Design and Construction of a Serpentine Solar Flat Plate Collector

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Abstract

The usage of solar energy system has been extended recent times to include many applications. Solar Water Heating System a recognized aspect which contains the Flat Plate Collector as its chief element. It has many configurations, having mainly two types depending on tubes (or tube) connected to the r plate's absorber. The collector is to be called tubular collector whenever the water gets inner side of a collective parallel tubes (acting as risers) between two bigger tubes (acting as headers), However, when the stream gets only into a single tube (usually in zigzag form) from the main source to the outlet of the collector it can be a serpentine collector. A little consideration has been given to Serpentine collector compared with the tubular one, so it was promoted to be the type used in this study. Depending on normal daily necessity from heated water, thermal load to be attained by the collector will have to be estimated and in connection with suitable collector efficiency, a proper size for the constructed collector is estimated. Secondly, after suitable selection of materials for all main parts of the collector, they are all manufactured and then accumulated together for constructing the solar collector, and finally it is tested by building an adequate test rig to estimate the competence of the constructed collector.

Keywords—Solar flat plate collector; eficiency of solar collector; Evacuated Tube Collectors (ETC)

I. INTRODUCTION

The energy collectors connected to the Solar system are considered to be an exceptional type of heat convers which alters the energy form solar radiation to inner energy of the transporting channel. The chief constituent regarding any solar system can be solar collector. The received solar radiation can be engrossed this method which changes it into heat, and send such heat into a liquid (commonly water, air, or oil) moving throughout the collector. Thus the collected solar energy can be taken from estimating liquid either straightly to the hot water or space conditioning equipment or to a storage system of thermal energy tank from that will be drawn for use at night and/or cloudy days.

There are basically two types of solar collectors: non-concentrating or stationary and concentrating. A non-concentrating collector possesses the similar area for interrupting and for engrossing solar radiation; however a sun-tracking focusing solar collector generally has bowl-shaped replicating surfaces to interrupt and emphasis the beam of the sun's radiation to a slighter receiving zone, by improving the fluidity of radiation. A large number of solar collectors are available in the market. Typical methods of different sorts of collectors are existed so as to indicate range of their practicability. These comprise Solar Water Heating, that contains thermosyphon, combined storage collector, air systems, direct and indirect systems and Space Heating and cooling System which contains Servicing hot water, water and air systems and heating pumps, freezing, processing heat of industry, that involves, water and air system and steam production system, purification, thermal power systems, which consists of tower of power and dish systems, solar heaters, and chemistry application. Thus Solar Energy Systems can be employed for various ranges of processes which can offer chief advantages, consequently, which can be employed whenever possible.

II. LITERATURE REVIEW

Radiation Concepts: solar constant (1367 W/m2) is a degree of radiation passing through a unit area at the highest point of atmosphere perpendicular the way of the radiation at the mean to Earth-sun distance.

Reduction of Solar Radiation by the Atmosphere: The earth is bounded by an atmosphere covering numerous gases and particle of dust. Because of clouds, greater size of particles and other factors of materials in the atmosphere a reflection in ration may occur. Substantial sum of solar radiation also gets absorbed by clouds which are of several types. Sometimes radiation goes back into the climate because of reflection of the ground and clouds. This portion of radiation reflected back is called albedo of the ground and on an average the albedo is 0.3. This solar radiation which reaches on the earth external part of earth un-attenuated (after spreading, reflection and absorption) is called direct radiation or beam radiation. The radiation which gets reflected, absorbed or scattered is not completely lost in the atmosphere and comes back on the surface of the earth in the short wavelength region and called sky or diffuse solar radiation. The sum of the diffuse and direct radiation on the surface of the earth is called global or total solar radiation. Factors governing availability of solar energy on the earth there are three factors governing availability of solar energy on the earth: - Earth sun distance

Tilt of the earth's axis and Atmospheric Attenuation.

Factors Affecting Solar Energy availability on a Collector Surface There are seven factors Affecting Solar Energy availability on a Collector surface:- Geographic location, site location of collector, collector orientation and tilt, time of day, time of year, atmospheric conditions, and type of collector.

