside the tubes to absorb solar energy and convert them into heat energy. Heat is transferred to the working fluid which instantly evaporates under the vacuum environment. The hot vapour moves upwards and condenses at the top end and transfers heat to the water in the manifold / tank. The condensed medium flows downwards along the pipe walls. In this gas-liquid cycle, the working medium inside the heat pipes continuously moves the absorbed solar energy to the condensation end for heating water.

The vacuum tubes do not have any water. Metal fins absorb heat. The ends are sealed with metals and glass airtight joint.

U tubular heat pipe vacuum tube solar heaters:



Fig22: U-Tubular Heat Pipe

In U tube type ETC, U-shaped metal tubes are used inside the all-glass vacuum tubes. Metal fins are attached to the metal tubes and these are in contact with the inner glass tube.

The working medium inside the metal tubes is heated by the solar radiation that is collected by the all-glass vacuum tube and passed via metal fins. This creates flow of the medium by convection.

Glass tubes do not come into direct contact with the heated working medium. The U tubular tubes have water as the working medium. Such heaters have the advantage of all-glass vacuum tubes. Since water is heated in the U tube pipes, heat may be transferred directly. Since water serves as the working medium, the solar heaters suffer from such problems as freezing and scale formation in metal tubes. Therefore, they are normally used in indirect heating system with forced circulation.

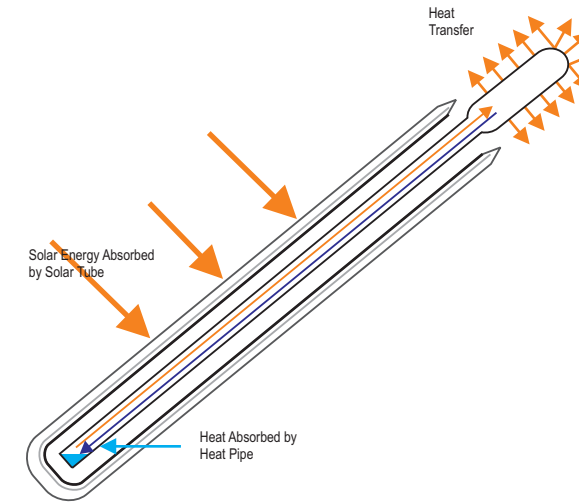


Fig23: Heat Pipe Evacuated Tube Collector (Working Principle)

Further classification of solar water heaters:

Solar water heaters may also be classified into pressurised and non-pressurised types, according to whether the hot water tanks of solar water heaters operate under pressure or without pressure: (The pressurised type refers to the system in which water tanks of solar water heaters can endure pressure of water supply and the pressure from expansion of water when it is heated. Solar collectors of any type may be used in these solar heaters with suitable design.

Non-pressurised:

Non-pressurised solar heaters have movement of water from water tanks by gravity, without pressure. The main pipelines of water tanks are pipes for supply of cold water into the tank and supply of hot water from the tank. When the solar heaters are in operation, hot water will flow out of the water outlet pipe under gravitational head. Water is the medium in the vacuum tubes of non-pressure heaters. While non pressure based systems are simple in structure and low in cost, these cannot provide pressurized water supply.

Pressurised:

In pressurised solar heaters hot water flows from water tank, under the pressure of cold water supply. During operation, the solar heaters must have water inlet valve opened to ensure uninterrupted supply of water. These systems are easy in operation, but have high production costs.

As per the connection of water tanks and solar collectors of solar water heaters, solar water heaters may be classified into the compact (direct insertion) type and non compact type.

Compact type (direct insertion):

Most of the solar water heaters installed in the country are the compact type, meaning that solar collectors are directly linked with water tanks.

Non-compact type (Body Separation Type)

Non-compact type solar water heaters use manifold or piping for movement of the fluid in the heating system. Solar collectors are separated from water tanks. Solar collectors may be installed on house roofs, walls or balconies, for convenient integration of solar collectors and buildings. Water tanks may be installed in all places. In such cases normally pumps are used for circulation of the heating medium.

