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Design and Fabrication of Solar Water Heater with CPC by using Wafers Packet

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Abstract: The objective of our project is to create a system which can heat water at maximum temperature and give more efficiency than the current system used in the market today for daily water heating purpose and also less costly which is the main factor. So we made a prototype system of less expensive material and another main material such as wafer packet which will absorbs more sunlight. The evacuated collector for natural circulation discharge through single ended water-in-glass evacuated tubes mounted over a diffuse reflector was also taken into consideration. Therefore, the concept of Compound Parabolic Collector (CPC) is used to heat the water and with a small aperture area as compared to other collectors is possible to achieve a maximum water temperature up-to 100°C. The system is of reasonable cost as compared to existing ones. Collector efficiency is nearly 65%, however if all the control about reflecting rays and insulation is used for reducing the heat loss may be efficiency increasable comparably.

Keywords: compound parabolic collector, wafers packet, solar radiation, water heater, concentration ratio, Absorber flux.

I. INTRODUCTION

Solar Water Heater with Compound Parabolic Collector is used for heating water purpose. The working is beneficial than that of other solar water heater system which are costlier and less efficiency in heating water. Solar water heaters are of two types, Flat Plate Collector (FPC) and Evacuated Tube Collector (ETC). ETC systems are not being used commonly. It's effectively a long half cylinder concentrates solar energy to a glass tube and in water is passed through copper tube which is present inside it. The solar energy or specifically the UVA radiation in turns kills the harmful bacteria and raises the temperature of water. Electricity utilization can be reduced by using solar water heater. It's developed for low level communities. We design to create the system which absorbs more sunrays so we used chip packet as a material that was easily made and modular. It's made from effectively scrap material.

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The simple design is constructed of a half cylinder with wafers packet as a reflecting material and a meter-and-a-half length of glass tube.

As the sun rays strikes the reflective material it is guided towards the water flowing through the glass. Therefore, more amounts of sun rays can be concentrated on the glass tube. The device can be attached to a water system making it more effective than the other method. The materials used for the system were cheap, light and accessible. The prototype system works as better than the high quality one and also a very cost effective solution.

II. CONSTRUCTION

The construction involves the following component

1. CPC
2. Solar Evacuated glass tube.
3. Tank
4. Copper tube and UPVC pipes for connection through which water will pass.

A. Compound Parabolic Collector

The compound parabolic concentrator is a non- focusing type collector. It is also called as Winston collector. Compound Parabolic Concentrators (CPCs) are so designed to concentrate sun rays, with desired angles. It forms a trough. In this case the solar radiations from all direction are reflected towards the receiver kept at the bottom. It collects both direct and diffused solar radiation with high acceptance angle. The concentration ratio achieved in this type of collector ranges from 3-7 these collectors require occasional sun tracking with seasonal variation. The receiver must have the high absorptivity for solar rays must be manufactured with more conductivity metals in order to conduct the absorbed heat into the heat transfer to fluid. The solar radiations are allowed by transparent insulated ideal cover to the reflector and receiver, having a low transmittance of thermal radiation and high transmittance of solar radiation from the receiver. Also, it must have high stability and minimum cost. The Solar concentrated reflectors must have the high reflectance. Its function is to concentrate on solar beam radiation on the receiver, which is located at the focus of the system.

Fig.1. Picture of Compound Parabolic Collector

B. Solar Evacuated glass tube

The evacuated tubes have advantage of its low heat loss at high temperatures relative to atmospheric temperature.

Evacuated tubes have thinner glass which is more vulnerable to breakage and required to change. Evacuated tubes have a vacuum seal to prevent heat loss. Over time this seal can be lost, again we have to replace it. The inner tube filled with cold water receives solar radiation. Thus the heat is transferred to the water. A thermosyphon circulation is established and the hot water comes out. The vacuum created in the tube lowers the heat loss by convection. This improves the collector efficiency. The glass is strong and also has superior light transparency.