Solar Radiation Components as

DIRECT RADIATION: Direct transmission of solar radiation to earth surface

DIFFUSE SOLAR RADIATION: Scattered by molecules and aerosols on entering the earth's atmosphere

GLOBAL SOLAR RADIATION = DIRECT RADIATION + DIFFUSE RADIATION

Flat Plate collectors use Direct and Diffuse Solar Radiation and also reflected Radiation.

FLATPLATE COLLECTORS: The flat plate collector forms the heart of any kind of solar system energy collection system and can be employed to heat liquid (liquid or air) from ambient to near 100˚C.The term "flat plate" is somewhat misused since surface is essentially flat but might be corrugated along with the other shapes. For the last 300 years the Flat plate collectors are being examined. Mr. H. B. Saussure a Swiss scientist during the second half of the seventeenth century, who established the first flat plate collector. Over the last six decades scientists in numerous countries chiefly from the USA, UK, Australia, India, Israel, Germany, South Africa and China have built, tested, studied and optimized various kinds of flat plate collectors largely liquid heating flat plate collector. Mr.Hottel and Whillier did a revolutionary work on solar flat-plate collectors, and Bliss from USA, exactly designed the collector and proposed Hottel-Whillier-Bliss formulas to comprehend the collectors.

Prof. H.P.Garg from India who did a noteworthy work on flat-plate collectors and proposed procedure for enhancing the configuration of collector and its design and thermal rating process of collectors, optimization of thermal loss, optimization of collector tilt and correction of dirt factor etc. Flat plate collectors are of two types: Liquid heating type. Air heating type. The clearest variance between the two is the mode of transferring of heat between the plate absorber and the heated fluid. In the finest kind of liquid plate collector that usually employs of a fin-tube structure, the absorbed heat is moved to the pipes by transmission. However in case of a traditional flat-plate air heater we can see a channel between the rear plate and absorbing plate. Therefore the other constituents like glazing, insulation, casing, orientation, tilt, exposure, etc. remain the same.

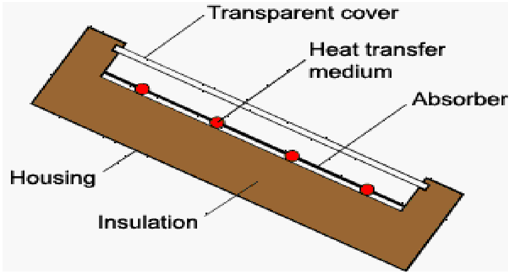


Fig. (1) Diagram of a typical solar collector with flat plate illustrating the major functional parts.

TUBE-SHAPED SOLAR ENERGY COLLECTORS.

There are two methods for improving the presentation of solar collectors. The first method increases solar flux occurrence over the absorber by using some type of concentrators. The next mode includes the reduction of heat loss from the absorbing surface. The (ETC) Evacuated Tube Collectors along with their integrally great power and impermeability to collapse are the most applied means for removing losses of convection by occupying the absorber with an emptiness of the 10-4 mm Hgt. Tubular collectors consist several benefits. They can be utilized to acquire slight ratio of concentration (1.5-2.0) by making a mirror from part of the inner bowl-shaped surface of a glass pipe. The radiation of the reflector can be focused on inner tube of the absorber. Performance may also be enhanced with noble gases by satisfying the envelope with high-molecular-weight. For the enhancement of its presentation exterior concentrators of radiation are usually used in an expatriate receiver. Philips from Holland and Sanyo from Japan manufacture various styles of expatriated tube collectors with new advancements connected to vacuum technology. Expatriated tube collectors are reliably mass produced mainly in China. Their great temperature efficiency is necessary for the efficient operation of solar air- conditioning systems and process heat systems and now even for water heating. For about 8 decades, these (SWH) Solar Water Heaters have been widely employed. The countries where these are extensively studied are. However in the USA, U.K., Australia, Israel, and India and South Africa these are broadly utilized in Australia, USA, Germany, U.K., India, Jordan, Cyprus, Israel, China, Greece, Japan, Sweden and several other countries. In recent years considerable knowledge has been developed regarding solar heat water systems. Basically these are either for domestic applications, large applications or swimming pool water heating applications.

