

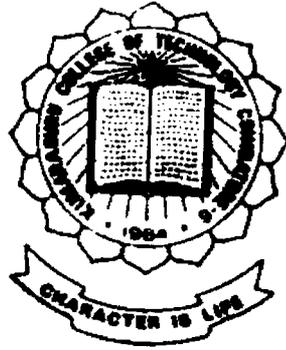
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THE PROJECT ENTITLED  
"SOLAR HOT WATER SYSTEMS"  
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# **CERTIFICATE**

THIS IS TO CERTIFY THAT THE PROJECT ENTITLED

**“SOLAR HOT WATER SYSTEMS”**

IS THE BONAFIDE RECORD OF WORK DONE AND

SUBMITTED IN PARTIAL FULFILMENT

OF THE REQUIREMENTS OF THE ENGLISH DEPARTMENT

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# INTRODUCTION

## ENERGY

The word energy means capacity for performing work. It also means vigour activity, Power ,etc. Thus the existence of life on the planet earth is directly related to the existence of energy. For a common man energy means food, heat, water, etc. but energy is hidden in every object in one form or the other. Today the energy for our day to day use is derived from coal, oil, gas, wood, water, etc. however, except water, other sources of energy are being consumed very fast and are likely to disappear soon. In order to preserve these source of energy, therefore mankind has to utilize other sources of energy like energy from solar, wind, water, heat from the earth, from the ocean etc.

## SOLAR ENERGY

Solar energy is received in the form of light and heat radiation. The radiant energy of the sun can be converted into thermal, electrical and mechanical energy, etc. and also other energies utilizing the modern methods of conversion. Out of these modes of converting solar radiant energy the thermal conversion mode is the easiest and most convenient. The thermal energy can be further used, (i) to heat water, air or any other fluid, (ii) to cook food, (iii) To dry industrial/agricultural products.

Solar water heating is a well known and established technology in many countries including India. However, Indian manufacturers have recently come in the market and need proper education and guidance in respect of fabrication and system design technology. The design and construction of solar hot water systems will depend on peoples needs, habits, resources and local conditions.

## SOLAR WATER HEATER

Solar water heaters are basically of two types, namely (1) collector coupled to storage tank and (2) collector-cum-storage system. Under the first category of a solar water heating system there can be two possible ways of extracting heat from the collector namely (i) through natural convection, generally known as the thermosyphon effect and (ii) electrically operated pump. the essential component of a solar water heating system under this category are:-

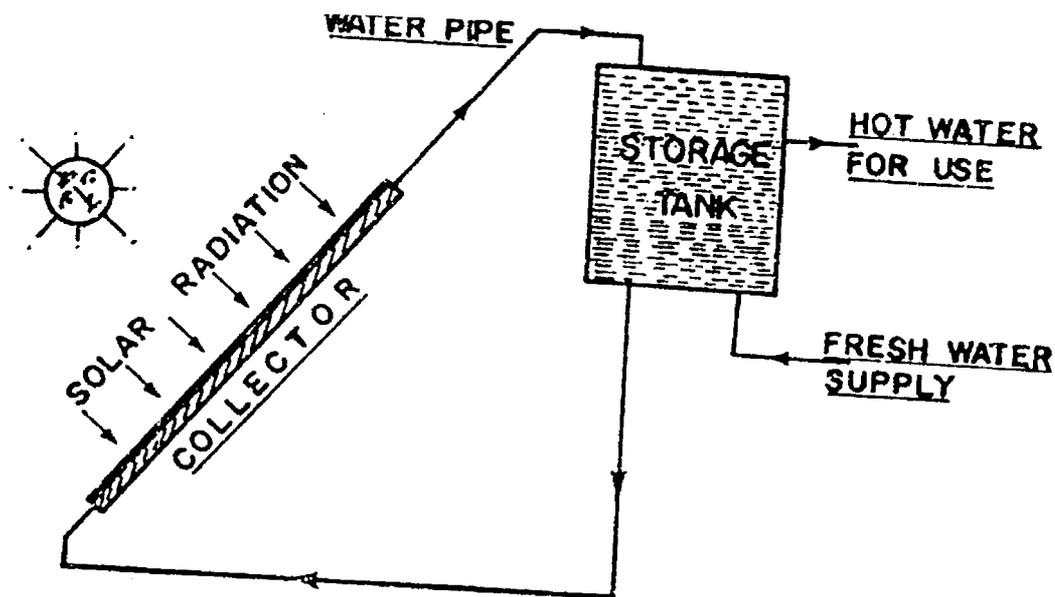
- E. Collector consisting of front glazing, metallic absorber, back insulation and collector box
- F. Insulated storage tank with or without heat exchanger,
- G. Piping,
- H. Controls & pumps.

The only additional component in a forced circulation system is a pump, which circulates water in the collector bank. The system may additionally have some control instruments like temperature indicator, differential thermostats, flow meters etc. These solar hot water systems are usually termed as open loop systems. In very cold climates water alone cannot be circulated through the collector loop. In these climates it is necessary to mix anti-freeze materials in the heat extracting fluid circulating through the collector channels. Heat exchanges is also required if two different types of fluids are used in the collector system and the utility circuit or the quantity of water is not suitable due to the presence of impurities.