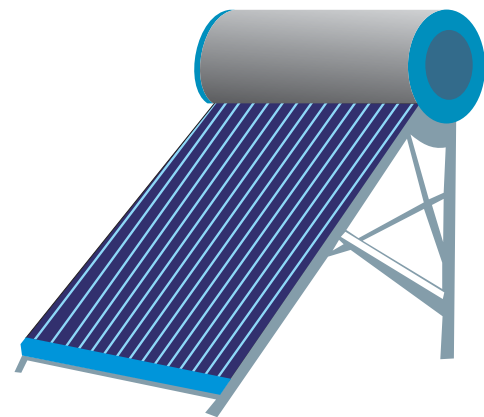


Fig24: Compact Type

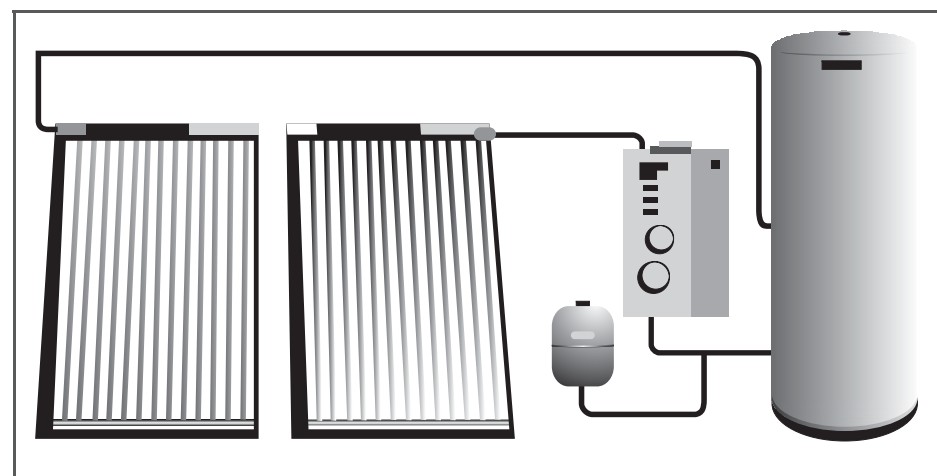


Fig25: Body separation type

Comparative advantages and limitations of different Solar Collectors

Table 11

	Plate type	All-glass vacuum tube
Working principle	<ul style="list-style-type: none"> Absorber plate with pure copper or with copper-aluminum compound. Water inside tubes Absorb heat with selectively coated fins 	<ul style="list-style-type: none"> All-glass tube structure Water inside the inner glass tubes Absorb heat with selective coating on the outer surface of the inner glass tube.
Merits	<ul style="list-style-type: none"> High pressure endurance Can be exposed to solar radiation even when there is no water inside the tubes. Body separation structure possible and layout of collectors can be made as per building plans. Energy output per unit of installed area of the FPC is higher than ETC because of larger collector occupancy area. 	<ul style="list-style-type: none"> Simple structure Lesser heat loss because of vacuum tubes. No corrosion of tubes as it is made of glass.
De merits	<ul style="list-style-type: none"> No anti-freezing capacity unless used with heat exchanger Poor heat insulation capacity No corrosion resistance with certain quality of water. Maximum temperature range is limited. Scale formation in the pipes due to bad water quality. 	<ul style="list-style-type: none"> Cannot be exposed to solar radiation even when there is no water inside the tubes. Gasket is a weak spot for leakage at the tube and tank joints. Scale formation in the pipes due to bad water quality. Temperature can shoot to very high level during summer when water is not in use. Glass tubes are made of thin glass and are prone to breakage. In case of breakage of tubes, the entire ETC system gets drained.
Guaranty period	<ul style="list-style-type: none"> Five years. (except for glass breakage) 	<ul style="list-style-type: none"> One years (except tube breakage)
Approximate Price	Rs. 18,000 - 24,000	Rs. 12,000- 15,000
Durability	<ul style="list-style-type: none"> Lasts for 15 years or more without major maintenance. 	<ul style="list-style-type: none"> Lasts for 3 to 5 years without major maintenance.