Kinds of Solar Water Heater, constructed-in-storage type, Solar Water Heater (Integrated - collector storage type), Domestic Solar Water Heaters (Natural Circulation type / thermosyphon type), Large Size Solar Water Heater (Industrial type), Swimming Pool Water Heater and Domestic Solar Water Heaters.

Various styles of solar water heaters are probable and they might be categorized in different methods. Each type consists of advantages and disadvantages, and depending on the situation a particular design is recommended. Certain solar water heating formations are as follows: A direct and indirect solar water heater with natural circulation, solar water heater, with an indirect forceful circulation, Solar Water Heater with an indirect forced single cylinder circulation and air heat collectors with an indirect system. Generally, it is said that the system related to solar water heating consists of the following components: Flat plate collectors, storage tank, and heat exchanger, automatic control Pumps, pipe work, valves and fittings.

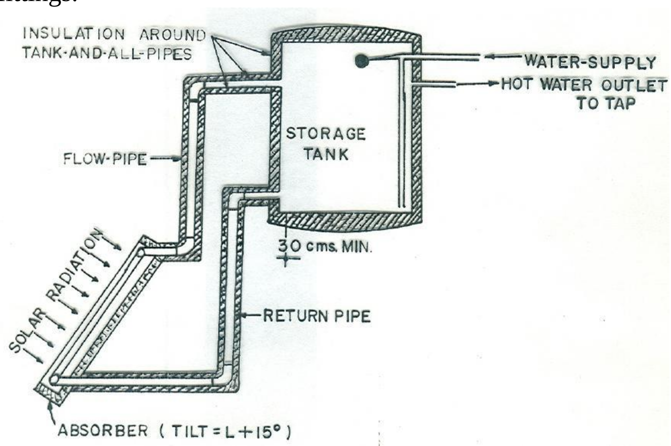


Figure (1-2) solar water heater with natural circulation kind (Schematic).

THE STORAGE TANK: The storing container stores the heat collected throughout the day for use when needed. For the storage of hot water, copper, steel, galvanized iron, aluminum, concrete, plastic, and sometimes wooden tanks are used. The container must be sized to hold between 1.5 and 2 days supply of hot water. The supporting heating preparations may depend on gas or electric booster and the central part of the tank must be fixed to the bottom of the tank. For internal and domestic uses and it is done in between 50-60˚C. In the form and design of the tank we can see several differences and some seem to be horizontal or vertical form, non-pressure or pressure kind, electric or gas or solid fuel booster, off-peak or constant tariff, interiorly or outwardly attached. For these types of storage only a little bit of information obtainable on system presentation

III. DESIGN APPROACH AND METHODOLOGY

Choosing a suitable type of flat plate solar collector, an adequate size is adopted for the required thermal load. Then, a design of the different parts of collector is made followed by constructing the collector by assembling these parts after manufacturing. Finally, a model one is built for examining the of the constructed collector. The required data for examining the collector is presented though measurement devices other than solar radiation which requires expensive measuring device which is not available, so it is estimated.

Depended on the daily necessity from heated water, thermal load to be attained by the collector has been estimated and in connection with suitable collector efficiency, a proper size for the constructed collector is estimated. If this daily need of the heated water exceeds the energy transmitted from the collector to water, then more units of the chosen collector can be put in parallel connection to reach the essential load. This will be shown in the portion of thermal design and sizing.

Secondly, the main parts of the collector: frame, panel, tray, Absorber plate Backing sheet, Insulation, Copper tubing, and Glazing are designed according to accurate engineering drawings. Then, after suitable selection of materials for all these parts, they are all manufactured and then accumulated to construct the twisting solar collector with flat plate. Finally, the constructed collector is tested by building an adequate test rig to estimate its efficiency. So as to examine the competence of the designed flat plate solar collector considering the bay and opening conditions, an experimental setup with a considerable manufacturing precision was designed and constructed. The different bay and opening conditions of the system have been measured in the testing program so as to provide quantitative calculated competence of the solar system. The conditions include: inlet temperature, flow rate, outlet temperature and severity of solar radiation. A proper estimation with an hourly based solar radiation on inclined (tilted) surface is presented in details based on accurate and previously adopted researches. The required data for this model of solar system of radiation estimation are the daily solar radiation, average daily total horizontal surface radiation, local latitude angle, hour angle, declination angle of sun, tilt angle of collector with horizontal, incidence angle, and solar zenith angle. The model is presented in details and applied to Rajasthan in India.