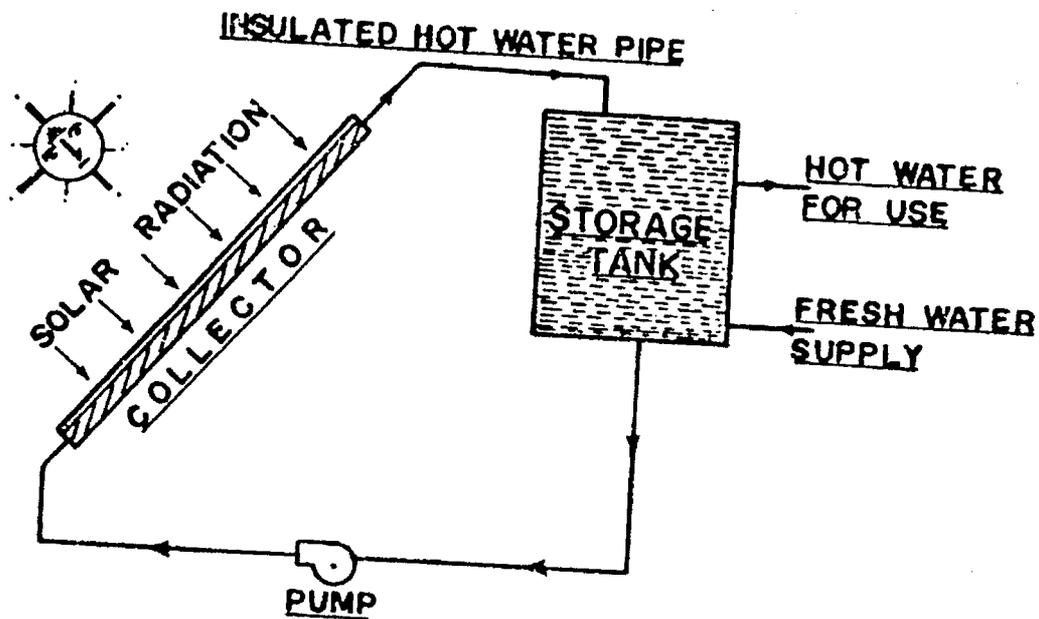
The collector-cum-storage type water heating system is extremely simple. It consists of essentially three main components, namely

4. Front glazing
5. Absorber sheet
6. Insulated storage tank.

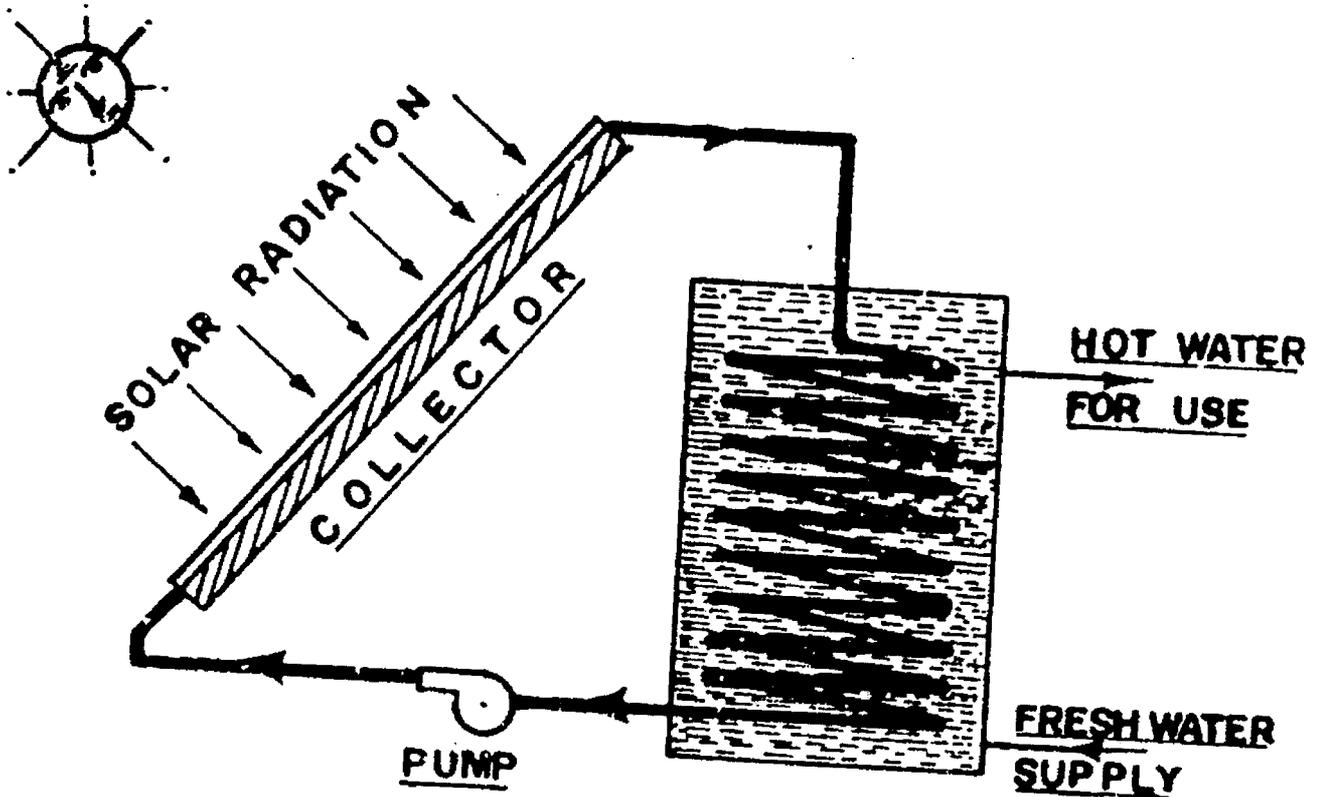
In such a water heater, sunlight passes through the front glazing and gets absorbed by the absorber which further heats the water. Thus the storage tank acts as a collector and storage for hot water. Solar ponds can also be categorised under this category.