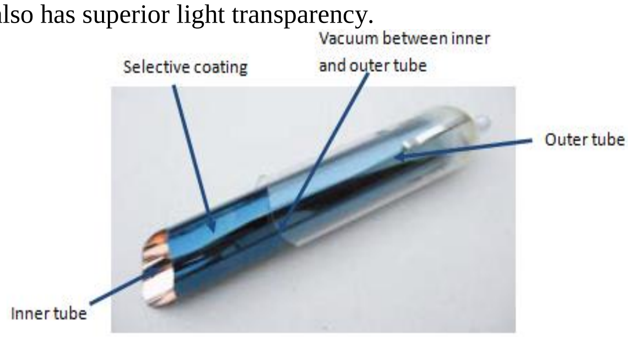

Fig.2. Solar Evacuated Glass Tube

C. Supply and Storage Tank

The supply and storage tanks may be any suitable form of storage which are able to hold a minimum of 40 L of water and contain appropriate inlets and outlets. The supply tank must be able to be elevated and simply refilled. Suitable supply and storage tanks could be in the form of a drums, e.g. plastic or galvanized, because they are readily available and inexpensive and currently used for water storage. In order to ensure continual flow through the system as the level in the supply tank decreases, the height of the pipes in the treatment system should also rise not higher than the outlet of the supply tank.

D. Copper tube and other component

The Copper tubing is widely used for supply of hot and cold tap water, and as refrigerant line in HVAC systems. The copper tubes are of two types, soft copper and rigid copper. It is joined by flare connection, compression connection, or solder. Rigid copper is generally used for water lines. Rigid copper has rigidity because of work hardening of the drawing process. Due to rigidness it cannot be bent therefore uses elbow fittings and joints to go around corners and around obstacles. It can be softening without cracking by heating and allowed to slowly cool in a process called annealing. The other UPVC pipes and other plumbing equipments are used to connect the pipes and water taps for the delivery of water.

E. Copper tube and other component

The stand is made from the raw material angles and bends. It is welded and joint together to be a stand which carries the CPC profile and the evacuated glass tube. The whole assembly is mounted on the stand. So stand is main construction. The stand can be made from other material also such as from wood but it should be a robust construction. CPC efficiency potentially reduced by poor construction. Simple design able to be constructed durably.

III. WORKING

Through the transparent cover solar rays enters the collector and reaches the absorber. Here the absorbed radiations are transformed to thermal energy. Better conductive material is needed to transmit the collected heat from the absorber sheet to the absorber pipes where the heat is finally transfer to the fluid. The collector is also protected by fluid from frost damage. The blackened absorber plate absorbs the solar radiations and converted into heat energy. The heat transfer takes place to the flow tubes by conduction. The water in the tubes heated by convection process between the tubes and the water grains. The heated water will have less density as compared to the water in the storage tank. The continuous steady circulation of hot water in the collector results in increasing the water temperature in the tank. During sunset the water supply line is confined to stop water circulation in the loop. This is to prevent excessive drop in temperature of the water in the tank since the absorber plate temperature is now the same as the atmospheric temperature and will increase heat loss.

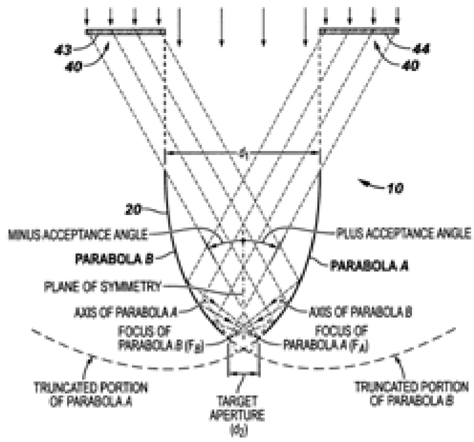

Fig.3. CPC Geometry

IV. DESIGN AND CALCULATIONS

L= 1.8288 m

H= 3 m

w = 3 m

Tube outer diameter D_o =

0.5588 m
Tube inner diameter D_i = 0.55
Ambient temperature = 25° C
Date= Apr 10
Time = 12:30 h (LAT)
I_b= 705 w/m²
I_i = 949 w/m²
Concentration ratio of the collector:

$$C = \frac{effective aperture area}{absorber tube area}$$

$$= \frac{(w - D_o) * L}{\pi D_o L}$$

$$= \frac{(w - D_o)}{\pi D_o}$$

$$= \frac{(3 - 0.5588) * 1.8288}{\pi * 0.5588}$$

$$= 2.54$$

Let,
Specular reflectivity of concentrator surface = 0.85
Glass cover transmissivity for solar radiation = 0.85
Glass cover emissivity / absorptivity = 0.88
Absorber tube emissivity / absorptivity = 0.95
Intercept factor = 0.95

Slope of aperture plane & angle of incidence:

On Apr 10, n = 100

$$\therefore \delta = 23.45 \sin\left(\frac{360}{365}(284 + n)\right)$$

$$\therefore \delta = 23.45 \sin\left(\frac{360}{365}(284 + 100)\right)$$

$\therefore \delta = 7.53\,°$

Therefore, substituting $\delta = 7.53°$, $\omega = -7.5°$ and $\phi = 19.12$

$$\therefore \tan(\phi - \beta) = \left(\frac{\tan\delta}{\cos\omega}\right)$$

$$\therefore \tan(19.12 - \beta) = \left(\frac{\tan 7.53}{\cos -7.5}\right)$$

$$19.12 - \beta = \tan^{-1}\left(\frac{\tan 7.53}{\cos(-7.5)}\right)$$

$$19.12 - \beta = 17.65$$

$$\therefore \beta = 11.52$$

Beam radiation:

$$\varepsilon_b = \frac{\cos\theta}{\cos\theta_z}$$

$$\therefore \varepsilon_b = \frac{0.99159}{\sin(19.12°) * \sin(7.53°) + \cos(19.12°) * \cos(7.53) * \cos(-7.5)}$$

$$\therefore \varepsilon_b = \frac{0.99159}{0.97159}$$

$$\varepsilon_b = 1.02058$$

Absorber flux:

$$S = I_b \varepsilon_b \rho \gamma (\tau\alpha)_b + I_b \varepsilon_b (\tau\alpha)_b \left(\frac{D_o}{W - D_o}\right)$$

$$= 705 * 1.02058 * [0.85 * 0.95 * 0.85 * 0.95] + \frac{0.85 * 0.95 * 0.5588}{3 - 0.55888}$$

$$S = 602.15\ W/m^2$$

Optical Efficiency of collector:

$$\eta_0 = \frac{S}{I_b r_b}\left(\frac{W - D_0}{W}\right)$$

$$= \frac{602.15}{705 * 1.02058}\left(\frac{3 - 0.5588}{3}\right)$$

$$\therefore \eta_0 = 68.10\ \%$$

Heat Supplied Q_s:

$$Q_s = mCP\,(T_2 - T_1)$$

$$= 1 * 4.186\,(80 - 25)$$

$$\therefore = 230.23\ J$$

System Efficiency:

$$\eta = \frac{T_2 - T_1}{T_2} * 100$$

$$= \frac{80 - 25}{80} * 100$$

$$\eta = 68.75$$

V. ADVANTAGES

The advantages of the project are:

- Simple, intuitive and non-time consuming to operate and maintain.
- Provide convenient and accessible supply to treat water when required.
- Require minimal maintenance and consumables after construction.
- Operation is simple, requiring only filling of supply tank and hand actuation of a number of small sized valves.
- Construction is relatively simple, although the production of highly accurate CPC profile may prove difficult utilizing local trade skills.
- It gives highest performance due to CPC tubes.
- It is perfect if higher temperatures are required and it gives more efficiency.
- High selective absorber coating.

VI. APPLICATIONS

The applications are as follows:

- Solar water heating system.
- The CPC can also be used for industrial air and water systems for process heat, desalination and solar chemical systems for thermal power systems.
- It can also be used for domestic hot water need, restaurant, hotels, hostel and in colleges where hot water is needed.
- It can be also used in textile mills, dairy industry, leather industry, metal plating and in food processing industries.

VII. FUTURE SCOPE

There is a great scope of this project as it is of very low cost and the materials required for the project are cheaply available in the market. The model system is only for testing and analysis of project. If the performance is positive, then large system can be designed and manufactured which will be connected to a tank and continuous supply of hot water will be there. In the present population is increasing due to that requirement of heating water is more. Hence the cost of solar water heater is increasing day by day. So low income family cannot pay high cost for solar water heater. So in the future maximum CPC type solar water heater will be used.

VIII. CONCLUSION

There are numerous practical applications where sensible temperature is required. Such as water heating, industrial process heating, power generation, steam generation, pumping of ground water etc. The temperature required for such application is about 100^{o}C. CPC is most suitable for this use. Even non-evacuated and without any surface coating, it can achieve the temperature up to 100^{o}C or even more. Flat plate collector may achieve the temperature up to 90 ^{o}C. That's why it has limited applications on moderate temperature range. Temperature upto 200 ^{o}C to 300 ^{o}C can also achieve by Compound parabolic collector (CPC) with more concentration ratio or by evacuation between absorber and envelope and the proper coating on absorber. The performance of the system can be improved by installing a transparent cover over the collector to prevent from dust collecting on the surface of the collector.

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