Economics of Solar Water Heating System:

A single collector system provides an equivalent of 5 KWH to 6 KWH of heat replacement on an average. It also replaces one to two geyser installations. The saving in terms of capital cost for two geysers may be up to Rs. 10000 to 12000 (including the cost of electricals and plumbing). The Solar water heating system may cost Rs 25000 including the cost of plumbing. Thus Solar systems are expensive by about Rs. 15000 for a single collector system. It may save an energy equivalent of 1800 KWh at the maximum and 900 KWh at the minimum per year.

At energy cost of Rs 5/KWh the saving is Rs 4500 To Rs 9000 per year depending on the usage of hot water. At present some incentives are available from governments in different states which provide easy financing and also capital subsidy.

Besides there is the significant advantage of regular availability of hot water, in the morning, when the power availability may be a problem due to high morning peak loads in winter months.

Environmental and other Advantages of Solar Water Heating Systems:

Each KWh of electricity produced uses 1 Kg of Coal for production of energy. Besides with transmission and distribution losses of 20% at the minimum, for each unit of power reaching a house hold the effective coal consumption is 1.25 Kg. Energy is spent in transporting coal to the power plants which may add 0.25 Kg equivalent of coal. Thus a saving in coal burning of 1.5 Kg is effected by saving one KWh of energy. The smallest solar water heating system will have a saving of equivalent of coal burning of 1350 to 2700 Kg per year of use.

Each unit of power produced, uses 3 litres of water, by evaporation for cooling purposes, in the power plant. A single collector system can save 2700 to 5400 liters of water every year.



Annexure B

SWH applications

Water heating system in high rise residential buildings:

Solar water heating systems are being installed on multistory buildings with a large no of apartments. There are different ways of installing these solar water heating systems. The system shown has been installed on top of the terrace of a 20 storied high rise building of Reserve Bank of India in Lower Parel, Mumbai with a capacity of 10000 litres /day of hot water. The system has supply and return piping to ensure hot water availability round the clock.



Name & Address		Key Statistics
Sun palazzo , Lower parel (formerly Matuliya Mills). RBI, Off S.V.Road, Lower Parel, Mumbai.	Capacity:	10,000 LPD system
	No of floors:	20
	Completion:	1998
	Total Cost:	Rs.
	System:	Closed loop forced circulation
	Electricity Savings	400 Kwh per day

Water heating system in apartment blocks

A number of systems of smaller capacity were installed on the terrace of the multistory building with large number of apartments. Each system in installed to meet the capacity requirement of apartments connected to a common pipe shaft. System shown in the picture has been installed on Vikas Plams in Thane. Total capacity of all systems put together is 16200 Liters per day for 54 Apartments.



Name & Address		Key Statistics
Vikas Palm, Thane	Capacity:	16,200 LPD system
	No of floors:	G+ 17
	Completion:	
	Total Cost:	Rs.
	System:	Thermo Siphon type
	Electricity Savings	

Water heating systems in Hotels

Solar water heating system is an effective solution for hot water requirement in hotels. A number of hotels has already installed solar hot water systems in their hotels and saved electricity considerably. In the following example of J P Siddhartha Hotel, payback was realized within 2 years of time.