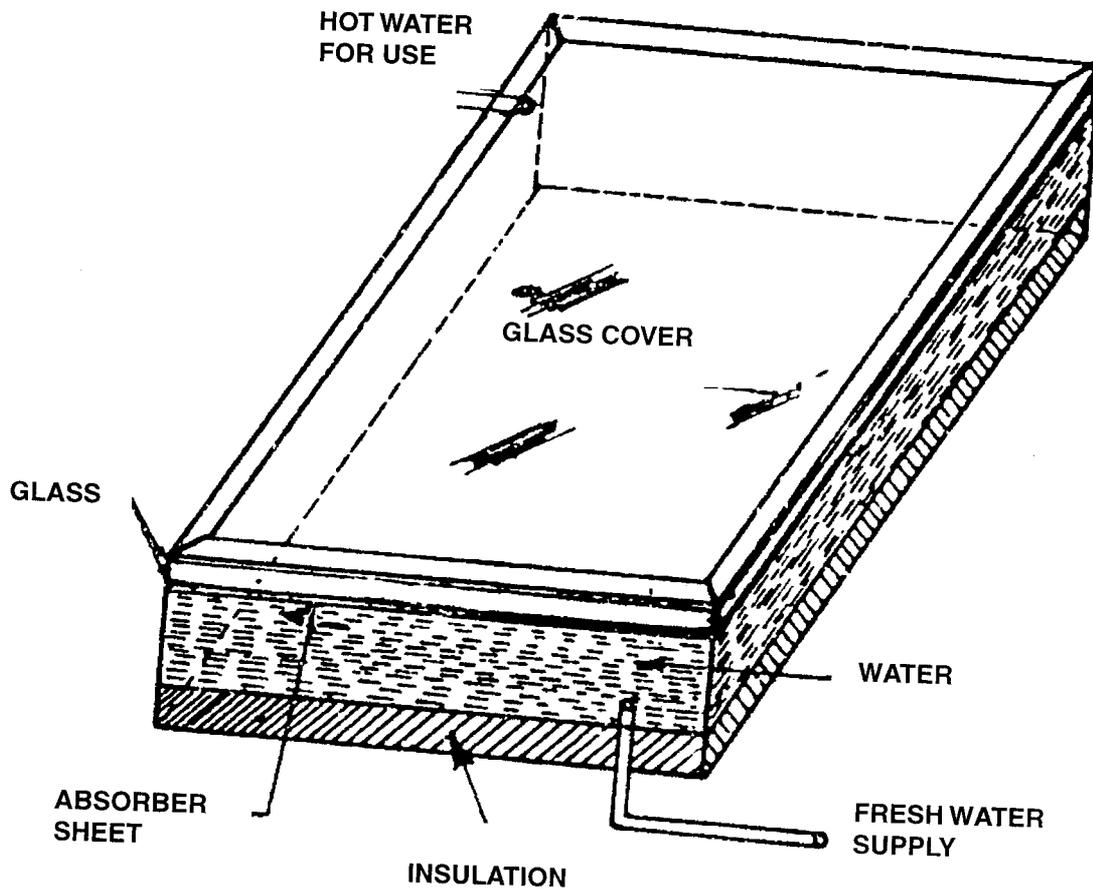
SCHMATIC OF A THERMOSYPHON  
SOLAR WATER HEATER



SCHMATIC OF A FORCED FLOW  
SOLAR WATER HEATER



**SOLAR WATER HEATER WITH HEAT EXCHANGER**



**COLLECTOR-CUM-STORAGE SOLAR  
WATER HEATER**

## SUB-COMPONENT OF SOLAR WATER HEATER

Various sub components are

Solar energy collector:

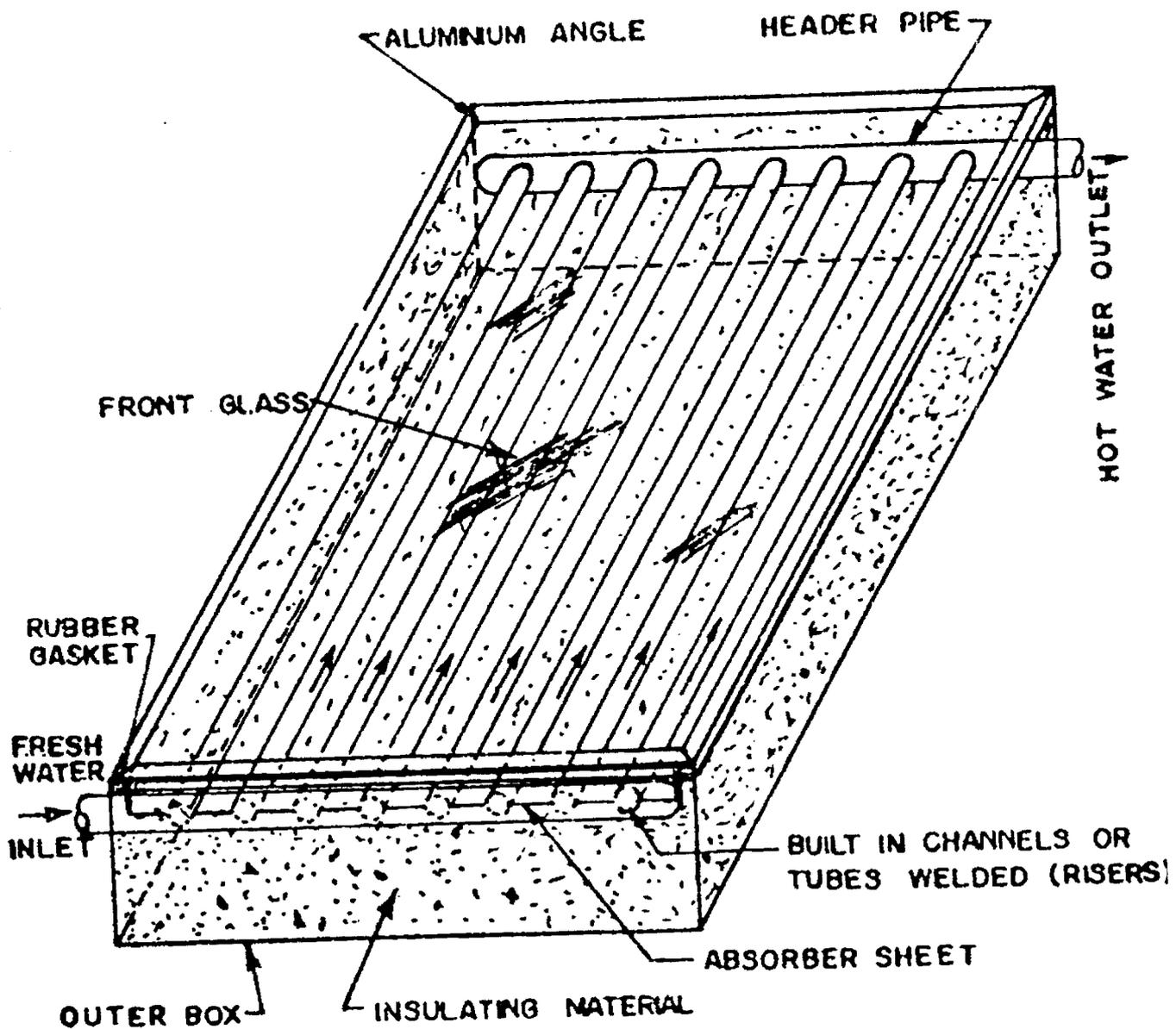
The most important system and its various parts are :