MATHEMATICAL MODELS AND FORMULATIONS

A. *Balance of Energy on Flat Plate Collector*

The general energy balance of a medium in which the radiation can be absorbed and transformed into heat that can be explained by the bellow said equation:

$Q\ inc, abs = Q\ useful + Q\ conv, abs + Q\ rad, abs + Q\ refl, abs + Q\ con$ (eqn-1)

Where is the entire global radiation incident on the absorber surface? $Q\ inc, abs$

$Q\ useful$ is the utilizable thermal flow. Furthermore, here are four different loss flows.

$Q\ conv, abs$ is the convection losses of absorber to the ambient air.

$Q\ rad, abs$ is the long-wave radiation losses of the absorber.

$Q\ refl, abs$ is the reflection losses of the absorber.

$Q\ cond, abs$ is the conductivity losses of thermal. The variation in between the energy at the bay and the outlet of the heating transmission medium is the hotness removed by the transfer medium; which can be described as follows:

$Q\ useful = m\ Cp\ (Tout - Tin)$ (eqn-2)

Where: m is the flow the rate of mass heat transferring fluid (kg/s)

Cp is the exact heat of the heat transferring fluid (J/kg K)

$Tout$ is the heat transferring fluid parting the absorber (K)

Tin is the heat transferring fluid arriving the absorber (K)

The total global radiation; $Q\ inc, abs$ will be considered as:

Q inc, abs = I × A (eqn-3)
Where: I is the incident radiation. A is the collector area
The worldwide radiation occurrence on the surface of the absorber
$Q\ inc,\ abs$ is defined by the portion of the entire global radiation,
$Q\ inc$ on the collector cover that transferred to the absorber; that will be considered by using equation (4)
$Q\ inc,\ abs = \tau\ cov$ x $Q\ inc$ (4)
The absorber's reflection $Q\ refl,\ abs$ will be counted with the absorber's radiation and the degree of reflection Equation (5) However the absorber can reflect the small portion of the radiation and is again reflected by the cover back towards the absorber. $\tau\ cov$ is the transmission coefficient of the cover and the constant reflection of the absorber is ρabs
$Q\ refl,\ abs = \tau\ cov$ x $Q\ inc$ x $\rho\ abs$ (5)
As per the Stefan-Boltzmann radiation law, the radiation losses $Q\ rad,abs$ result from the degree of emission ε, the alteration between the absorber temperature $Tabs$ and external temperature(Te), to the fourth part of power (in Kelvin), plus the Stefan-Boltzmann-constant, σ 5.67×108 $Wm2K$ according to Equation(6). In addition, they are relative to radiating absorber area, $Sabs$.
$Q\ rad,\ abs = \varepsilon\ cov$ x σ $(Tabs4 - Te4)\ S\ abs$ (6)
Equation (7) absorber's convective thermal losses are initially transported to the cover plate. In a steady state (i.e. the temperature changes of the cover plate don't change) this thermal flow is then transferred entirely to the environment. This convective thermal flow; $Q\ conv,\ abs$ will be presumed to be approximately linear. It based on the variance between the temperature of the absorber $Tabs$ and the ambient air temperature, Te, and will be explained by using the coefficient heat transfer $Ucoll*$ that is constant in the first calculation. The corresponding equation is as follows:
$Q\ conv,\ abs = Ucoll*\ Tabs - Te\ Sabs$ (7)
The thermal flow $Q\ cond,\ abs$ owing to the heat conduction from the absorber to the frame and the insulation is very small compared to the other thermal flow and can be neglected. The energy balance results therefore in (Equation 8) for the heat $Q\ useful$ transported by the heat transfer medium.
$Q\ useful = \tau\ cov$ x $Q\ inc - \tau\ cov$ x $Q\ inc$ x $\rho abs - Ucoll*\ Tabs - T\ e$ x $S\ abs - \varepsilon cov$ x σ $(Tabs4 - Te4)$ x $Sabs$ (8)
The main two expressions of equation can be joined. Furthermore, the absorber normally has low degrees of emission. If the variance of the temperature between the absorber and the environment is kept low, the last term of Equation can be neglected in many cases. The complete losses of radiation and heat can be described, in an approximation using a heat transfer
Coefficient, $Ucoll*$, as linearly dependent on the temperature that takes the whole thermal losses into account. These assumptions results in equation.