J P Siddhartha Hotel

Name & Address	Key Statistics	
J P Siddhartha Hotel	Capacity:	3500 LPD system
	Completion:	2008
	Total Cost:	Rs. 490000.00
	System:	Biler feed
	Electricity Savings	175 Kwh per day

More pictures of SWH applications in hotels



Name & Address	Key Statistics	
Leo Inn – Jullandhar	Capacity:	6000 LPD system
	Completion:	2002
	Total Cost:	Rs.
	System:	Direct
	Electricity Savings	Kwh per day

Water heating system in hostels

Solar water heater can be a solution to the hostels for hot water requirement. Following is an example of Infosys hostel in Mysore which was developed by M/S Shobha Developers with a capacity of 1,77,000 liters per day.



Name & Address		Key Statistics
Infosys Hostels – Mysore	Capacity:	16,000 LPD system
	Pool size:	600,000 liters
	Completion:	2007
	Total Cost	Rs. 30 lacs
	System:	Pressurized recirculation
	Electricity Savings	1550 Kwh per day

Water heating system in hostels

Solar heating systems can be used efficiently for swimming pool heating as well. Following is an example of a swimming pool heating in the Golf-Club of Chandigarh which has a capacity of 6 lacs liters. The project cost was Rs.30 Lacs with par day electricity savings of 1550 units. Even if the swimming pool heating is operated for 6 months a year, the pay back would be realized in 2.5 years.



Name & Address		Key Statistics
Golf Club – Chandigarh	Capacity:	16,000 LPD system
	Pool size:	600,000 liters
	Completion:	2007
	Total Cost	Rs. 30 lacs
	System:	Pressurized recirculation
	Electricity Savings	1550 Kwh per day

Water heating system in textile mills

Solar water heating system is a solution for low and medium pressure process heating and boiler pre heating in industrial applications. Textile is one such industry which requires hot water for dyeing purposes. Following is an example of a 25 Kcal per day system in Chelsea Jeans mill in Haryana which helped the company to save 271 liters of diesel per day. Considering an average price of Rs.30 per liter of diesel, the payback to the company would come in approximately 3 years of time.



25 Lakh Kcal perday system at Chelsea Jeans Manesar in Haryana

Name & Address		Key Statistics
Chelsea Mills – Manesar Haryana	No of collectors	410 Numbers
	Tank capacity:	10,000 liters
	System size:	50,000 liters
	Completion:	2006
	Total Cost	Rs.46.50 Lacs
	System:	Pressurized recirculation
	Energy displaced	25 lakh Kcal per day
	Fueal Savings	271 liters diesel per day

Water heating system in Dairy applications



Solar Water Heating System at MILMA Dairy

Name & Address		Key Statistics
MILMA dairy – Kannur, Pallakad, Kerala	No of collectors	720 Numbers
	System size:	60,000 liters
	Completion:	2003
	Total Cost	Rs.46.50 Lacs
	Application	Pasteurization of milk
	System:	Pressurized recirculation
	Fueal Savings:	250 liters diesel per day

Water heating system in Leather industry



Solar Water Heating System at Leo Leather Industry Jullundhar

Name & Address		Key Statistics
Leo Leather– Jullandhar Punjab	No of collectors	150 Numbers
	System size:	15,000 liters
	Completion:	1998
	Total Cost	Rs.
	Application	Chemical mixing, drying
	System:	Boiler feed

Water heating system in Metal plating



12 Lakh Kcal per day system for Nickle Bath at Kangaroo Industry Ludhiana

Name & Address		Key Statistics
KangarooIndia Limited Ludhiana	No of collectors	220 Numbers
	Tank Size:	5000 liters
	System size:	60,000 liters
	Completion:	2006
	Total Cost	Rs.30 Lacs
	Application	Nickel bath
	System:	Pressurized recirculation
	Fueal Savings:	110 liters diesel per day

Water heating system in food processing



Name & Address	Key Statistics	
Kwality Walls ice cream Delhi	No of collectors	60 Numbers
	System size:	6,000 liters
	Completion:	2000
	Total Cost	Rs.
	Application	Cleaning and making sugar solution
	System:	Thermo siphon type
	Energy Savings	240 Kwh per day