### **COLLECTOR ABSORBER:**

The nucleus of a solar collector is the black absorber plate which absorbs solar energy and converts it into heat. The heat is extracted from the absorber plate by allowing any fluid to flow through built in channels or tubes welded in to it to carry the heat extracting fluid. To minimize heat losses from the absorber plate it is enclosed in a box covered with transparent glazing from one side, and thermal insulating material from the back and sides.

A solar absorber should have high thermal conductivity, good heat transfer properties, high solar energy absorptance and low emittance at higher temperatures. It should be non corrosive and temperature stable.

During the working of a solar-water heating system, the ambient temperature may fluctuate between 30°C and 50°C depending on the climatic condition of the place. If the circulation of fluid in the absorber channels tubes stops due to some reasons, the stagnation temperature may reach as high as 200°C and the pressure can be more than 2.5 bar. Not every absorber material can withstand these conditions without damage. Most common absorber materials are steel, aluminum, copper and some plastics.



**VARIOUS PARTS OF A FLAT PLATE SOLAR COLLECTOR**

## COLLECTOR GLAZING

A transparent cover over the absorber of the collector has the function of allowing the solar radiation to pass through it and act as an opaque curtain to the radiation emitted by the hot absorber. An ideal glazing over the absorber should have the following characteristics:

5. Maximum transitivity for solar radiation ( $0.3\mu\text{m}$  to  $2\mu\text{m}$ )
6. Minimum transmissivity for long wave radiation (above  $2\mu\text{m}$ )
7. Low thermal conductivity and
8. High weather resistance.

Tempered glass is an excellent material for the outer-most glazing. The tempering is necessary for the added strength. Glass is lasting, durable and weather resistant and gives a very high quality experience. Low iron glass is recommended for solar applications.

## BLACK COATING

In order to convert Solar radiation falling on the absorber system into heat the absorber has to be coated with black coloured paints or other similar materials.

An ideal absorber coating is the one, which absorbs most of the incident radiation falling on it and emits nothing in the long wave region of the electromagnetic spectrum. The usually employed black paints can absorb up to 95% of the incident solar radiation but their emissivity at the higher temperatures is also above 90% as a result of which the heat loss is so large that these absorbers cannot attain temperature about  $120^{\circ}\text{C}$  to  $130^{\circ}\text{C}$ . Therefore, such collectors cannot be used for applications above about  $60^{\circ}\text{C}$  to  $65^{\circ}\text{C}$  as their efficiency becomes too low above these temperatures. The other type of coatings known as selective

coatings have high absorptance and low emissivity even above 100°C and hence are used to heat water above 70°C. The coatings must be highly adhesive, resistant to temperature and humidity variations and also to impinging radiation. It must not evaporate under the operating condition of temperature and pressure.

### **COLLECTOR INSULATION**

Thermal insulation is provided in solar collector to minimize heat losses from the back and sides of the absorber system. As the Collectors may have to operate / remain at temperature as high as 200°C the insulation must not deteriorate, out gas, expand or contract at temperatures between 30°C and 200°C. It should not attract moisture and should be fire resistant. Insulating materials should be free from sulphur and binders which may out gas or evaporate between -30°C and 200°C. It should be light in weight.

### **COLLECTOR HOUSING**

The collector housing is provided to protect the insulation and absorber plate from the environment and also to minimize heat loss. Materials like aluminium, galvanized steel, fiberglass etc are used for making the collector housing. It is advisable to use the same materials for Collector Structure and Housing to avoid contact corrosions. Such problems however may not arise with fiber glass or plastic housing. The collector housings should be capable of withstanding weathering effects it should also withstand loading and handling stresses.

The collector housing must be constructed in such a way that condensed water is not accumulated in a manner which might impair its functional capability. The construction must

ensure that no undue stress arises in the cover / front glazing even at the extreme temperature conditions. Joint seals and other components must be capable of with standing the weather variations and also stagnation temperature variations.