$Q\ useful = \tau cov\ \alpha abs\ Qinc - Ucoll*\ Tabs - Te\ Sabs$ (9)

B. *solar flat plate collector and its Efficiency*

The efficiency, η of the alteration of radiation of solar energy into functioning heat in the collector results from the ratio of beneficial transported medium of thermal flow by the of heat transfer $Q\ useful$ to the total radiation occurrence on the collector, $Q\ inc$. The efficiency will be enhanced by:
1. Improving transmittance- absorbance product.
2. Reducing losses of thermal
3. Efficiency of optimizing collector formation for a fine exchanger of heat
4. Optimizing tilt, orientation and exposures of the collector.
$\eta = Quseful\ /\ Qinc$ (10)
For a collector with given transmission and absorption coefficients, plus a given thermal conductivity coefficient, the efficiency will be counted in the next equation:
$\eta = \tau cov\ \alpha abs - (Ucoll*\ (Tabs - Te)\ Sabs\ /\ Q\ inc)$ (11)
with given material parameters, the highest efficiency is achieved at the lowest possibility of heat difference between a maximum radiation and the absorber, and environment.

C. *Thermal testing of solar collectors*

There are varieties of solar collectors and each behaves differently under different climatic conditions, operating parameters and design variables. Therefore, for rating the collectors thermally a combined method is necessary for identifying prompt competence, consequence of solar radiation angle of occurrence, and constant purpose of collector time (a measure of effective heat capacity). The ASHRAE 93-77 was adopted with some slightest variations in many countries of the world. The collector performance equations as discussed earlier are:
$Q^{\circ}u = m^{\circ}Cp\ (Tout - Tin)$ (eqn - 12)
$Qu = Ac\ FR\ (Io\ (\tau\alpha)\ e - (Ti - Ta))$ (eqn - 13)
$\eta i = Qu\ /\ AcIo = FR\ (\tau\alpha)\ e - FR\ UL\ (Ti - Ta)\ /\ Io$ (eqn - 14)
$\eta i = m^{\circ}\ Cp\ (Tw,o - Tw,i)\ /\ Ac\ Io$ (eqn - 15)

IV. DESIGN PROCEDURE AND IMPLEMENTATION

A. *Design Procedure*

Grounded on the everyday need from heated water, thermal load to be attained by the collector will have been estimated in connection with suitable collector efficiency; a proper size for the constructed collector is estimated. If this daily necessity of the heated water exceeds the energy transmitted from the collector to water, then more units of the chosen collector can be put in parallel connection to reach the needed load. This will be shown in the portion of thermal design and sizing. Secondly, the main portions of the collector are designed according to engineering illustrations displayed in Figures (4-1) to (4-4). Then, afterwards suitable selection of materials for all these parts, they are all manufactured and then accumulated together to build solar collector. Finally, the constructed collector is tested by building an adequate test rig to estimate its efficiency. So as to examine the competence of the constructed solar flat plate collector a practical setup with a substantial designing exactness has been intended. The different bay and opening circumstances of the system have been measured in the testing program to provide quantitative calculated ability of solar system. The conditions include: inlet temperature, flow rate, outlet temperature and solar radiation intensity.