At least two pipes of tubes pass two sides of a Collector Housing it is essential that these be sealed to prevent dust from entering the collector. The seals should also prevent rain, water / snow etc from entering into the Collector. These seals must be capable of accommodating the expansion / contraction of various collector components, Silicon, Teflon EPDM etc. seals /gaskets are preferred for these applications.

## WATER STORAGE

Depending on whether the system is under the pressure of the city supply or it is non pressurized, two types of storage tanks are usually recommended for solar energy applications.

### PRESSURIZED WATER STORAGE TANK

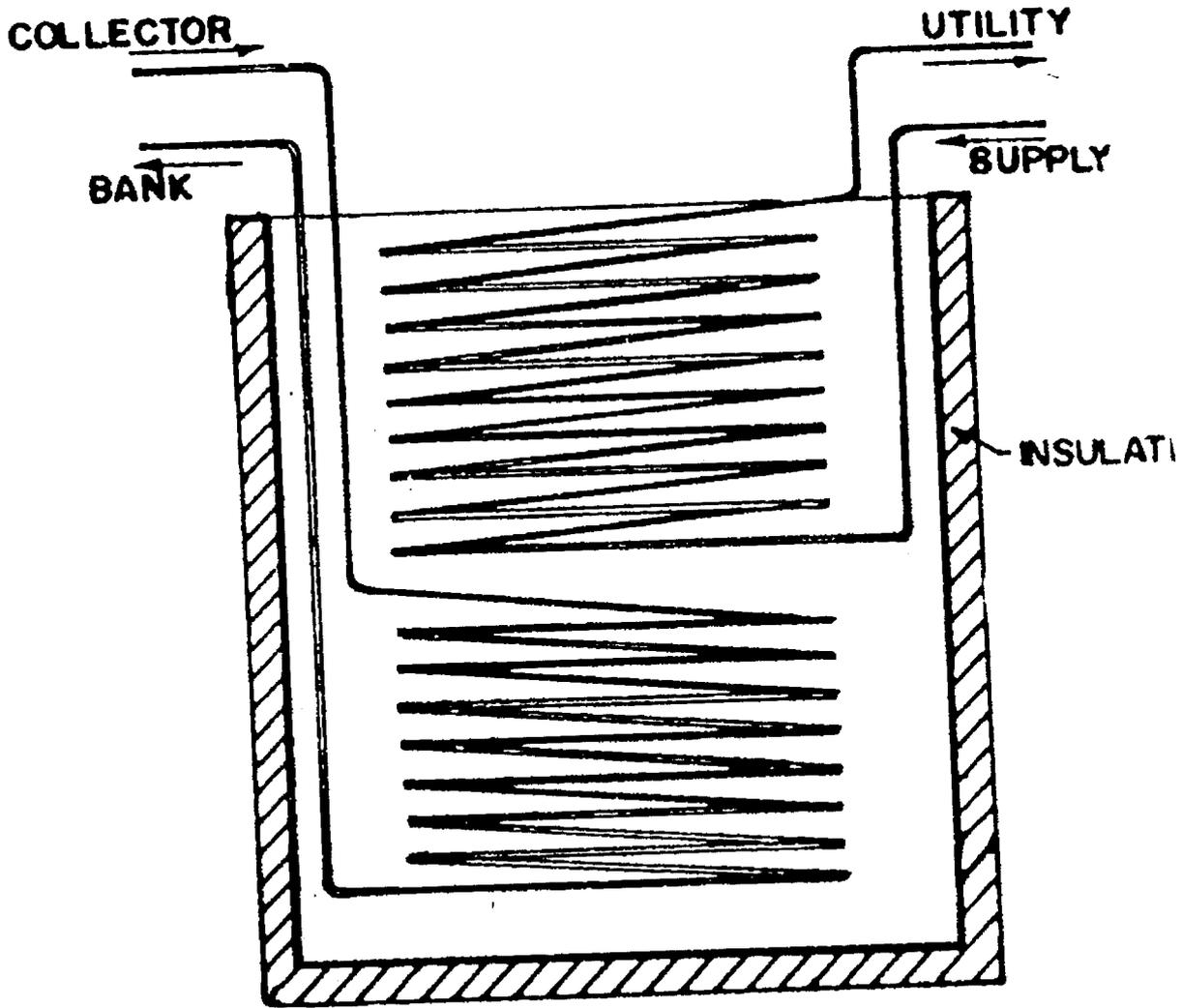
The pressurized water tanks are either made from stainless steel or enamelled steel, but rarely with plastic materials. Since cold water after getting heated, automatically goes up, the heat exchanger in this system if required, is placed at the bottom of the tank for a good heat transfer between the exchanger and the fluid in the tank.

### NON PRESSURIZED TANK

They have the advantage that these can be easily fabricated using materials like fiber, glass, plastic, metal etc. The following heat exchanger designs are possible in these tanks :-

- i Collector and storage carry the same (water) heat transfer fluid.
- ii Heat exchanger in the collector loop circuit

In such cases the collectors loop carries a mixture of water and anti - freeze chemicals or some non-corrosive fluid. This fluid heats the water in the storage tank.



**NON-PRESSURIZED TANK WITH  
TWO HEAT EXCHANGERS**

- iii In the third design there are two heat exchangers in the tank, one for the collector loop and the other for the load supply.

All the storage tanks are thermally insulated to avoid heat loss.

The inner tank should be of a material which does not contaminate the water, non-corrosive and stable at the temperature of operation. The outer insulation is covered either with a thin metal sheet / foil or cemented to protect it from exposure to rain, dust and other atmospheric variations. The thickness of the insulation is decided on the basis of the hot water temperature, the minimum ambient temperature, wind velocity plus thermal resistance of the material. It is desirable that the hot water temperature does not decrease by more than 6°C to 8°C in about 16hrs time.

### **PIPING**

Pipes are used to carry hot and cold fluids from and to the collector. The pipe material should therefore, be non corrosive and stable at operating temperatures. It should not contaminate the fluid flowing through the pipes. The pipe diameters in the flow direction should be such that there is a minimum pressure loss.

## ORIENTATION OF THE COLLECTOR

In order to minimize optical losses due to reflections from the absorbing surfaces it is essential that the impinging radiation's strike the surface at right angles. However, the positions of the sun does not remain fixed, it changes with time during the day and year. The angle of incidence on the surface of the Earth thus depends upon parameters like latitudes of the place, time of the day and time of the year. Therefore, solar collectors are always kept at an inclined position facing the sun such that a maximum amount of solar radiation is received by the collector and converted in to heat. The inclination with the horizontal surface depends upon the utility pattern of the hot water. If temperature requirement is more in summer months, the inclination is kept at attitude minus  $15^{\circ}$ . For maximum utilization in winter months the inclination is  $15^{\circ}$  more than the attitude of the place. For round the year utilization, the inclination is kept at the latitude of the place.

## PERFORMANCE OF COLLECTOR

The performance is defined as

Useful heat gain = (solar radiation observed - heat loss) \* collector area

$$\text{Or, } q_u = A_c [ I(T_a) - U_l (T_p - T_a) ]$$

Where:

$Q_u$  = useful heat delivered

$A_c$  = collector area  $m^2$

$T$  = solar energy received on the upper surface of the slopping collector per

Unit area,  $W/ m^2$

$T$  = fraction of solar radiation reaching the absorber surface,

$L$  = fraction of solar radiation absorbed by the absorber,

$U_l$  = over all heat loss coefficient ,  $W/ m^2 \text{ } ^\circ c$

$T_p$  = average temperature of the absorber plate  $^\circ c$

$T_a$  = ambient temperature  $^\circ c$

Equation tells that in order to get maximum value of the product (t.c) should be large and should be as low as possible for collector. The product depends upon the transmittance of the glass cover and absorptance of the absorber sheet . The heat loss will depend mainly upon the quality of the back and edge insulation and also how nicely the collector has been assembled . In other words there should be as low air leakage as possible

The other parameters which will contribute to the value of  $U_L$  is the emittance of the absorber surface. It should be as low as possible selective surfaces are used for applications where low emittance materials are needed. The bonding between the riser and the sheet is another parameter which affects the performance. It should be as tight as possible. welding, brazing, etc will give best results.

## COLLECTOR DESIGN

Several types of collector designs for solar water heating few systems have emerged as a result of the intensive R and D activities during the last few years. These collectors and systems differ in absorber design mainly. Some absorber systems are:-

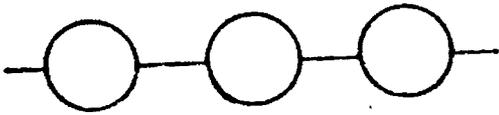
- a) Built -in- channel
- b) Tubes bonded on the blackened surface of the absorber sheet.
- c) Tubes bonded on the lower surface of the absorber sheet
- d) Tube fitted in grooves
- e) Corrugated sheet fixed on the flat sheet
- f) Both sides corrugated sheets
- g) Hexagonal channel etc

Different mechanisms are adopted to fix the tubes on to the absorber sheet. It may be noted that heat will be transferred from the heated absorber sheet to the heat transfer fluid flowing through the built in channels / tubes. In order to extract maximum heat from the absorber the contact between the sheet and tubes should be as good as possible. Built in channels are best for such applications. Tubes welded to an absorber sheet are also equally effective provided welding has been done properly and no air gap is left between the sheet and tube surfaces. Welding is however not possible between two dissimilar metals like cu-Al.

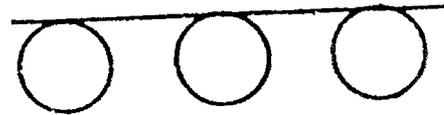
Absorber plates of aluminum sheets and copper tubes are quite common nowadays . Most of them are mechanically bonded with each other. The efficiency of the

such collectors are not good, since there cannot be perfect contact the two surfaces. Recently, methods have been developed to join cu and Al metallurgically . copper tubes are inserted in the channels of aluminum and are joined together by pressure- temperature techniques. Such systems are not yet available in India these absorber are however, quite common in other countries.

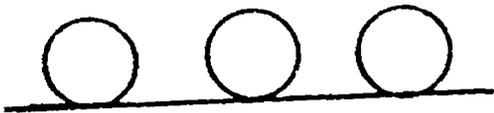
Extraction of heat from the absorber also depends upon the closeness of the riser tubes. Theoretically best performances will be obtained when the riser tubes touch each other. However such an arrangement will increase the cost of collector. The design is therefore , optimized for best performance at low-cost. Normally the riser tubes are separated by a distance of 10cm. When riser diameter is about 1.2cm.