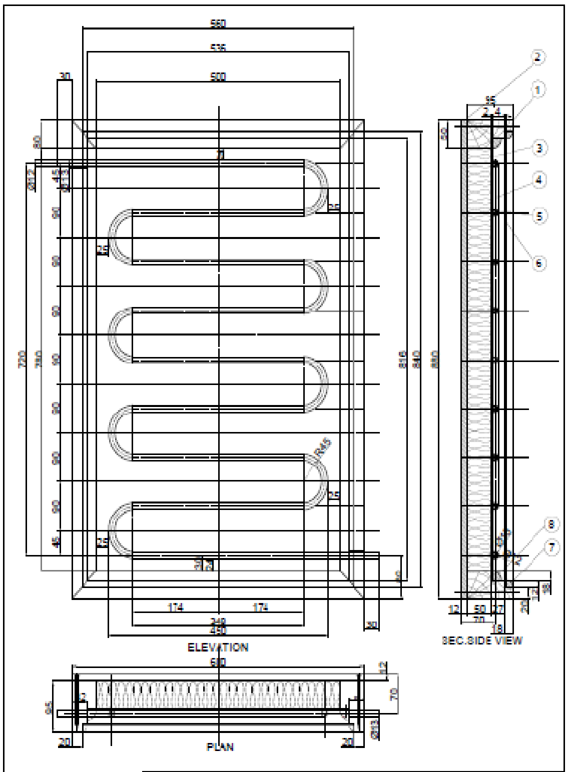
B. *Thermal Design and Sizing*

The daily requirement is 100L of water heated to 45˚C.
20˚C is assumed to be the starting temperature from the mains supply. Energy required for heating water (K.Cal) = Volume x temperature difference x exact capacity of heat water = 100 L x 25 (˚C) x 1k.cal/(L ̣˚C) = 2500 K.Cal which is equivalent to 2.91KWh
Assume daily available radiation of solar is equal to 5 KWh/m2 to estimate an appropriate Collector area:
Solar Collector zone is needed to meet this requirement = requirement of Energy for Heating Water / Available Solar Energy/ m² x Collector Efficiency below Table determination of number of collectors required to reach the heat requirements based on different hypothetical efficiencies of the collector.

Hypothetical system efficiency %	Collector area required to meet thermal demand	Number of Serpentine Collectors based on existing 0.39 m² area
75	0.776	2
65	0.895	2-3
60	0.97	2-3
55	1.06	3
45	1.29	3-4

C. *Mechanical design, manufacturing, and assembly*

As shown in figures (4-1), (4-2), (4-3) and (4-4) the designed details of constructed panel are consists of six parts as follows:
1. Frame and Panel tray
2. Backing sheet
3. Absorber plate
4. Copper tubing
5. Insulation
6. Glazing



Flat Plate Collector or Solar Panel			
8	FIXING ABSORBER PLATE	1	WOOD; QUARTER COLUMN 18mm
7	FIXING GLAZING PLATE	1	WOOD ; QUARTER COLUMN 12mm
6	GLAZING	1	GLASS SHELL 4mm Thick
5	INSULATION	1	ROCK FIBRE WOOL AND POLYSTYRENE FOAM
4	COPPER TUBING	1	COPPER ½ InchDia.
3	ABSORBER PLATE	1	ALUMINUM 2mm Thick
2	BACKING SHEET	1	WOOD 12 mm Thick
1	PANEL TRAY AND FRAME	1	WOOD
P.No	DESIGNATION	R.No	MATERIAL

Figure (4-1) Projection views of the designed solar flat plate collector.

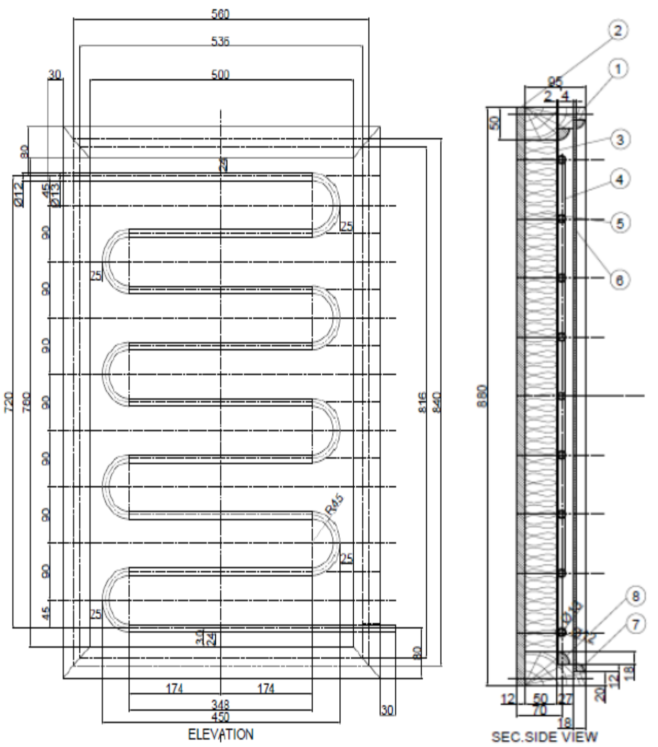


Figure (4-2) Elevation of the designed solar flat plate collector. Figure (4-3) Section side view of the designed solar flat plate collector.

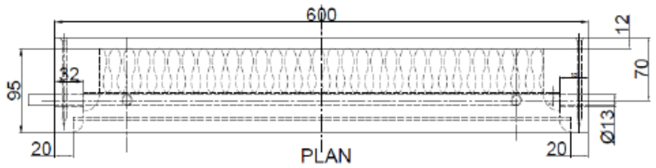


Fig. (4-4) Plan of the designed solar flat plate collector.

1. Panel tray and frame

From teak or cedar wood that is hardwood frame from which panel tray and frame are usually made of such as a good preservative coating must be added to the tray to ensure minimum maintenance during its exposed life. The panel tray and frame comprise the one out of two with dimensions 880 mm x 95 mm x 50 mm, the second two 600 mm x 95 mm x 50 mm. Two rebates or lips are designed for receiving both of the plate collector and glass, which can be cut out with a circular saw in the form the four parts. The four parts are assembled together by needles and hammer on their 45° ends to achieve good corners joints. After the frame is being designed for two holes of 13mm diameter must be bored in the longer two ways of the frame, the inlet of copper tube and opening one on the top left hand way of the frame will be facilitated in the lowest of the right hand way of the frame.

2. Backing sheet

The supporting sheet is cut from marine ply quality for best results with 880 mm x 600 mm x12 mm. It is fixed on the tray frame exactly by using needle and hammer. The complete frame of tray and supporting sheets are covered with a good protective wood to guarantee a durable finish

3. Absorber Plate

the radiant energy of the sun is to be accumulated by the absorber plate and sends it to the water filled copper tubing. The plate must be prepared from aluminum or copper to achieve the best results. It is cut from raw aluminum sheet with dimensions 816 mm x 536 mm x 2 mm. The two sides of plate of the absorber will be gutted to reduce any drop of oil present there. Go to the gleaming side of the sheet and employ some paper on the surface. This will remove small traces of oil and allow the paint to adhere to the surface better. Go all over the aluminum sheet in small circular rubbing movements. Next apply a good primer such as zinc chromate or red oxide. It is best to obtain the paint and primer in aerosol form to achieve the flattest possible coating on the plate of the absorber. It will also dry quicker and give an attractive finish. The absorber plate is kept in a timber tray.

4. Copper Tubing

Copper tubing is used throughout its collector zone to continue the internal water as Copper is commonly suitable for drains and water schemes. It does not disintegrate in oxygenated water. Copper contains high level current conductivity possessions, needed to facilitate effective transmission of gathered heat of solar for supplying of water. Copper is soft and can be turned easily into any the required form as well as it's also cheap.

As discussed work out how much copper tubing you will need. (4.574 m) is about right. The type to obtain is half inch diameter. This is widely used in the central heating systems and is obtainable from any good plumbers' merchant. The copper tube will be formed by winding it exactly as bottle or by utilizing a little hand winding machine like an ideal Preston Hand Bender and will ensure a perfect bend, resulting in well flowing of water throughout the system. since copper is soft which can be easily compress or crushed the tube when making a bend without the aid of a forming machine, therefore if you wind it by hand make sure that you bend the tube gradually. It may be time-consuming but you will avoid kinking the pipe bringing outcomes in furring caused by restricted water flow, thus reducing efficiency. The shaped tube must be dangled from a piece of wire and scattered with a dull paint in black colour. On the top (black side) of the aluminum absorber plate the shaped copper tube must be kept with a little growth on every part so that the water always reaches to the lowest opening to drain. Onto the black absorber plate white chalk marks have to be used for the design of the copper tubing, and for avoiding copper tube. Next, a sequence of little holes is drilled on any way of the cross piece of tubing. the copper tube will be attached by the absorber plate using small copper clips at each fixing point; they will be fixed in position with small rivets or small nut sand bolts. Copper tube may also be fused to the aluminum sheet using special solder and flux and is added to the darkened absorber plate.