BUILT IN CHANNELS



TUBES BONDED ON THE UNEXPOSED SURFACE



TUBES BONDED ON THE EXPOSED SURFACE



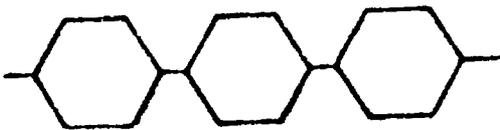
TUBES FITTED IN GROVES



CORRUGATED SHEET ON PLANE SHEET



BOTH SIDE CORRUGATED SHEETS

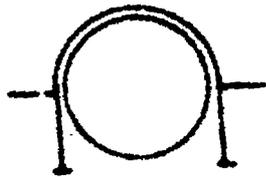


HEXAGANAL CHANNELS

## VARIOUS DESIGNS OF ABSORBER SYSTEMS



BRAZED

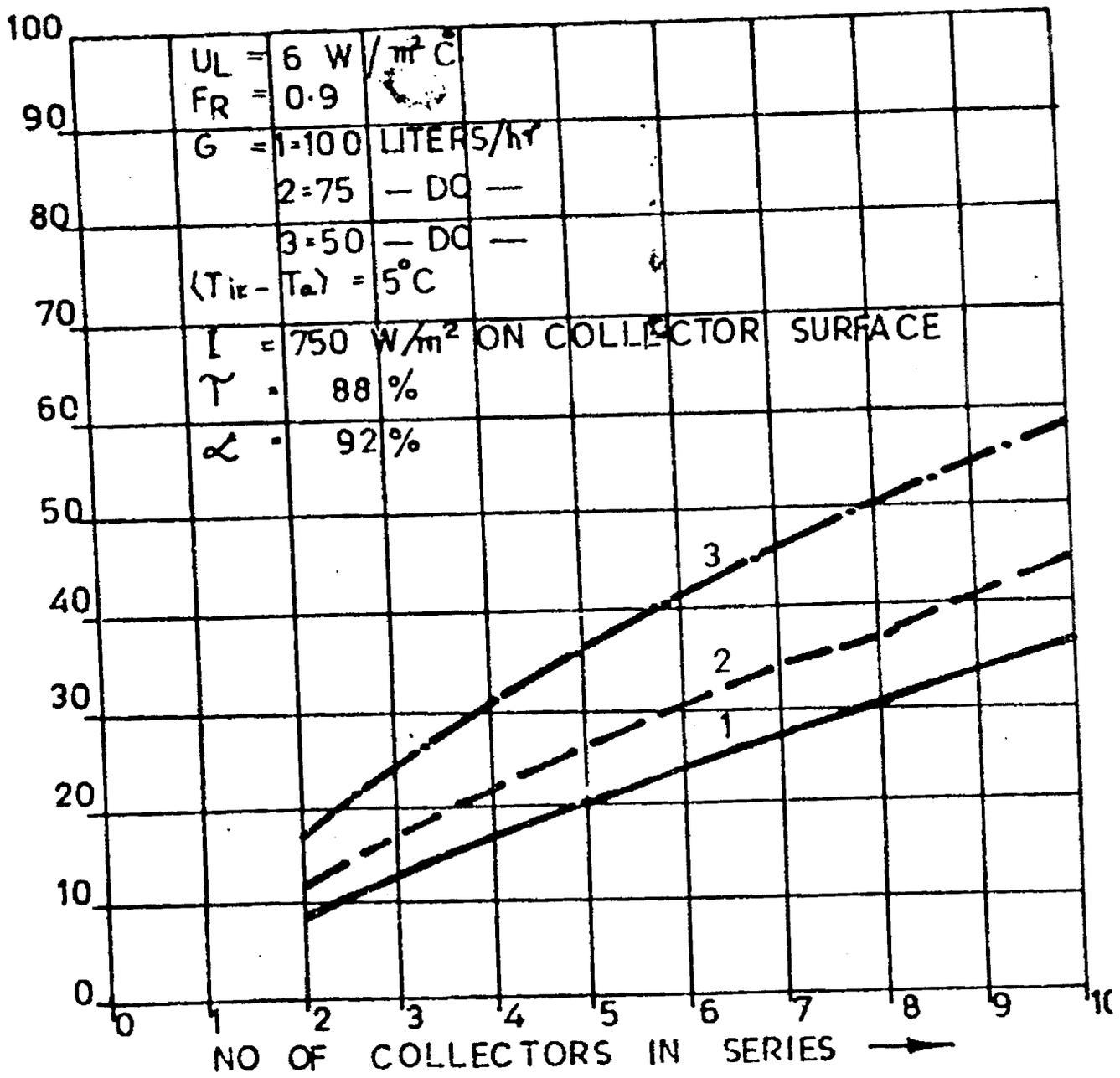


TIE



CLAMP

DIFFERENT BONDING ARRANGEMENTS



**PERFORMANCE OF COLLECTORS IN SERIES  
 FOR  $750 \text{ W/m}^2$  INSOLATION**

## ENERGY SAVINGS

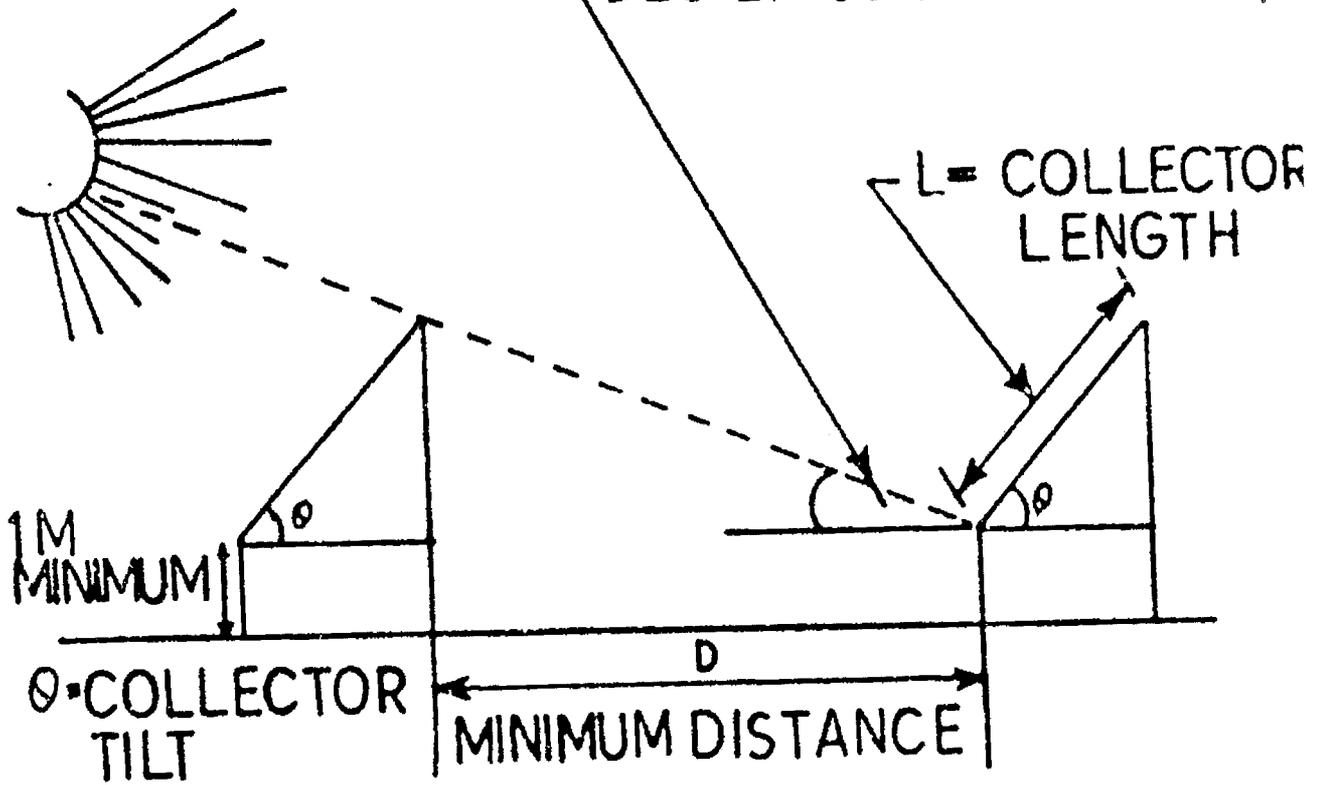
Solar energy is available during the day time for 6 to 8 hrs. only with varying intensity from morning till evening. The solar energy received in a day on a fiat surface varies from 5 kWh to 7.5 kWh, per square metre in most of the places in India . the total amount will however, depend upon the season of the year and sky conditions during the day time. On an average about 300 days in a year can be taken as clear days in most parts of the country. Thus, on an average 1800kwh/sq metre of the solar radiation is received per year which is as tremendous amount of energy.

Solar hot water systems developed in the country can heat the water from ambient temperatures to about 85°C. The amount of energy required per year to heat different amounts of water to different temperatures vary . These temperature can be attained by using solar collector to heat the water. Thus solar hot water system can help to a large extent in saving other sources of energy.

Energy saving from solar hot water systems look quite attractive. But the potential market for solar water heaters should be analysed carefully hot water consumption carefully, social habits, commercial and non commercial energy spent on hot water, standard requirements, affordability, use of various conventional heating systems, etc are some of the important aspects to consider. Besides local conditions like availability of solar radiation, daily and seasonal variations, temperatures, and other climatic condition should also be considered.

Large systems should be installed after careful study. Possibility of energy conservation in an existing hot water system should be studied before introducing a solar system. Designing a solar water heating system is obviously not as easy from the, "efficiency point of view" as it may appear. It is merely a matter of optimization and cost effectiveness rather than simply maximizing efficiency.

SOLAR ANGLE AT NOON  
DEC. 21 =  $66.5^\circ$  - LATITUDE,



$$D = L \frac{\sin \theta}{\tan(66.5^\circ - \text{Lat.})}$$

MINIMUM DISTANCE REQUIRED BETWEEN  
ROWS OF COLLECTORS

## INSTALLATION INSTRUCTION

Collector should always:

1. Face within  $15^{\circ}$  of true south
2. Receive six hours of sunlight per day without shading
3. Be installed within  $10^{\circ}$  of site latitude for best performance (during winter months  $10^{\circ}$  and during summer months  $-10^{\circ}$  and round the year latitude )
4. Be arranged in series parallel combination such that the flow is uniform in all the collectors

With layout of pipe runs always remember to

1. Use GI pipes grade B-ISI mark of suitable diameter to minimize pressure drops.
2. Choose suitable insulation to protect the pipes from losing heat and protect it from weather and U-V radiation.
3. Support runs properly.
4. Determine entry method through walls or foundation.
5. Try for the most direct route available with as few turns as possible and introduce airvents at suitable places to avoid air locking. Avoid direct contact between two dissimilar metals and also rubber / plastic joints.

With collector mounting stands always remember to :

1. Determine materials of choice (speed rail pipe stand, welded angle iron, etc)
2. Construct to provide proper pitch, means of fastening collectors of aesthetically pleasing appearance.
3. Install to provide long term stability to wind and frost, proper orientation ,protection from shading.
4. Use common sense in handling collectors to installers for safety
5. Leave sufficient space between two adjacent rows to avoid shading.

With storage tank and heat exchanger always aim for closest :

1. Proximity to cold feed water.
2. proximity to feed and return of heat transfer fluid.

With thermosyphon system always remember to:

1. Keep a difference of at least 40cm between the outlet of the collector and outlet of the storage tank.
2. Avoid bends in the connecting pipes to minimize pressure loss.
3. Select proper sizes of riser and header pipes so that a natural thermosyphon flow is maintained.
4. Use heat exchanger and antifreeze mixtures in cold climatic regions.

With forced flow system always remember to:

1. Use electrically operated pumps of suitable size to maintain a flow rate of 70-100 liters/ hr per m<sup>2</sup> (parallel connections)
2. Use differential temperature controllers to operate the pump.

Install controller in proximity to pump installation.

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