5. Insulation

The insulation is a composite layer which is consists of two layers and is inserted in panel tray on the baking plate. First layer of the insulation is cut from raw polystyrene foam sheet with dimensions 780mm x 500mm x 30 mm; that size is appropriated for fitting into the constructed panel tray on the baking plate. The second layer of the insulation is cut from raw rock fiber wool and aluminum foil sheet 780 mm x 500mm x 30 mm and should be laid on the first layer insulation, this will compress to 20mm thickness when the plate of the absorber is lowered on the higher level of it. A layer of aluminium baking foil can be sandwiched between the rock fiber wool and the plate comprising of gleaming side of the plate. It helps for stopping loss of hotness by reproducing temperature to its plate. Be sure about that the cove and opening of pipe ends are twisted back and put into 13mm holes in the ways of the panel tray. The plate can be held in place by four strips of wood beading (two with 816mm length and cross section is half quarter column 18mm radius and two with 536mm length and cross section is half quarter column 18mm radius) screwed to the side ways of the internal frame work of paint is needed in order to cover any scrapes upon the paint caused by the clips a last sprig of lusterless black is required as well as protecting the inside wall of the wooden frame.

6. Glazing

A translucent sheet is required to stop losing of heat in a cool climate. Heat Glass is desired since it is obtainable and contains high light transmission value. It enhances competence of the panel by trapping a long wave radiation. However Acrylic sheeting and 4 mm floating glass have to be used which bring the outcomes in a lighter panel. Acrylic is generally so inexpensive than floating glass, keep in mind that glass does not scratch or discolor. A single layer of glazing is a glass sheet with dimensions 840mm x 560mm x 4mm; the recommended quality for such size panels is a float glass. It is kept on the top edge of the cross-section of woody panel frame. After placing the glass in the tray, secure in place by four strips of wood beading two with 840mm length and cross section is a quarter column 12mm radius and two with 560mm length and cross section is a quarter column 12mm radius)and seal through a better sealant to keep out moisture. The light transmittance of 4mm glass is approximately 88% to 90% with a reflectance of 8%. Thicker glass will have slightly lower transmittance. Take care of the glass very sensibly and the glazier should be asked to carry if this is probable. the inner of the frame must be measured correctly accurately and cut the glass as per the size. It is a gap of 13 mm between the upper part of the copper piping and the cover. A larger gap can bring the outcomes of lower efficiency.

Fig - A photograph shows an outline of the testing rig description.

V. RESULTS AND DISCUSSION

The consequences of a sample test through it, the collector is tested, are tabulated in Table. The variation of efficiency of flat plate collector with volumetric flow-rate is exposed in above Figure. It can be easily noticed that; increasing rate of flow of water leads to lower efficiency of the collector. This result may be of the need for fluid to be slow inside the collector so that it can receive more radiation energy.

1	39.1	45.2	425.7	67%
1.5	39.1	42.8	387.3	61%
2	39.2	41.7	348.9	55%
2.5	39.2	41.1	331.47	52%
3	39.3	40.9	335	53%
3.5	39.3	40.6	317.5	50%
4	39.4	40.5	307	48%

The above table indicates the relationship between competence of the collector and the rate of mass.

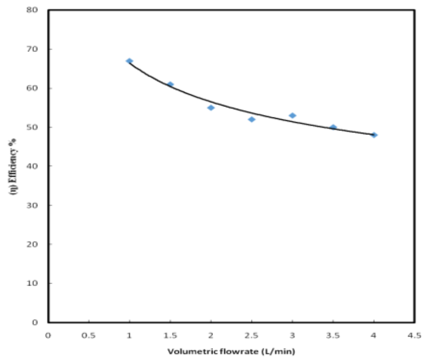


Fig. Variation of volumetric flow rate Vs. the competence of collector.

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